to give to
of public
farther, the
and an an-

ng money,
mankind,
a bro-
, and
e ye
not
doth

l in
pter
t a
it is
ry

proved. Some may periſh by ſuch a conduct. Men are ſometimes overtaken by diſtreſs, for which all other relief would come too late. Beſides which, reſolutions of this kind compel us to offer ſuch violence to our humanity, as may go near, in a little while, to ſuffocate the principle itſelf; which is a very ſerious conſideration. A good man, if he do not ſurrender himſelf to his feelings without reſerve, will at leaſt lend an ear to importunities which come accompanied with outward atteſtations of diſtreſs; and after a patient hearing of the complaint, will direct himſelf by the circumſtances and credibility of the account that he receives.

There are other ſpecies of charity well contrived to make the money expended *go far;* ſuch as keeping down the price of fuel or proviſions in caſe of a monopoly or temporary ſcarcity, by purchaſing the articles at the beſt market, and retailing them at prime coſt, or at a ſmall loſs; or the adding a bounty to a particular ſpecies of labour, when the price is accidentally depreſſed.

The proprietors of large eſtates have it in their power to facilitate the maintenance, and thereby encourage the eſtabliſhment of families (which is one of the nobleſt purpoſes to which the rich and great can convert their endeavours), by building cottages, ſplitting farms, erecting manufactures, cultivating waſtes, embanking the ſea, draining marſhes, and other expedients, which the ſituation of each eſtate points out. If the profits of theſe undertakings do not repay the expence, let the authors of them place the difference to the account of charity. It is true of almoſt all ſuch projects, that the public is a gainer by them, whatever the owner be. And where the loſs can be ſpared, this conſideration is ſufficient.

It is become a queſtion of ſome importance, Under what circumſtances works of charity ought to be done in private, and when they may be made public without detracting from the merit of the action? if indeed they ever may, the Author of our religion having delivered a rule upon this ſubject, which ſeems to enjoin univerſal ſecrecy. “When thou doeſt alms, let not thy left hand know what thy right hand doth; that thy alms may be in ſecret: and thy Father which ſeeth in ſecret, himſelf ſhall reward thee openly.” (Matth. vi. 3, 4.) From the preamble to this prohibition, it is plain, that our Saviour's ſole deſign was to forbid *oſtentation*, and all publiſhing of good works which proceeds from that motive. “Take heed that ye do not your alms before men, *to be ſeen of them;* otherwiſe ye have no reward of your Father, which is in heaven; therefore, when thou doeſt thine alms, do not ſound a trumpet before thee, as the hypocrites do, in the ſynagogues and in the ſtreets, *that they may have glory of men*. Verily I ſay unto thee, they have their reward,” v. 2. There are motives for the doing our alms in public beſides thoſe of oſtentation; with which therefore our Saviour's rule has no concern: ſuch as to teſtify our approbation of ſome particular ſpecies of charity, and to recommend it to others; to take off the prejudice which the want, or, which is the ſame thing, the ſuppreſſion, of our name in the liſt of contributors, might excite againſt the charity or againſt ourſelves. And ſo long as theſe motives are free from any mixture of vanity, they are in no danger of invading our Saviour's prohibition: they rather ſeem to comply with another direction which he has left us: “Let your light ſo ſhine before men, that they may ſee your good works, and glorify your Father which is in heaven.” If it be neceſſary to propoſe a preciſe diſtinction upon the ſubject, there can be none better than the following: When our bounty is beyond our fortune or ſtation, that is, when it is more than could be expected from us, our charity ſhould be private, if privacy be practicable: when it is not more than might be expected, it may be public: for we cannot hope to influence others to the imitation of extraordinary generoſity, and therefore want, in the former caſe, the only juſtifiable reaſon for making it public.

The pretences by which men excuſe themſelves from giving to the poor are various; as,

1. “That they have nothing to ſpare;” i. e. nothing, for which they have not ſome other uſe; nothing, which their plan of expence, together with the ſavings they have reſolved to lay by, will not exhauſt; never reflecting whether it be in their power, or that it is their duty, to retrench their expences, and contract their plan, “that they may have to give to them that need;” or rather that this ought to have been part of their plan originally.

2. “That they have families of their own, and that charity begins at home.” A father is no doubt bound to adjuſt his economy with a view to the reaſonable demands of his family upon his fortune; and until a ſufficiency for theſe is acquired, or in due time probably will be acquired (for in human affairs probability is enough, he is juſtified in declining *expenſive* liberality; for to take from thoſe who want, in order to give to thoſe who want, adds nothing to the ſtock of public happineſs. Thus far, therefore, and no farther, the plea in queſtion is an excuſe for parſimony, and an anſwer to thoſe who ſolicit our bounty.

3. “That charity does not conſiſt in giving money, but in benevolence, philanthropy, love to all mankind, goodneſs of heart,” &c. Hear St James. “If a brother or ſiſter be naked, and deſtitute of daily food, and one of you ſay unto them, depart in peace, be ye warmed and filled, notwithſtanding *ye give them not thoſe things which are needful for the body*, what doth it profit?” (James ii. 15, 16.)

4. “That giving to the poor is not mentioned in St Paul's deſcription of charity, in the 13th chapter of his firſt epiſtle to the Corinthians.” This is not a deſcription of charity, but of good nature; and it is not neceſſary that every duty be mentioned in every place.

5. “That they pay the poor rates.” They might as well allege that they pay their debts; for the poor have the ſame right to that portion of a man's property which the laws aſſign them, that the man himſelf has to the remainder.

6. “That they employ many poor perſons:”—for their own ſake, not the poor's—otherwiſe it is a good plea.

7. “That the poor do not ſuffer ſo much as we imagine; that education and habit have reconciled them to the evils of their condition, and make them eaſy under it.” Habit can never reconcile human nature to the extremities of cold, hunger, and thirſt, any more than it can reconcile the hand to the touch

of a red-hot iron: beſides the queſtion is not, how unhappy any one is, but how much more happy we can make him?

8. "That theſe people, give them what you will, will never thank you, or think of you for it." In the firſt place, this is not true: in the ſecond place, it was not for the ſake of their thanks that you relieved them.

9. "That we are ſo liable to be impoſed upon." If a due inquiry be made, our motive and merit is the ſame: beſide that the diſtreſs is generally real, whatever has been the cauſe of it.

10. "That they ſhould apply to their pariſhes." This is not always practicable: to which we may add, that there are many requiſites to a comfortable ſubſiſtence, which pariſh-relief does not always ſupply; and that there are ſome who would ſuffer almoſt as much from receiving pariſh-relief as by the want of it; and laſtly, that there are many modes of charity, to which this anſwer does not relate at all.

11. "That giving money encourages idleneſs and vagrancy." This is true only of injudicious and indiſcriminate generoſity.

12. "That we have too many objects of charity at home to beſtow any thing upon ſtrangers; or that there are other charities which are more uſeful, or ſtand in greater need." The value of this excuſe depends entirely upon the *fact*, whether we actually relieve thoſe neighbouring objects, and contribute to thoſe other charities.

Beſides all theſe excuſes, pride, or prudery, or delicacy, or love of eaſe, keep one half of the world out of the way of obſerving what the other half ſuffer.

Charity Schools, are ſchools erected and maintained in various pariſhes by the voluntary contributions of the inhabitants, for teaching poor children to read, write, and other neceſſary parts of education. See School.

Brothers of Charity, a ſort of religious hoſpitallers, founded about the year 1297, ſince denominated *Billetins*. They took the third order of St Francis, and the ſcapulary, making the three uſual vows, but without begging.

Brothers of Charity, alſo denote an order of hoſpitallers, ſtill ſubſiſting in Romiſh countries, whoſe buſineſs is to attend the ſick poor, and miniſter to them both ſpiritual and temporal ſuccour.

They are all laymen, except a few prieſts, for adminiſtering the ſacraments to the ſick in their hoſpitals. The brothers of charity uſually cultivate botany, pharmacy, ſurgery, and chemiſtry, which they practiſe with ſucceſs.

They were firſt founded at Granada, by St John de Dieu; and a ſecond eſtabliſhment was made at Madrid in the year 1553: the order was confirmed by Gregory XIII. in 1572: Gregory XIV. forbade them to take holy orders; but by leave of Paul V. in 1609, a few of the brothers might be admitted to orders. In 1619 they were exempted from the juriſdiction of the biſhop. Thoſe of Spain are ſeparated from the reſt; and they, as well as the brothers of France, Germany, Poland and Italy, have their diſtinct generals, who reſide at Rome. They were firſt introduced into France by Mary of Medicis in 1601, and have ſince built a fine hoſpital in the Fauxbourg St Germain.

Charity of St Hippolitus, a religious congregation founded about the end of the 14th century, by one Bernardin Alvarez, a Mexican, in honour of St Hippolitus the martyr, patron of the city of Mexico; and approved by Pope Gregory XIII.

Charity of our Lady, in church hiſtory, a religious order in France, which, though charity was the principal motive of their union, grew in length of time ſo diſorderly and irregular, that their order dwindled, and at laſt became extinct.

There is ſtill at Paris, a religious order of women, called *nuns hoſpitallers of the charity of our lady*. The religious of this hoſpital are by vow obliged to adminiſter to the neceſſities of the poor and the ſick, but thoſe only women.

CHARLATAN, or Charletan, ſignifies an empiric or quack, who retails his medicines on a public ſtage, and draws people about him with his buffooneries, feats of activity, &c. The word, according to Calepine, comes from the Italian, *ceretano*; of *Cæretum*, a town near Spoletto in Italy, where theſe impoſtors are ſaid to have firſt riſen. Menage derives it from *ciarlatano*, and that from *circulatorius*, of *circulator*, a quack.

CHARLEMAGNE, or Charles I. king of France by ſucceſſion, and emperor of the weſt by conqueſt in 800 (which laid the foundation of the dynaſty of the weſtern Franks, who ruled the empire 472 years till the time of Rodolphus Auſpurgenſis, the founder of the houſe of Auſtria). Charlemagne was as illuſtrious in the cabinet as in the field; and, though he could not write his name, was the patron of men of letters, the reſtorer of learning, and a wiſe legiſlator; he wanted only the virtue of humanity to render him the moſt accompliſhed of men; but when we read of his beheading 4500 Saxons, ſolely for their loyalty to their prince, in oppoſing his conqueſts, we cannot think he merits the extravagant encomiums beſtowed on him by ſome hiſtorians. He died in 814, in the 74th year of his age, and 47th of his reign.

France had nine ſovereigns of this name, of whom Charles V. merited the title of *the wiſe*, (crowned in 1364 died in 1380): and Charles VIII. ſignalized himſelf in the field by rapid victories in Italy; (crowned in 1483, died in 1498.) The reſt do not deſerve particular mention in this place. See (*Hiſtory of*) France.

CHARLEMONT, a town of the province of Namur in the Auſtrian Netherlands, about 18 miles ſouth of Namur. E. Long. 4. 40. N. Lat. 50. 10.

Charlemont is alſo the name of a town of Ireland, ſituated on the river Blackwater, in the county of Armagh, and province of Ulſter, about ſix miles ſouth-eaſt of Dungannon. W. Long. 6. 50. N. Lat. 50. 16.

CHARLEROY, a ſtrong town in the province of Namur in the Auſtrian Netherlands, ſituated on the river Sambre, about 19 miles weſt of Namur. E. Long. 4. 20. N. Lat. 50. 30.

CHARLES Martel, a renowned conqueror in the early annals of France. He depoſed and reſtored

Childeric king of France; and had the entire government of the kingdom, once with the title of *mayor of the palace*, and afterwards as *duke of France;* but he would not accept the crown. He died regretted, in 741.

Charles le Gros, emperor of the weſt in 881, king of Italy and Suabia, memorable for his reverſe of fortune; being dethroned at a diet held near Mentz, by the French, the Italians, and the Germans, in 887: after which he was obliged to ſubſiſt on the bounty of the archbiſhop of Mentz. He died in 888.

Charles V. (emperor and king of Spain), was ſon of Philip I. archduke of Auſtria and of Jane queen of Caſtile. He was born at Ghent, February 24. 1500. and ſucceeded to the crown of Spain in 1517. Two years afterwards he was choſen emperor at Françfort after the death of Maximilian his grandfather. He was a great warrior and politician: and his ambition was not ſatisfied with the many kingdoms and provinces he poſſeſſed; for he is ſuppoſed, with reaſon, to have aſpired at univerſal empire. He is ſaid to have fought 60 battles, in moſt of which he was victorious. He took the king of France (Francis I.) priſoner, and ſold him his liberty on very hard terms; yet afterwards, when the people of Ghent revolted, he aſked leave to paſs through his dominions: and though the generous king thus had him in his power, and had an opportunity of revenging his ill treatment, yet he received and attended him with all pomp and magnificence. He ſacked Rome, and took the pope priſoner; and the cruelties which his army exerciſed there are ſaid to have exceeded thoſe of the northern barbarians. Yet the pious emperor went into mourning on account of this conqueſt: forbade the ringing of bells; commanded proceſſions to be made, and prayers to be offered up for the deliverance of the pope his priſoner; yet did not inflict the leaſt puniſhment on thoſe who treated the holy father and the holy ſee with ſuch inhumanity. He is accuſed by ſome Romiſh writers of favouring the Lutheran principles, which he might eaſily have extirpated. But the truth is, he found his account in the diviſions which that ſect occaſioned; and he forever made his advantage of them, ſometimes againſt the pope, ſometimes againſt France, and at other times againſt the empire itſelf. He was a great traveller, and made 50 different journeys into Germany, Spain, Italy, Flanders, France, England, and Africa. Though he had been ſucceſsful in many unjuſt enterpriſes, yet his laſt attempt on Metz, which he beſieged with an army of 100,000 men, was very juſt, and very unſucceſsful.

Vexed at the reverſe of fortune which ſeemed to attend his latter days, and oppreſſed by ſickneſs, which unfitted him any longer for holding the reins of government with ſteadineſs, or to guide them with addreſs, he reſigned his dominions to his brother Ferdinand and his ſon Philip; and retreated to the monaſtery of St Juſtus near Placentia in Eſtremadura.

When Charles entered this retreat, he formed ſuch a plan of life for himſelf as would have ſuited a private gentleman of moderate fortune. His table was neat, but plain; his domeſtics few; his intercourſe with them familiar; all the cumberſome and ceremonious forms of attendance on his perſon were entirely aboliſhed, as deſtructive of that ſocial eaſe and tranquillity which he courted in order to ſoothe the remainder of his days. As the mildneſs of the climate, together with his deliverance from the burdens and cares of government, procured him at firſt a conſiderable remiſſion from the acute pains of the gout, with which he had been long tormented, he enjoyed perhaps more complete ſatisfaction in this humble ſolitude than all his grandeur had ever yielded him. The ambitious thoughts and projects which had ſo long engroſſed and diſquieted him were quite effaced from his mind. Far from taking any part in the political tranſactions of the princes of Europe, he reſtrained his curioſity even from an inquiry concerning them; and he ſeemed to view the buſy ſcene which he had abandoned with all the contempt and indifference ariſing from his thorough experience of its vanity, as well as from the pleaſing reflection of having diſentangled himſelf from its cares.

Other amuſements, and other ſubjects, now occupied him. Sometimes he cultivated the plants in his garden with his own hand; ſometimes he rode out to the neighbouring wood on a little horſe, the only one that he kept, attended by a ſingle ſervant on foot. When his infirmities confined him to his apartment, which often happened, and deprived him of theſe more active recreations, he either admitted a few gentlemen who reſided near the monaſtery to viſit him, and entertained them familiarly at his table; or he employed himſelf in ſtudying mechanical principles, and in forming curious works of mechaniſm, of which he had always been remarkably fond, and to which his genius was peculiarly turned. With this view he had engaged Turriano, one of the moſt ingenious artiſts of that age, to accompany him in his retreat. He laboured together with him in framing models of the moſt uſeful machines, as well as in making experiments with regard to their reſpective powers; and it was not ſeldom that the ideas of the monarch aſſiſted or perfected the inventions of the artiſt. He relieved his mind at intervals with ſlighter and more fantaſtic works of mechaniſm, in faſhioning puppets, which, by the ſtructure of internal ſprings, mimicked the geſtures and actions of men, to the no ſmall aſtoniſhment of the ignorant monks, who, beholding movements which they could not comprehend, ſometimes diſtruſted their own ſenſes, and ſometimes ſuſpected Charles and Turriano of being in compact with inviſible powers. He was particularly curious with regard to the conſtruction of clocks and watches; and having found, after repeated trials, that he could not bring any two of them to go exactly alike, he reflected, it is ſaid, with a mixture of ſurpriſe as well as regret, on his own folly, in having beſtowed ſo much time and labour in the more vain attempt of bringing mankind to a preciſe uniformity of ſentiment concerning the intricate and myſterious doctrines of religion.

But in what manner ſoever Charles diſpoſed of the reſt of his time, he conſtantly reſerved a conſiderable portion of it for religious exerciſes. He regularly attended divine ſervice in the chapel of the monaſtery, every morning and evening; he took great pleaſure in reading books of devotion, particularly the works of St Auguſtine and St Bernard; and converſed much with his confeſſor, and the prior of the monaſtery, on pious ſubjects. Thus did Charles paſs the firſt year of his retreat in a manner not unbecoming a man perfectly diſengaged from the affairs of this preſent life, and ſtanding on the confines of a future world, either in innocent amuſements which ſoothed his pains, and relieved a mind worn out with exceſſive application to buſineſs; or in devout occupations, which he deemed neceſſary in preparing for another ſtate.

But, about ſix months before his death, the gout, after a longer intermiſſion than uſual, returned with a proportional increaſe of violence. His ſhattered conſtitution had not ſtrength enough remaining to withſtand ſuch a ſhock. It enfeebled his mind as much as his body; and from this period we hardly diſcern any traces of that ſound and maſculine underſtanding which diſtinguiſhed Charles among his cotemporaries. An illiberal and timid ſuperſtition depreſſed his ſpirit. He had no reliſh for amuſements of any kind. He endeavoured to conform, in his manner of living, to all the rigour of monaſtic auſterity. He deſired no other ſociety than that of monks, and was almoſt continually employed in chanting with them the hymns of the miſſal. As an expiation for his ſins, he gave himſelf the diſcipline in ſecret, with ſuch ſeverity, that the whip of cords which he employed as the inſtrument of his puniſhment, was found, after his deceaſe, tinged with his blood. Nor was he ſatisfied with theſe acts of mortification, which, however ſevere, were not unexampled. The timorous and diſtruſtful ſolicitude which always accompanies ſuperſtition, ſtill continued to diſquiet him, and depreciating all that he had done, prompted him to aim at ſomething extraordinary, at ſome new and ſingular act of piety, that would diſplay his zeal, and merit the favour of heaven. The act on which he fixed was as wild and uncommon as any that ſuperſtition ever ſuggeſted to a diſordered fancy. He reſolved to celebrate his own obſequies before his death. He ordered his tomb to be erected in the chapel of the monaſtery. His domeſtics marched thither in funeral proceſſion, with black tapers in their hands. He himſelf followed in his ſhroud. He was laid in his coffin with much ſolemnity. The ſervice for the dead was chanted; and Charles joined in the prayers which were offered up for the reſt of his ſoul, mingling his tears with thoſe which his attendants ſhed, as if they had been celebrating a real funeral. The ceremony cloſed with ſprinkling holy water on the coffin in the uſual form, and, all the aſſiſtants retiring, the doors of the chapel were ſhut. Then Charles roſe out of the coffin, and withdrew to his apartment, full of thoſe awful ſentiments which ſuch a ſingular ſolemnity was calculated to inſpire. But either the fatiguing length of the ceremony, or the impreſſion which this image of death left on his mind, affected him ſo much, that next day he was ſeized with a fever. His feeble frame could not long reſiſt its violence; and he expired on the 21ſt of September, after a life of 58 years 6 months and 21 days.

CHARLES I. } Kings of Britain. See BRITAIN,
CHARLES II. } N° 49——254.

CHARLES XII. king of Sweden was born in 1682. By his father's will, the adminiſtration was lodged in the hands of the queen dowager Eleonora, with five ſenators, till the young prince was 18: but he was declared major at 15, by the ſtates convened at Stockholm. The beginning of his adminiſtration raiſed no favourable ideas of him, as he was thought both by Swedes and foreigners to be a perſon of mean capacity. But the difficulties that gathered round him, ſoon afforded him an opportunity to diſplay his real character. Three powerful princes, Frederick king of Denmark, Auguſtus king of Poland and elector of Saxony, and Peter the Great czar of Muſcovy, preſuming on his youth, conſpired his ruin almoſt at the ſame inſtant. Their meaſures alarming the council, they were for diverting the ſtorm by negotiations; but Charles, with a grave reſolution that aſtoniſhed them, ſaid, "I am reſolved never to enter upon an unjuſt war, nor to put an end to a juſt one but by the deſtruction of my enemies. My reſolution is fixed: I will attack the firſt who ſhall declare againſt me; and when I have conquered him, I may hope to ſtrike a terror into the reſt." The old counſellors received his orders with admiration; and were ſtill more ſurpriſed when they ſaw him on a ſudden renounce all the enjoyments of a court, reduce his table to the utmoſt frugality, dreſs like a common ſoldier, and, full of the ideas of Alexander and Cæſar, propoſe theſe two conquerors for his models in every thing but their vices. The king of Denmark began by ravaging the territories of the duke of Holſtein. Upon this Charles carried the war into the heart of Denmark, and made ſuch a progreſs that the king of Denmark thought it beſt to accept of peace, which was concluded in 1700. He next reſolved to advance againſt the king of Poland, who had blocked up Riga. He had no ſooner given orders for his troops to go into winter quarters, than he received advice that Narva, where Count Horne was governor, was beſieged by an army of 100,000 Muſcovites. This made him alter his meaſures, and move toward the czar; and at Narva he gained a ſurpriſing victory, which coſt him not above 2000 men killed and wounded. The Muſcovites were forced to retire from the provinces they had invaded. He purſued his conqueſts, till he penetrated as far as where the diet of Poland was ſitting; when he made them declare the throne of Poland vacant, and elect Staniſlaus their king: then making himſelf maſter of Saxony, he obliged Auguſtus himſelf to renounce the crown of Poland, and acknowledge Staniſlaus by a letter of congratulation on his acceſſion. All Europe was ſurpriſed with the expeditious finiſhing of this great negotiation, but more at the diſintereſtedneſs of the king of Sweden, who ſatisfied himſelf with the bare reputation of this victory, without demanding an inch of ground for enlarging his dominions. After thus reducing the king of Denmark to peace, placing a new king on the throne of Poland, having humbled the emperor of Germany, and protected the Lutheran religion, Charles prepared to penetrate into Muſcovy, in order to dethrone the czar. He quickly obliged the Muſcovites to abandon Poland, purſued them into their own country, and won ſeveral battles over them. The czar, diſpoſed to peace, ventured to make ſome propoſals; Charles only anſwered, "I will treat with the czar at Moſcow." When this haughty anſwer was brought to Peter, he ſaid, "My brother Charles ſtill affects to act the Alexander, but I flatter myſelf he will not in me find a Darius.” The event juſtified him: for the Muſcovites, already beaten into diſcipline, and under a prince of ſuch talents as Peter, entirely deſtroyed the Swediſh army at the memorable battle of Pultowa, July 8. 1709; on which deciſive day, Charles loſt the fruits of nine years labour, and of almoſt 100 battles! The king, with a ſmall troop, purſued by the Muſcovites, paſſed the Boriſthenes to Oczakow in the Turkiſh territories: and from thence, through deſert countries, arrived at Bender; where the ſultan, when informed of his arrival, ſent orders for accommodating him in the beſt manner, and appointed him a guard. Near Bender Charles built a houſe, and intrenched himſelf; and had with him 1800 men, who were all clothed and fed, with their horſes, at the expence of the grand ſignior. Here he formed a deſign of turning the Ottoman arms upon his enemies; and is ſaid to have had a promiſe from the vizir of being ſent into Muſcovy with 200,000 men. While he remained here, he inſenſibly acquired a taſte for books: he read the tragedies of Corneille and Racine, with the works of Deſpreaux, whoſe ſatires he reliſhed, but did not much admire his other works. When he read that paſſage in which the author repreſents Alexander as a fool and a madman, he tore out the leaf. He would ſometimes play at cheſs: but when he recovered of his wounds, he renewed his fatigues in exerciſing his men; he tired three horſes a-day; and thoſe who courted his favour were all day in their boots. To diſpoſe the Ottoman Porte to this war, he detached about 800 Poles and Coſſacks of his retinue, with orders to paſs the Nieſter, that runs by Bender, and to obſerve what paſſed on the frontiers of Poland. The Muſcovite troops, diſperſed in thoſe quarters, fell immediately upon this little company, and purſued them even to the territories of the grand ſignior. This was what the king expected. His miniſters at the Porte excited the Turks to vengeance; but the czar's money removed all difficulties, and Charles found himſelf in a manner priſoner among the Tartars. He imagined the ſultan was ignorant of the intrigues of his grand vizir. Poniatowſky undertook to make his complaints to the grand ſignior. The ſultan, in anſwer, ſome days after, ſent Charles five Arabian horſes, one of which was covered with a ſaddle and houſing of great richneſs; with an obliging letter, but conceived in ſuch general terms, as gave reaſon to ſuſpect that the miniſter had done nothing without the ſultan's conſent: Charles therefore refuſed them. Poniatowſky had the courage to form a deſign of depoſing the grand vizir, who accordingly was deprived of his dignity and wealth, and baniſhed. The ſeal of the empire was given to Numan Cuproughly; who perſuaded his maſter, that the law forbade him to invade the czar, who had done him no injury; but to ſuccour the king of Sweden as an unfortunate prince in his dominions. He ſent his majeſty 800 purſes, every one of which amounted to 500 crowns, and adviſed him to return peaceably to his own dominions. Charles rejected this advice, threatening to hang up the baſhaws, and ſhave the beards of any janizaries who brought him ſuch meſſages, and ſent word that he ſhould depend upon the grand ſignior's promiſe, and hoped to re-enter Poland as a conqueror with an army of Turks. After various intrigues at the Porte, an order was ſent to attack this *head of iron*, as he was called, and to take him either alive or dead. He ſtood a ſiege in his houſe, with forty domeſtics, againſt the Turkiſh army; killed no leſs than 20 janizaries with his own hand; and performed prodigies of valour on a very unneceſſary and unwarrantable occaſion. But the houſe being ſet on fire, and himſelf wounded, he was at laſt taken priſoner, and ſent to Adrianople, where the grand ſignior gave him audience, and promiſed to make good all the damages he had ſuſtained. At laſt, after a ſtay of above five years, he left Turkey; and, having diſguiſed himſelf, traverſed Wallachia, Tranſylvania, Hungary, and Germany, attended only by one perſon: and in ſixteen days riding, during which time he never went to bed, came to Stralſund at midnight, November 21. 1714. His boots were cut from his ſwollen legs, and he was put to bed; where, when he had ſlept ſome hours, the firſt thing he did was to review his troops, and examine the ſtate of the fortifications. He ſent out orders that very day to renew the war with more vigour than ever. But affairs were now much changed: Auguſtus had recovered the throne of Poland; Sweden had loſt many of its provinces, and was without money, trade, credit, or troops. The kings of Denmark and Pruſſia ſeized the iſland of Rugen; and beſieged him in Stralſund, which ſurrendered; but Charles eſcaped to Carlſcroon. When his country was threatened with invaſion by ſo many princes, he, to the ſurpriſe of all Europe, marched into Norway with 20,000 men. A very few Danes might have ſtopped the Swediſh army; but ſuch a quick invaſion they could not foreſee. Europe was yet more at a loſs to find the czar ſo quiet, and not making a deſcent upon Sweden, as he had before agreed with his allies. This inaction was the conſequence of one of the greateſt deſigns, and at the ſame time the moſt difficult of any that were ever formed by the imagination of man. In ſhort, a ſcheme was ſet on foot for a reconciliation with the czar; for replacing Staniſlaus on the throne of Poland; and ſetting James II.'s ſon upon that of England, beſides reſtoring the duke of Holſtein to his dominions. Charles was pleaſed with theſe grand ideas, though without building much upon them, and gave his miniſter leave to act at large. In the mean time, Charles was going to make a ſecond attempt upon Norway in 1718; and he flattered himſelf with being maſter of that kingdom in ſix months; but while he was examining the works at Frederickſhall, a place of great ſtrength and importance, which is reckoned to be the key of that kingdom, he was killed by a ſhot from the enemy, as has been generally believed, though it has been alſo reported that he fell by the treachery of one of his own officers, who had been bribed for that purpoſe.

This prince experienced the extremes of proſperity and of adverſity, without being ſoftened by the one or diſturbed for a moment at the other; but was a man rather extraordinary than great, and fitter to be admired than imitated. He was honoured by the Turks for his rigid abſtinence from wine, and his regularity in attending public devotion.

As to his perſon, he was tall and of a noble mein, had a fine open forehead, large blue eyes, flaxen hair, fair complexion, a handſome noſe, but little beard, and a laugh not agreeable. His manners were harſh and auſtere, not to ſay ſavage: and as to religion, he was indifferent towards all, though exteriorly a Lutheran, and a ſtrong believer in predeſtination. A few anecdotes will illuſtrate his character. No dangers, however great, made the leaſt impreſſion upon him. When a horſe or two were killed under him at the battle of Narva, in 1700, he leaped nimbly upon freſh ones, ſaying, “ Theſe people find me exerciſe.” One day, when he was dictating letters to a ſecretary, a bomb fell through the roof into the next room of the houſe where they were ſitting. The ſecretary, terrified leſt the houſe ſhould come down upon them, let his pen drop out of his hand: “ What is the matter?” ſays the king calmly. The ſecretary could only reply, “ Ah, Sir, the bomb.” “ The bomb (ſays the king)! what has the bomb to do with what I am dictating to you! Go on.”

He preſerved more humanity than is uſually found among conquerors. Once, in the middle of an action, finding a young Swediſh officer wounded and unable to march, he obliged the officer to take his horſe, and continued to command his infantry on foot. The princeſs Lubomirſki, who was very much in the intereſt and good graces of Auguſtus, falling by accident into the hands of one of his officers, he ordered her to be ſet at liberty: ſaying, “ That he did not make war with women.” One day, near Leipſic, a peaſant threw himſelf at his feet, with a complaint againſt a grenadier, that he had robbed him of certain eatables provided for himſelf and his family. “ Is it true (ſaid Charles ſternly), that you have robbed this man?” The ſoldier replied, “ Sir, I have not done near ſo much harm to this man as your majeſty has done to his maſter; for you have taken from Auguſtus a kingdom, whereas I have only taken from this poor ſcoundrel a dinner.” Charles made the peaſant amends, and pardoned the ſoldier for his firmneſs: “ However, my friend (ſays he to him), you will do well to recollect that if I took a kingdom from Auguſtus, I did not take it for myſelf.”

Though Charles lived hardily himſelf, a ſoldier did not fear to remonſtrate to him againſt ſome bread, which was very black and mouldy, and which yet was the only proviſion the troops had. Charles called for a piece of it, and calmly ate it up; ſaying, “ that it was indeed not good, but that it might be eaten.” From the danger he was in in Poland, when he beat the Saxon troops in 1702, a comedy was exhibited at Marienburg, where the combat was repreſented to the diſadvantage of the Swedes. “ Oh, (ſays Charles, hearing of it), I am far from envying them in this pleaſure. Let them beat me in the theatres as long as they will, provided I do but beat them in the field.” He wrote ſome obſervations on war, and on his own campaigns from 1700 to 1709: but the MS. was loſt at the unfortunate battle of Pultowa.

CHARLES'S CAPE, a promontory of Virginia, in North America, forming the northern headland of the ſtrait that enters the bay of Cheſapeak.

CHARLES's Fort, a fortreſs in the county of Corke, and province of Munſter, in Ireland, ſituated at the mouth of Kinſale harbour. W. Long. 8. 20. N. Lat. 51. 21.

CHARLESTON, the metropolis of South Carolina, is the moſt conſiderable town in the ſtate; ſituated in the diſtrict of the ſame name, and on the tongue of land formed by the confluent ſtreams of Aſhley and Cooper, which are ſhort rivers, but large and navigable. Theſe waters unite immediately below the city, and form a ſpacious and convenient harbour; which communicates with the ocean juſt below Sullivan's iſland; which it leaves on the north, ſeven miles ſouth-eaſt of Charleſton. In theſe rivers the tide riſes, in common, about 6½ feet; but uniformly riſes 10 or 12 inches more during a night tide. The fact is certain; the cauſe unknown. The continual agitation which the tides occaſion in the waters which almoſt ſurround Charleſton, the refreſhing ſea breezes which are regularly felt, and the ſmoke ariſing from ſo many chimneys, render this city more healthy than any part of the low country in the ſouthern ſtates. On this account it is the reſort of great numbers of gentlemen, invalids from the Weſt India iſlands, and of the rich planters from the country, who come here to ſpend the ſickly months, as they are called, in queſt of health and of the ſocial enjoyments which the city affords. And in no part of America are the ſocial bleſſings enjoyed more rationally and liberally than here. Unaffected hoſpitality, affability, eaſe of manners and addreſs, and a diſpoſition to make their gueſts welcome, eaſy, and pleaſed with themſelves, are characteriſtics of the reſpectable people of Charleſton. In ſpeaking of the capital, it ought to be obſerved, for the honour of the people of Carolina in general, that when in common with the other colonies, in the conteſt with Britain, they reſolved againſt the uſe of certain luxuries, and even neceſſaries of life; thoſe articles, which improve the mind, enlarge the underſtanding, and correct the taſte, were excepted; the importation of books was permitted as formerly.

The land on which the town is built, is flat and low, and the water brackiſh and unwholeſome. The ſtreets are pretty regularly cut, and open beautiful proſpects, and have ſubterranean drains to carry off filth and keep the city clean and healthy; but are too narrow for ſo large a place and ſo warm a climate. Their general breadth is from 35 to 66 feet. The houſes which have been lately built, are brick, with tiled roofs. The buildings in general are elegant, and moſt of them are neat, airy, and well furniſhed. The public buildings are, an exchange, a ſtate-houſe, an armoury, a poor-houſe, and an orphan's houſe. Here are ſeveral reſpectable academies. Part of the old barracks has been handſomely fitted up, and converted into a college, and there are a number of ſtudents; but it can only be called as yet a reſpectable academy. Here are two banks, a branch of the national bank, and the South Carolina bank, eſtabliſhed in 1792. The houſes for public worſhip are two Epiſcopal churches, two for Independents, one for Scotch Preſbyterians, one for Baptiſts, one for German Lutherans, two for Methodiſts, one for French Proteſtants, a meeting-houſe for Quakers, a Roman Catholic chapel, and a Jewiſh ſynagogue.

Little attention is paid to the public markets; a great proportion of the moſt wealthy inhabitants having plantations from which they receive ſupplies of almoſt every article of living. The country abounds with poultry and wild ducks. Their beef, mutton and veal are not generally of the beſt kind; and few fiſh are found in the market.

In 1787, it was computed that there were 1600 houſes in this city, and 15,000 inhabitants, including 5400 ſlaves; and what evinces the healthineſs of the place, upwards of 200 of the white inhabitants were above 60 years of age. In 1791, there were 16,359 inhabitants, of whom 7684 were ſlaves. This city has often ſuffered much by fire: the laſt and moſt deſtructive happened as late as June 1796.

Charleſton was incorporated in 1783, and divided into three wards, which choſe as many wardens, from among whom the citizens elect an intendant of the city. The intendant and wardens form the city-council, who have power to make and enforce bye-laws for the regulation of the city.

The value of exports from this port, in the year ending November 1787, amounted to 505,278l. 19s. 5d. ſterling. The number of veſſels cleared from the cuſtomhouſe the ſame year, was 947, meaſuring 62,118 tons; 735 of theſe, meaſuring 41,531 tons, were American; the others belonged to Great Britain, Ireland, Spain, France, and the United Netherlands.

Charles's Wain, in *Aſtronomy*, ſeven ſtars in the conſtellation called *Urſa Major*, or the Great Bear.

CHARLETON, an iſland at the bottom of Hudſon's bay, in North America, ſubject to Great Britain. W. Long. 80. 0. N. Lat. 52. 30.

Charleton, *Walter*, a learned Engliſh phyſician, born in 1619, was phyſician in ordinary to Charles I. and Charles II. one of the firſt members of the royal ſociety, and preſident of the college of phyſicians. He wrote on various ſubjects; but at laſt his narrow circumſtances obliged him to retire to the iſland of Jerſey, where he died in 1707.

CHARLOCK, the Engliſh name of the Raphanus: it is a very troubleſome weed among corn, being more frequent than almoſt any other. There are two principal kinds of it: the one with a yellow flower, the other with a white. Some fields are particularly ſubject to be overrun with it, eſpecially thoſe which have been manured with cow dung alone, that being a manure very favourable to the growth of it. The farmers in ſome places are ſo ſenſible of this, that they always mix horſe dung with their cow dung, when they uſe it for arable land. When barley, as is often the caſe, is infeſted with this weed to ſuch a degree as to endanger the crop, it is a very good method to mow down the charlock in May, when it is in flower, cutting it ſo low as juſt to take off the tops of the leaves of barley with it: by this means the barley will get up above the weed: and people have got four quarters of grain from an acre of ſuch land as would have ſcarce yielded any thing without this expedient. Where any land is particularly ſubject to this weed, the beſt method is to ſow it with graſs ſeed, and make a paſture of it; for then the plant will not be troubleſome, it never growing where there is a coat of graſs upon the ground.

Queen CHARLOTTE's *Iſland*, an iſland in the South ſea, firſt diſcovered by Captain Wallis in the Dolphin, in 1767, who took poſſeſſion of it in the name of King George III. Here is good water, and plenty of cocoa nuts, palm nuts, and ſcurvy graſs. The inhabitants are of a middle ſtature, and dark complexion, with long hair hanging over their ſhoulders; the men are well made, and the women handſome; their clothing is a kind of coarſe cloth, or matting, which they faſten about their middle.

Queen Charlotte's Iſlands, a cluſter of South ſea iſlands, diſcovered in 1767 by Captain Carteret. He counted ſeven, and there were ſuppoſed to be many more. The inhabitants of theſe iſlands are deſcribed as extremely nimble and vigorous, and almoſt as well qualified to live in the water as upon land: they are very warlike: and, on a quarrel with ſome of Captain Carteret's people, they attacked them with great reſolution; mortally wounded the maſter and three of the ſailors; were not at all intimidated by the fire arms; and at laſt, nowithſtanding the averſion of Captain Carteret to ſhed blood, he was obliged to ſecure the watering places by firing grape ſhot into the woods, which deſtroyed many of the inhabitants. Theſe iſlands lie in S. Lat. 11°. E. Long. 164°. They are ſuppoſed to be the Santa Cruz of Mandana, who died there in 1595.

CHARM, a term derived from the Latin *carmen*, "a verſe;" and uſed to denote a magic power, or ſpell, by which, with the aſſiſtance of the devil, ſorcerers and witches were ſuppoſed to do wonderful things, far ſurpaſſing the power of nature.

CHARNEL, or Charnel house, a kind of portico, or gallery, uſually in or near a churchyard, over which were anciently laid the bones of the dead, after the fleſh was wholly conſumed. Charnel-houſes are now uſually adjoining to the church.

CHARON, in fabulous hiſtory, the ſon of Erebus and Nox, whoſe office was to ferry the ſouls of the deceaſed over the waters of Acheron, for which each ſoul was to pay a piece of money. For this reaſon the Pagans had a cuſtom of putting a piece of money into the mouth of the dead, in order that they might have ſomething to pay Charon for their paſſage.

CHARONDAS, a celebrated legiſlator of the Thurians, and a native of Catanea in Sicily, flouriſhed 446 before Chriſt. He forbade any perſon's appearing armed in the public aſſemblies of the nation; but one day going thither in haſte, without thinking of his ſword, he was no ſooner made to obſerve his miſtake than he ran it through his body.

CHAROST, a town of France, in Berry, with the title of a duchy. It is ſeated on the river Arnon. E. Long. 2. 15. N. Lat. 46. 56.

CHAROUX, a town of France, in the Bourbonnois, ſeated on an eminence, near the river Sioulle. It has two pariſhes, which are in different dioceſes. E. Long. 3. 15. N. Lat. 46. 10.

CHARPENTIER, Francis, dean of the French academy, was born in 1620. His early capacity inclined his friends to educate him at the bar: but he was much more delighted with the ſtudy of languages and antiquity than of the law; and preferred repoſe to tumult. M. Colbert made uſe of him in eſtabliſhing his new academy of medals and inſcriptions; and no perſon of that learned ſociety contributed more than himſelf toward that noble ſeries of medals which were ſtruck on the conſiderable events that diſtinguiſhed the reign of Louis XIV. He publiſhed ſeveral works, which were all well received; and died in 1702.

CHARR. See Salmo, Ichthyology *Index*.

CHARRON, Peter, the author of a book entitled *Of Wiſdom*, which gained him great reputation, was born at Paris in the year 1541. After being advocate in the parliament of Paris for five or ſix years, he applied himſelf to divinity; and became ſo great a preacher, that the biſhops of ſeveral dioceſes offered him the higheſt dignities in their gift. He died at Paris, ſuddenly in the ſtreet, November 16. 1603.

CHART, or Sea Chart, an hydrographical map, or a projection of ſome part of the earth's ſuperficies *in plano*, for the uſe of navigators.

Charts differ very conſiderably from geographical or land maps, which are of no uſe in navigation. Nor are ſea charts all of the ſame kind, ſome being what we call plane charts, others Mercator charts, and others globular charts.

Plane Chart, is a repreſentation of ſome part of the ſuperficies of the terraqueous globe, in which the meridians are ſuppoſed parallel to each other, the parallels of latitude at equal diſtances, and conſequently the degrees of latitude and longitude everywhere equal to each other. See *Plane Chart*.

Mercator's Chart, is that where the meridians are ſtraight lines, parallel to each other, and equidiſtant; the parallels are alſo ſtraight lines, and parallel to each other: but the diſtance between them increaſes from the equinoctial towards either pole, in the ratio of the ſecant of the latitude to the radius. See Navigation.

Globular Chart, a meridional projection, wherein the diſtance of the eye from the plane of the meridian, upon which the projection is made, is ſuppoſed to be equal to the ſine of the angle 45°. This projection comes the neareſt of all to the nature of the globe, becauſe the meridians therein are placed at equal diſtances; the parallels alſo are nearly equidiſtant, and conſequently the ſeveral parts of the earth have their proper proportion of magnitude, diſtance, and ſituation, nearly the ſame as on the globe itſelf. See *Globular Projection*.

Hydrographic Charts, ſheets of large paper, whereon ſeveral parts of the land and ſea are deſcribed, with their reſpective coaſts, harbours, ſounds, flats, rocks, ſhelves, ſands, &c. together with the longitude and latitude of each place, and the points of the compaſs. See *Mercator's Chart*.

Selenographic Charts, particular deſcriptions of the ſpots, appearances, and maculæ of the moon. See Astronomy *Index*.

Topographic Charts, draughts of ſome ſmall parts of the earth only, or of ſome particular place, without regard to its relative ſituation, as London, York, &c.

CHARTA, or Carta, primarily ſignifies a ſort of paper made of the plant *papyrus* or *biblus*. See Paper and Charter.

Charta Emporetica, in *Pharmacy*, &c. a kind of paper made very ſoft and porous, uſed to filter withal. See Filtration, &c.

Charta is alſo uſed in our ancient cuſtoms for a charter, or deed in writing. See Charter.

Magna Charta.

Magna Charta, the great charter of the liberties of Britain, and the baſis of our laws and privileges.

This charter may be ſaid to derive its origin from King Edward the Confeſſor, who granted ſeveral privileges to the church and ſtate by charter: theſe liberties and privileges were alſo granted and confirmed by King Henry I. by a celebrated great charter now loſt; but which was confirmed or re-enacted by King Henry II. and King John. Henry III. the ſucceſſor of this laſt prince, after having cauſed 12 men make inquiry into the liberties of England in the reign of Henry I. granted a new charter; which was the ſame as the preſent magna charta. This he ſeveral times confirmed, and as often broke; till, in the 37th year of his reign, he went to Weſtminſter Hall, and there, in preſence of the nobility and biſhops, who held lighted candles in their hands, magna charta was read, the king all the time holding his hand to his breaſt, and at laſt ſolemnly ſwearing faithfully and inviolably to obſerve all the things therein contained, &c. Then the biſhops extinguiſhing the candles, and throwing them on the ground, they all cried out, "Thus let him be extinguiſhed, and ſtink in hell, who violates this charter." It is obſerved, that, notwithſtanding the ſolemnity of this confirmation, King Henry, the very next year, again invaded the rights of his people, till the barons entered into a war againſt him; when, after various ſucceſs, he confirmed this charter, and the charter of the foreſt, in the 52d year of his reign.

This charter confirmed many liberties of the church, and redreſſed many grievances incident to feodal tenures, of no ſmall moment at the time; though now, unleſs conſidered attentively and with this retroſpect, they ſeem but of trifling concern. But, beſides theſe feodal proviſions, care was alſo taken therein to protect the ſubject againſt other oppreſſions, then frequently ariſing from unreaſonable amercements, from illegal diſtreſſes or other proceſs for debts or ſervices due to the crown, and from the tyrannical abuſe of the prerogative of purveyance and pre-emption. It fixed the forfeiture of lands for felony in the ſame manner as it ſtill remains; prohibited for the future the grants of excluſive fiſheries; and the erection of new bridges ſo as to oppreſs the neighbourhood. With reſpect to private rights, it eſtabliſhed the teſtamentary power of the ſubject over part of his perſonal eſtate, the reſt being diſtributed among his wife and children; it laid down the law of dower, as it hath continued ever ſince; and prohibited the appeals of women, unleſs after the death of their huſbands. In matters of public police and national concern, it enjoined an uniformity of weights and meaſures; gave new encouragements to commerce, by the protection of merchant ſtrangers; and forbade the alienation of lands in mortmain. With regard to the adminiſtration of juſtice; beſides prohibiting all denials or delays of it, it fixed the court of common pleas at Weſtminſter, that the ſuitors might no longer be haraſſed with following the king's perſon in all his progreſſes; and at the ſame time brought the trial of iſſues home to the very doors of the freeholders, by directing aſſizes to be taken in the proper counties, and eſtabliſhing annual circuits: it alſo corrected ſome abuſes then incident to the trials by wager of law and of battle; directed the regular awarding

ing of inqueſts for life or member; prohibited the king's inferior miniſters from holding pleas of the crown, or trying any criminal charge, whereby many forfeitures might otherwiſe have unjuſtly accrued to the exchequer; and regulated the time and place of holding the inferior tribunals of juſtice, the county-court, ſheriff's torn, and court-leet. It confirmed and eſtabliſhed the liberties of the city of London, and all other cities, boroughs, towns, and ports of the kingdom. And laſtly (which alone would have merited the title that it bears, of the *great charter*), it protected every individual of the nation in the free enjoyment of his life, his liberty, and his property, unleſs declared to be forfeited by the judgment of his peers, or the law of the land.

This excellent charter, ſo equitable, and beneficial to the ſubject, is the moſt ancient written law in the kingdom. By the 25th Edward I. it is ordained, that it ſhall be taken as the common law; and by the 43d Edward III. all ſtatutes made againſt it are declared to be void.

CHARTEL, in *Law*, a written inſtrument, or evidence of things acted between one perſon and another. The word charter comes from the Latin *charta*, anciently uſed for a public and authentic act, a donation, contract, or the like; from the Greek χαρτης, "thick paper" or "paſteboard," whereon public acts were wont to be written. Britton divides charters into thoſe of the king, and thoſe of private perſons. 1. Charters of the king, are thoſe whereby the king paſſeth any grant to any perſon or body politic, as a *charter of exemption*, of privilege, &c. *charter of pardon*, whereby a man is forgiven a felony, or other offence committed againſt the king's crown and dignity; *charter of the foreſt*, wherein the laws of the foreſt are compriſed, ſuch as the charter of Canutus, &c. 2. Charters of private perſons, are deeds and inſtruments for the conveyance of lands, &c. And the purchaſer of lands ſhall have all the charters, deeds, and evidences, as incident to the ſame, and for the maintenance of his title.

Charter-*Governments* in America. See Colony.

Charter-*Land*, ſuch land as a perſon holds by charter; that is, by evidence in writing; otherwiſe called *freehold*.

CHARTERPARTY, in commerce, denotes the inſtrument of freightage, or articles of agreement for the hire of a veſſel. See Freight, &c.

The charterparty is to be in writing; and to be ſigned both by the proprietor or the maſter of the ſhip, and the merchant who freights it. It is to contain the name and the burden of the veſſel; the names of the maſter and the freighter; the price or rate of freight; and the time of loading and unloading: and the other conditions agreed on. It is properly a deed, or policy, whereby the maſter or proprietor of the veſſel engages to furniſh immediately a tight ſound veſſel, well equipped, caulked, and ſtopped, provided with anchors, ſails, cordage, and all other furniture to make the voyage required, as equipage, hands, victuals, and other munitions; in conſideration of a certain ſum to be paid by the merchant for the freight. Laſtly, The ſhip with all its furniture, and the cargo, are reſpectively ſubjected to the conditions of the *charterparty*. The *charterparty* differs from a *bill of lading*, in that the firſt is for the entire freight, or lading, and that both for going and returning; whereas the latter is only for a part of the freight, or at moſt only for the voyage one way.

Boyer ſays, the word is derived from hence, that *per medium charta incidebatur, et ſic fiebat charta partita;* becauſe, in the time when notaries were leſs common, there was only one inſtrument made for both parties: this they cut in two, and gave each his portion; joining them together at their return, to know if each had done his part. This he obſerves to have been practiſed in his time; agreeable to the method of the Romans, who, in their ſtipulations, uſed to break a ſtaff, each party retaining a moiety thereof as a mark.

CHARTOPHYLAX, the name of an officer of the church of Conſtantinople, who attends at the door of the rails when the ſacrament is adminiſtered, and gives notice to the prieſts to come to the holy table. He repreſents the patriarch upon the bench, tries all eccleſiaſtical cauſes, keeps all the marriage regiſters, aſſiſts at the conſecration of biſhops, and preſents the biſhop elect at the ſolemnity, and likewiſe all other ſubordinate clergy. This office reſembles in ſome ſhape that of the *bibliothecarius* at Rome.

CHARTRES, a large city of France, in the province of Orleannois, ſituated on the river Eure, in E. Long. 1. 32. N. Lat. 48. 47. It is a biſhop's ſee.

CHARTREUSE, or Chartreuse-grand, a celebrated monaſtery, the capital of all the convents of the Carthuſian monks, ſituated on a ſteep rock in the middle of a large foreſt of fir trees, about ſeven miles north-eaſt of Grenoble, in the province of Dauphiny in France. E. Long. 5. 5. N. Lat. 45. 20. See Carthusians.

From this mother-convent, all the others of the ſame order took their name; among which was the Chartreuſe of London, corruptly called the *charterhouſe*, now converted into an hoſpital, and endowed with a revenue of 600l. per annum.

Here were maintained 80 decayed gentlemen, not under 50 years of age; alſo 40 boys are educated and fitted either for the univerſity or trades. Thoſe ſent to the univerſity have an exhibition of 20l. a-year for eight years: and have an immediate title to nine church-livings in the gift of the governors of the hoſpital, who are ſixteen in number, all perſons of the firſt diſtinction, and take their turns in the nomination of penſioners and ſcholars.

CHARTULARY, Chartularius, a title given to an ancient officer in the Latin church, who had the care of charters and papers relating to public affairs. The chartulary preſided in eccleſiaſtical judgments, in lieu of the pope. In the Greek church the chartulary was called *chartophylax;* but his office was there much more conſiderable; and ſome even diſtinguiſh the chartulary from the chartophylax in the Greek church. See Chartophylax.

CHARYBDIS, in *Ancient Geography*, a whirlpool in the ſtraits of Meſſina, according to the poets; near Sicily, and oppoſite to Scylla, a rock on the coaſt of Italy. Thucydides makes it to be only a ſtrong flux and reflux in the ſtrait, or a violent reciprocation of the tide, eſpecially if the wind ſets ſouth. But on diving into the Charybdis, there are found vaſt gulfs and whirlpools below, which produce all the commotion on the ſurface of the water.

Charybdis is uſed by Horace to denote a rapacious proſtitute.

CHASE, or Chace, in *Law*, is uſed for a driving of cattle to or from any place; as to a diſtreſs, or fortlet, &c.

Chase, or *Chace*, is alſo a place of retreat for deer and wild beaſts; of a middle kind between a foreſt and a park, being uſually leſs than a foreſt, and not poſſeſſed of ſo many privileges; but wanting, v. g. courts of attachment, ſwainmote, and juſtice ſeat *. Yet it is of a large extent, and ſtocked both with a greater diverſity of wild beaſts or game, and more keepers than a park. Crompton obſerves, that a foreſt cannot be in the hands of a ſubject, but it forthwith loſes its name, and becomes a *chaſe;* in regard all thoſe courts loſe their nature when they come into the hands of a ſubject; and that none but a king can make a lord chief juſtice in eyre of the foreſt. See *Justice in Eyre*.

* See *Foreſt*.

Britiſh Zool. I. 42. The following hiſtory of the Engliſh chaſe is given by Mr Pennant. "At firſt the beaſts of chaſe had this whole iſland for their range; they knew no other limits than the ocean, nor confeſſed any particular maſter. When the Saxons had eſtabliſhed themſelves in the heptarchy, they were reſerved by each ſovereign for his own particular diverſion. Hunting and war, in thoſe uncivilized ages, were the only employ of the great; their active, but uncultivated minds, being ſuſceptible of no pleaſures but thoſe of a violent kind, ſuch as gave exerciſe to their bodies, and prevented the pain of thinking.

"But as the Saxon kings only appropriated thoſe lands to the uſe of foreſts which were unoccupied, ſo no individuals received any injury; but when the Conqueſt had ſettled the Norman line on the throne, this paſſion for the chaſe was carried to an exceſs, which involved every civil right in a general ruin: it superſeded the conſideration of religion even in a ſuperſtitious age: the village communities, nay even the moſt ſacred edifices, were turned into one vaſt waſte, to make room for animals, the objects of a lawleſs tyrant's pleaſure. The new foreſt in Hampſhire is too trite an inſtance to be dwelt on; ſanguinary laws were enacted to preſerve the game; and in the reigns of William Rufus, and Henry I. it was leſs criminal to deſtroy one of the human ſpecies than a beaſt of chaſe. Thus it continued while the Norman line filled the throne; but when the Saxon line was reſtored under Henry II. the rigour of the foreſt laws was immediately ſoftened.

"When our barons began to form a power, they claimed a vaſt, but more limited, tract for a diverſion that the Engliſh were always fond of. They were very jealous of any encroachments on their reſpective bounds, which were often the cauſe of deadly feuds; ſuch a one gave cauſe to the fatal day of *Chevy-chaſe;* a fact which, though recorded only in a ballad, may, from what we know of the manners of the times, be founded on truth; not that it was attended with all the circumſtances which the author of that natural but heroic compoſition hath given it; for, on that day neither a *Percy* nor a *Douglas* fell: here the poet ſeems to have claimed his privilege, and mixed with this fray ſome of the events of the battle of *Otterbourne*.

"When property became happily more divided by the relaxation of the feodal tenures, theſe extenſive hunting grounds became more limited; and as tillage and huſbandry increaſed, the beaſts of chaſe were obliged to give way to others more uſeful to the community. The vaſt tracts of land, before dedicated to hunting, were then contracted; and, in proportion as the uſeful arts gained ground, either loſt their original deſtination, or gave riſe to the invention of *parks*. Liberty and the arts ſeem coeval; for when once the latter got footing, the former protected the labours of the induſtrious from being ruined by the licentious ſportſman, or being devoured by the objects of his diverſion: for this reaſon, the ſubjects of a deſpotic government ſtill experience the inconveniences of vaſt waſtes and foreſts, the terrors of the neighbouring huſbandmen; while in our well regulated monarchy very few chaſes remain. The Engliſh ſtill indulge themſelves in the pleaſures of hunting; but confine the deer kind to parks, of which England boaſts of more than any other kingdom in Europe. The laws allow every man his pleaſure; but confine them in ſuch bounds as prevent them from being injurious to the meaneſt of the community. Before the Reformation, the prelates ſeem to have guarded ſufficiently againſt this want of amuſement, the ſee of Norwich, in particular, being poſſeſſed, about that time, of thirteen parks."

Chase, in the ſea language, is to purſue a ſhip; which is alſo called *giving chaſe*.

Stern-Chase, is when the chaſer follows the chaſed aſtern directly upon the ſame point of the compaſs.

To lie with a ſhip's fore foot in a Chase, is to ſail and meet with her by the neareſt diſtance; and ſo to croſs her in her way, or to come acroſs her fore-foot.

A ſhip is ſaid to have a *good chaſe*, when ſhe is ſo built forward on, or a-ſtern, that ſhe can carry many guns to ſhoot forwards or backwards; according to which ſhe is ſaid to have a *good forward* or *good ſtern chaſe*.

Chase Guns, are ſuch whoſe ports are either in the head (and then they are uſed in chaſing of others); or in the ſtern, which are only uſeful when they are purſued or chaſed by any other ſhip.

Chase of a Gun, is the whole bore or length of a piece taken withinſide.

Wild-gooſe Chase, a term uſed to expreſs a ſort of racing on horſeback uſed formerly, which reſembled the flying of wild geeſe; thoſe birds generally going in a train one after another, not in confuſed flocks as other birds do. In this ſort of race the two horſes, after running twelve ſcore yards, had liberty, which horſe ſoever could take the leading, to ride what ground the jockey pleaſed, the hindmoſt horſe being bound to follow him within a certain diſtance agreed on by the articles, or elſe to be whipped in by the tryers and judges who rode by; and whichever horſe could diſtance the other won the race. This ſort of racing was not long in common uſe; for it was found inhuman, and deſtructive to good horſes, when two ſuch were matched together. For in this caſe neither was able to diſtance the other till they were both ready to ſink under their riders; and often two very

good

good horſes were both ſpoiled, and the wagers forced to be drawn at laſt. The miſchief of this ſort of racing ſoon brought in the method now in uſe, of running only for a certain quantity of ground, and determining the plate or wager by the coming in firſt at the poſt.

Chasing of Gold, Silver, &c. See Enchasing.

CHASTE tree. See Vitex, Botany *Index*.

CHASTITY; Purity of the body, or freedom from obſcenity.—The Roman law juſtifies homicide in defence of the chaſtity either of one's ſelf or relations; and ſo alſo, according to Selden, ſtood the law in the Jewiſh republic. Our law likewiſe juſtifies a woman for killing a man who attempts to raviſh her. So the huſband or father may juſtify killing a man who attempts a rape upon his wife or daughter; but not if he takes them in adultery by conſent; for the one is forcible and felonious, but not the other.

Chaſtity is a virtue univerſally celebrated. There is indeed no charm in the female ſex that can ſupply its place. Without it, beauty is unlovely, and rank is contemptible; good breeding degenerates into wantonneſs, and wit into impudence. Out of the numerous inſtances of eminent chaſtity recorded by authors, the two following are ſelected on account of the leſſon afforded by the different modes of conduct which they exhibit.

Lucretia was a lady of great beauty and noble extraction; ſhe married Collatinus, a relation of Tarquinius Superbus king of Rome. During the ſiege of Ardea, which laſted much longer than was expected, the young princes paſſed their time in entertainments and diverſions. One day as they were at ſupper *, at Sextus Tarquin's the king's eldeſt ſon, with Collatinus, Lucretia's huſband, the converſation turned on the merit of their wives: every one gave his own the preference. "What ſignify ſo many words?" ſays Collatinus; "you may in a few hours, if you pleaſe, be convinced by your own eyes, how much my Lucretia excels the reſt. We are young: let us mount our horſes, and go and ſurpriſe them. Nothing can better decide our diſpute than the ſtate we ſhall find them in at a time, when moſt certainly they will not expect us." They were a little warmed with wine: "Come on, let us go," they all cried together. They quickly galloped to Rome, which was about twenty miles from Ardea, where they find the princeſſes, wives of the young Tarquins, ſurrounded with company, and every circumſtance of the higheſt mirth and pleaſure. From thence they rode to Collatia, where they ſaw Lucretia in a very different ſituation. With her maids about her, ſhe was at work in the inner part of her houſe, talking on the dangers to which her huſband was expoſed. The victory was adjudged to her unanimouſly. She received her gueſts with all poſſible politeneſs and civility. Lucretia's virtue, which ſhould have commanded reſpect, was the very thing which kindled in the breaſt of Sextus Tarquin a ſtrong and deteſtable paſſion. Within a few days he returned to Collatia; and upon the plauſible excuſe he made for his viſit, he was received with all the politeneſs due to a near relation, and the eldeſt ſon of a king. Watching the fitteſt opportunity; he declares the paſſion ſhe had excited at his laſt viſit, and employed the moſt tender entreaties, and all the artifices poſſible to touch a woman's heart; but all to no purpoſe. He then endeavoured to extort her compliance by the moſt terrible threatenings. It was in vain. She ſtill perſiſted in her reſolution; nor could ſhe be moved even by the fear of death. But when the monſter told her that he would firſt deſpatch her, and then having murdered a ſlave, would lay him by her ſide, after which he would ſpread a report, that having caught them in the act of adultery, he had puniſhed them as they deſerved; this ſeemed to ſhake her reſolution. She heſitated, not knowing which of theſe dreadful alternatives to take, whether, by conſenting to diſhonour the bed of her huſband, whom ſhe tenderly loved; or by refuſing, to die under the odious character of having proſtituted her perſon to the luſt of a ſlave. He ſaw the ſtruggle of her ſoul; and ſeizing the unlucky moment, obtained an inglorious conqueſt. Thus Lucretia's virtue, which had been proof againſt the fear of death, could not hold out againſt the fear of infamy. The young prince, having gratified his paſſion, returned home as in triumph. On the morrow, Lucretia overwhelmed with grief and deſpair, ſent early in the morning to deſire her father and her huſband to come to her and bring with them each a truſty friend, aſſuring them there was no time to loſe. They came with all ſpeed, the one accompanied with Valerius (ſo famous after under the name of Publicola), and the other with Brutus. The moment ſhe ſaw them come, ſhe could not command her tears; and when her huſband aſked her if all was well? "By no means," ſaid ſhe, "it cannot be well with a woman after ſhe has loſt her honour. Yes, Collatinus, thy bed has been defiled by a ſtranger: but my body only is polluted: my mind is innocent, as my death ſhall witneſs. Promiſe me only not to ſuffer the adulterer to go unpuniſhed: it is Sextus Tarquinius, who laſt night, a treacherous gueſt, or rather cruel foe, offered me violence, and reaped a joy fatal to me; but, if you are men, it will be ſtill more fatal to him." All promiſed to revenge her; and at the ſame time, tried to comfort her with repreſenting, "That the mind only ſins, not the body; and where the conſent is wanting, there can be no guilt." What Sextus deſerves," replies Lucretia, "I leave you to judge; but for me, though I declare myſelf innocent of the crime, I exempt not myſelf from puniſhment. No immodeſt woman ſhall plead Lucretia's example to outlive her diſhonour." Thus ſaying, ſhe plunged into her breaſt a dagger ſhe had concealed under her robe, and expired at their feet. Lucretia's tragical death hath been praiſed and extolled by Pagan writers, as the higheſt and moſt noble act of heroiſm. The Goſpel thinks not ſo: it is murder, even according to Lucretia's own principles, ſince ſhe puniſhed with death an innocent perſon, at leaſt acknowledged as ſuch by herſelf. She was ignorant that our life is not in our own power, but in his diſpoſal from whom we receive it. St Auſtin, who carefully examines, in his book *De Civitate Dei*, what we are to think of Lucretia's death, conſiders it not as a courageous action flowing from a true love of chaſtity, but as an infirmity of a woman too ſenſible of wordly fame and glory; and who, from a dread of appearing in the eyes of men an accomplice of the violence ſhe abhorred, and of a crime to which ſhe was entirely a ſtranger, commits a real crime upon herſelf voluntarily and deſignedly. But what cannot

[*] *Liv.* l. i. c. 56—60. *Dionyſ.* i. iv. p. 261—277. *Flor.* l. iii. 9.

be ſufficiently admired in this Roman lady, is her abhorrence of adultery, which ſhe ſeems to hold ſo deteſtable as not to bear the thoughts of it. In this ſenſe, ſhe is a noble example for all her ſex.

Chiomara, the wife of Ortiagon, a Gauliſh prince, was equally admirable for her beauty and chaſtity.

During the war between the Romans and the Gauls, A. R. 563, the latter were totally defeated on Mount Olympus. Chiomara, among many other ladies, was taken priſoner, and committed to the care of a centurion, no leſs paſſionate for money than women. He at firſt endeavoured to gain her conſent to his infamous deſires; but not being able to prevail upon her, and ſubvert her conſtancy, he thought he might employ force with a woman whom misfortune had reduced to ſlavery. Afterwards, to make her amends for that treatment, he offered to reſtore her liberty; but not without ranſom. He agreed with her for a certain ſum, and to conceal this deſign from the other Romans, he permitted her to ſend any of the priſoners ſhe ſhould chooſe to her relations, and aſſigned a place near the river where the lady ſhould be exchanged for gold. By accident there was one of her own ſlaves amongſt the priſoners. Upon him ſhe fixed; and the centurion ſoon after carried her beyond the advanced poſts, under cover of a dark night. The next evening two of the relations of the princeſs came to the place appointed, whither the centurion alſo carried his captive. When they had delivered him the Attic talent they had brought, which was the ſum they had agreed on, the lady, in her own language, ordered thoſe who came to receive her to draw their ſwords and kill the centurion, who was then amuſing himſelf with weighing the gold. Then, charmed with having revenged the injury done her chaſtity, ſhe took the head of the officer, which ſhe had cut off with her own hands, and hiding it under her robe, went to her huſband Ortiagon, who had returned home after the defeat of his troops. As ſoon as ſhe came into his preſence, ſhe threw the centurion's head at his feet. He was ſtrangely ſurpriſed at ſuch a ſight: and aſked her whoſe head it was, and what had induced her to do an act ſo uncommon to her ſex? With her face covered with a ſudden bluſh, and at the ſame time expreſſing her fierce indignation, ſhe declared the outrage which had been done her, and the revenge ſhe had taken for it. During the reſt of her life, ſhe ſtedfaſtly retained the ſame attachment for the purity of manners which conſtitutes the principal glory of the ſex, and nobly ſuſtained the honour of ſo glorious, bold, and heroic an action.—This lady was much more prudent than Lucretia, in revenging her injured honour by the death of her raviſher, rather than by her own. Plutarch relates this fact, in his treatiſe upon the virtue and great actions of women; and it is from him we have the name of this, which is well worthy of being tranſmitted to poſterity.

The above virtue in men is termed *continence.* See Continence.

CHATEAU-BRIANT, a town of France in Brittany, with an old caſtle. W. Long. 1. 20. N. Lat. 47. 40.

Chateau-Chinon, a town of France in Nivernois, and capital of Morvant, with a conſiderable manufacture of cloth. E. Long. 3. 48. N. Lat. 47. 2.

Chateau-Dauphin, a very ſtrong caſtle of Piedmont in Italy, and in the marquiſate of Saluces, belonging to the king of Sardinia. It was taken by the combined army of France and Spain in 1744, and was reſtored by the treaty of Aix-la-Chapelle.

Chateau-du-Loire, a town of France, in Maine, famous for ſuſtaining a ſiege of ſeven years againſt the Count of Mans. It is ſeated on the river Loire, in E. Long. 0. 25. N. Lat. 47. 40.

Chateau-Dun, an ancient town of France, and capital of the Dunois, with a caſtle and rich monaſtery; ſeated on an eminence near the river Loire, in E. Long. 1. 26. N. Lat. 48. 4.

Chateau-Neuf, the name of ſeveral towns of France, viz. one in Perche; another in Angumois, on the river Charente, near Angouleſme; a third in Berry, ſeated on the river Cher; and ſeveral other ſmall places.

Chateau-Portien, a town of France, in Champagne, and in a diſtrict called Portien, with a caſtle built on a rock, near the river Aiſne. E. Long. 4. 23. N. Lat. 49. 35.

Chateau-Renaud, a town of France, in the Gatenois, where clothes are made for the army, and where there is a trade in ſaffron. E. Long. 4. 25. N. Lat. 48. 0. This is alſo the name of a town of Touraine, in France, with the title of marquiſate. E. Long. 2. 41. N. Lat. 47. 22.

Chateau-Roux, a town of France, in Berry, with the title of a duchy. It has a cloth manufacture, and is ſeated in a very large pleaſant plain on the river Indre, in E. Long. 1. 47. N. Lat. 46. 49.

Chateau-Thiery, a town of France, in Champagne, with the title of a duchy, and a handſome caſtle on an eminence, ſeated on the river Maine, in E. Long. 3. 23. N. Lat. 49. 12.

Chateau-Vilain, a town of France, in Champagne, with a caſtle, and the title of a duchy; ſeated on the river Anjou. E. Long. 2. 59. N. Lat. 48. 0.

CHATEL, or Chate, a town of Lorraine, in the Voſque, ſeated on the river Moſelle, eight miles from Mirecourt.

Chatel-Allon, a maritime town of France, in Saintonge, five miles from Rochelle; formerly very conſiderable, but now greatly decayed.

Chatel-Chalon, a town of France, in Franche Comte, remarkable for its abbey of Benedictine nuns. E. Long. 5. 25. N. Lat. 46. 50.

CHATELET, a town of the Netherlands, in Namur, ſeated on the Sambre, in the biſhopric of Liege. E. Long. 4. 28. N. Lat. 50. 25.

Chatelet, the name of certain courts of juſtice eſtabliſhed in ſeveral cities in France. The grand chatelet at Paris is the place where the preſidial or ordinary court of juſtice of the provoſt of Paris is kept; conſiſting of a preſidial, a civil chamber, a criminal chamber, and a chamber of policy. The little chatelet is an old fort, now ſerving as a priſon.

CHATELLERAULT, a town of France, in Poitou, with the title of a duchy; ſeated in a fertile and pleaſant country, on the river Vienne, over which there is a handſome ſtone bridge. E. Long. 0. 40. N. Lat. 46. 34.

CHATHAM, a town of Kent, adjoining to Rocheſter, and ſeated on the river Medway. It is the principal

principal ſtation of the royal navy ; and the yards and magazines are furniſhed with all kinds of naval ſtores, as well as materials for building and rigging the largeſt men of war. The entrance into the river Medway is defended by Sheerneſs and other forts ; notwithſtanding which, the Dutch fleet burnt ſeveral ſhips of war here in the reign of Charles II. after the peace of Breda had been agreed upon. In the year 1757, by direction of the duke of Cumberland, ſeveral additional fortifications were begun at Chatham ; ſo that now the ſhips are in no danger of an inſult either by land or water. It has a church, a chapel of eaſe, and a ſhip uſed as a church for the ſailors. It has likewiſe about 500 houſes, moſtly low, and built with brick ; the ſtreets are narrow, and paved ; and it contains about 3000 inhabitants. The principal employment of the labouring hands is ſhip-building in the king's yard and private docks. This town gave title of earl to that great ſtateſman William Pitt in the reigns of George II. and III. E. Long. 0. 40. N. Lat. 51. 20.

CHATIGAN, a town of Aſia, in the kingdom of Bengal, on the moſt eaſterly branch of the river Ganges. It is but a poor place, though it was the firſt the Portugueſe ſettled at in theſe parts, and who ſtill keep a ſort of poſſeſſion. It has but a few cotton manufactures ; but affords the beſt timber for building of any place about it. The inhabitants are ſo ſuſpicious of each other, that they always go armed with a ſword, piſtol, and blunderbuſs, not excepting the prieſts. It is ſubject to the Great Mogul. E. Long. 91. 10. N. Lat. 23. 0.

CHATILLON sur Seine, a town of France, in Burgundy, divided into two by the river Seine. It is 32 miles from Langres, and 40 from Dijon ; and has iron works in its neighbourhood. E. Long. 4. 33. N. Lat. 47. 45.

CHATRE, a town of France, in Berry, ſeated on the river Indre, 37 miles from Bourges. It carries on a conſiderable trade in cattle. E. Long. 1. 55. N. Lat. 46. 35.

CHATTELS, a Norman term, under which were anciently comprehended all moveable goods ; thoſe immoveable being termed *fief* or *fee*.

Chattels, in the modern ſenſe of the word, are all ſorts of goods, moveable or immoveable, except ſuch as are in the nature of freehold.

CHATERER. See Ampelis, Ornithology *Index*.

CHATTERTON, Thomas, a late unfortunate poet, whoſe fate and performances have excited in no ſmall degree the public attention, as well as given riſe to much literary controverſy. He was born at Briſtol, Nov. 20. 1752 ; and educated at a charity ſchool on St Auguſtine's Back, where nothing more was taught than reading, writing, and accounts. At 14 years of age, he was articled clerk to an attorney at Briſtol, with whom he continued about three years ; yet, though his education was thus confined, he diſcovered an early turn towards poetry and Engliſh antiquities, and particularly towards heraldry. How ſoon he began to be an author is not known. In the Town and Country Magazine for March 1769, are two letters, probably from him, as they are dated from Briſtol, and ſubſcribed with his uſual ſignature, D. B. that is, *Dunhelmus Briſtolienſis*. The former contains ſhort extracts from two MSS. "written 300 years ago by one Rowley a monk," concerning dreſs in the age of Henry II. ; the latter, "Ethelgar, a Saxon poem," in bombaſt proſe. In the ſame magazine for May 1769, are three communications from Briſtol, with the ſame ſignature D. B. one of them entitled "Obſervations upon Saxon Heraldry, with drawings of Saxon Achievements ;" and in the ſubſequent months of 1769 and 1770, there are ſeveral other pieces in the ſame magazine, which are undoubtedly of his compoſition.

In April 1770, he left Briſtol, diſguſted with his profeſſion, and irreconcilable to the line of life in which he was placed ; and coming to London in hopes of advancing his fortune by his pen, he ſunk at once from the ſublimity of his views to an abſolute dependence on the patronage of bookſellers. Things, however, ſeem ſoon to have brightened up a little with him ; for, May 14. he writes to his mother, in high ſpirits, upon the change of his ſituation, with the following ſarcaſtic reflection upon his former patrons at Briſtol. "As to Mr ——, Mr ——, Mr ——, &c, &c. they rate literary lumber ſo low, that I believe an author, in their eſtimation, muſt be poor indeed : but here matters are otherwiſe. Had Rowley been a Londoner inſtead of a Briſtowyan, I could have lived by copying his works." In a letter to his ſiſter, May 30. he informs her that he is to be employed in writing a voluminous Hiſtory of London, to appear in numbers the beginning of next winter. Meanwhile, he had written ſomething in praiſe of Beckford, then lord mayor, which had procured him the honour of being preſented to his lordſhip ; and, in the letter juſt mentioned, he gives the following account of his reception, with certain obſervations upon political writing. "The lord mayor received me as politely as a citizen could : but the devil of the matter is, there is no money to be got on this ſide of the queſtion.—However, he is a poor author who cannot write on both ſides.—Eſſays on the patriotic ſide will fetch no more than what the copy is ſold for. As the patriots themſelves are ſearching for places, they have no gratuity to ſpare.—On the other hand, unpopular eſſays will not even be accepted, and you muſt pay to have them printed ; but then you ſeldom loſe by it, as courtiers are ſo ſenſible of their deficiency in merit, that they generouſly reward all who know how to daub them with the appearance of it."

He continued to write inceſſantly in various periodical publications. July 11th, he tells his ſiſter that he had pieces laſt month in ſeveral magazines ; in The Goſpel Magazine, The Town and Country, The Court and City, The London, the Political Regiſter, &c. But all theſe exertions of his genius brought in ſo little profit, that he was ſoon reduced to the extremeſt indigence ; ſo that at laſt, oppreſſed with poverty and diſeaſe, in a fit of deſpair he put an end to his exiſtence, Auguſt 1770, with a doſe of poiſon. This unfortunate perſon, though certainly a moſt extraordinary genius, ſeems yet to have been a moſt ungracious compoſition. He was violent and impetuous to a ſtrange degree. From the firſt of the above cited letters he ſeems to have had a portion of ill humour and ſpleen more than enough for a lad of 17 ; and the editor of his

his Miſcellanies records, "that he poſſeſſed all the vices and irregularities of youth, and that his profligacy was at leaſt as conſpicuous as his abilities."

In 1777 were publiſhed in one volume 8vo, "Poems, ſuppoſed to have been written at Briſtol, by Thomas Rowley and others, in the 15th century: the greateſt part now firſt publiſhed from the moſt authentic copies, with an engraved ſpecimen of one of the MSS. To which are added, a Preface, an introductory Account of the ſeveral Pieces, and a Gloſſary." And in 1778, were publiſhed, in one volume 8vo, "Miſcellanies in Proſe and Verſe by Thomas Chatterton, the ſuppoſed author of the Poems publiſhed under the names of Rowley, &c."

Of Rowley's poems, we have the following account in the preface, given in the words of Mr George Catcot of Briſtol, to whom, it is ſaid, the public is indebted for them. "The firſt diſcovery of certain MSS. having been depoſited in Redclift church above three centuries ago, was made in the year 1768, at the time of opening the new bridge at Briſtol; and was owing to a publication in Farley's Weekly Journal, Oct. 1ſt, containing an account of the ceremonies obſerved at the opening of the old bridge, taken, as it was ſaid, from a very ancient MS. This excited the curioſity of ſome perſons to inquire after the original. The printer, Mr Farley, could give no account of it, or of the perſon who brought the copy; but, after much inquiry, it was diſcovered that this perſon was a youth between 15 and 16 years of age, whoſe name was Thomas Chatterton, and whoſe family had been ſextons of Redclift church for near 150 years. His father, who was now dead, had alſo been maſter of the free ſchool in Pile ſtreet. The young man was at firſt very unwilling to diſcover from whence he had the original: but, after many promiſes made to him, was at laſt prevailed on to acknowledge that he had received this, together with many other MSS. from his father, who had found them in a large cheſt in an upper room over the chapel, on the north ſide of Redclift church." It is added, that ſoon after this Mr Catcot commenced an acquaintance with Chatterton, and partly as preſents, partly as purchaſes, procured from him copies of many of his MSS. in proſe and verſe; as other copies were diſpoſed of in like manner to others. It is concluded, however, that whatever may have been Chatterton's part in this very extraordinary tranſaction, whether he was the author, or only (as he conſtantly aſſerted) the copier of all theſe productions, he appears to have kept the ſecret entirely to himſelf, and not to have put it in any one's power to bear certain teſtimony either of his fraud or of his veracity.

This affair, however, hath ſince become the foundation of a mighty controverſy among the critics, which hath yet ſcarcely ſubſided. The poems in queſtion, publiſhed in 1777, were republiſhed in 1778, with an "Appendix, containing ſome obſervations upon their language; tending to prove that they were written, not by any ancient author, but entirely by Chatterton." Mr Warton, in the third volume of his Hiſtory of Engliſh Poetry, hath eſpouſed the ſame ſide of the queſtion. Mr Walpole alſo obliged the world with a Letter on Chatterton, from his preſs at Strawberry hill. On the other hand have appeared, "Obſervations" upon theſe poems, "in which their authenticity is aſcertained," by Jacob Bryant, Eſq; 1781, 2 vols. 8vo.; and another edition of the "Poems, with a Comment, in which their antiquity is conſidered and defended, by Jeremiah Milles, D. D. dean of Exeter, 1782," 4to. In anſwer to theſe two works, we have had three pamphlets: 1. "Curſory Obſervations on the Poems, and Remarks on the Commentaries of Mr Bryant and Dr Milles; with a ſalutary propoſal addreſſed to the friends of thoſe gentlemen." 2. "An Archæological Epiſtle to Dean Milles, editor of a ſuperb edition of Rowley's Poems, &c." 3. "An Inquiry into the authenticity of the Poems attributed to Thomas Rowley, in which the Arguments of the deans of Exeter and Mr Bryant are examined, by Thomas Warton;" and other pieces in the public prints and magazines: All preparatory to the complete ſettlement of the buſineſs in "A Vindication of the Appendix to the Poems called Rowley's, in reply to the Anſwers of the dean of Exeter, Jacob Bryant, Eſq; and a third Anonymous Writer; with ſome further Obſervations upon thoſe Poems, and an Examination of the Evidence which has been produced in ſupport of their Authenticity. By Thomas Tyrwhitt, 1782," 8vo.

CHAUCER, Sir Geofrey, an eminent Engliſh poet in the 14th century, born at London in 1328. After he left the univerſity, he travelled into Holland, France, and other countries. Upon his return he entered himſelf in the Inner Temple, where he ſtudied the municipal laws of England. His firſt ſtation at court was page to Edward III. and he had a penſion granted him by that prince till he could otherwiſe provide for him. Soon after we find him gentleman of the king's privy chamber; next year, ſhield-bearer to the king. Eſteemed and honoured, he ſpent his younger days in a conſtant attendance at court, or for the moſt part living near it, in a ſquare ſtone houſe near the park-gate at Woodſtock, ſtill called *Chaucer's Houſe*.

Soon after, having got the duke of Lancaſter for his patron, Chaucer began every day to riſe in greatneſs. In 1373, he was ſent with other perſons to the republic of Genoa to hire ſhips for the king's navy (our want of ſhipping in thoſe times being uſually ſupplied by ſuch means); and the king was ſo well ſatisfied with his negotiation, that, on his return, he obtained a grant of a pitcher of wine daily in the port of London, to be delivered by the butler of England; and ſoon after was made comptroller of the cuſtoms for wool, wool fells, and hides; an office which he diſcharged with great diligence and integrity. At this period, Chaucer's income was about 1000l. a-year; a ſum which in thoſe days might well enable him to live, as he ſays he did, with dignity in office, and hoſpitality among his friends. It was in this meridian blaze of proſperity, in perfect health of body and peace of mind, that he wrote his moſt humorous poems. His ſatires againſt the prieſts were probably written to oblige his patron the duke of Lancaſter, who favoured the cauſe of Wickliff, and endeavoured to expoſe the clergy to the indignation of the people. In the laſt year of Edward III. our poet was employed in a commiſſion to treat with the French; and in the beginning of King Richard's reign, he was in ſome degree of favour at court.

The duke of Lancaſter at laſt finding his views checked, began to abandon Wickliff's party: upon which

which Chaucer likewiſe, how much ſoever he had eſpouſed that divine's opinions, thought it prudent to conceal them more than he had done. With the duke's intereſt that of Chaucer entirely ſunk; and the former paſſing over ſea, his friends felt all the malice of the oppoſite party. Theſe misfortunes occaſioned his writing that excellent treatiſe, *The Teſtament of Love* in imitation of Boethius on the Conſolation of Philoſophy. Being much reduced, he retired to Woodſtock, to comfort himſelf with ſtudy, which produced his admirable treatiſe of the *Aſtrolabe*.

The duke of Lancaſter at laſt ſurmounting his troubles, married Lady Catharine Swynford, ſiſter to Chaucer's wife; ſo that Thomas Chaucer, our poet's ſon, became allied to moſt of the nobility, and to ſeveral of the kings of England. Now the ſun began to ſhine upon Chaucer with an evening ray; for by the influence of the duke's marriage, he again grew to a conſiderable ſhare of wealth. But being now 70, he retired to Dunnington caſtle near Newbury. He had not enjoyed this retirement long before Henry IV. ſon of the duke of Lancaſter, aſſumed the crown, and in the firſt year of his reign gave our poet marks of his favour. But however pleaſing the change of affairs might be to him at firſt, he afterwards found no ſmall inconveniences from it. The meaſures and grants of the late king were annulled: and Chaucer, in order to procure freſh grants of his penſions, left his retirement, and applied to court: where, though he gained a confirmation of ſome grants, yet the fatigue of attendance, and his great age, prevented him from enjoying them. He fell ſick at London: and ended his days in the 72d year of his age, leaving the world as though he deſpiſed it, as appears from his ſong of *Flie from the Preſe*. The year before his death he had the happineſs, if at his time of life it might be ſo called, to ſee the ſon of his brother-in-law (Hen. IV.) ſeated on the throne. He was interred in Weſtminſter abbey; and in 1556, Mr Nicholas Bingham, a gentleman of Oxford, at his own charge, erected a handſome monument for him there. Caxton firſt printed the Canterbury Tales; but his works were firſt collected and publiſhed in one volume folio, by William Thynne, London, 1542. They were afterwards reprinted in 1561, 1598, 1602. Oxford, 1721.

Chaucer was not only the firſt, but one of the beſt poets which theſe kingdoms ever produced. He was equally great in every ſpecies of poetry which he attempted; and his poems in general poſſeſs every kind of excellence, even to a modern reader, except melody and accuracy of meaſure; defects which are to be attributed to the imperfect ſtate of our language, and the infancy of the art in this kingdom at the time when he wrote. "As he is the father of Engliſh poetry (ſays Mr Dryden) ſo I hold him in the ſame degree of veneration as the Grecians did Homer, or the Romans Virgil. He is a perpetual fountain of good ſenſe, learned in all ſciences, and therefore ſpeaks properly on all ſubjects. As he knew what to ſay, ſo he knows alſo when to leave off; a continence which is practiſed by few writers, and ſcarcely by any of the ancients, except Virgil and Horace." This character Chaucer certainly deſerved. He had read a great deal; and was a man of the world, and of ſound judgment. He was the firſt Engliſh poet who wrote *poetically*, as Dr Johnſon obſerves in the preface to his Dictionary, and (he might have added) who wrote like a gentleman. He had alſo the merit of improving our language conſiderably, by the introduction and naturalization of words from the Provençal, at that time the moſt poliſhed dialect in Europe.

CHALCIS, in *Ancient Geography*, the country of the Chauci, a people of Germany: divided into the *Minores*, now *Eaſt Frieſland*, and the county of *Oldenburg*; and into the *Majores*, now the duchy of *Bremen* and a part of *Lunenburg*.

CHAUD MEDLEY, in *Law*, is of much the ſame import with *CHANCE Medley*. The former in its etymology ſignifies an affray in the heat of blood or paſſion: the latter, a caſual affray. The latter is in common ſpeech too often erroneouſly applied to any manner of homicide by miſadventure; whereas it appears by the ſtat. 24 Hen. VIII. c. 5. and ancient books (Standf. P. C. 16.), that it is properly applied to ſuch killing as happens in ſelf-defence upon ſudden encounter.

CHAL, a town of the Eaſt Indies, on the coaſt of Malabar, in the province of Blagana, and kingdom of Viſapour. Its river affords a good harbour for ſmall veſſels. The town is fortified, and ſo is the iſland on the ſouth ſide of the harbour. It had formerly a good trade, but is now miſerably poor. It was taken by the Portugueſe in 1507, to whom it ſtill belongs. It is 15 miles ſouth of Bombay, and five miles from the ſea. E. Long. 72. 45. N. Lat. 18. 30.

CHAULIEU, WILLIAM AMFRYEDE, Abbé d'Amale, one of the moſt polite and ingenious of the French poets, was born in 1639, and died at the age of 84. The moſt complete edition of his poems is that printed in two vols. 8vo. in 1733.

CHAUMONT, a town of France, in Champagne, and in the diſtrict of Baſſigni, of which it is the capital. It is ſeated on a mountain near the river Marne. E. Long. 5. 15. N. Lat. 48. 6.

CHAUNE, a town of France, in Picardy, and in the diſtrict of Sanſterre, with the title of a duchy. E. Long. 2. 55. N. Lat. 49. 45.

CHAUNTRY. See CHANTRY.

CHAUNY, a town of France, in Picardy, ſeated on the river Oiſe, in Chantry. E. Long. 3. 17. N. Lat. 49. 37.

CHAUVIN, STEPHEN, a celebrated miniſter of the reformed religion, born at Niſmes, left France at the revocation of the edict of Nantz, and retired to Rotterdam, where he began a new *Journal des Sçavans*; and afterwards removing to Berlin, continued it there three years. At this laſt place, he was made profeſſor of philoſophy, and diſcharged that office with much honour and reputation. His principal work is a philoſophical dictionary, in Latin, which he publiſhed at Rotterdam in 1692; and gave a new edition of it much augmented, at Lewarden, in 1703, folio. He died in 1725, aged 85.

CHAVEZ, a ſtrong town of Tralos-Montes in Portugal, ſeated at the foot of a mountain on the river Tamega. It has two ſuburbs, and as many forts; one of which looks like a citadel. Between the town and ſuburb of Magdalena, is an old Roman ſtone bridge about 92 geometrical paces long. W. Long. 7. 1. N. Lat. 41. 45.

CHAZELLES, Joan Matthew, a celebrated French mathematician and engineer, was born at Lyons in 1657. M. du Hamel, with whom he got acquainted, finding his genius incline towards aſtronomy, preſented him to M. Caſſini, who employed him in his obſervatory. In 1684, the duke of Mortemar made uſe of Chazelles to teach him mathematics; and, the year after, procured him the preferment of hydrography profeſſor for the galleys of Marſeilles, where he ſet up a ſchool for young pilots deſigning to ſerve abroad the galleys. In 1686, the galleys made four little campaigns, or rather four courſes, purely for exerciſe. Chazelles went on board every time with them: kept his ſchool upon the ſea, and ſhowed the practice of what he taught. In the years 1687 and 1688, he made two other ſea campaigns, in which he drew a great many plans of ports, roads, towns, and forts, which were lodged with the miniſters of ſtate. At the beginning of the war, which ended with the peace of Ryſwick, ſome marine officers, and Chazelles among the reſt, fancied the galleys might be ſo contrived as to live upon the ocean; that they might ſerve to tow the men of war when the wind failed or proved contrary, and alſo help to ſecure the coaſt of France upon the ocean. Chazelles was ſent to the weſt coaſts in July 1689, to examine the practicableneſs of this ſcheme; and in 1690, fifteen galleys new built ſet ſail from Rochefort, and cruiſed as far as Torbay, in England, and proved ſerviceable at the deſcent upon Tinmouth. After this, he digeſted into order the obſervations he had made on the coaſts of the ocean; and drew diſtinct maps, with a portulan to them, viz. a large deſcription of every haven, of the depth, the tides, the dangers and advantages diſcovered, &c. Theſe maps were inſerted in the *Neptune Françoiſe*, publiſhed in 1692, in which year Chazelles was engineer at the deſcent at Oneille. In 1693, Monſieur de Pontchartrain, then ſecretary of ſtate for the marine, and afterwards chancellor of France, reſolved to get the *Neptune Françoiſe* carried on to a ſecond volume, which was alſo to take in the Mediterranean. Chazelles deſired that he might have a year's voyage on this ſea, for making aſtronomical obſervations; and the requeſt being granted, he paſſed by Greece, Egypt, and the other parts of Turkey, with his quadrant and teleſcope in his hand. When he was in Egypt, he meaſured the pyramids: and finding the ſides of the largeſt preciſely facing the four cardinal points, naturally concluded this poſition to have been intended, and alſo that the poles of the earth and meridians had not ſince deviated. Chazelles likewiſe made a report of his voyage in the Levant, and gave the academy all the ſatisfaction they wanted concerning the poſition of Alexandria: upon which he was made a member of the academy in 1695. He died in 1710.

CHAZINZARIANS, a ſect of heretics who roſe in Armenia in the ſeventh century. The word is formed of the Armenian *chazus*, "croſs." They are alſo called *ſtaurolatræ*, which in Greek ſignifies the ſame as *Chazinzarians* in Armenian, viz. *adorers of the croſs*; they being charged with paying adoration to the croſs alone. In other reſpects they were Neſtorians; and admitted two perſons in Jeſus Chriſt. Nicephorus aſcribes other ſingularities to them; particularly their holding an annual feaſt in memory of the dog of their falſe prophet Sergius, which they called *artzibartzes*.

CHESAPEAK bay, in North America, the entrance between Cape Henry and Cape Charles, running up 300 miles between Virginia and Maryland. It is navigable almoſt all the way for large ſhips, and has ſeveral navigable rivers that fall into it, by means of which ſhips go up to the very doors of the planters, to take in their lading of goods.—Here was a ſea engagement in 1781 between the Britiſh fleet under Admiral Graves conſiſting of 19 ſhips of the line, and the French fleet of 24 line-of-battle ſhips under the Count de Graſſe, which ended in the Count's keeping poſſeſſion of the bay, by which Lord Cornwallis and his whole army were made priſoners of war at York-town, being inveſted both by ſea and land by very ſuperior numbers.

CHEATS, are deceitful practices in defrauding, or endeavouring to defraud, another of his known right, by means of ſome artful device, contrary to the plain rules of common honeſty: as by playing with falſe dice, or by cauſing an illiterate perſon to execute a deed to his prejudice, by reading it over to him in words different from thoſe in which it was written, &c.—If any perſon deceitfully get into his hands or poſſeſſion any money or other things of any other perſon's, by colour of any falſe token, &c. being convicted, he ſhall have ſuch puniſhment by impriſonment, ſetting upon the pillory, or by any corporeal pain except pains of death, as ſhall be adjudged by the perſons before whom he ſhall be convicted.—As there are frauds which may be relieved civilly, and not puniſhed criminally; ſo there are other frauds which in a ſpecial caſe may not be helped civilly, and yet ſhall be puniſhed criminally. Thus, if a minor goes about the town, and, pretending to be of age, defrauds many perſons by taking credit for a conſiderable quantity of goods, and then inſiſting on his nonage, the perſons injured cannot recover the value of their goods, but they may indict and puniſh him for a common cheat. Perſons convicted of obtaining money or goods by falſe pretences, or of ſending threatening letters in order to extort money or goods, may be puniſhed with fine or impriſonment, or by pillory, whipping, or tranſportation.

CHEBRECHIN, a town of Poland, in the province of Ruſſia and palatinate of Belſkow. It is ſeated on the declivity of a hill, and the river Wierpi waters its walls, and afterwards falls into the river Bog. The Jews there are very rich. E. Long. 23. 51. N. Lat. 50. 35.

CHECAYA, in Turkiſh affairs, the ſecond officer of the janizaries, who commands them under the aga, and is otherwiſe called *protogero*.

There is alſo a checaya of the treaſury, ſtables, kitchen, &c. the word ſignifying as much as lieutenant, or the ſecond in any office.

CHECK, or *Check-Roll*, a roll or book, wherein are contained the names of ſuch perſons as are attendants and in the pay of the king, or other great perſonages, as their houſehold ſervants.

Clerk of the Check *in the king's houſehold*, has the check and controlment of the yeomen of the guard, and all the uſhers belonging to the royal family, allowing their abſence or defects in attendance, or dimi-

niſhing

niſhing their wages for the ſame, &c. He alſo, by himſelf or deputy, takes the view of thoſe who are to watch in the court, and has the ſetting of the watch, &c.

Clerk of the Check *in the royal dock yards*, an officer who keeps a muſter or regiſter of all the men employed aboard his majeſty's ſhips and veſſels, and alſo of all the artificers and others in the ſervice of the navy at the port where he is ſettled.

Check, in falconry, a term uſed of a hawk, when ſhe forſakes her proper game, to fly at pies, crows, rooks, or the like, that croſs her in her flight.

CHECKY, in *Heraldry*, is when the ſhield, or a bordure, &c. is chequered, or divided into chequers or ſquares, in the manner of a cheſsboard.

This is one of the moſt noble and moſt ancient figures uſed in armoury; and a certain author ſaith, that it ought to be given to none but great warriors, in token of their bravery; for the cheſsboard repreſents a field of battle; and the pawns placed on both ſides repreſent the ſoldiers of the two armies, which move, attack, advance, or retire, according to the will of the gameſters, who are the generals.

This figure is always compoſed of metal and colour. But ſome authors would have it reckoned among the ſeveral ſorts of furs.

CHEEK, in *Anatomy*, that part of the face ſituated below the eyes on each ſide.

Cheeks, a general name among mechanics, for almoſt all thoſe pieces of their machines and inſtruments that are double and perfectly alike. Thus, the cheeks of a printing preſs are its two principal pieces: they are placed perpendicular, and parallel to each other; ſerving to ſuſtain the three ſommers, viz. the head, ſhelves, and winter, which bear the ſpindle, and other parts of the machine. See *Printing Preſs*.

The *cheeks of a turner's lathe*, are two long pieces of wood, between which are placed the puppets, which are either pointed or otherwiſe, ſerving to ſupport the work and the mandrils of the workman. Theſe two pieces are placed parallel to the horizon, ſeparated from one another by the thickneſs of the tail of the puppets, and joined with tenons to two other pieces of wood placed perpendicularly, called the *legs of the lathe*.

Cheeks of the glazier's vice, are two pieces of iron joined parallel at top and bottom; in which are the axles, or ſpindles, little wheel, cuſhions, &c. whereof the machine is compoſed.

The cheeks of a mortar, or the *brackets*, in artillery, are made of ſtrong planks of wood, bound with thick plates of iron, and are fixed to the bed by four bolts; they riſe on each ſide of the mortar, and ſerve to keep her at what elevation is given her, by the help of ſtrong bolts of iron which go through both cheeks, both under and behind the mortar, betwixt which are driven quoins of wood; theſe bolts are called the *bracket bolts*, and the bolts which are put one in each end of the bed, are the traverſe bolts, becauſe with handſpikes the mortar is by theſe traverſed to the right or left.

Cheeks, in *Ship-building*, are two pieces of timber, fitted on each ſide of the maſt at the top, ſerving to ſtrengthen the maſts there. The uppermoſt bail or piece of timber in the beak of a ſhip is called the *cheek*. The knees which faſten the beak head to the ſhip are called *cheeks;* and the ſides of any block, or the ſides of a ſhip's carriage of a gun, are alſo called *cheeks*.

CHEESE, a ſort of food prepared of curdled milk purged from the ſerum or whey, and afterwards dried for uſe.

Cheeſe differs in quality according as it is made from new or ſkimmed milk, from the curd which ſeparates ſpontaneouſly upon ſtanding, or that which is more ſpeedily produced by the addition of runnet. Cream alſo affords a kind of cheeſe, but quite fat and butyraceous, and which does not keep long. Analyzed chemically, cheeſe appears to partake much more of an animal nature than butter. It is inſoluble in every liquid except ſpirit of nitre, and cauſtic alkaline ley. Shaved thin, and properly treated with hot water, it forms a very ſtrong cement if mixed with quicklime *. When prepared with the hot water, it is recommended in the Swediſh Memoirs to be uſed by anglers as a bait; it may be made into any form, is not ſoftened by the cold water, and the fiſhes are fond of it.—As a food, phyſicians condemn the too free uſe of cheeſe. When new, it is extremely difficult of digeſtion: when old, it becomes acrid and hot; and, from Dr Percival's experiments, is evidently of a ſeptic nature. It is a common opinion that old cheeſe digeſts every thing, yet is left undigeſted itſelf; but this is without any ſolid foundation. Cheeſe made from the milk of ſheep digeſts ſooner than that from the milk of cows, but is leſs nouriſhing; that from the milk of goats digeſts ſooner than either, but is alſo the leaſt nouriſhing. In general, it is a kind of food fit only for the laborious, or thoſe whoſe organs of digeſtion are ſtrong.

Every country has places noted for this commodity: thus Cheſhire and Glouceſter cheeſe are famous in England; and the Parmeſan cheeſe is in no leſs repute abroad, eſpecially in France. This ſort of cheeſe is entirely made of ſweet cow milk: but at Rochefort in Languedoc, they make it of ewes milk; and in other places it is uſual to add goat or ewes milk in a certain proportion to that of the cow. There is likewiſe a kind of medicated cheeſe made by intimately mixing the expreſſed juice of certain herbs, as ſage, baum, mint, &c. with the curd before it is faſhioned into a cheeſe.—The Laplanders make a ſort of cheeſe of the milk of their rein deer; which is not only of great ſervice to them as food, but on many other occaſions. It is a very common thing in theſe climates to have a limb numbed and frozen with the cold: their remedy for this is the heating an iron red hot, and thruſting it through the middle of one of theſe cheeſes; they catch what drops out, and with this anoint the limb, which ſoon recovers. They are ſubject alſo to coughs and diſeaſes of the lungs, and theſe they cure by the ſame ſort of medicine: they boil a large quantity of the cheeſe in the freſh deer's milk, and drink the decoction in large draughts warm ſeveral times a-day. They make a leſs ſtrong decoction of the ſame kind alſo, which they uſe as their common drink, for three or four days together, at ſeveral times of the year. For an account of the different proceſſes for making cheeſe, ſee Cheese, Agriculture *Index*.

Cheese-Rennet. See Galium and Runnet.

---

* See *Cement*.

CHEGOE, or Nigua, the Indian name of an inſect common in Mexico, and alſo found in other hot countries where it is called *pique*, is an exceeding ſmall animal, not very unlike a flea, and is bred in the duſt. It fixes upon the feet, and breaking inſenſibly the cuticle, it neſtles betwixt that and the true ſkin, which alſo, unleſs it is immediately taken out, it breaks, and pierces at laſt to the fleſh, multiplying with a rapidity almoſt incredible. It is ſeldom diſcovered until it pierces the true ſkin, when it cauſes an intolerable itching. Theſe inſects, with their aſtoniſhing multiplication, would ſoon depopulate thoſe countries, were it leſs eaſy to avoid them, or were the inhabitants leſs dexterous in getting them out before they begin to ſpread. On the other hand, nature, in order to leſſen the evil, has not only denied them wings, but even that conformation of the legs and thoſe ſtrong muſcles which are given to the flea for leaping. The poor, however, who are in ſome meaſure doomed to live in the duſt, and to an habitual neglect of their perſons, ſuffer theſe inſects ſometimes to multiply ſo far as to make large holes in their fleſh, and even to occaſion dangerous wounds.

CHEIRANTHUS, stock-gilliflower, or *Wall-flower*. See Botany *Index*.

CHEKAO, in *Natural Hiſtory*, the name of an earth found in many parts of the Eaſt Indies, and ſometimes uſed by the Chineſe in their porcelain manufactures. It is a hard and ſtony earth; and the manner of uſing it is this: they firſt calcine it in an open furnace, and then beat it to a fine powder. This powder they mix with large quantities of water: then ſtirring the whole together, they let the coarſer part ſubſide; and pouring off the reſt yet thick as cream, they leave it to ſettle, and uſe the matter which is found at the bottom in form of a ſoft paſte, and will retain that humidity a long time. This ſupplies the place of the earth called *hoache*, in the making of that elegant ſort of china-ware which is all white, and has flowers which ſeem formed by a mere vapour within its ſurface. The manner of their uſing it is this: they firſt make the veſſel of the common matter of the manufacture; when this is almoſt dry, they paint upon it the flowers, or whatever other figures they pleaſe, with a pencil dipt in this preparation of the chekao; when this is thoroughly dry, they cover the whole veſſel with the varniſh in the common way, and bake it as uſual. The conſequence is, that the whole is white: but the body of the veſſel, the figures, and the varniſh, being three different ſubſtances, each has its own particular white; and the flowers being painted in the fineſt white of all, are diſtinctly ſeen through the varniſh upon the veſſel, and ſeem as if traced by a vapour only. The hoache does this as well as the chekao; and has beſides this the quality of ſerving for making the porcelain ware either alone, or in the place of kaolin: the chekao has not this property, nor any other ſubſtance beſides this hoache, which appears to be the ſame with our ſteatites or ſoap-rock.

CHEKE, Sir John, a celebrated ſtateſman, grammarian, and divine, of an ancient family in the iſle of Wight, was born at Cambridge in the year 1514, and educated at St John's college in that univerſity; where, after taking his degrees in arts, he was firſt choſen Greek lecturer, and in 1540 profeſſor of that language, with a ſtipend of 40l. a-year. In this ſtation he was principally inſtrumental in reforming the pronunciation of the Greek language, which, having been much neglected, was imperfectly underſtood. About the year 1543 he was incorporated maſter of arts at Oxford, where, we are told, he had ſtudied for ſome time. In the following year he was ſent to the court of King Henry VIII. and appointed tutor for the Latin language, jointly with Sir Anthony Cooke, to Prince Edward, about which time he was made canon of the college newly founded in Oxford: wherefore he muſt have now been in orders. On the acceſſion of his royal pupil to the crown, Mr Cheke was firſt rewarded with a penſion of 100 merks, and afterwards obtained ſeveral conſiderable grants from the crown. In 1550 he was made chief gentleman of the privy-chamber, and was knighted the following year; in 1552, chamberlain of the exchequer for life; in 1553, clerk of the council; and ſoon after ſecretary of ſtate and privy-councillor. But theſe honours were of ſhort duration. Having concurred in the meaſures of the duke of Northumberland for ſettling the crown on the unfortunate Jane Grey, and acted as her ſecretary during the nine days of her reign, on the acceſſion of Queen Mary, Sir John Cheke was ſent to the tower, and ſtript of the greateſt part of his poſſeſſions. In September 1554 he obtained his liberty, and a licenſe from her majeſty to travel abroad. He went firſt to Baſil, thence to Italy, and afterwards returned to Straſburg, where he was reduced to the neceſſity of reading Greek lectures for ſubſiſtence. In 1556 he ſet out in an evil hour to meet his wife at Bruſſels: but, before he reached that city, he was ſeized by order of King Philip II. hoodwinked, and thrown into a waggon; and thus ignominiouſly conducted to a ſhip, which brought him to the tower of London. He ſoon found that religion was the cauſe of his impriſonment; for he was immediately viſited by two Romiſh prieſts, who piouſly endeavoured to convert him, but without ſucceſs. However, he was at laſt viſited by Fleckenham; who told him from the queen, that he muſt either comply or burn. This powerful argument had the deſired effect; and Sir John Cheke accordingly complied in form, and his lands, upon certain conditions, were reſtored; but his remorſe ſoon put an end to his life. He died in September 1557, at the houſe of his friend Mr Peter Oſborne in Wood-ſtreet, London, and was buried in St Alban's church. He left three ſons, the eldeſt of whom, Henry, was knighted by Queen Elizabeth. He wrote 1. A Latin tranſlation of two of St Chryſoſtom's homilies. Lond. 1543, 4to. 2. The Hurt of Sedition. Lond. 1549, 1576, 1641. 3. Latin Tranſlation of the Engliſh Communion Service. Printed among Bucer's opuſcula. 4. *De pronunciatione Græcæ.* Baſil, 1555, 8vo. 5. Several letters publiſhed in his life by Strype; and a great number of other books.

CHE-KYANG, or Tche-kiang, a maritime province of China, and one of the moſt conſiderable in the empire; is bounded on the ſouth by Fo-kien; on the north and weſt by Kiang-nan and Kiangſi; and on the eaſt by the ſea. The air is pure and healthful, and the ſoil fertile, being watered by a number of rivers and canals, as well as ſprings and lakes. The chief produce is ſilk; a vaſt quantity of which is cultivated here, and for which the whole country is covered with mulberry trees. Theſe are purpoſely checked in their growth by the natives, experience having taught them, that the leaves of the ſmalleſt trees produce the beſt ſilk. The ſtuffs made in this province, which are embroidered with gold and ſilver, are reckoned the beſt in the empire; and notwithſtanding a vaſt exportation to the Japan and Philippine iſlands, as well as to every part of China, and to Europe, ſuch an abundance is left in the province, that a complete ſuit of ſilk may be bought here as cheap as one of the coarſeſt woollen in France.

This province is alſo remarkable for a particular ſpecies of muſhrooms, which is exported to every part of the empire. They are pickled, and then dried; when they will keep good for a whole year. When uſed they muſt be ſoaked in water, which renders them as freſh as at firſt. Here alſo the tallow tree is met with; and the province affords excellent hams, and thoſe ſmall gold fiſhes with which the ponds are uſually ſtocked.

Che-kyang contains 11 cities of the firſt claſs, 72 of the third, and 18 fortreſſes, which, in Europe, would be accounted large cities. The principal of theſe are, 1. Hang-tcheou-fou, the metropolis, accounted by the Chineſe to be the paradiſe of the earth. It is four leagues in circumference, excluſive of the ſuburbs; and the number of its inhabitants are computed at more than a million, and 10,000 workmen are ſuppoſed to be employed within its walls in manufacturing of ſilk. Its principal beauty is a ſmall lake, cloſe to the walls on the weſtern ſide, the water of which is pure and limpid, and the banks almoſt everywhere covered with flowers. Its banks are likewiſe adorned with halls and open galleries ſupported by pillars, and paved with large flag ſtones for the convenience of thoſe who are fond of walking; and the lake itſelf is interſected with cauſeways caſed with cut ſtone, openings covered with bridges being left in them for the paſſage of boats. In the middle are two iſlands with a temple and ſeveral pleaſure houſes, and the emperor has a ſmall palace in the neighbourhood. The city is garriſoned by 3000 Chineſe and as many Tartars, and has under its juriſdiction ſeven cities of the third claſs. 2. Hou-tcheou-fou is alſo ſituated on a lake, and manufactures an incredible quantity of ſilk, inſomuch, that the tribute of a city under its juriſdiction amounts to more than 500,000 ounces of ſilver. 3. Ning-po-fou, by Europeans called Liampo, is an excellent port, oppoſite to Japan. Eighteen or twenty leagues from it is an iſland called Tcheou-chan, where the Engliſh firſt landed on their arrival at China. 4. Ning-po is remarkable for the ſilk manufactured there, which is much eſteemed in foreign countries, eſpecially Japan, where it is exchanged for gold, ſilver, and copper. 5. Chao-hing-fou, ſituated in an extenſive and fertile plain, is remarkable for a tomb about half a league diſtant, which is ſaid to be that of *Yu*. The people of this province are ſaid to be the moſt verſed in chicanery of any in China. 6. Tchu-tcheou-fou, remarkable for having in its neighbourhood pines of an extraordinary ſize, capable of containing 40 men in their trunks. The inhabitants are ingenious, polite, and courteous to ſtrangers, but very ſuperſtitious.

CHELIDONIAS, according to Pliny, an anniverſary wind, blowing at the appearance of the ſwallows; otherwiſe the Favonius, or Zephyrus.

CHELIDONIUM, CELANDINE, and HORNED or PRICKLY POPPY. See BOTANY *Index*.

CHELIDONIUS LAPIS, in *Natural Hiſtory*, a ſtone ſaid by the ancients to be found in the ſtomachs of young ſwallows, and greatly eſteemed for its virtues in the falling ſickneſs.

CHELM, a town of Poland, capital of a palatinate of the ſame name. It is ſituated in the province of Red Ruſſia. E. Long. 23. 30. N. Lat. 51. 25.

CHELMSFORD, the county town of Eſſex, ſituated on the river Chelmer, in E. Long. 0. 30. N. Lat. 51. 40. It ſends two members to parliament.

CHELONE. See BOTANY *Index*.

CHELSEA, a fine village ſituated on the northern bank of the river Thames, a mile weſtward of Weſtminſter, remarkable for a magnificent hoſpital of invalids and old decrepid ſoldiers; and a pleaſure houſe, called Ranelagh, to which a great deal of fine company reſort in ſummer; and a noble botanic garden belonging to the company of apothecaries. The royal hoſpital of invalids was begun by Charles II. carried on by James II. and finiſhed by King William. It conſiſts of a vaſt range of buildings, that form three large ſquares, in which there is an uncommon air of neatneſs and elegance obſerved. It is under the direction of commiſſioners, who conſiſt generally of the officers of ſtate and of war. There is a governor with 500l. ſalary, a lieutenant-governor with 400l. and a major with 250l. beſides inferior officers, ſerjeants, corporals, and drums, with above 400 men, who all do garriſon duty; and there are above 10,000 out-penſioners who receive an annuity of 7l. 12s. 6d. each; all which expence is defrayed by a poundage deducted from the army, deficiencies being made good by parliament.—The botanic garden is very extenſive, enriched with a vaſt variety of domeſtic and exotic plants, the original ſtock of which was given to the apothecaries of London by Sir Hans Sloane.—At Ranelagh garden and amphitheatre, the entertainment is a fine band of muſic, with an organ and ſome of the beſt voices: and the regale is tea and coffee.

CHELTENHAM, or CHILTENHAM, a market town of Glouceſterſhire, ſeven miles north-eaſt of Glouceſter. W. Long. 2. 10. N. Lat. 51. 50. It is chiefly remarkable for its mineral waters, of the ſame kind with thoſe of Scarborough. See SCARBOROUGH.

CHEMISE, in *Fortification*, the wall with which a baſtion, or any other bulwark of earth, is lined for its greater ſupport and ſtrength: or it is the ſolidity of the wall from the talus to the ſtone row.

Fire CHEMISE, a piece of linen cloth, ſteeped in a compoſition of oil of petrol, camphor, and other combuſtible matters, uſed at ſea to ſet fire to an enemy's veſſel.

CHEMISTRY.

INTRODUCTION.

1 Definition. CHEMISTRY is defined by Dr Black, to be " the ſtudy of the effects produced by heat and by mixture, in all bodies, or mixtures of bodies, natural or artificial, with a view to the improvement of the arts, and the knowledge of nature :" or, according to the definition propoſed by the learned editor of his lectures, " chemiſtry is the ſtudy of the effects of heat and mixture, with the view of diſcovering their general and ſubordinate laws, and of improving the uſeful arts."

Fourcroy has defined " chemiſtry to be that ſcience which teaches the knowledge of the intimate and reciprocal action of all the bodies in nature on one another." To this definition it has been objected, that it requires much explanation, that the terms reciprocal and intimate action not being readily underſtood, would need new definitions to explain them, and that it embraces more than what ſtrictly belongs to the ſcience of chemiſtry. When motion is communicated, or taken away by the colliſion of different bodies, the action between theſe bodies is intimate and reciprocal; but the ſtudy of this action belongs to mechanics, and not to chemical ſcience.

Perhaps no definition of chemiſtry has yet been given which is of ſufficient logical preciſion to be entirely free from objection. The object of chemiſtry, however, admits of no ambiguity. It is the province of natural hiſtory to arrange and diſtribute natural bodies into claſſes and orders, each being accurately characterized, ſo that the objects which it includes may be readily recognized and diſtinguiſhed by eaſy marks of reference. Mechanical ſcience is employed about the external properties of bodies, and their effects on each other, the force and meaſure of which is ſubject to calculation; but it is the object of chemiſtry to diſcover the component parts of bodies, to examine the properties and uſes of the combinations formed, either naturally or artificially, from theſe ſimple ſubſtances, and to obſerve and trace the laws by which theſe combinations take place.

Sect. I. *Diviſion of Natural Knowledge.*

2 Variety of objects immenſe. When we conſider the immenſe and endleſs variety of objects which preſent themſelves to the eye, it muſt appear, at firſt ſight, impoſſible to acquire even a general knowledge of their qualities and properties. And, indeed, the longeſt life, with the moſt vigorous mind and the moſt indefatigable induſtry, would be greatly inadequate to the taſk of examining every individual object. Hence it is, by a law of the human mind, that we arrange the objects of our inveſtigations into certain claſſes, the individuals of which are found to poſſeſs certain general properties. Theſe are again ſubdivided into other claſſes with additional diſcriminative marks; and theſe laſt are ſtill farther ſubdivided, till we arrive at the individual; and, if the arrangement be correct, this muſt poſſeſs all the characteriſtic marks of reference to the general and ſubordinate diviſions of that claſs of objects to which it belongs. In this way the mind is aided in its inveſtigations, and the communication of knowledge is facilitated and improved. 3 Natural hiſtory. Thus it is the province of natural hiſtory to arrange the objects which come under our obſervation, and to deſcribe them with ſuch preciſion and accuracy as they may be eaſily diſtinguiſhed from each other. It may be conſidered as a deſcriptive view of the material world in a ſtate of reſt or inaction, without taking into account the motions or mutual action of bodies on each other. It is the firſt ſucceſsful ſtep in the progreſs of knowledge.

4 Natural philoſophy. But the operations of nature are ſeldom at reſt. Change ſucceeds change, new combinations are formed and new productions make their appearance. The primary planets revolve round the ſun as their centre; the ſecondary planets, or the moons, attracted by the primary, perform ſimilar revolutions; the air of the atmoſphere preſſes on the ſurface of the earth with a certain force; a ſtone, when unſupported, falls to the earth in a courſe directed towards its centre; water deprived of a certain portion of heat becomes ſolid, and appears in the form of ice; when combined with a greater portion of heat than what is neceſſary to retain it in the fluid ſtate, it aſſumes the form of vapour, aſcends into the atmoſphere, is there by certain proceſſes, robbed of its heat, and re-appears in the form of rain; or, when a greater portion is abſtracted, takes that of ſnow or hail, and falls to the earth. A ſeed is put into the ground; and if heat, air, and moiſture be applied, it germinates and ſprings up; and, with the addition of light, if the operation of the ſame agents be continued, it becomes a new plant, puts forth leaves and flowers, and produces ſeeds ſimilar to that from which it ſprung.

5 Phyſics. Now to determine what are theſe changes, to obſerve the laws by which ſuch changes are effected, and to aſcertain the meaſure and quantity of the effect produced, belong to that department of knowledge which is included under the general term *natural philoſophy* or *phyſics*. But of theſe changes or motions, ſome are obvious and palpable, others entirely elude our ſenſes. We ſee a ſtone deſcend to the earth; and experience informs us, that it falls with a force in a certain proportion to its weight and the height from which it fell. The peculiar change or motion which takes place when water aſſumes the ſolid form, when a fluid undergoes the proceſs of fermentation, or when a combuſtible body is burned, is altogether imperceptible. Theſe motions are too minute to be recognized. The effect is produced before we can diſcover the change.

6 Chemiſtry. Thus natural philoſophy divides itſelf into two great branches. The objects of the *firſt* are the ſenſible changes or motions which are obſerved in the material world; and the conſideration of theſe objects is, properly ſpeaking, natural philoſophy or phyſics. The *ſecond* great branch which is employed in diſcovering the

the

the laws, and appreciating the effects, of the inſenſible motions of bodies, conſtitutes the ſcience of chemiſtry (A).

SECT. II. *Of the Objects and Importance of Chemiſtry.*

7 Uſeful in explaining natural phenomena;

The importance and extenſive utility of this ſcience muſt appear obvious to thoſe who have at all conſidered the ſubject. But for the ſake of thoſe who are yet unacquainted with it, we ſhall take a general view of the objects which it embraces, and the advantages to be derived from the ſtudy of chemiſtry, whether in explaining many of the ſtriking operations of nature, or in improving the arts of life.

The moſt wonderful effects, after frequent repetition, become familiar, and ceaſe to produce any emotion in the mind. It is on this account that many of the moſt ſtriking appearances of nature paſs unheeded as trifling occurrences, and are unnoticed by common obſervers. Had we been always accuſtomed to the rigour of winter, and never known the genial warmth of ſpring, or experienced the ripening ſummer's heat, the aſtoniſhing changes effected by the return of theſe ſeaſons could not fail to fill us with admiration. Theſe changes are of ſuch univerſal influence, that they are limited to no department of nature. Their beneficial effects are felt in the inanimate, as well as in the animated creation. The ſame power which is ſeen in the gay profuſion of the vegetable tribes, reſtores to a new exiſtence myriads of animals, whoſe vital functions had been ſuſpended. The air, the earth, the waters, ſwarm with life.

The principal agent in the production of theſe changes is heat; an agent, the moſt powerful and irreſiſtible in its operations, unlimited in its effects, and extenſive in its importance and utility. This agent, therefore, acting ſo powerfully in chemical operations, becomes an eſſential object of chemical ſcience. Cloſely connected with heat is light, which is alſo a powerful agent in many of the proceſſes of nature. This, too, is neceſſarily a ſubject of chemical inveſtigation, not leſs curious and intereſting. Such, indeed, is the univerſal importance of light and heat in all the proceſſes of nature, that no change takes place, no new combination is formed, or new product makes its appearance, in which the one or the other, or both, are not evolved or abſorbed.

In the knowledge of the conſtitution of the atmoſphere, in inveſtigating the changes to which it is ſubject, the variations of temperature, winds, dew, rain, hail and ſnow, chemiſtry is our principal, our only ſatisfactory guide. Theſe remarkable changes are to be conſidered as immenſe chemical operations, and can only be explained by chemical laws.

8 To man in the ſtudy of

But in the midſt of the infinite variety of objects from which man muſt derive the means of his comfort, his happineſs and his luxuries, the means, it might be added, of his very exiſtence, chemiſtry affords him the moſt important aid. Whether his reſearches be carried into the mineral, the vegetable, or the animal kingdoms, the ſtudy and cultivation of chemical ſcience become eſſentially requiſite for the ſucceſsful progreſs of his inveſtigations.

9 Minerals,

Of the importance of chemiſtry to the mineralogiſt, the limited and unſettled ſtate of this ſcience previous to the improvements of modern chemiſtry, is a convincing proof. In mineralogy, the knowledge of chemiſtry is not only neceſſary in detecting and diſcriminating the various ſubſtances of which the globe which we inhabit is compoſed, in ſeparating and purifying theſe ſubſtances, but alſo in preparing and accommodating them to the numerous purpoſes of life.

10 Vegetables

Of the knowledge which we poſſeſs of the vegetable kingdom, chemiſtry furniſhes a very large ſhare. It is from this ſcience that we derive the means of tracing the progreſs of vegetation, of illuſtrating the peculiar functions of plants, and diſcovering the compounds which are formed from a few ſimple principles, the nature and properties of theſe compounds, and their relative proportions, which exhibit an immenſe variety of new productions, many of them of the utmoſt importance to man, on account of their nutritious qualities, or indirectly uſeful to him by affording nouriſhment to thoſe animals which he employs as food. Hence the advantage of applying chemical knowledge to agriculture, in determining the nature of the ſoil fit for the reception of plants, their proper food, and the mode of ſupplying it in the preparation of manures. With theſe objects in view, chemiſtry holds out incalculable advantages in the improvement of many departments of agriculture and rural economy, many of which, from the rapid and ſucceſsful progreſs of the ſcience, there is room to hope, may be ſoon obtained.

11 Animals,

Nor is the application of chemical ſcience to the economy of animals leſs limited in its importance and utility. It not only contributes to the means of decompoſing animal matters, and of exhibiting and examining ſeparately the conſtituent parts of animal ſubſtances; but alſo ſerves to explain in ſome meaſure many of the eſſential functions of the living animal body: ſuch are digeſtion, reſpiration, ſecretion, which, ſo far as matter is concerned, and the changes which it undergoes, are to be conſidered as true chemical proceſſes, and can only be inveſtigated by chemical principles. But it is here neceſſary to obſerve, that the functions of the living vegetable or animal, cannot be wholly accounted for from the nature of chemical action, without taking into conſideration the exiſtence of the vital principle, which counteracts and regulates the operation of chemical agents, aids and promotes the beneficial effects of thoſe that are uſeful to its health and growth, and reſiſts and deſtroys thoſe that are hurtful.

12 Medicine,

The utility of chemiſtry in medicine is too obvious to require much illuſtration. Such, indeed, is its importance that it is now univerſally received and acknowledged as one of the eſſential branches of medical education. So far as the principles of chemiſtry can be applied in inveſtigating the nature of the functions of

---

(A) For this view of the diviſion of natural knowledge, we are indebted to the Introductory Lectures of Profeſſor Robiſon of Edinburgh.

of the animal body in a ſtate of health, or can be employed in accounting for the irregular action of theſe powers, whether exceſſive or deficient, which indicates a deranged ſtate of the functions, and conſtitutes diſeaſe, its relation to medicine muſt be conſidered cloſe and intimate. But the medical art comprehends more than a bare knowledge of the ſtructure and functions of the animal body. It alſo includes an accurate knowledge of the ſubſtances employed as remedies, of their nature and properties as ſimple ſubſtances, and their new qualities and effects under new combinations. This knowledge can only be acquired by the ſtudy of chemiſtry, which is indebted to medicine for ſome part of its progreſs as an art, in the diſcoveries which were accidentally made by the rude and uncertain experiments of medical practitioners in the early ages, to aſcertain the ſenſible qualities and ſalutary effects of the remedies which they employed. Chemiſtry, by its rapid progreſs in modern times, has amply repaid theſe advantages, and in the hands of the intelligent and accurate obſerver, has greatly contributed to give more rational and ſimple views of medical ſcience.

13 The arts.

In conſidering the application of chemiſtry to the improvement of the arts of civilized life, a wide field of contemplation opens to our view. So extenſive indeed are its influence and importance, that in moſt of the arts, many of the proceſſes, in ſome all that are employed, depend on chemical principles. Barely to mention ſome of theſe arts will afford ample illuſtration of its extenſive utility. In the art of extracting metals from their ores, in purifying and combining them with each other, and in forming inſtruments and utenſils, whether for uſeful or ornamental purpoſes, almoſt all the proceſſes are purely chemical. The eſſential improvements which modern chemiſtry has introduced in the manufacture of glaſs and porcelain ſhew its importance and utility in theſe arts. Nor has it contributed leſs by the application of its principles to the arts of tanning, ſoapmaking, dyeing, and bleaching. All the proceſſes in baking, brewing, and diſtilling, moſt of the culinary arts, and many others in domeſtic economy, are chemical operations. In ſhort, wherever, in any of the proceſſes of nature or of art, the addition or the abſtraction of heat takes place; wherever ſubſtances in combination are to be decompoſed or ſeparated; wherever the union of ſimple ſubſtances is wanted, and new compounds are formed, there effects are produced which can only be explained and underſtood by chemical principles.

From this view of the extenſive application of chemical ſcience in explaining many of the operations of nature, and in elucidating many of the proceſſes of the arts of life, thoſe who have not conſidered the objects which it embraces will be enabled to judge of the importance of this ſtudy.

14 As a ſcience.

But however much we may be intereſted in obſerving and admiring the changes and effects produced by chemical action, if we extend our views, and conſider chemiſtry as a ſcience, as the ſubject of philoſophical inveſtigation, it will command a greater ſhare of our attention and ſtudy. And perhaps there is no ſtudy better calculated to promote and encourage that generous and ardent love of truth which confers dignity and ſuperiority on thoſe who ſucceſsfully purſue it. Chemiſtry is not one of thoſe barren diſcuſſions which terminate in the diſcovery of ſome ſpeculative truth, which is merely gratifying to curioſity. In this view, indeed, no ſcience holds out more intereſting ſubjects of reſearch, in the ſingular and ſurpriſing changes which everywhere preſent themſelves. And it is ſurely no ſmall recommendation to the ſtudy of chemiſtry, that while we ſtore the mind with intereſting truths, we add ſomething to the ſtock of human knowledge, which is perhaps immediately applicable to ſome of the moſt important purpoſes of life. Thus might the value of the facts and diſcoveries in any ſcience be fairly eſtimated, in proportion as they enlarge our reſources by their uſeful application, and intereſt and gratify the mind as ſubjects of curious ſpeculation. From both theſe conſiderations the whole range of chemical facts derives the higheſt value; and from theſe conſiderations chemiſtry is entitled to a diſtinguiſhed place among the ſciences.

15 In contemplating the works of nature.

Chemiſtry has yet a higher claim to our attention and conſideration, as it affords us ſome of the moſt ſtriking proofs of the wiſdom and beneficence of the Creator of the univerſe. A machine conſtructed by human art is admired according to the ſimplicity of its contrivance, and the extent of its uſefulneſs; and in proportion to the perfection which we diſcover, we eſtimate the ingenuity and excellence of the plan of the artiſt. But the works of man, with all his boaſted ſkill and attainments, ſink into nothing when brought into compariſon with the works of nature. In our examination of the former, every ſtep of our progreſs is obſcured with defects: in contemplating the latter, we behold perfection riſe on perfection, and new wonders meet our view. By the aid which we derive from chemiſtry we are enabled to take a minuter ſurvey of the great ſyſtem of the univerſe. And ſo far as our limited powers can comprehend it, the whole is nicely balanced and adjuſted, and all its changes tend to the moſt beneficial purpoſes. What on a ſuperficial view were ſeeming imperfections and defects, a cloſer inſpection points out to be real excellencies. In all the changes which are conſtantly going forward, the more cloſely we obſerve and examine them, the more we ſhall admire the ſimple means by which they are accompliſhed, and the intelligent deſign and perfect wiſdom which are diſplayed in the beneficial ends to which they are directed.

Sect. III. *Hiſtory of Chemiſtry.*

The word chemiſtry, which is ſuppoſed to have been of Egyptian origin, ſeems to have been firſt uſed in a very extenſive ſenſe (B). It appears to have included

---

(B) According to ſome it is derived from the word *kema*, which was ſuppoſed to be a book of ſecrets given to the women by the demons. Others derive it from *Cham* the ſon of Noah, from whom Egypt took the name of *Chemie*, or *Chamie*. Sometimes the origin of the word is aſcribed to *Chemmis*, a king of the Egyptians; and cluded all the knowledge which the ancients poſſeſſed of natural objects. It was afterwards more limited in its ſignification, and ſolely confined to the art of working metals. The great importance which the antients attached to this art was probably the cauſe of this limitation. Such indeed was its importance, that thoſe who were ſuppoſed to have diſcovered or improved it, were regarded by mankind as their greateſt benefactors. They were raiſed above the level of the human race, were deemed worthy of being enrolled among the gods; and temples and ſtatues were conſecrated to their honour.

It is not neceſſary minutely to trace the hiſtory of chemiſtry to the remote periods of antiquity, or labour to prove its origin to be coeval with the early ages of the world. Man indeed could not exiſt long without ſome knowledge of chemical proceſſes; and as he improved in civilization and accurate obſervation, this knowledge muſt have been improved and extended. Tubal-Cain, who is mentioned in the ſacred Scriptures, as a worker in metals, and is ſuppoſed to have given riſe to the fabulous ſtory of Vulcan, in antient mythology and poetry, is conſidered by ſome as the firſt chemiſt whoſe name has been tranſmitted to the preſent time. 16 Chemiſtry exiſted as an art. But although the working of metals, and other chemical arts, were known in the early ages of the world; and among the Egyptians, Greeks, and Romans, many of the arts dependent on chemiſtry had reached ſome degree of perfection; yet this knowledge muſt be regarded as conſiſting only of a number of ſcattered, unconnected facts, which deſerve not to be dignified with the name of ſcience. A carpenter may erect a piece of machinery, arranged and conſtructed exactly ſimilar to what he has ſeen, without the knowledge of a ſingle principle of its conſtruction; but the man of ſcience, who can neither handle the axe nor the chiſſel, obſerves and eſtimates the power and operation of all its parts, and determines the general effect of the whole machine.

Nor will it afford us much inſtruction to purſue the ſuppoſed hiſtory of chemiſtry, even to a later period. Moſes, who is ſaid to have been ſkilled in all the wiſdom of the Egyptians, has been ranked among the number of the firſt chemiſts; and as a proof of his knowledge of chemiſtry, the means he employed of diſſolving the golden calf made by the Iſraelites, to render it potable, are adduced. It is ſaid, that Democritus, of all the Greeks who travelled into Egypt to acquire knowledge, was alone admitted into their myſteries. 17 among the Egyptians, According to Diodorus Siculus, the art of chemiſtry had made very conſiderable progreſs among the Egyptians. The knowledge of their prieſts is ſuppoſed to have conſiſted chiefly of chemical proceſſes. They were acquainted, it is ſaid, with the preparation of many medicines, perfumes, plaſters, and ſoaps; they uſed burnt aſhes as cauſtic ſubſtances; they fabricated bricks, glaſs, porcelain; they painted on glaſs, and practiſed the art of gilding with ſilver and gold. They extracted natron or ſoda from the mud of the Nile. They prepared alum, ſea-ſalt, and ſal ammoniac; and beſides working in gold and copper, they poſſeſſed many other proceſſes in metallurgy. The extraction of oils, and the preparation of wine and vinegar, were well known; and they were alſo acquainted with the art of dying ſilk by means of mordants.

18 Greeks, Fewer traces of chemiſtry are found among the Greeks, although they derived the knowledge of many of their arts from Egypt. The ancient philoſophers of Greece, as Pythagoras, Thales, and Plato, were more devoted to the cultivation of mathematical and aſtronomical knowledge, than the phyſical ſciences. Some chemical arts, however, were not unknown to this people. The alloy of metals formed at Corinth, has been much celebrated. Cinnabar was employed in ſome parts of Greece. Tychius knew the art of tanning leather; Plato has deſcribed the proceſs of filtration; Hippocrates was acquainted with that of calcination; Galen ſpeaks of diſtillation *per deſcenſum*, and the word *embic* is mentioned by Dioſcorides a long time before the Arabic particle *al* was prefixed to it. According to Athenæus, there was a manufactory of glaſs eſtabliſhed at Leſbos. Democritus of Abdera prepared and examined the juices of plants: Ariſtotle and Theophraſtus treated of ſtones and of metals.

19 Phœnicians, The Phœnicians are ſpoken of as being acquainted with the making of glaſs, and the celebrated Tyrian purple was found among this people. They were alſo ſkilled in the working of metals and other mineral ſubſtances. The Perſians are ſaid firſt to have diſtinguiſhed the metals by the names of the planets, which they retained for many centuries.

20 Chineſe, Among the Chineſe, if we may believe their hiſtorians, many chemical arts were known from the earlieſt ages: they were acquainted with nitre, borax, alum, gunpowder, verdigris, mercurial ointments, ſulphur, and colouring matters; nor were the arts of dying linen and ſilk, paper-making, manufacturing of pottery and porcelain, unknown. They were ſkilled in the art of alloying metals, and in the working of ivory and of horn. From the early knowledge which the Chineſe poſſeſſed of theſe arts, they have been ſuppoſed by ſome to have been a colony from Egypt.

21 Romans, The wars in which the Romans were almoſt conſtantly engaged, and the ſpirit which prompted them to military affairs, gave them neither time nor taſte to cultivate and improve the arts of peace. Chemiſtry, therefore, appears to have been little known among that people. Petronius indeed ſpeaks of malleable glaſs, which was preſented to Cæſar; and the ſame, or a ſimilar fact, is mentioned by Pliny with regard to Tiberius. But this art, it appears, was long known before the time of the Romans.

To us it may appear ſomewhat ſingular, that chemiſtry, now of ſuch univerſal importance to mankind, ſhould be indebted, in ſome meaſure, for its origin as an art, and for ſome part of its progreſs, to one of the leſs noble or generous of the human paſſions. Yet, in its early dawn, it was cultivated by men who were inſtigated

---

and ſometimes to the Greek word χυμος, which ſignifies *liquid*, becauſe the art was at firſt applied in the preparation of liquids; and ſometimes to the Greek verb χεω, "to pour out," becauſe chemiſtry is the art of fuſing metals.

22 The alchemiſts.

ſtigated by avarice to proſecute and ſtudy it. About the 10th century, or perhaps earlier, a ſet of men aroſe, and continued to flouriſh till the 16th, who aſſumed by way of diſtinction, the name of *alchemiſts*, that is, *the chemiſts*, becauſe they conſidered themſelves, on account of the knowledge they poſſeſſed, more highly favoured than the reſt of mankind. It was natural enough for men who obſerved the remarkable changes produced by chemical action, to be ſtruck with the effects; and overlooking the variations and differences in the reſults of their operations, which were the conſequences of partial or inaccurate obſervation, to flatter themſelves that their power over the ſubſtances on which they operated, was only limited by their wiſhes. Hence, perhaps, originated all the extravagances and follies, ſimilar indeed to thoſe of ſpeculators and projectors of every age, with which the hiſtory and works of the alchemiſtical writers are filled. Many of the alchemiſts, it is not improbable, were the dupes of their own ignorance and credulity; but many more, there is little doubt, took advantage of the ignorance and barbarity which prevailed in the dark ages, during which period they chiefly flouriſhed, and impoſed on the weakneſs and credulity of mankind.

23 Philoſophers ſtone.

It was one of the firſt principles among the alchemiſts, that all metals are compoſed of the ſame ingredients, or, that the ſubſtances which enter into the compoſition of gold, are found in all metals, but mixed with many impurities, from which, by certain proceſſes, it might be freed. The great, the conſtant object of all their labours and reſearches was the diſcovery of a ſubſtance poſſeſſed of the wonderful property of converting the baſer metals into gold, which, on account of its ſcarcity and durability, is more valued and eſteemed than the other metals, which are more abundant, and generally more uſeful. This celebrated ſubſtance was denominated the *philoſopher's ſtone*, and thoſe who were ſo ſingularly fortunate as to accompliſh this great diſcovery, or thoſe to whom it was imparted by others, were regarded, as might naturally be expected, as the peculiar favourites of heaven. When they were in poſſeſſion of this grand ſecret, they were ranked among the higheſt order of alchemiſts, and then aſſumed the name of *adepts;* and thus initiated, they profeſſed themſelves maſters of the enviable ſecret of tranſmuting or changing metals of inferior value, into gold.

But the adepts never ſeem to have thought of enriching themſelves by their great diſcoveries. They were too generous to monopolize the wealth of the world. They accordingly offered their ſervices to others, and liberally propoſed to communicate the fruit of their labours for a moderate reward. The ambitious man to procure riches, that he might increaſe his power, and the opulent man to add to his wealth, eagerly ſought after, employed, and encouraged them in the proſecution of their extravagant ſchemes. They were therefore kept in the pay of princes, to fill and repair their exhauſted treaſures, and of great men who aſpired after boundleſs wealth. Theſe flattering hopes, it may well be ſuppoſed, were never realized. The rich proſpect fled before them, and the golden prize which they often ſuppoſed was juſt within their reach, eluded their eager graſp. The magnitude of the plan, however, fired the imagination, and produced ſomething like conviction in the mind, of the poſſibility, and even certainty, of obtaining the object of all their wiſhes and all their labours. With unabating ardour, with unexampled aſſiduity, they purſued their reſearches, perſuading themſelves and their employers, that they were on the point of being ſoon in poſſeſſion of unlimited wealth.

24 Univerſal medicine.

But the alchemiſts beholding man by anticipation poſſeſſed of immenſe riches, ſaw that ſomething more was requiſite, that he might be ſecured in the uninterrupted enjoyment of them. Experience fatally taught them, that the feeble frame of man was liable to the pains and languor of diſeaſe; that gold and ſilver could neither prevent the fit of a fever, nor give to the poſſeſſor the bleſſings of conſtant health. Thus another moſt deſirable object was held up to view, and deluded their diſtempered minds into the falſe hope of attaining it. This was the famous *panacea*, or univerſal medicine, which was to cure all diſeaſes; and not only to cure, but abſolutely to prevent their occurrence. Thus fortunate in the enjoyment of vaſt riches; thus bleſſed with unbroken health, the deſires of man were yet unſatisfied. Another ſeeming evil ſtill remained, which was naturally to be dreaded as the deſtroyer of this fancied ſcene of apparently perfect felicity. The melancholy reflection, that it was limited by the ſhort ſpan of human life, rouſed the alchemiſts again into exertion, and produced new efforts of ingenuity in their labours, to ſecure to man exemption from the common lot of mortality. In imagination they had diſcovered the means of prolonging life at pleaſure to an indefinite length, of reſcuing man from the grave, and of making him immortal upon earth.

Such were the extraordinary views and purſuits of the alchemiſts. The exact period of the origin of this ſtudy is unknown; nor can it now be aſcertained what progreſs it had made, or indeed whether it was at all cultivated among the antients. Julius Firmicus Maternus is the firſt hiſtorian who mentions this ſtudy as well known in his day, and the period when he flouriſhed was about the beginning of the 4th century. A ſubſequent author, Æneas Blaſius, who lived in the following century, alſo makes mention of it: and Suidas defines the term by informing us, that it is the art of making gold and ſilver. Diocleſian, he ſays, prohibited all chemical operations, during his perſecution of the Chriſtians, that his ſubjects might not be inſtigated to acts of rebellion againſt him by the formation of gold. In ſome places where gold is waſhed down in minute particles, by brooks and rivulets from the mountains, it is cuſtomary to ſuſpend the ſkins of animals in the water, by which means the particles containing the gold are detained; a circumſtance from which the fabulous ſtory of the golden fleece probably derived its origin. Suidas, however, who flouriſhed in the 10th century, is not entitled to any high degree of credit, eſpecially as the antient authors are wholly ſilent as to the ſubject of alchemy.

It is from the phyſicians of Arabia that we obtain the moſt ſatisfactory evidence concerning alchemy. Avicenna, who lived in the 10th century, is ſaid to have written on this ſubject, according to one of his own diſciples, who likewiſe takes notice of roſe-water and ſome other chemical preparations; and in the 12th century we find the cultivating an acquaintance with the chemiſts recommended to phyſicians. Another Arabian writer ſays, that the method of preparing roſe-water, &c. was at that time well underſtood. Theſe proofs of the exiſtence of alchemy among the Arabians, and particularly from the particle *Al* prefixed to it, have induced ſome to conclude, that the doctrine of the tranſmutation of metals firſt originated with the Arabians, which the cruſades were inſtrumental in introducing into Europe, as well as the rapid conqueſts of the Arabians, in Europe, Aſia, and Africa. At that period Europe was in a ſtate of the utmoſt barbarity, owing to the incurſions of the northern nations; but ſome of the ſciences, among which alchemy was comprehended, were happily revived by the Arabians: and about the middle of the 17th century, the extravagance of ſuch as were the profeſſors of alchemy arrived at its greateſt height.

It appears that the alchemiſts began to be eſtabliſhed in the weſt of Europe, as early as the ninth century; and between the eleventh and fifteenth centuries, this ſtudy was in its moſt flouriſhing ſtate. 25 Principal alchemiſts. Among the principal alchemiſts who flouriſhed during this period, and who were diſtinguiſhed for their diſcoveries and writings, were Albertus Magnus, Roger Bacon, Arnoldus de Villanova, and Raymond Lully. They all lived in the 13th century. Albertus Magnus was a Dominican monk of Cologne, and was regarded by his cotemporaries, no doubt on account of his ſtudies, as a magician. He was born in the year 1205, and died in 1280. He left numerous works, one of the moſt curious of which is a treatiſe entitled *De Alchemia*, which exhibits a diſtinct view of the ſtate of chemiſtry at the time he lived. Roger Bacon, another monk, was born in the county of Somerſet in England, in 1214, and died in 1294. He was celebrated for many ingenious inventions and diſcoveries in chemiſtry and mechanics. Among theſe are mentioned the *camera obſcura*, the *teleſcope*, and gunpowder. His works diſcover aſtoniſhing ſagacity and acuteneſs, and conſidering the age in which he lived, are compoſed with no ſmall degree of elegance and conciſeneſs. Some of them, however, bearing the character of the times, are myſtical and obſcure. Arnoldus de Villanova, was a native of Languedoc in France, and was born about the year 1240. He has mentioned the mineral acids, and joined to his chemical ſtudies, extenſive knowledge in medicine. His writings are diſtinguiſhed by all the obſcurity of the alchemiſtical authors. Raymond Lully, whoſe reputation raiſed him to the rank of *adept*, was born at Barcelona in 1235. He wrote on ſtrong waters and metals. His laſt will and teſtament is one of the moſt celebrated of his writings, which are not leſs obſcure than thoſe of his cotemporaries.

About the end of the 14th century, Baſil Valentine, a German Benedictine monk, was the firſt who formally applied chemiſtry to medicine. He was the original diſcoverer of many of the virtues of antimonial medicines; and in his celebrated treatiſe on antimony, entitled *currus triumphalis antimonii*, are found many preparations which have ſince been announced to the world as new diſcoveries. About the ſame time lived Iſaacus Hollandus, whoſe works have been greatly commended by Boerhaave.

26 Paracelſus

In the beginning of the 16th century aroſe Paracelſus, one of the moſt extraordinary men who ever lived. He was born in 1493, near Zurich in Switzerland. Of a bold and enterpriſing ſpirit, he deſpiſed the common rules of conduct by which men are uſually guided. By this means he raiſed his reputation to a great height; he became an enthuſiaſt in chemiſtry, and in the application of ſubſtances prepared by chemical proceſſes to the cure of diſeaſes. 27 the firſt public teacher of chemiſtry. He was the firſt public teacher of chemiſtry in Europe, having been appointed to deliver lectures on that ſubject in the city of Baſil: but his reſtleſs ſpirit did not permit him to remain long in this ſituation. In two years he was involved in a quarrel with the magiſtrates, from whom he had received his appointment, and he left the city. Deſpiſing the common principles of medical practice, and having performed ſome wonderful cures by the free uſe of opium and of mercury, he thought he had diſcovered the univerſal medicine, and promiſed immortality to himſelf and to his patients. But while he thus made ſuch flattering promiſes, his own fate was a ſad proof of the futility and abſurdity of his doctrine. For after an almoſt uninterrupted courſe of debauchery; having wandered a great part of his life from place to place, he died at an inn in Saltzburg, in the 48th year of his age.

A great number of medical practitioners, in the courſe of the 16th century, adopted and propagated the principles of Paracelſus. Among the moſt diſtinguiſhed of theſe was Van Helmont, a man of conſiderable genius, who was born in the year 1577. 28 Alchemy declines. Many of the followers of Paracelſus were greatly devoted to the ſtudy of chemiſtry; and this, with the abſurd and unprincipled conduct of their maſter, tended not a little to bring the views and ſpeculations of the alchemiſts into diſrepute. Chemiſtry, now freed from the trammels of alchemy, conſiſted only of a number of detached, unconnected facts. To bring theſe facts together in one point of view, and to arrange them into claſſes, ſo that the knowledge of them might be applied to uſeful purpoſes, and to thoſe objects to which future reſearches might be advantageouſly directed, were now wanted. 29 Chemiſtry aſſumes the form of a ſcience. This taſk was accompliſhed by Beccher, who diſtinguiſhed himſelf by the extent of his views, in a work entitled, *Phyſica ſubterranea*, which was publiſhed at Frankfort in the year 1669. This was the firſt dawn of chemical ſcience, and the publication of Beccher's work formed an important æra in the hiſtory of its progreſs.

30 Diſcoveries of the alchemiſts.

In taking a retroſpective view of the progreſs of chemiſtry, previous to the publication of Beccher's work, we find that a great number of important facts had been diſcovered and collected. To the claſs of acids, the ſulphuric, the nitric, and the muriatic were added; the alkalies were better known, and the volatile alkali was obtained from ſal ammoniac by Baſil Valentine, by decompoſing it by means of ſoda or potaſs; the ſulphate of potaſs prepared in three or four different ways, received as many different names; the nitrate of potaſs was called nitre, a name which was formerly applied to ſoda; Sylvius diſcovered the muriate of potaſs, which he denominated digeſtive ſalt; and Glauber, the ſulphate of ſoda, to which he gave the name of *wonderful ſalt*, though better known by the name of Glauber's ſalt, by which it is ſtill diſtinguiſhed. Some of the earthy ſalts began to be known about this period, and among others the muriate of lime, which received the name of fixed ſal ammoniac.

The earths themſelves were alſo better known; lime water was prepared, and ſome of the alkaline ſulphurets were pointed out and examined.

The properties of ſome of the metallic ſalts were ſtudied and examined; the nitrate of ſilver, under the name and form of *cryſtals of Diana*, and of *lapis infernalis;* the muriate of ſilver, under that of *luna cornea*. The two muriates of mercury were deſcribed, and employed for various purpoſes. The red precipitate, *arcanum corallinum*, *ſaccharum ſaturni* or ſugar of lead, the butter of antimony, and the powder of algaroth, were either diſcovered, or their properties more attentively inveſtigated and aſcertained.

During this period alſo, the diſtinction was made between the brittle and the ductile metals. Biſmuth, zinc, antimony, and even arſenic itſelf, were obtained in a metallic ſtate. A number of oxides, ſome metallic dyes, fulminating gold, turpith mineral, the ſaline precipitates of mercury, or the mercurial oxides of different colours; minium and litharge, colcothar, the ſaffron of Mars, and diaphoretic antimony, were diſcovered, and their preparation ſufficiently deſcribed.

During this period, the preparation of oils by diſtillation commenced, and the diſtinction was made between volatile and empyreumatic. Ethers were diſcovered, and the ſpirit of wine was well known by the ſame name, alcohol, which it at preſent bears.

31 Their hiſtory uſeful.

But however extravagant it may ſeem to us, the hiſtory of the alchemiſts is inſtructive, as it affords a uſeful leſſon to moderate our expectations in the purſuit of knowledge, and to reſtrain them within the bounds which the Almighty has preſcribed as the range of our inveſtigations; for of the knowledge and of the power of man, as well as of that of the natural elements, he has probably fixed the limits, and ſaid: Hitherto ſhalt thou come, but no farther. This hiſtory is inſtructive alſo, as it preſents a ſingular and extraordinary feature in the hiſtory of mankind; but it is immediately uſeful to our preſent purpoſe, as it ſhews us the commencement of chemical reſearches. It is true, chemiſtry in the hands of the alchemiſts, like every other department of knowledge during the dark ages, was involved in myſtery, and the knowledge of it communicated in a barbarous jargon, to be underſtood only by the initiated, and ſcarcely to be decyphered and comprehended at the preſent day, with the aſſiſtance of the extenſive knowledge of chemical facts which we now poſſeſs. But notwithſtanding the extravagance of the objects they purſued, the means they employed were uſeful to the progreſs of chemiſtry. By their inceſſant labours, diſcovery was added to diſcovery, facts were multiplied on facts, but without any regular train of reſearch or reaſoning being followed.

32 Their diſcoveries comparatively few.

33 The reaſon.

But notwithſtanding theſe important diſcoveries, it may appear ſurpriſing that they were not more numerous. The alchemiſts had laboured inceſſantly in chemical purſuits for near a thouſand years, and with all the zeal and ardour of enthuſiaſts; the labour of whole lives was exhauſted, and immenſe fortunes were diſſipated in endeavouring to obtain the grand object of all their reſearches. Conſidering the long period during which they flouriſhed, and the numbers who were employed in theſe purſuits, there is indeed room for wonder, that they bequeathed to the firſt ſcientific inquirers ſo ſmall a ſtock of chemical knowledge. But the ſpirit which prevailed among the alchemiſts was directly hoſtile to the free communication and accumulation of knowledge. The prominent feature of the character of the alchemiſts was ſecrecy. This indeed was cloſely connected with the nature of the object, to attain which, all their purſuits and inquiries were directed; and ſo ſtrongly was this impreſſed upon their minds, that they believed, or pretended to believe, that the dreadful wrath of heaven would fall on him who ſhould preſume to diſcloſe to any, but to the initiated, the ſecrets of the art. That ſpirit, which aroſe from motives of avarice and ſelf-conceit, became at laſt one of the leading principles of their conduct. With ſo great, ſo important an object in view, as the diſcovery of the means of putting themſelves in poſſeſſion of unlimited wealth, it is little to be wondered at, if they ſhould carefully conceal from the world, and even from each other, the ſteps in the progreſs which led to the accompliſhment of this end. Thus, all their proceſſes were carried on in private, and all their diſcoveries were kept ſecret. In their pretended communication of knowledge with each other, they employed certain ſigns and figures, and aſſumed a myſterious mode of writing, that they might be underſtood only by *adepts*, and might be totally unintelligible to the reſt of mankind.

Conſidering this ſpirit, and the character which diſtinguiſhed the alchemiſts, it was ſcarcely to be expected that they ſhould reveal to the world, either by ſpeech or writing, diſcoveries which moſt of them probably believed were to be of ſuch vaſt benefit to themſelves. And in this view, we ſhould rather be ſurpriſed that any of their proceſſes were ever made known. But here vanity, and even avarice, probably had conſiderable influence in calling forth what they pretended was an account of their attainments and diſcoveries. Some of the alchemiſts, perhaps by means of trick and impoſture, had acquired a high reputation for knowledge, and had impoſed a belief on many, that they were actually in poſſeſſion of the philoſopher's ſtone. They were therefore ſought after, and often received great rewards for their labour, in proving the effects, or trying the ſucceſs of this wonderful agent. To be thus employed was perhaps the object of many in the publication of their works. But at the ſame time, they cautiouſly avoided revealing their knowledge, by employing myſterious and metaphorical language. Thus we may account for the impenetrable obſcurity and numerous abſurdities which characterized their writings.

In this view, therefore, of the character of the alchemiſts, it is not to be expected that the ſtore of chemical facts could be very ample from their labours. And indeed, conſidering the caution with which they concealed and carried on all their proceſſes, it is not improbable that many important diſcoveries were never announced by the firſt obſervers; for the very appearance of any thing new or unexpected, would flatter their hopes that they had advanced another ſtep towards the attainment of their object, and that the next would put them in full poſſeſſion of it. Thus, ſuch a diſcovery would be held inviolably ſecret, and in this way it might be loſt for ever.

34 Stahl improves the theory of Beccher.

We have already mentioned, that the work of Beccher gave the firſt ſcientific form to chemical knowledge. This appeared about the middle of the ſeventeenth century, when the light of knowledge began to ſpread over Europe, and chemiſtry received its ſhare. The facts which had been accumulated by the labours of the alchemiſts, and to which Beccher had given a ſyſtematic form, were ſtill farther methodized and extended by his pupil Stahl. Indeed ſo much was done by the latter, in ſimplifying and improving the theory of his maſter, that it was afterwards denominated from his name the *Stahlian* or *phlogiſtic theory*. This theory was then received and adopted by all chemiſts, and continued to flouriſh for more than half a century.

35 Chemiſtry ſtudied in

After the middle of the ſeventeenth century, the eſtabliſhment of philoſophical ſocieties in Europe greatly contributed to the diffuſion of knowledge. It was about this time that the academy of ſciences was eſtabliſhed in France, and ſome of its members roſe high in reputation by their experiments and diſcoveries in chemiſtry. The royal ſociety of London was alſo founded about the ſame period; but its members, after the example of Newton, were more occupied in mechanical philoſophy, and paid leſs attention to chemical ſcience. It was not, however, entirely overlooked. Newton himſelf threw out ſome important hints, and took ſome general views of chemical phenomena; Boyle, along with his reſearches in mechanical philoſophy, proſecuted the ſtudy of chemiſtry; and the experiments of Hooke and Mayow, on the nature of combuſtion and reſpirable air, diſcover no mean degree of ſagacity and ſkill in their inveſtigations.

36 Britain.

37 In France.

Towards the middle of the eighteenth century, the ſtudy of chemiſtry became general, and even faſhionable, in France. Before this time Homberg, Geoffroy, and Lemery, had diſtinguiſhed themſelves by their chemical experiments and diſcoveries. Among theſe Geoffroy is ſtill deſervedly celebrated for his invention of the tables of chemical affinities, an ingenious method of exhibiting, at one view, the principal reſults of experiments in this ſcience. Theſe tables were afterwards improved by ſeveral chemiſts, but eſpecially by Rouelle, Wenzel, and Bergman.

38 Black's diſcovery.

But the diſcovery of Dr Black formed one of the moſt important æras in the hiſtory of this ſcience, and gave a new and unexpected turn to the views of chemiſts. It was the object of Dr Black's reſearches to diſcover the cauſe of the remarkable change which a piece of limeſtone undergoes when it is calcined or burnt, and to point out the reaſon of the great difference of the properties of this ſubſtance in its different ſtates; and his inveſtigations were crowned with ſucceſs. For, in the year 1755, he aſcertained that theſe changes were owing to the combination or ſeparation of a peculiar kind of air, different in its properties from the air of the atmoſphere. When this air is combined with lime, it is in the mild ſtate, or the ſtate of limeſtone; when this air is driven off, which is the proceſs of calcination or burning, the limeſtone has changed its properties; it is reduced to the cauſtic ſtate, and has loſt conſiderably of its weight; and this loſs of weight, Dr Black proved, was exactly equal to the weight of the air which had been driven off. To this air Dr Black gave the name of *fixed air*; becauſe, when united to the lime and other ſubſtances, with which it enters into combination, it is in a fixed ſtate. This diſcovery, one of the moſt important in chemiſtry, opened a new field for inveſtigation; for it had not been once ſuſpected, that aërial ſubſtances formed combinations with ſolid bodies.

39 Other important diſcoveries.

From this time, the progreſs of chemiſtry was rapid and brilliant. Facts and diſcoveries were daily multiplied, and a ſpirit of enthuſiaſm for the ſtudy burſt forth, and was diffuſed far and wide. In the year 1774, Dr Prieſtley, who had contributed largely to the ſtock of chemical knowledge, diſcovered pure or vital air, and that this air only was fit for the purpoſes of reſpiration and combuſtion. In the year 1781 Mr Cavendiſh, another ingenious Engliſh chemiſt, proved that water is not a ſimple element, but that it is compoſed of pure or vital air, and inflammable air; or, in chemical language, of oxygen and hydrogen.

But, previous to this time, two chemiſts had appeared in Sweden, had diſtinguiſhed themſelves by their zeal, ingenuity and indefatigable induſtry, and had merited and obtained the higheſt reputation for the valuable diſcoveries which they had made in chemical ſcience. Thoſe who are at all acquainted with the hiſtory of chemiſtry, need not be told, that theſe celebrated names are thoſe of Bergman and Scheele; names which will not be forgotten as long as modeſty, candour, and truth, are honoured and reſpected among mankind.

In the mean time, the French chemiſts were not idle. The celebrated Lavoiſier, in conjunction with ſome of his philoſophical friends, confirmed, by the moſt deciſive experiments, the truth of Mr Cavendiſh's diſcovery of the compoſition of water, which was now received and adopted by almoſt every chemiſt. The ſame unfortunate philoſopher, whoſe bright career was cut ſhort by the horrors of the French revolution, had, previous to the time alluded to, enriched chemical ſcience with many valuable and important facts. He had greatly contributed to overthrow the phlogiſtic theory, by a ſeries of accurate experiments and obſervations on the calcination of metals. It had now become a queſtion, whether metals, during the proceſs of calcination, gave out any ſubſtance; that is, whether they contained any phlogiſton; and Lavoiſier inconteſtably proved, that metals cannot be calcined, excepting in contact with pure air, and that the calx thus obtained was, in all caſes, exactly equal to the weight of the metal, and the quantity of air which had diſappeared.

40 New nomenclature.

Chemiſtry, by its rapid and unexampled progreſs, had now ſo far extended itſelf, and had accumulated ſo large a body of facts, that the barbarous, unmeaning, and arbitrary language which the alchemiſts employed to veil their myſteries, and part of which had been adopted and imitated in language equally obſcure and arbitrary by the earlier chemiſts, rendered it extremely difficult to be acquired or underſtood. This was loudly and juſtly complained of, but the difficulties in the way of remedying it ſeemed almoſt inſurmountable. The French chemiſts, however, undertook the arduous taſk, and completely ſucceeded in their labours. To theſe illuſtrious philoſophers we are indebted for the preſent language of chemiſtry, which is ſo conſtructed, that every word, and every combination, has an appropriate meaning, and is intended to expreſs the nature and compoſition of the ſubſtance which is repreſented. It is to this improvement in its language, that we are to aſcribe the facility and preciſion with which the knowledge of chemiſtry can now be communicated, and which has undoubtedly contributed greatly to its general diffuſion and cultivation. And if there be any ground for hope of its future progreſs, from diſtinguiſhed talents, ardent zeal, and unceaſing induſtry, thoſe who are now engaged in the ſtudy of this ſcience, give fair promiſe of a rich harveſt.

Sect. IV. *Of the Firſt Principles of Bodies, and of the Methods of ſtudying and arranging them.*

41 Elements of bodies among the ancients.

1. According to the ancient philoſophers, all matter conſiſted of four principles or elements. Theſe were fire, air, water, and earth; and this opinion, with certain modifications, ſeems to have univerſally prevailed. But the diſcoveries of modern chemiſtry have proved, that three of theſe elements, at leaſt, are compound ſubſtances. Fire is a compound of light and heat; air is compoſed of oxygen and azotic gaſes; and water conſiſts of oxygen and hydrogen.

42 The alchemiſts.

The alchemiſts, not ſatiſfied with this diviſion of the principles of bodies, adopted another, which was more appropriate to the nature of their labours and experiments, and was better calculated to explain the appearances with which they were acquainted. The elements of all bodies, according to their theory, were *ſalt*, *ſulphur*, and *mercury*: and theſe were long known among the alchemiſts by the appellation of the *tria prima*. Theſe principles were admitted by all the alchemiſtical writers till the time of Paracelſus, who alſo adopted them, and added two more to the number. Theſe five elements or principles are thus characterized. Every thing came under the name of *ſalt* which was ſoluble and ſapid; all inflammable ſubſtances were called *ſulphur*; and every volatile ſubſtance, which flies off without burning, was called *mercury* or *ſpirit*. What was liquid and inſipid was called *phlegm* or *water*; every thing that was dry, inſipid, fixed, and inſoluble, was called *earth*, or *caput mortuum*. The two laſt, which were added by Paracelſus, are the water and earth of the ancients. According to the original theory of the alchemiſts, all bodies may be decompoſed by fire, and reſolved into their three conſtituent principles. The mercury or ſpirit, during the proceſs of combuſtion, eſcapes in the form of ſmoke; the ſulphur is inflamed; and the ſalt, which was ſuppoſed to be the fixed principle, remains behind.

43 Beccher's elements.

But Beccher, whom we have already mentioned as the founder of chemical ſcience, perceiving the vague and unſettled notions of the alchemiſts, with regard to the principles of bodies, generalized and ſimplified ſtill more, the chemical facts which were then known. According to his theory, all bodies conſiſted of earth and water. Under the former he included every thing that was dry, and under the latter, whatever was humid. He admitted three earthy principles, namely, the fuſible earth, the inflammable earth, and the mercurial earth. The firſt was the principle of dryneſs, of infuſibility and hardneſs. The fuſible earth, combined with water, compoſed an acid, which was called the *univerſal acid*, becauſe all other acids owed their properties to it. The inflammable earth was conſidered as the principle of combuſtibility; and the mercurial earth was the principle of volatility. The fuſible and the mercurial earths, with water, compoſe common ſalt; and the inflammable earth, with the univerſal acid, forms ſulphur. The metals were compoſed of theſe three earths in equal proportions. When the mercurial earth was in ſmall proportion, the compound was *ſtone*; when the fuſible was in greater proportion, the compound was *precious ſtones*; and the compounds are the colorific earths, when the inflammable earth is in the greateſt, and the fuſible in the ſmalleſt proportion.

44 Stahl's.

This theory of Beccher was conſiderably modified by his pupil Stahl. The inflammable earth of Beccher ſeems to have been changed by him into the principle of inflammability or fixed fire, which he diſtinguiſhed by the name of *phlogiſton*. He admitted the univerſal acid, but rejected the mercurial earth. The number of elements in the theory thus modified by Stahl, amounted to five. Theſe were, *air*, *water*, *phlogiſton*, *earth*, and the *univerſal acid*.

This mode of conſidering the elements of bodies, or their firſt principles, and of admitting ſuch arbitrary and erroneous diſtinctions, is juſtly baniſhed from chemical ſcience. All ſubſtances are ſuppoſed to be ſimple, which have not been decompoſed, without regard to their primitive elements or principles, the knowledge of which is, perhaps, beyond the reach of human power ever to arrive at.

2. To acquire the knowledge of thoſe properties of bodies, inveſtigation of which is properly included under the chemical ſcience, two methods are employed: The one is the method of analyſis or decompoſition, the other is that of ſyntheſis, or compoſition. By the one, the different ſimple ſubſtances of which compound bodies conſiſt, are ſeparated, and their properties individually examined; by the other, the ſimple ſubſtances are combined together, and the properties of the new compound are conſidered and inveſtigated.

45 Analyſis.

Different kinds or modes of analyſis have been admitted and deſcribed by chemical writers. Some bodies, when expoſed to the action of heat and air, undergo a total ſeparation of their component parts. This is called *ſpontaneous* analyſis. Thus, ſome minerals, and all vegetable and animal matters, when they are deprived of life, in favourable circumſtances ſlowly ſeparate into their component parts; and in the ſame way the principles of which ſome liquids are compoſed, re-act on each other, and ſpontaneouſly ſeparate, which gives an opportunity of inveſtigating the nature of theſe ſubſtances.

Analyſis by fire, operates by the accumulation of caloric in bodies; and by the power which it has of ſeparating their particles to favour their examination. But this inſtrument of analyſis is to be conſidered only as one of the means which ſhould concur with many others, to throw light on the real compoſition of bodies. For it will afterwards appear, that the different quantities of caloric accumulated in bodies, have the greateſt effects in giving different reſults, and changing the order of decompoſition.

Another mode of analyſis is by means of re-agents.

This is conducted by placing the compound body which is to be examined, in contact with various ſubſtances, which have the power of ſeparating its conſtituent parts. It is here that the genius and ſcience of the chemiſt appear moſt conſpicuous; for every ſubſtance in nature, and all the products of art, become valuable inſtruments in his hands, to aſcertain the nature, and to examine the properties, of the ſubſtances which come under his examination. The different means of analyſis which chemiſts have employed, to arrive at the knowledge of compound bodies, have been deemed of ſuch importance and utility, that chemiſtry has been called *the ſcience of analyſis*.

46 Syntheſis.

Syntheſis, or compoſition, is the union of two or more ſimple ſubſtances. This union, from whence reſults a new compound, has become an important ſtep in arriving at the knowledge of the properties of bodies, and in forming a number of products uſeful in the arts, and neceſſary to our wants; and thus it is conſidered by chemiſts as in ſome meaſure the inverſe of the method of analyſis, as the perfection of their art, and one of the great inſtruments of their operations. The method of ſyntheſis or compoſition, conſidered as a chemical proceſs to acquire the knowledge of the intimate and reciprocal action of bodies, is in reality more frequently employed than that of analyſis; and the name of the ſcience, if we were to regard theſe two methods, ſhould rather be called the *ſcience of ſyntheſis* than the ſcience of analyſis. In all caſes of complicated analyſis, the operations are ſynthetic. Compounds of an inferior order are formed, but more numerous than the firſt compounds which were ſubjected to analyſis or examination.

But beſides, there are many bodies which have never yet been decompoſed. It is only by compoſition or ſyntheſis, that is, by combining them with others, and by examining the nature of the compounds which are formed by this combination, that their chemical properties can be inveſtigated.

However various the operations of chemiſtry may be; however numerous and different from each other, the reſults which are obtained; they may all be referred to analyſis or ſyntheſis, and be regarded either as combinations or decompoſitions; and to theſe two general methods, all our operations may be limited.

3. It muſt be univerſally allowed, that it is of vaſt importance, in acquiring or communicating knowledge, to have a clear view of the objects of our ſtudies; and this becomes the more neceſſary, as the facts in any ſcience are accumulated, and the objects which it comprehends become more numerous. In many of the arrangements of chemical knowledge which have been propoſed to the world, the objects of this ſcience have been claſſed together according to certain reſemblances in one or two points, while they are totally diſtinct in all others. But an arrangement which is founded on the properties and characters of ſubſtances which have not been fully aſcertained and generally admitted, muſt tend to obſtruct, rather than facilitate the acquiſition of ſcience. If, for inſtance, the objects of chemical knowledge are to be arranged according to their combuſtibility or incombuſtibility, the nature of the proceſs of combuſtion ſhould be fully underſtood, and the effect of combuſtion on the ſubſtances to be claſſed in this way, clearly eſtabliſhed. If all this has not been previouſly attended to, the principles of the arrangement muſt be falſe, and muſt unavoidably lead to error. As a proof of the truth of our remarks, the ſame ſubſtance has been conſidered by one chemiſt as a combuſtible body, while it is arranged by another among the claſs of incombuſtibles; and even by the ſame chemiſt it is ſaid to be combuſtible at one time, and incombuſtible at another, according to the theory which then prevails.

47 Arrangement.

Without purſuing any method of arrangement founded on particular theories or ſyſtems, we ſhall endeavour, in the following treatiſe, to lay before our readers a full view of the preſent ſtate of chemical ſcience; and in arranging the great body of facts of which the ſcience conſiſts, we ſhall obſerve the two following rules. 1. To introduce the ſubſtances to be examined according to the ſimplicity of their compoſition; and, 2. According to their importance as chemical agents. The plan which we propoſe to purſue, in treating of theſe different claſſes of bodies, is, 1. To conſider their properties as ſimple ſubſtances, and, 2. The combinations which they form with thoſe which have been already deſcribed. By this method of arrangement, and by following out this plan, we hope to have leſs anticipation and repetition than in moſt other ſyſtems which have yet been propoſed. But we wiſh not to think too confidently of our own labours. We ſhall probably be conſidered by the world as the worſt judges in this caſe; and we are not too ſelfiſh to ſubmit to the opinion of thoſe to whom it is addreſſed, to whoſe candour and impartiality we implicitly truſt. We may however, obſerve, that this arrangement has been found extremely convenient for teaching the ſcience; and we hope that our readers will find it equally ſo in acquiring the knowledge of it.

According to the principles which we have ſtated, the following table exhibits a view of the order which we ſhall obſerve in this treatiſe. In the preſent ſtate of chemical ſcience, and in its application to explain the phenomena of nature, or to improve the arts of life, the whole may be conveniently arranged into twenty chapters.

I. AFFINITY.
II. LIGHT.
III. HEAT.
IV. OXYGEN GAS.
V. AZOTIC GAS, AND ITS COMBINATIONS.
VI. HYDROGEN, &c.
VII. CARBONE, &c.
VIII. PHOSPHORUS, &c.
IX. SULPHUR, &c.
X. ACIDS, &c.
  1. Sulphuric,
  2. Nitric,
  3. Muriatic,
  4. Oxymuriatic, &c. &c.
XI. INFLAMMABLE SUBSTANCES.
  1. Alcohol,
  2. Ether,
  3. Oils.
XII. ALKALIES.
  1. Potaſh and its combinations,
  2. Soda, &c.
  3. Ammonia, &c.

XIII.

XIII. Earths.
   1. Lime and its combinations,
   2. Barytes, &c.
   3. Strontites, &c.
   4. Magneſia, &c.
   5. Alumina, &c.
   6. Silica, &c.
   7. Yttria, &c.
   8. Glucina, &c.
   9. Zirconia, &c.

XIV. Metals.
   1. Arſenic and its combinations.
   2. Tungſten, &c.
   3. Molybdena, &c.
   4. Chromium, &c.
   5. Columbium, &c.
   6. Titanium, &c.
   7. Uranium, &c.
   8. Cobalt, &c.
   9. Nickel, &c.
   10. Manganeſe, &c.
   11. Biſmuth, &c.
   12. Antimony, &c.
   13. Tellurium, &c.
   14. Mercury, &c.
   15. Zinc, &c.
   16. Tin, &c.
   17. Lead, &c.
   18. Iron, &c.
   19. Copper, &c.
   20. Silver, &c.
   21. Gold, &c.
   22. Platina, &c.

XV. The atmosphere.

XVI. Waters.
   1. Sea water,
   2. Mineral waters.

XVII. Minerals.
   1. Component parts,
   2. Analyſis.

XVIII. Vegetables.
   1. Functions,
   2. Decompoſition,
   3. Component parts.

XIX. Animals.
   1. Functions,
   2. Decompoſition,
   3. Component parts.

XX. Arts and Manufactures.
   1. Soaps,
   2. Glaſs,
   3. Porcelain,
   4. Tanning,
   5. Dyeing,
   6. Bleaching.

48 explained. In the above arrangement, the firſt chapter treats of affinity, or the laws of chemical action. In the two following chapters, the properties of light and heat are detailed. Theſe are conſidered as material ſubſtances; but their properties can only be known in combination with other bodies, as they have never been found in a ſeparate ſtate. Oxygen, azote, and hydrogen, which are conſidered as the baſis of oxygen, azotic, and hydrogen gaſes, are treated of in the 4th, 5th, and 6th chapters; but theſe ſubſtances, as well as light and heat, are not cognizable by our ſenſes. They are only known in a ſtate of combination, the aeriform or gaſeous ſtate, when they are combined with caloric, or the matter of heat. The three following ſubſtances, carbone, phoſphorus, and ſulphur, which are the ſubjects of the 7th, 8th, and 9th chapters, are conſidered as ſimple, becauſe they have never been decompoſed. They can be exhibited in the ſolid ſtate. Two of them being very abundantly diffuſed in nature, and entering into an immenſe number of combinations with other bodies; and the third, namely, phoſphorus, poſſeſſing very ſingular properties, it becomes of great importance that they ſhould be early known.

The acids are treated of in the 10th chapter. They are naturally arranged in this place, becauſe the conſtituent parts of ſome of the moſt important are derived from the ſubſtances which have been already treated of. But the properties of the claſs of acid bodies ought alſo to be early known, becauſe they are the moſt powerful inſtruments of analyſis in the hands of the chemiſt. Indeed ſuch is their importance in his inveſtigations, that in many of them he can ſcarcely proceed a ſingle ſtep without their aid.

The bodies treated of in the 11th chapter, namely, alcohol, ether, and oils, under the head of inflammable ſubſtances, are properly introduced, becauſe the nature and properties of the ſubſtances which enter into their compoſition have been previouſly examined; becauſe one of them is the reſult of a chemical action between the acids and alcohol; and becauſe ſome of them are employed as chemical agents. In the 12th, 13th, and 14th chapters, the properties and combinations of the alkalies, earths, and metals, are detailed. Excepting one, theſe three claſſes of bodies are ſimple, undecompounded ſubſtances. Many of them have long been the ſubjects of chemical inveſtigation, and they afford ſome of the moſt important and intereſting chemical reſearches. They are firſt to be treated of as ſimple ſubſtances; and next, as they enter into combination with the different claſſes of bodies which are already known, particularly with that of the acids, forming the numerous claſſes of alkaline, earthy, and metallic ſalts, moſt of which are of vaſt importance, not only as objects of chemical reſearch, but alſo of extenſive utility in the arts of life.

In the ſix following chapters, our chemical knowledge is to be applied in explaining the appearances of nature, ſo far as theſe are ſuppoſed to depend on chemical action. The 15th chapter treats of the chemical changes and combinations which take place in the atmoſphere. The waters, as they are found on the earth; the different ingredients with which they are impregnated; the nature and quantity of theſe ingredients, and the methods of diſcovering and aſcertaining them, form the ſubject of the 16th chapter. The 17th chapter is employed in giving a view of the component parts of mineral productions, and in deſcribing the methods of analyzing or ſeparating the parts which enter into their compoſition. The functions of vegetables and animals, or thoſe changes which take place in them in the living ſtate, which ſeem to be dependent on chemical action; the changes which they undergo by ſpontaneous analyſis, or ſeparation into their conſtituent parts, and the nature and properties of theſe

theſe elements, will be the ſubject of diſcuſſion in the 18th and 19th chapters. The 20th chapter, in which chemical ſcience is applied to the improvement of arts and manufactures, is not one of the leaſt important and intereſting, and a full view of this part of the ſubject would exhauſt the whole of the uſeful detail of chemical knowledge. But, in the following treatiſe, it is not propoſed to enter at full length into the different branches of the arts and manufactures, but only to give a ſlight view of their general principles, ſo far as they depend on chemiſtry, referring for the particular diſcuſſion of each to the different heads under which they will be found arranged in the courſe of the work.

Chap. I. Of AFFINITY.

Before we enter into the detail of thoſe changes which take place by the action of bodies upon each other, producing compounds which are poſſeſſed of totally different properties, and thus exhibiting the characters of chemical action, it is neceſſary to take a view of the circumſtances in which theſe changes are effected, or in other words, the laws of combination or chemical affinity.

The term *affinity*, which is the expreſſion of a force by which ſubſtances of different natures combine with each other, ſeems to have been pretty early employed by chemical writers. Barchuſen, it would appear, is among the firſt who employed it, and thus characterizes it. "Arctam enim atque reciprocam inter ſe habent affinitatem." It was afterwards brought into more general uſe, and its application more preciſely defined by Boerhaave*. His words are remarkable. "Particulæ ſolventes et ſolutæ, ſe affinitate ſuæ naturæ colligunt in corpora homogenea." And to explain his meaning ſtill more clearly, he adds, "non igitur hic etiam actiones mechanicæ, non propulſiones violentæ, non inimicitiæ cogitandæ, ſed amicitia." To avoid the metaphorical expreſſion *affinity*, Bergman propoſed the term *attraction;* and to diſtinguiſh chemical attraction, which exiſts only between particular ſubſtances, from that attraction which exiſts between all the bodies in nature, he prefixed the word *elective*. The word affinity, however, is now generally adopted, and employed by all chemiſts.

The different tendency of bodies to combine with each other, or the relative degree of affinity which exiſts between them, could not long be overlooked by thoſe whoſe attention was occupied in obſerving chemical changes. And to explain this difference of action, a maxim of the ſchoolmen was adopted; *ſimile venit ad ſimile*. The ſame doctrine was held by Beccher, that ſubſtances which were capable of chemical combination, poſſeſſed a ſimilarity of particles. Other attempts were made to explain chemical action, by conſidering ſolvents as conſiſting of points, finer or coarſer, which were mechanically diſpoſed to enter into the pores of certain ſubſtances which they were capable of holding in ſolution. But Stahl, as appears from his works, rejected the notion of mechanical force, and aſcribes the power of ſolvents to contact, or to the attraction of coheſion. "Combinationes quaſcunque non aliter fieri, quam per arctam appoſitionem." And afterwards, he ſpeaks ſtill more preciſely when he ſays, "non per modum cunei, neque per modum incurſus, in unam particulam ſeparandam, ſed potius per modum apprehenſionis, ſeu arctæ applicationis;" and then he adds, "eſt inde rationi quam maxime conſentaneum, quod effectus tales potius arctiore unione ſolventis cum ſolvente contingant, quam nuda et ſimplici formali inſtrumentali diviſione †."

Having made this important ſtep in the conſideration of chemical action, the experiments and obſervations of the ſagacious chemiſt led him to conclude, that a combination between two ſubſtances once formed, could not be deſtroyed, without effecting a more intimate union of one of the conſtituent parts with ſome other ſubſtance.

52 Tables invented,

The next ſtep in the method of obſerving and ſtudying chemical affinity was made by Geoffroy the elder. He collected the ſcattered facts, to determine the force or meaſure of their degrees of union, and to eſtabliſh rules of analyſis and compoſition. His firſt table of affinity was preſented to the Royal Academy of ſciences at Paris in the year 1718. This conſiſted only of 17 columns, which were but imperfectly filled up, and exhibited rules which have been moſtly changed; but with all its errors, it ought to be conſidered as one of the firſt guides to chemical knowledge.

53 enlarged,

The firſt material improvement on Geoffroy's table was made by Gellert, profeſſor at Freyburg. In his *Chemia Metallurgica*, publiſhed in 1750, there is a new table of affinity, which extends to 28 columns. At the bottom of each column there is a liſt of ſubſtances with which the body at the head of the column had no action. Rudiger, in the year 1756, inſerted a table of affinity in his ſyſtem of chemiſtry, in which he reduced the number of columns to 15. In this table he placed the fixed alkalies and lime parallel with each other, and before ammonia, the column of acids. He pointed out alſo with a good deal of accuracy, in a ſmall ſeparate table, thoſe ſubſtances which refuſe to combine without ſome intermediate ſubſtance.

54 and improved

55 by Limbourg.

The next important addition to the knowledge of affinities, was made by M. Limbourg. In his table the number of columns was extended to 33. This table was the fulleſt and moſt accurate of any that had yet appeared. He had juſtly obſerved that zinc, of all metallic ſubſtances, ſhould be placed at the head in the column of acids, and that even in the dry way it precipitated them all. He aſſerted that lime and the cauſtic alkalies acted by affinity on animal matters; and beſides, he ſtated ſome caſes in which a change took place in the order of affinities, by a change of temperature, or by the volatility of one of the ſubſtances.

56 By Bergman.

This ſubject, the importance of which was ſufficiently obvious, was now aſſiduouſly inveſtigated by many chemiſts. The number of tables was multiplied, and the ſyſtem of affinity more fully eſtabliſhed. But the greateſt improvement which it had hitherto received, was made by the celebrated Bergman, in his diſſertation on elective attractions, publiſhed in the tranſactions of the Royal Society of Upſal, in the year 1775. Theſe tables, editions of which appeared in 1779 and 1783, have been juſtly regarded as ſtriking inſtances of the ſagacity and induſtry of the author. The affinities of 59 ſubſtances are aſcertained with great accuracy; and the diſtinction between thoſe that take place in the moiſt and dry way, is particularly ſtated, as well as the diſtinction between ſimple and compound affinities,

---

† Specim. Beccher. ſect. 1.

affinities, which has led to the explanation of a great number of apparent anomalies. Since the time of Bergman, this ſubject has been proſecuted by many of the moſt diſtinguiſhed philoſophical chemiſts. Among theſe we may mention the induſtrious and indefatigable Kirwan of our own country; and among the French philoſophers, Morveau, and more eſpecially Berthollet, diſtinguiſhed for his ſkill and ſagacity, who has lately in his reſearches concerning the laws of affinity, opened a new field of inquiry, corrected many former errors, and pointed out ſome new laws in this intereſting and important ſubject.

57
All bodies attract.

All bodies with which we are acquainted, are influenced by a certain force, by which they are attracted, or drawn towards each other. A ſtone, when it is unſupported, falls to the ground; the planets are attracted by the ſun; two poliſhed plates of metal, of glaſs, or of marble, when brought into cloſe contact, adhere with a certain force; a piece of wood or ſtone requires a conſiderable degree of force to ſeparate the particles, or to draw it aſunder; and lime and ſulphuric acid enter into ſuch cloſe combination, that it requires an equal degree of force to overcome that combination, or to ſeparate the particles from each other. Whatever may be the nature of theſe attractions, or the cauſe of theſe different combinations, or whether they are to be aſcribed to the ſame univerſal law pervading matter, as ſome have ſuppoſed, they have been deſcribed by philoſophers under different names. The attraction which exiſts between all bodies in the ſolar ſyſtem, was denominated by Newton, by the general term *attraction;* and he demonſtrated that this uniform and univerſal law was preciſely the ſame as the law of gravitation, or the deſcent of heavy bodies towards the earth; and that this attraction was an eſſential property of all matter; that the minuteſt particles, in proportion to their bulk, were equally influenced with the largeſt maſſes; that the ſame power which retained the planets in their orbits, gave form to the drops of rain.

58
Different names of affinity.

We have ſaid, that theſe different forces or attractions have been diſtinguiſhed by different names. That attraction which is exerted between two poliſhed ſurfaces brought into contact, has been called *adheſion.* When particles of the ſame nature are attracted or held together, the expreſſion of the force by which this is effected, has received the name of *coheſion, homogeneous affinity*, or the *attraction of aggregation;* but when diſſimilar particles, or the particles of two ſubſtances of different qualities combine together, the force or attraction which is here exerted has been called *heterogeneous affinity, the attraction of compoſition;* or, ſtrictly ſpeaking, *chemical affinity.* In the three following ſections, we propoſe to give an account of the opinions and doctrines which have been held by philoſophers with regard to the nature and force of theſe attractions. Of the two firſt we ſhall only take a ſhort view; but ſhall enter more fully into the detail of the latter, namely, chemical affinity, which more ſtrictly belongs to our preſent ſubject.

SECT. I. *Of* ADHESION.

59
In what circumſtances it happens.

By adheſion, then, is to be underſtood, that force which retains different ſubſtances in contact with each other. Thus, water adheres to the finger, which is ſaid to be wet, and mercury brought into contact with gold, adheres with great force. Adheſion takes place, either between two ſolids, as marble or glaſs; or between ſolids and fluids, as when water riſes in capillary tubes; or between two fluids, as water and oil. In an experiment made by Dr Deſaguliers, he obſerved, that two plates of glaſs, of one-tenth of an inch in diameter, adhered with a force equal to 19 ounces. The adheſion of two fluids has been proved by the experiment of Lagrange and Cigna, as that of oil and water, between which it was formerly ſuppoſed there exiſted a natural repulſion; and the experiments on capillary attraction, and particularly the aſcent of water between two panes of glaſs, which was aſcertained by Dr Brook Taylor, have eſtabliſhed the attraction between ſolids and fluids.

60
Accounted for.

This adheſive force, or the cauſe of this attraction, has been differently accounted for by philoſophers. In a diſſertation on the weight of the atmoſphere, publiſhed in 1682 by James Bernouilli, he aſcribes the reſiſtance which two poliſhed pieces of marble oppoſed to their ſeparation to the preſſure of the air; and in proof of this, he ſtates as a fact, that the two plates could be eaſily ſeparated *in vacuo.* But it has been ſuppoſed that he had either never attempted to verify this fact, or that the experiment had been accompanied by ſome fallacy. From the experiments made by Dr Taylor, he concluded that the intenſity of the adheſive power of ſurfaces might be meaſured by the weight which was required to ſeparate them. About the ſame time Mr Hawkſbee proved by experiment, that the adheſion of ſurfaces and capillary attraction were not to be aſcribed to the preſſure of the atmoſphere, as Bernouilli had ſuppoſed; but Lagrange and Cigna, after having proved the adheſion between oil and water, thought that it was owing to a different cauſe from that of attraction. They ſuppoſed that it was occaſioned by the preſſure of the air, and that the opinion of Dr Taylor was not well founded. Such were the opinions held by philoſophers on this ſubject, when Morveau, in the year 1773, was led to inſtitute a ſeries of experiments on adheſion, which he exhibited at Dijon. By theſe experiments he proved, that this attraction was not owing to the preſſure of the air, but entirely to the attraction of the two ſubſtances between themſelves. To prove this, a poliſhed plate of glaſs was ſuſpended from the arm of a balance, and placed in contact with a ſurface of mercury. The weight neceſſary to ſeparate the two ſurfaces was equal to nine gros and ſome grains. The whole apparatus was placed under the receiver of an air-pump, which was exhauſted of the air as much as poſſible. It required exactly the ſame force to ſeparate the ſurfaces. The ſame diſk of glaſs brought into contact with pure water, adhered to it with a force equal to 258 grains; but from the ſurface of a ſolution of potaſh, it required only a force of 210 grains. This inequality of effects with equal diameters, and in the inverſe order of the reſpective denſities, ſeemed not only to be deciſive in favour of Dr Taylor's method, but appeared to point out the poſſibility of applying it to the calculation of chemical affinities. For the force of adheſion being neceſſarily proportional to the points of contact, and the ſum of the points of contact not varying in the adheſion of a fluid and a ſolid with equal ſurfaces, but by by the figure of their conſtituent parts, the difference of the reſults points out to us preciſely a cauſe analogous to that which produces affinity, the force of which it becomes eaſy, in theſe circumſtances, to meaſure and compare.

61 Morveau's experiments.

To aſcertain the accuracy of this method, plates of the different metals of an inch in diameter, and of equal thickneſs, perfectly round, and well poliſhed, were procured. They were furniſhed, each with a ſmall ring in the centre, to keep them ſuſpended parallel to the horizon. Each of the plates was ſuſpended in turn to the arm of an aſſay balance, and exactly counterpoiſed by weights in the oppoſite ſcale. Thus balanced, the plate was applied to the ſurface of mercury in a cup, by ſliding it over the mercury in the ſame manner as is practiſed for ſilvering mirrors, to exclude the whole of the air. Weights were then put into the oppoſite ſcale, till the adheſion between the plate and the mercury was broken. In each experiment freſh mercury was employed. The following table exhibits the reſults of theſe experiments.

	Grains.
Gold adheres to mercury with a force equal to	446
Silver	429
Tin	418
Lead	397
Biſmuth	372
Zinc	204
Copper	142
Antimony	126
Iron	115
Cobalt	8

In conſidering the remarkable differences, it muſt appear that the preſſure of the atmoſphere has no influence, ſince its effects muſt have been preciſely ſimilar; nor do they depend on the difference of poliſh on the ſurface; for a plate of iron, ſimply ſmoothed and filed, adheres more ſtrongly than a plate of the ſame diameter which has received the higheſt poliſh. Nor are theſe differences owing to the difference of denſity; for in this caſe ſilver ſhould follow lead; cobalt would adhere with a greater force than zinc, and iron greater than that of tin. On the contrary, the order of their denſities is reverſed. What then is the order in which the adheſion of theſe different ſubſtances takes place? It is preciſely, ſays Morveau, the order of affinity, or the degrees of the greater or leſs ſolubility of the metals for mercury. Gold, of all the metals, attracts mercury moſt ſtrongly; but mercury diſſolves neither iron nor cobalt, and therefore they are placed at the bottom of the liſt. This correſpondence, he farther obſerves, cannot certainly be the effect of chance, but that it clearly depends on the general property of matter called attraction. This property which is always the ſame, and always ſubject to the ſame laws, produces very different effects, according to the different diſtances between the particles occaſioned by the variety of elementary forms; and that thus it may be poſſible to eſtimate the force of chemical affinity by the force of adheſion. In the preſent caſe, for inſtance, the real affinities which tend to combine mercury with gold, ſilver, zinc, and copper, may be expreſſed by the above numbers 446, 429, 204, and 142.

62 Achard's.

Achard of Berlin, convinced by Morveau's experiments, of the accuracy of Dr Taylor's method, ſaw its importance in chemiſtry; and having examined the principle, made a great number of applications of it, which he publiſhed in 1780. The reſult of theſe obſervations, if accurately obtained, can alone guide us in eſtimating the points of contact by adheſion, and by calculating theſe points of contact, to aſcertain the figure of the particles which touch, and the reſulting affinities.

63 Requiſites.

Three eſſential conditions are neceſſary for the accuracy and uniformity of each experiment. 1. That the ſolid body whoſe adheſion with a fluid is to be eſtimated be ſo ſuſpended as to be in a horizontal poſition, and that the force employed to detach it, ſhould always act in a line which forms a right angle with the ſurface of the fluid. 2. That there be no air interpoſed between the ſurface of the ſolid and the fluid: and, 3. That the weights employed as a counterpoiſe may be added, eſpecially towards the end, in very ſmall quantity, not more than a quarter of a grain each; and to avoid any ſudden jerk, they ſhould be placed gently in the ſcale.

The firſt point which he wiſhed to aſcertain was, whether the difference of atmoſpherical preſſure, the temperature remaining the ſame, cauſed any difference in the adheſion of ſurfaces. For he found that the adheſive force between a plate of glaſs and diſtilled water was the ſame at all preſſures, but the uniformity of the reſults varied when he operated at different degrees of temperature, while the elevation of the barometer continued the ſame; and he found that this variation did not ariſe from the different temperatures of the ſurrounding air, but from that of the water. When the fluids are colder, the adheſion is the ſtronger; and the reaſon is obvious: as they contain more matter under the ſame volume, they ought to preſent a greater number of points of contact in the ſame ſpace; and ſince the force of the adheſion is in proportion to the number of the points of contact, it ought to increaſe when the fluids are condenſed by cold, and to diminiſh when they are rarefied by heat. Achard did not ſtop by obſerving theſe variations of the force of adheſion between glaſs and water heated to different temperatures; he ſubjected them to calculation, to verify his obſervations, and render their application eaſy to all degrees. The following table exhibits the force of adheſion by obſervation, and alſo by calculation. He proceeded on the following data.

Let x be the temperature of the water, y the correſponding adheſion, b its coefficient, and a the conſtant force. We have then the equation $x=a-by$. To find the value of a and b, he employed two obſervations; the one in which water at 104° of Sulzer's thermometer, adhered to the glaſs diſk with a force equal to 80 grains, and the other in which water at 56° adhered with a force equal to 89 grains. Proceeding from theſe two terms

$$104^\circ=a-80\,b$$
$$56=a-89\,b,$$

we have

$$a=530$$
$$b=\frac{-48}{9}$$

And thus the relation of the temperature of water to its adheſion to glaſs may be thus expreſſed: $x=530-\frac{48}{9}y$; and from thence are deduced the correſponding values of x and y for all the adheſions of glaſs to water at any temperature. Such are the data from which and the correſponding experiments, Achard formed the

the table which exhibits the adheſive force of a glaſs diſk of 1½ inch in diameter, to water at different temperatures; and ſhewing the difference of the reſults.

64
Adheſion of glaſs to water.

TABLE I.

Degrees of Sulzer's Therm.	Degrees of Fahren. Therm.	Adheſion by Experiment.	Adheſion found by Calculation.	Difference.
95	141.687	81.25 grs.	81.55	—0.3
90	135.914	82.5	82.5	0
85	130.141	83.75	83.43	+0.34
80	124.368	84.5	84.37	+0.13
75	118.595	85.75	85.31	+0.46
70	112.822	86.	86.25	—0.25
65	107.049	87.25	87.18	+0.07
60	101.276	88.5	88.12	+0.38
55	95.503	89.	89.06	—0.06
50	89.730	90.25	90.	+0.25
45	83.957	90.75	90.93	—0.16
40	78.184	92.	91.87	+0.13
35	72.411	92.75	92.81	—0.04
30	66.638	93.75	93.73	+0.02
25	60.865	94.5	94.68	—0.18
20	55.092	95.75	95.62	+0.13
15	49.319	96.25	96.56	—0.31
10	43.546	97.5	97.5	0

The temperature being ſuppoſed to continue the ſame, if this principle be well founded, the force of adheſion of any given body with water, ought not only to increaſe or diminiſh according to the extent of ſurface, but theſe differences ought to be as the difference of the ſurfaces.

If then p be the force with which a diſk of glaſs whoſe diameter is a, adheres to water, and y the force of adheſion of another diſk, whoſe diameter is b, we ſhall have the proportion $a^2 : b^2 :: p : y$ and $y = \frac{b^2 p}{a^2}$

To verify the order of this progreſſion, either with water or other fluids, Achard employed diſks of glaſs from 1½ to 7 inches in diameter, having firſt aſcertained their force of adheſion with theſe fluids, by the number of grains which were neceſſary to overcome it. He afterwards calculated the ſame by the above equation. The following Table exhibits the reſults of experiment and of calculation, which, if the procedure be free from error, correſpond as nearly as could be expected.

TABLE II.

The force of adheſion between glaſs diſks of different diameters, and different kinds of fluids, determined by experiment and calculation.

65
To different fluids.

Diameter of the Diſk.	Diſtilled water.		Alcohol.		Liquid ammonia.		Solution of potaſh.		Oil of Turpentine.		Linſeed. oil.	
Inches	Experim. grs.	Calcul. grs.	Exper. grs.	Calcul. grs.	Experim. grs.	Calcul. grs.	Experim. grs.	Calcul. grs.	Experim. grs.	Calcul. grs.	Experim. grs.	Calcul. grs.
1.5	364.		216.		328.		420.		240.		268.	
1.75	494.5	49.5	294.25	294.	447.	446.	571.	571.	326.5	326.	363.25	364.
2.	647.25	647.	384.	384.	582.	583.	746.	746.	425.	426.	475.	476.
2.25	818.75	819.	457.5	457.	738.	738.	945.	945.	539.	540.	604.	603.
2.5	1010.	1011.	600.	600.	912.	911.	1167.	1166.	667.	666.	744.	744.
2.75	1223.5	1223.	725.	726.	1103.	1102.	1410.75	1411.	806.	806.	901.	900.
3.	1457.	1456.	863.25	864.	1311.5	1312.	1680.5	1680.	961.	960.	1072.25	1072.
3.25	1709.	1708.	1015.	1014.	1538.25	1539.	1970.	1971.	1126.5	1126.	1259.	1258.
3.5	1981.5	1982.	1177.	1176.	1786.	1785.	2287.	2286.	1305.75	1306.	1458.5	1459.
3.75	2257.	2257.	1350.	1350.	2049.	2050.	2624.5	2625.	1500.	1500.	1675.25	1675.
4.	2587.	2588.	1538.	1536.	2332.	2332.	2986.	2986.	1707.	1706.	1905.	1905.
5.	4044.	4044.	2399.	2400.	3645.	3644.	4665.8	4666.	2666.	2666.	2977.	2977.
6.	5824.5	5824.	3455.5	3456.	5248.25	5248.	6721.	6720.	3839.5	3840.	4289.25	4288.
7.	7926.25	7927.	4703.	4704.	7143.	7143.	9146.	9146.	5227.	5226.	5835.75	5836.

Achard alſo inſtituted a ſeries of experiments with different ſolid ſubſtances, formed into diſks of equal diameters, and applied to the ſurface of different fluids. The following table ſhows the reſults of theſe experiments; but from theſe reſults it appears, that the force of adheſion does not depend on the ſpecific gravity, either of the ſolid or the fluid; nor does it correſpond with the order of chemical affinities. But beſides, ſome of the reſults cannot be admitted as perfectly legitimate, on account of the chemical action which would neceſſarily take place when ſome of the ſubſtances were brought into contact; as ſome of the metals would be acted on by the acids, and others by the ſolutions of metallic ſalts.

66 Of different ſolids to different fluids.

TABLE III.

The force of adheſion of different ſolids, in diſks 1.5 inch in diameter, with water and other fluids, at 70° Fahrenheit's thermometer, determined in grains.

Solids. Fluids.	Diſtilled water.	Sulphuric acid.	Concentrated vinegar.	Alcohol.	Acetite of lead	Acetite of copper.	Deliquiated potaſh.	Liquid ammonia.	Sulphuric ether.	Oil of turpentine.	Oil of almonds.
Specific gravity.	1000.	1868.4	1019.7	842.	1131.5	1000.	1368.4	1046.	828.9	881.5	907.8
Plate-glaſs -	91.	115.	87.	54.	98.	96.	105.	82.	54.5	60.	66.
Rock cryſtal	90.	112.	86.	52.	98.75	95.	103.	80.	53.	58.5	66.
Green oriental jaſper.		96.	120.5	96.25	99.8	88.5	91.	122.	85.5	84.	56.5
Gypſum -	80.	199.75	78.	46.5	87.25	85.	93.	71.	48.	52.5	56.5
Sulphur -	965	123.	92.5	58.	107.	101.5	110.5	86.	57.5	64.	69.
Yellow wax -	97.	120.5	92.75	56.5	106.5	103.	111.	88.	59.	64.	71.
Ivory - -	90.	114	90	92.	84.	86.	113.	80.	77.5	52.	
Horn - -	84.	104.75	85	83.75	76.25	81.	106.	74.5	73.	48.75	
Iron - -	93.5	116.	88.	56.	104.	98.25	108.	83.5	55.5	61.	68.
Copper - -	96.5	123.	92.	57.25	106.	102.	112.	87.	58.	62.5	68.85
Tin - -	94.5		91.	55.5	103.5	100.	108.5	86.	54.75	61.	69.
Lead - -	100.25	129.25	98.	59.	111.	107.	115.	91.5	61.	67.	72.
Braſs - -	99.	124.5	96.	59.	110.	103.5	114.	90.	60.	65.	70.5
Zinc - -	96.		90.25	57.	106.25	102.	110.	85.75	56.75	61.25	69.

From all theſe obſervations, then, we may conclude, that the force of adheſion between different bodies is altogether independent of the preſſure of the air; that it varies according to the number of points of contact of the touching ſurfaces; and that it is probably owing to the ſame cauſe as the force of affinity. It appears alſo, that the force of adheſion between ſolids and fluids is in the inverſe ratio of the temperature indicated by the thermometer, and the direct ratio of the ſquares of their ſurfaces; that different ſolids adhere with different degrees of force to the ſame fluid; but ſtill it muſt be allowed, that experiments and obſervations are yet wanting, to derive any advantage from the reſults of adheſive force which have been obtained, in the calculation of chemical affinities.

Sect. II. *Of the Attraction of Aggregation.*

67 Cohesion.

That force which is inherent in the particles of matter, by which they are held together, and form maſſes, is called *coheſion;* and when particles of the ſame kind are united together, it is denominated the *attraction of aggregation*, or *homogeneous affinity*. It is probably the ſame in kind with that which we have already conſidered, but differing in degree. Thus, it requires a much greater force to ſeparate the particles of a maſs of marble, than two poliſhed ſurfaces of the ſame ſubſtance brought into contact.

68 Difference of force.

As the force of coheſion oppoſes itſelf to chemical action, ſo that the chemiſt in his reſearches is obliged to deſtroy or overcome it; it becomes a matter of conſiderable importance to be able to eſtimate it. This force is very different in different bodies. A very great force is neceſſary to overcome the power of coheſion among the particles of an iron or gold wire, while a ſmall degree of force can ſeparate the particles of a piece of wood or ſtone. To aſcertain this force, experiments have been made by different philoſophers, and particularly by Muſchenbroeck, on that of the coheſion of ſolid bodies. A rod of the ſubſtance whoſe coheſive force was to be eſtimated, was ſuſpended perpendicularly, and weights attached to the lower extremity. The weight neceſſary to deſtroy the coheſive force of the particles of matter in the rod, or to tear it aſunder, was conſidered as the meaſure of that force. The following are the reſults of his experiments made on different ſubſtances. The ſubſtances employed were rods of an inch ſquare, and the numbers in the table indicate pounds avoirdupois.

Metals.

Steel, bar	135,000
Iron, bar	74,500
Iron, caſt	50,100
Copper, caſt	28,600
Silver, caſt	41,500
Gold, caſt	22,000
Tin, caſt	4,440
Biſmuth,	2,900
Zinc,	2,600
Antimony,	1000
Lead, caſt	860

Alloys of Metals.

Gold 2 parts, ſilver 1 part,	28,000
Gold 5, copper 1,	50,000
Silver 5, copper 1,	48,500
Silver 4, tin 1,	41,000
Copper 6, tin 1,	55,000
Braſs,	51,000
Tin 3, lead 1,	10,200
Tin 8, zinc 1,	10,000
Tin 4, antimony 1,	12,000
Lead 8, zinc 1,	4500
Tin 4, lead 1, zinc 1,	13,000

Woods.

Locuſt tree,	20,100
Jujeb,	18,500
Beech and oak,	17,300
Orange,	15,500
Alder,	13,900
Elm,	13,200
Mulberry,	12,500
Willow,	12,500
Aſh,	12,000
Plum,	11,800
Elder,	10,000
Pomegranate,	9750
Lemon,	9250
Tamarind,	8750
Fir,	8330
Walnut,	8130
Pitch pine,	7656
Quince,	6750
Cypreſs,	6000
Poplar,	5500
Cedar,	4880

Bones.

Ivory,	16,270
Bone,	15,250
Horn,	8750
Whalebone,	7500
Tooth of ſea-calf,	4075

69 Opinions on the nature of coheſion.

Various opinions have been entertained of the nature of this coheſive force. According to Newton, as we have already obſerved, it is properly eſſential to all matter, and the cauſe of the variety obſerved in the texture of different bodies.

70 Newton's.

"The particles," ſays he, "of all hard homogeneous bodies which touch one another, cohere with a great force; to account for which ſome philoſophers have recourſe to a kind of hooked atoms, which, in effect, is nothing elſe but to beg the thing in queſtion. Others imagine that the particles of bodies are connected by reſt; that is, in effect, by nothing at all; and others by conſpiring motions, that is, by a relative reſt among themſelves. For myſelf, it rather appears to me, that the particles of bodies cohere by an attractive force, whereby they tend mutually towards each other: which force, in the very point of contact, is very great; at little diſtances is leſs, and at a little farther diſtance is quite inſenſible."

71 Deſaguliers's.

"If compound bodies," Dr Deſaguliers obſerves, "be ſo hard as by experience we find ſome of them to be, and yet have a great many hidden pores within them, and conſiſt of parts only laid together; no doubt thoſe ſimple particles which have no pores within them, and which were never divided into parts, muſt be vaſtly harder. For ſuch hard particles gathered into a maſs, cannot poſſibly touch in more than a few points; and therefore much leſs force is required to ſever them, than to break a ſolid particle whoſe parts touch throughout all their ſurfaces, without any intermediate pores or interſtices. But how ſuch hard particles only laid together, and touching only in a few points, ſhould come to cohere ſo firmly, as in fact we find they do, is inconceiveable; unleſs there be ſome cauſe by which they are attracted and preſſed together. Now, the ſmalleſt particles of matter may cohere by the ſtrongeſt attractions, and conſtitute larger, whoſe attractive force is feebler: and again, many of theſe larger particles cohering, may conſtitute others ſtill larger, whoſe attractive force is ſtill weaker; and ſo on for ſeveral ſucceſſions, till the progreſſion end in the largeſt particles on which the operations in chemiſtry, and the colours of natural bodies, do depend; and which, by cohering, compoſe bodies of a ſenſible magnitude."

72 Boſcovich's.

A theory, which poſſeſſes great ingenuity and plauſibility, has been propoſed by Boſcovich, to account for coheſive attraction; and ſome ſuppoſe, that it is on immaterial

immaterial means or powers that this attraction, according to this theory, depends. Dr Hutton [*] ſeems to think, that Dr Prieſtley applies it in this view, in the following paſſage, in which he attempts to ſolve ſome difficulties with regard to the Newtonian doctrine of light. "The eaſieſt method," ſays Dr Prieſtley, ſpeaking of this ſubject, "of ſolving all difficulties, is to adopt the hypotheſis of Mr Boſcovich, who ſuppoſes that matter is not impenetrable, as has, perhaps, been univerſally taken for granted; but that it conſiſts of phyſical points only, endued with powers of attraction and repulſion, in the ſame manner as ſolid matter is generally ſuppoſed to be: provided, therefore, that any body move with a ſufficient degree of velocity, or have a ſufficient momentum to overcome any powers of repulſion that it may meet with, it will find no difficulty in making its way through any body whatever; for nothing elſe will penetrate one another but powers ſuch as we know do in fact exiſt in the ſame place, and counterbalance or overrule one another. The moſt obvious difficulty, and indeed almoſt the only one, that attends this hypotheſis, as it ſuppoſes the mutual penetrability of matter, ariſes from the idea of the nature of matter; and the difficulty we meet with in attempting to force two bodies into the ſame place. But it is demonſtrable, that the firſt obſtruction ariſes from no actual contact of matter, but from mere powers of repulſion. This difficulty we can overcome, and having got within one ſphere of repulſion, we fancy that we are now impeded by the ſolid matter itſelf. But the very ſame is the opinion of the generality of mankind, with reſpect to the firſt obſtruction. Why, therefore, may not the next be only another ſphere of repulſion, which may only require a greater force than we can apply to overcome it, without diſordering the arrangement of the conſtituent particles, but which may be overcome by a body moving with the amazing velocity of light. [†]"

73 Explained. According to the theory of Boſcovich, the firſt elements or atoms of matter, are indiviſible, unextended, but ſimple, homogeneous, and finite in number. They are diſperſed in one immenſe ſpace, in ſuch a manner, that any two or more may be diſtant from each other any aſſignable interval. This interval may be indefinitely augmented or diminiſhed, but cannot entirely vaniſh. Actual contact of the atoms is therefore impoſſible, ſeeing that the repulſive power which prevents the entire vaniſhing of the interval muſt be ſufficient to deſtroy the greateſt velocities by which the atoms tend to unite. The repulſive power muſt encircle every atom, muſt be equal at equal diſtances from the atoms, and, moreover, muſt increaſe as the diſtance from the atoms diminiſhes. On the contrary, if the diſtance from the atoms increaſes, the repulſive power will diminiſh, and at laſt will become equal to nothing or vaniſh; then, and not till then, an attractive power commences, increaſes, diminiſhes, vaniſhes. But the theory does not ſtop here; for it ſuppoſes, that a repulſive power ſucceeds to the ſecond or attractive, increaſes, diminiſhes, vaniſhes; and that there are ſeveral alternations of this kind, till at the laſt an attractive power prevails; and though diminiſhing ſenſibly, as the ſquares of the diſtances increaſe, extends to the moſt diſtant regions of our ſyſtem. All the varieties of coheſion, Boſcovich has ſhown, may be ſatisfactorily accounted for from the diverſity of ſize, figure, and denſity of the cohering particles.

74 Matter in three ſtates. Bodies exiſt in three different ſtates, which are quite diſtinct from each other; in the ſolid ſtate, the liquid, and in the ſtate of elaſtic fluid. 75 Solid. Solidity, he ſuppoſes, is the conſequence of the irregular figure of the particles, and their great deviation from the ſpherical form, by which free motion among them is prevented. And thus, in ſolid bodies, the motion of one particle is followed by that of the whole maſs; or if the motion of the whole maſs requires a greater force to effect it than what is neceſſary to deſtroy the coheſion of the particles, the latter takes place. The diverſity in ſolids ariſes from the various degrees of force in the limits of coheſion.

76 Fluid. The particles of fluid bodies, according to Boſcovich, are ſpherical, and their forces are more directed to their centres than to their ſurfaces; by which motion is freely allowed when any force is applied. 77 Of three kinds. Fluids, he ſuppoſes, are of three kinds; one in which the particles have no mutual power, as ſand and fine powders; one in which they have repulſive power; ſuch are the elaſtic fluids, as air; and the third in which they have an attractive power, as water, mercury, &c. And theſe three kinds are produced by the primary differences in the particles which compoſe them.

78 Viſcid ſubſtances. There is a claſs of bodies which are intermediate between the ſolids and fluids; the nature of which may be explained on the ſame principles. Theſe are the viſcid ſubſtances, the particles of which attract each other more ſtrongly than the fluids, but not ſo ſtrongly as the ſolids. In theſe bodies the particles deviate ſo far from the ſpherical form, as to produce a certain reſiſtance among each other, and to impede their relative motion.

79 Solution. According to this theory, chemical phenomena may be traced to the ſame principle, namely the law of the forces and the differences in the particles which thence ariſe. Solution, for inſtance, is thus explained. The particles of ſome ſolid bodies have a leſs attraction for each other than for the particles of ſome fluids, and conſequently when theſe are applied to each other, the particles of the ſolid ſeparate, and combine with thoſe of the fluid; and thus a mixture of the two is formed. But the ſeparation of the particles of the ſolid can only take place ſo long as the particles of the fluid are in the ſphere of their attraction; and when either of them get beyond it, or when the attraction of the mixture thus formed becomes equal to the attraction of the particles of the ſolid for each other, no farther ſolution takes place, and the fluid is ſaid to be ſaturated. But if, into this mixture, another ſolid, whoſe particles have a greater attraction for the fluid, be introduced, the fluid will leave the former ſolid and combine with the particles of the latter. The particles of the former will fall to the bottom, or what is called *precipitation* takes place.

80 Evaporation. Subſtances which are diſſolved, may not only be obtained again by precipitation, but alſo by ſlowly abſtracting part of the fluid in which they are diſſolved. This is called *evaporation*, and the ſolid bodies which are thus ſlowly formed, generally aſſume ſome regular ſhape, and are denominated *cryſtals*. As the fluid is removed, the particles come gradually into the ſphere of the attractive power of each other, and thus attain to ſome limit of coheſion, when the fluid which kept them

---

[*] *Math. Dict.* 287.

[†] *Hiſt. of Viſion*, vol. i. p. 392.

them aſunder is removed. But when a ſolid is obtained by precipitation, the fluid is ſuddenly removed from betwixt the particles, which are conſequently left beyond the ſphere of attraction of each other, and do not therefore aſſume any regular form. And thus it will follow, that the more ſlowly the proceſs of evaporation goes on, the more regular will be the cryſtals which are formed; and this correſponds with experiment and obſervation *.

81 Cryſtallization.

Thus, ſolid bodies are found, either in irregular maſſes, or aſſume regular forms by cryſtallization; and the ſame ſubſtances which are capable of aſſuming regular figures, uniformly affect the ſame form; ſubject, however, to certain variations from particular circumſtances. No bodies can aſſume the form of cryſtals, excepting ſuch as can be reduced to the fluid ſtate. This, as is well known, is the uſual method of cryſtallizing ſalts. The ſubſtances to be cryſtallized are diſſolved in water, which is then ſlowly evaporated; and as the bulk of the fluid is diminiſhed, the particles gradually come nearer to each other, combine together, and form cryſtals. Theſe cryſtals, which are at firſt ſmall, receiving the addition of other particles, become larger, and fall to the bottom by their gravity.

Some ſaline bodies which are very ſoluble in hot water, are diſſolved but in ſmall proportion in cold water. Hot water, which is ſaturated with any of theſe ſalts, is no longer capable of holding them in ſolution when it cools. The particles then gradually approach each other, and arrange themſelves according to certain determinate forms, or in other words, they cryſtallize. Many of the ſaline bodies which cryſtallize in this manner, when they aſſume the ſolid form, combine with a conſiderable portion of water, which is called the *water of cryſtallization*. But on the other hand, there is another claſs of ſaline bodies which aſſume regular forms according to a different law. Being equally ſoluble in hot and in cold water, they cannot be cryſtallized by cooling the fluid in which they are diſſolved, but by diminiſhing its quantity; and this is effected by continuing the application of heat; that is, by the proceſs of evaporation. Salts which are cryſtallized in theſe circumſtances, contain but a ſmall quantity of water of cryſtallization. This is the caſe with common ſalt, which is cryſtallized by boiling the fluid which holds it in ſolution.

Many ſubſtances aſſume regular forms which are not ſoluble in any liquid. Such, for inſtance, is the caſe with metallic ſubſtances, and with glaſs, as well as ſome other bodies. To cryſtallize ſubſtances of this nature, they muſt be ſubjected to fuſion, and thus by combining with caloric, they are reduced to the liquid ſtate, and the particles being ſeparated from each other, are left at liberty to arrange themſelves into regular forms, or to cryſtallize, and by ſlow and gradual cooling, the cryſtals are obtained more perfect.

But what is the cauſe that the particles of bodies, in theſe circumſtances, arrange themſelves in this manner? or what is the cauſe of the ſame bodies in the ſame circumſtances aſſuming regular figures?

82 Accounted for by

According to ſome of the ancient philoſophers, the elements of bodies conſiſted of certain regular geometrical figures; but it does not appear that they employed this theory to explain cryſtallization. The regular figure of cryſtals was aſcribed by the ſchoolmen to their ſubſtantial forms; while others ſuppoſed that it was owing merely to the aggregation of the particles, without, however, explaining the reaſon of this aggregation, or of the regular figures which it formed.

83 Newton;

According to Newton, and the theory of Boſcovich which we have quoted, the particles of bodies which are held in ſolution by a fluid, are arranged in regular order, and at regular diſtances. When the force of coheſion between the particles and the fluid is diminiſhed, it is increaſed between the particles themſelves; they therefore ſeparate from the fluid, and combine together in groups, which are compoſed of the particles neareſt to each other. If it be ſuppoſed, that the particles which compoſe the ſame body have the ſame figure, the aggregation of any determinate number of ſuch particles will produce ſimilar figures.

84 by Hauy,

According to the ingenious theory of the Abbé Hauy, the integrant particles always combine in the ſame body in the ſame way; they attach themſelves together by the ſame faces or the ſame edges; but theſe faces and edges are different in different cryſtals. And although the ſame ſubſtances are obſerved to cryſtallize in a great variety of different forms, yet they all contain what Hauy calls the *primitive* form, or have it within them as a nucleus; and this nucleus or primitive figure may be extracted by careful mechanical diviſion.

85 who aſcribes it to

If then the figure of cryſtals is owing to the figure of the integrant particles, and to the peculiar mode of their arrangement in combination, theſe particles, when they are left at full liberty, as is the caſe when they are diſſolved in a fluid, will combine in the ſame way, and thus the cryſtals of the ſame body will always exhibit ſimilar forms.

86 the primitive forms.

In proſecuting this ſubject, Hauy found that all the primitive forms of cryſtals which he had obſerved, might be reduced to ſix; namely,

1. The parallelopiped.
2. The tetrahedron.
3. The octahedron.
4. The regular ſix-ſided priſm.
5. The dodecahedron, terminated by equal rhombs.
6. The dodecahedron, with triangular faces, compoſed of two pyramids, united baſe to baſe.

But the nucleus or primitive form of a cryſtal, he obſerves, is not the laſt term of its mechanical diviſion. It may be ſubdivided parallel to its different faces, and ſometimes alſo in different directions. If the nucleus or primitive form be a parallelopiped which cannot be ſubdivided, but in a direction parallel to its faces, as takes place in carbonate of lime, it is obvious that the integrant particle or molecule is ſimilar to the nucleus itſelf.

87 Figure of the integrant particles.

And he has found by experiment, that the figure of the integrant particles of all cryſtals may be reduced to the three following. Theſe are,

1. The tetrahedron, or the ſimpleſt of all pyramids.
2. The triangular priſm, or the ſimpleſt of all the priſms.
3. The parallelopiped, or the ſimpleſt of the ſolids, which have their faces parallel.

From theſe primitive forms, the difference of ſize, proportion, and denſity of the different particles of bodies, he ſuppoſes, may account for all the differences of attraction which take place in ſimple aggregation and compoſition of bodies. The integrant particles ſometimes

---

* See *Boſcovich's theory.*

ſometimes unite by their faces, and ſometimes by their edges, in forming the primitive cryſtals; and this accounts for the different figures of the primitive cryſtals, which are compoſed of integrant particles of the ſame form. But bodies when they are cryſtallized, do not always exhibit the ſame primitive form. The deviations from this, and the varieties of

88 Secondary forms

forms which are produced, are called by Hauy *ſecondary forms*. In ſome ſalts, for inſtance, the primitive form is the octahedron; but in deviating from this form, they aſſume, when cryſtallized, that of the cube or the dodecahedron.

Theſe ſecondary forms ſeem to depend ſometimes on variations in the ingredients which compoſe the integrant particles of particular bodies, the ſolvent in which the cryſtals are formed, or the different decrements of the laminæ of the cryſtals. But for a full view of this ingenious theory ſee CRYSTALLIZATION.

SECT. III. *Of the Attraction of* COMPOSITION.

Bodies which are compoſed of particles of the ſame nature cohere with a certain force, as in the particles of water or of mercury, and thoſe of wood or of metal; and this force, we have ſeen, acts with very different degrees of intenſity. In the two former, the water and the mercury, it is comparatively weak, but in the two latter it is very powerful.

89 explained.

But the diſſimilar particles of bodies alſo enter into combination; and thus combined, form homogeneous ſubſtances, whoſe particles cohere with very great force; and wherever theſe combinations take place, the force of coheſion between the particles of each of the bodies muſt be deſtroyed or overcome, before the new combination can take place. Thus a piece of marble is diſſolved in muriatic acid; but before this can take place, the force of coheſion which exiſted between the particles of the marble muſt be overcome; or, in other words, the force of attraction between the particles of muriatic acid and the particles of the marble is greater than that between the particles of marble themſelves. This attraction then which exiſts between the particles of ſubſtances of a different nature, has been called the *attraction of compoſition*, *heterogeneous affinity*, or more properly *chemical affinity*.

90 This affinity limited.

This attraction, or this affinity, does not exiſt between the particles of all bodies. Thus there is no affinity between a piece of marble and water, as is the caſe between marble and muriatic acid; and it is ſaid that there is no affinity between oil and water, becauſe the particles of the one do not enter into combination with thoſe of the other.

91 Importance of it.

Chemiſtry may be ſaid to be the hiſtory of affinities, as it conſiſts in the detail of the numerous and various compoſitions and decompoſitions which take place among natural bodies. Without attending to the phenomena which ariſe from affinity, the chemiſt could carry on no proceſs, either of ſyntheſis or analyſis; for it is by means of their affinities that the chemical nature of bodies can be diſcovered.

In taking a general view of the phenomena which depend upon chemical attraction, the changes or events which are the reſults of this action, have been divided into certain claſſes, and from their being conſtant and uniform, they have been characterized by the name of *laws of chemical affinity*. Theſe may be conſidered as chemical axioms which are the principles or foundation of the ſcience, and therefore it is neceſſary that they ſhould be well underſtood, before we enter into the detail of the facts which it embraces.

92 Laws.

The celebrated Fourcroy, whoſe indefatigable labours and extenſive views in chemical ſcience will always be admired and valued, has arranged the facts which depend on chemical affinity under ten different heads, which he has denominated *the laws of affinity*. In illuſtrating this intereſting part of chemical ſcience, we ſhall obſerve the ſame arrangement.

FIRST LAW.

93 Affinity between diſſimilar particles.

Chemical affinity takes place only between bodies of a different nature, or between diſſimilar particles.

This law, when conſidered as a law of chemical affinity, may be regarded as negative; for when the particles of bodies of the ſame nature combine together, it is by the force of coheſion, and therefore comes under that ſpecies of affinity called the attraction of aggregation. No chemical action has taken place, no new compound is formed; which are the characteriſtics of chemical affinity.

But as an inſtance of the effect of chemical affinity between two bodies of a different nature, we may refer to the experiment above alluded to, of the combination which takes place between a piece of marble and muriatic acid; for by the mutual action between theſe two bodies the marble has diſappeared, and the acid has totally changed its properties. The compound, which is the reſult of this combination, proves that the heterogeneous bodies have entered into intimate union with each other.

Chemical affinity may act between two bodies, and a combination take place, when theſe bodies are totally uncombined with all others. In this caſe the combination is produced by the force of affinity between the two bodies; but when one or both of theſe bodies is in a ſtate of combination with others, the bodies which are ſaid to have the greater affinity for each other, do not entirely combine together, and leave the bodies with which they were firſt in combination. Suppoſe A and B are two bodies which have an affinity for each other, and are in a ſtate of combination; and ſuppoſe C is a third body which has a ſtronger affinity for the body B than the affinity which exiſts between A and B. Now, the body C having a greater affinity for the body B than what exiſts between the compound body AB when it is brought into circumſtances where the force of that affinity can be exerted, the compound body AB will be decompoſed, that is, the body C will combine with the body B, and will leave the body A. It was formerly ſuppoſed by chemical philoſophers, that this decompoſition was complete; that is, as in the caſe ſtated above, the affinity between C and B being greater than the affinity between A and B, the body C, when in ſufficient quantity, abſtracted every particle of the body B from its combination with the body A. But the experiments and obſervations of the ſagacious Berthollet have placed this matter in a new light. This will be beſt illuſtrated by detailing ſome of the experiments by which this ingenious

nious philoſopher has clearly aſcertained many curious facts with regard to chemical affinity (D).

94 Examples. The ſulphuric acid has a very ſtrong affinity for the earth called barytes, forming with it a compound which is inſoluble either in hot or cold water. Sulphuric acid alſo has an affinity for potaſh, but it is much weaker than that which exiſts between the acid and barytes; yet the potaſh, although poſſeſſed of the weaker affinity, abſtracts part of the ſulphuric acid from the barytes, and combines with it. This is proved by Berthollet in the following experiment.

1. He took equal quantities of pure potaſh, and ſulphate of barytes (E), and boiled them together in a ſmall quantity of water. According to the views of former chemiſts with regard to chemical affinity, no decompoſition ſhould take place, becauſe the affinity between the ſulphuric acid and the barytes was ſtronger than that between the acid and the potaſh. But from the reſult of this experiment it appears, that the ſulphate of barytes was partially decompoſed by the potaſh, and that the ſulphuric acid was divided between the two baſes; that is, between the barytes and the potaſh.

2. The oxalic acid has a greater affinity for lime than for potaſh; but if oxalate of lime, that is oxalic acid combined with lime, be boiled along with potaſh in a ſmall quantity of water in the proportion of one part of the oxalate of lime to two of the potaſh, a partial decompoſition of the oxalate of lime will take place, part of the oxalic acid is abſtracted from the lime, and combines with the potaſh *.

95 Affinity increaſed by the maſs. 3. One part of phoſphate of lime was boiled together in a ſmall quantity of water with two parts of potaſh. The phoſphoric acid has a greater affinity for lime than for potaſh; but from this experiment it appeared that the phoſphate of lime was partially decompoſed, and part of the phoſphoric acid having combined with the potaſh, formed the new compound, phoſphate of potaſh.

From theſe experiments Berthollet obſerves, that the baſes which are ſuppoſed to form the ſtrongeſt combinations with the acids may be ſeparated from them by others whoſe affinities are ſuppoſed to be weaker, and that the acid divides itſelf between the two baſes. Where a ſmall quantity only of the decompoſing ſubſtance is employed, the effect is not perceptible; but if a large quantity be employed, as in one of the above experiments, if the ſulphate of barytes had been treated with ſucceſſive portions of potaſh, it would have been ultimately and almoſt entirely decompoſed; for the weaker affinity of any body is made up by increaſing the quantity of that body.

Bergman has remarked, that if ſix times as much of the decompoſing ſubſtance be employed as is ſufficient to ſaturate the baſe, a decompoſition will be effected which may be conſidered as total, becauſe the oppoſing ſubſtance retains ſo ſmall a part of that with which it was combined, that it may eſcape the obſerver's notice, and be conſidered as an evaneſcent quantity. But the above experiments ſhew, that a ſimilar decompoſition could be produced, if the reverſe of the experiment which Bergman recommends had been attempted.

When one ſubſtance acts on another in combination with a third, the ſubject of combination divides itſelf between the two others, not only in proportion to the energy of their reſpective affinities, but alſo in proportion to their quantities. The two ſubſtances which act on the combination may be conſidered as oppoſing forces acting on the ſubject of combination, and ſharing it between them in proportion to the intenſity of their action; and this intenſity may be eſtimated by the quantity of the ſubſtance and the energy of its affinity. The effect, therefore, muſt increaſe or diminiſh as the quantity increaſes or diminiſhes. Thus it appears that elective affinity in general does not act as a determinate force by which one body can completely ſeparate another from a combination; but that in all compoſitions and decompoſitions produced by affinity, there is a partition of the ſubject of the combination between the two bodies, the energy of whoſe affinities is oppoſed, and the proportions of this partition depend not ſolely on the difference of energy in the affinities, but alſo on the difference of the quantities of the bodies; for it has been obſerved that an exceſs of the quantity of the body whoſe affinity is the weaker, compenſates for the weakneſs of affinity.

SECOND LAW.

96 Affinity between the ultimate particles. *Chemical affinity takes place only between the ultimate particles of bodies.*

The attraction of aggregation or coheſion which is exerted between the integrant particles of bodies, is oppoſed to the action of chemical affinity. For, as in the caſe juſt mentioned, of the combination that takes place between a piece of marble and muriatic acid, the force of coheſion between the particles of the marble muſt be overcome before chemical action begins, and a new compound can be formed. The new compound conſiſts of the conſtituent particles of the two bodies, which are now intimately united by the force of affinity which exiſts between them.

THIRD LAW.

97 Between ſeveral bodies. *Chemical affinity takes place between ſeveral bodies.*

It is not merely compounds conſiſting of the particles of two bodies, that are formed by chemical affinity, for we ſhall find that there are numerous inſtances of three or four ſubſtances entering into chemical combination. Alum, a well-known ſubſtance, is a compound of three ſubſtances which have entered into chemical union. Theſe are, ſulphuric acid, alumina or pure clay, and potaſh. The ſame thing happens alſo in all thoſe compounds which are called triple ſalts, which conſiſt, like alum, of three different ſubſtances; but

* Reſearches, Tranſl.

(D) The reader, it is hoped, will find no difficulty in underſtanding the general reaſonings on this ſubject; but he will be able to comprehend it fully, after the ſubſtances whoſe affinities are given as examples, are treated of in detail in their proper places.

(E) This is the compound of ſulphuric acid and barytes, according to the new chemical nomenclature, the principles of which will be afterwards explained.

but the moſt remarkable inſtances of the effects of chemical affinity on ſeveral bodies are obſerved in the alloys of ſome of the metals. The temperature at which the metals are fuſed is generally pretty high,

98
Alloy of metals.

but an alloy of ſome of them may be brought to a ſtate of fuſion at a low temperature. This is the caſe with the alloy of biſmuth, lead, and tin, which may be melted at the temperature of boiling water, which is far below the fuſing point of any of the uncombined metals, and ſhews by this change of their properties, that a chemical union has been effected.

Fourth Law.

99
One body muſt be fluid.

That chemical affinity may take place between two bodies, it is neceſſary that one of them be in the liquid or fluid ſtate.

The ſolution of a ſolid body in a fluid, may be conſidered as the deſtruction of the coheſion of its particles, and their equal diffuſion in that fluid. It is the combination of the particles of the ſolid with thoſe of the fluid; and the compound ſtill poſſeſſes the characteriſtic phyſical properties of the fluid. Thus, in the firſt place, the force of coheſion between the particles of a ſolid body is deſtroyed, by its ſolution in a fluid; which force muſt always be overcome before a new compound can be formed by the action of chemical affinity. But, 2dly, The particles of a body diſſolved in a fluid are in their ultimate, or at leaſt very minute, ſtate of diviſion; by which means the points of contact between the particles of the body held in ſolution, and thoſe of any other with which it may combine, are greatly multiplied; and thus the operation of chemical action between theſe particles is greatly extended. Many familiar proceſſes are examples of the effects of ſolution, as ſugar diſſolved in water; common ſalt in the ſame fluid; or the experiment mentioned above, of marble in muriatic acid. In the proceſs of making glaſs we have another example of the ſame nature. The two ſubſtances which enter into the compoſition of glaſs are in the ſolid ſtate. Theſe are ſiliceous earth or ſand, and an alkali. But to effect the combination of the two ſolids, one of them is brought to the fluid ſtate by the application of heat. The alkali firſt melts, and in the ſtate of fuſion the ſand or ſiliceous earth combines with it, and forms an uniform compound, which is glaſs.

100
Effect of ſolubility.

But Berthollet has ſhewn, that the ſolubility of bodies has a very great influence in modifying the action of chemical affinity. For he obſerves, when a body is in ſome degree ſoluble, its action is compoſed of that of the part diſſolved and of that of the part which has retained its ſolidity. It follows that its action does not increaſe in proportion to the quantity employed. Lime, for inſtance, acts by the part diſſolved, and by that which remains ſolid; but it is probably the diſſolved part which contributes principally to the effect produced. If the quantity of lime employed in an experiment be doubled, without increaſing the quantity of the liquid, the quantity of lime diſſolved will rather be diminiſhed than increaſed, becauſe a part of the liquid is abſorbed by the lime which has been added.

If an inſoluble combination can become ſoluble by being deprived of a part of its compoſition, the inconvenience of inſolubility is eaſily removed. Thus it is, when the phoſphate of lime is acted on by an acid. The part of it which is within the ſphere of action is inſtantly converted into an acidulous phoſphate, and the other part ſucceſſively, until both the oppoſed ſubſtances be reduced to a liquid ſtate.

" When an eliminated ſubſtance becomes inſoluble, the precipitate which is formed retains a portion of the ſubſtance with which it was combined, in proportion to the individual forces which acted in the moment of the precipitation. The operation is no farther influenced by this portion, ſo that the quantity of the precipitating body adequate to the precipitation is all that is neceſſary until the end of the operation. But the caſe is different when the eliminated ſubſtance aſſumes the liquid ſtate, for then the reſiſtance increaſes according to the progreſs of the decompoſition; and hence it follows, if a ſubſtance nearly inſoluble be oppoſed to a combination, and its action be conſequently only partial, whilſt the ſubſtance eliminated remains liquid, that the decompoſition muſt be quickly ſtopped, whatever may be the force of the affinities. Becauſe it has been already ſhewn that the decompoſing action depends not merely on the affinities, but alſo on the relative quantities in action. When the ſulphate of potaſh was decompoſed by means of lime, the operation was neceſſarily ſtopped as ſoon as the ſulphuric acid was entirely divided between the potaſh and lime, in proportion to their reſpective affinities, and to the quantity of each which had acted on the ſulphuric acid; that is, in proportion to their reſpective maſſes" *.

101
Elaſtic fluids.

But fluids in the elaſtic ſtate, or the ſtate of gas, produce effects which are contrary to thoſe of the force of coheſion; and thus modify in a different manner the effects of the particular affinity of each ſubſtance. Elaſticity acts, either by the removal of ſome ſubſtances from the action of others, or by diminiſhing their proportion within the ſphere of action. But if all the ſubſtances in action be in the elaſtic ſtate, this effect will not follow, becauſe then they all exiſt in a ſimilar condition. When a ſubſtance on ſeparating from an intimate combination, aſſumes the ſtate of gas, it becomes elaſtic, and then it can oppoſe no further reſiſtance to the decompoſing action. And thus it appears that ſubſtances of this nature do not act by their maſs. A complete decompoſition can then be effected by the decompoſing ſubſtance, and no greater quantity of it is required than what would have been neceſſary to form the compound by direct combination. Thus, carbonic acid, which is an elaſtic fluid, may be diſengaged from its combination by another ſubſtance whoſe affinity for the baſe may be leſs, becauſe that other ſubſtance can act by its maſs, and can therefore overcome the affinity of the carbonic acid by its ſucceſſive action. But if the whole of the carbonic acid is to be expelled, the decompoſing ſubſtance muſt be uſed in greater quantity than what is juſt neceſſary to produce ſaturation.

102
Example.

The action which takes place when concentrated ſulphuric acid is poured on dry common ſalt, that is, both ſubſtances being as much as poſſible deprived of water, affords a good illuſtration of the effect of the elaſticity of one of the ſubſtances. Common ſalt is compoſed of muriatic acid and ſoda. The affinity of the ſulphuric acid for ſoda is greater than that

---

* *Berthollet's Reſearches*, art. 4.

of muriatic acid. When, therefore, the ſulphuric acid is poured on the common ſalt, it combines with the ſoda, and the affinity of the muriatic acid is diminiſhed. It conſequently aſſumes the gaſeous ſtate, and acts no longer by its maſs. But if a ſolution of common ſalt in water be employed, or a diluted acid, then the muriatic acid may be retained in the water, and in this caſe it can act by its maſs.

When, therefore, a ſubſtance is in the ſtate of gas, its elaſticity is to be conſidered as a force oppoſed to the affinity of liquid ſubſtances. When the elaſticity of gaſeous ſubſtances is diminiſhed, as happens by compreſſion, they then combine in greater quantity with liquids. When water is brought into contact with carbonic acid, which is in the ſtate of gas, it does not become ſaturated with that acid, becauſe the elaſticity of the gaſeous acid oppoſes the diſſolving power of the water: and before its diſſolving force is exhauſted, the two forces are balanced. But when the oppoſing elaſtic force is diminiſhed, as by compreſſion, the diſſolving power of the water continues its action, and thus it is more fully ſaturated with the acid.

Fifth Law.

103 Change of temperature.

When bodies combine together, they undergo a change of temperature.

In all bodies there exiſts a certain quantity of caloric, or the matter of heat; but when any change takes place in the nature or conſtitution of any body, its power of retaining that portion of caloric is alſo changed. During theſe changes heat is either given out or abſorbed; and this increaſe or diminution of temperature becomes obvious to our ſenſes, or may be meaſured by the thermometer.

The effects of this variation of temperature will be greater or leſs, in promoting or retarding the action of chemical affinity, according to the change which takes place on the ſubſtances which are decompoſed, or according to the ſtate of the compound which is formed. When there is a great elevation of temperature, in conſequence of the heat produced by the combination of ſubſtances, it is neceſſary to attend to the difference of volatility of which the ſubſtances are ſuſceptible by that elevation of temperature. If the ſubſtances are not all in the liquid ſtate, or if one of them only be ſoluble, the effect of heat is to favour their mutual action; becauſe the force of coheſion, which acts even between the particles of bodies in the liquid ſtate, is thus diminiſhed. If the expanſion by heat of the one of two ſubſtances be greater than that of the other, the more expanded ſubſtance acquires a greater degree of elaſticity, and this, as has been already obſerved, muſt be conſidered as a force oppoſing the affinity which exiſted between the two bodies.

In chemical combinations, according to this law, the temperature changes, and it is either increaſed or diminiſhed, according to the nature of the combination which is effected. This will be beſt illuſtrated by an example or two.

104 Examples.

1. When lime is ſlacked, that is, when water is thrown upon burnt lime, a great elevation of temperature takes place. The water enters into combination with the lime; it paſſes from the fluid to the ſolid ſtate; and, during this change, a great quantity of caloric, or the matter of heat, is given out, which is the cauſe of the increaſe of temperature (F).

2. As an example of two fluids when mixed together producing a ſimilar effect, take four parts of concentrated ſulphuric acid, and pour it on one part of water; the temperature of the combined fluids will be elevated to the boiling point of water.

In the ſolution of ſolid bodies in a fluid, there is a great change of temperature; but in this caſe it is diminiſhed. This is particularly the caſe when ſalts are diſſolved in water.

1. Take muriate of ammonia, or ſal ammoniac, and diſſolve it in water, and while the ſolution is going on, if a thermometer be plunged into it, there will be a conſiderable fall of the mercury in conſequence of the abſorption of caloric, or the diminution of temperature.

2. If one part of water, at the temperature of 50° or 60° of Fahrenheit, be poured on an equal quantity of ice, the temperature of the water will be diminiſhed to the freezing point, or 32°.

3. A very low temperature is produced by a mixture of ice and common ſalt; and a ſtill lower by a mixture of ſnow and powdered muriate of lime. But we ſhall become better acquainted with the effects of theſe ſubſtances in explaining the method of producing artificial cold.

Sixth Law.

105 Compounds have new properties.

The compounds formed by chemical affinity poſſeſs new properties, and different from thoſe of their conſtituent parts.

We are too little acquainted with the nature of chemical affinity, to be able to determine, *à priori*, what is to be the reſult of a combination between two ſubſtances. No information can be obtained what the nature of the union will be, from knowing the properties of the ſubſtances which are to be combined. It is only by experiment that the nature and properties of the new compound can be aſcertained.

Unwilling to ſuppoſe, or unable to conceive, that the properties of the two ſubſtances which enter into combination, had totally diſappeared in the new compound, the earlier chemiſts imagined that the properties of the latter were of a middle nature, conſiſting of the mixed properties of the compoſing ſubſtances. Hence the compounds of the acids and the alkalies were denominated *middle ſalts*, *ſales medii*, from poſſeſſing the combined properties of their component ſubſtances.

But the truth of this doctrine, with regard to the nature of compound ſubſtances, has been fully diſproved by the more accurate obſervations of modern chemiſts; for it is found by experiment that the compound formed exhibits not a ſingle property of any of the ſubſtances of which it is compoſed. On the contrary, of two mild and inſipid ſubſtances, a compound is formed which is highly acrid and corroſive;

(F) The explanation of this phenomenon will be given, when we come to treat of heat.

ſive; and the reſult of the combination of two powerfully corroſive ſubſtances, is frequently a mild and inſipid compound.

It is indeed one of the characteriſtics of chemical affinity, that there be a total change in the properties of the ſubſtances which enter into combination. This change takes place in the ſenſible qualities of many of the compounds, and ſome of theſe, as an illuſtration of this law, may be mentioned.

(1.) Changes of colour. The colour of lead is a bluiſh white, but when it combines with oxygen it aſſumes a bright yellow or red colour, in proportion to the quantity of oxygen. Cobalt, which is of a gray colour, when combined with oxygen, becomes of a fine blue; and copper, which is red, combined in the ſame way, exhibits a green colour.

(2.) Changes in ſmell. 1. The ſmell of muriatic acid is highly pungent; ammonia, or the volatile alkali, is not leſs ſo; but when theſe two are combined, forming muriate of ammonia, or ſal ammoniac, the new compound is perfectly inodorous. This laſt is a remarkable inſtance of two highly volatile and odorous ſubſtances becoming fixed in the compound, and deſtitute of ſmell, and thus exhibiting a total change of their properties.

2. The ſmell of ſulphur and of potaſh is ſcarcely perceptible in the uncombined ſtate; but when they are united together, and moiſtened with water, a moſt fœtid and offenſive odour is emitted.

(3.) Changes in taſte. 1. The taſte of ſulphur is nearly inſipid; and oxygen, which is one of the component parts of the atmoſphere, is not only innocent, but neceſſary for the exiſtence of animals: but when theſe two enter into union, the compound formed, which is ſulphuric acid, is one of the moſt corroſive ſubſtances.

2. Sulphuric acid, which is ſour and corroſive, forms a combination with ſoda, which is alſo of a corroſive nature; the reſult, which is Glauber ſalt, or ſulphate of ſoda, is a compound of a bitter, nauſeous taſte, but poſſeſſing none of the properties of its component parts.

SEVENTH LAW.

106 Force of affinity

The force of chemical affinity, is eſtimated by the force which is neceſſary to ſeparate the ſubſtances which enter into combination.

In treating of coheſion, or the attraction of aggregation, it was ſtated, that the method employed by philoſophers to eſtimate that force, was to meaſure the oppoſite force, or that which was neceſſary to overcome the coheſive force. Thus, the weight attached to the lower extremity of a metallic wire perpendicularly ſuſpended, which was juſt ſufficient to tear it aſunder, is conſidered as the meaſure of its power of coheſion. But it will appear from what follows that this law muſt be adopted with conſiderable modification.

107 eſtimated by the time of ſolution; In eſtimating the force of chemical affinity, various methods have been propoſed by different philoſophical chemiſts. It was thought by Wenzel, that the time which one body required to diſſolve another, might be conſidered as the meaſure of the force of affinity between theſe two bodies; but it muſt appear from what has been already ſaid, that the time of ſolution muſt depend greatly on the coheſive force of the body which is to be diſſolved, and the nature of the compound which is formed; ſo that from theſe deviations, no certain meaſure can be obtained from this method.

108 by the difficulty of ſeparation; According to ſome, the meaſure of the force of chemical affinity may be eſtimated by the difficulty of ſeparating the ſubſtances which have entered into combination; or, by taking the compound ratio of the facility with which they are combined. But as no method has been invented to aſcertain either the one or the other, which are the neceſſary previous ſteps in the method propoſed, it is impoſſible, in this way, to eſtimate the force of chemical affinities.

109 by the affinity for caloric. Obſerving the effects of the union and abſtraction of caloric, in the operations of chemical affinity, Lavoiſier and La Place, in a memoir publiſhed in 1783, propoſed this as the method of eſtimating the force of affinity. But it ſeems ſcarcely poſſible to meaſure the force of chemical affinity between two ſubſtances by the degree of temperature which is required to overcome the force of coheſion; or, as this degree of temperature has no meaſurable proportion with the force of chemical affinity, it can afford no data for eſtimating this force. And this quantity being variable and unknown, a fixed term is wanting to form a ſcale of compariſon.

We have already mentioned, in treating of adheſion, the experiments of Dr Taylor on the adheſion of ſurfaces, and the experiments and concluſions of Morveau and Achard on the ſame ſubject. From theſe Morveau has propoſed to deduce a method of eſtimating the force of chemical affinities. But for an account of this, we refer the reader to the firſt ſection.

110 Kirwan's method. A different method has been propoſed by Mr Kirwan, in his experiments and obſervations on the attractive powers of mineral acids *. He obſerves, that the principal end which he had "in view was, to aſcertain and meaſure the degrees of affinity or attraction that ſubſiſt between the mineral acids, and the various baſes with which they may be combined; a ſubject of the greateſt importance, as it is upon this foundation that chemiſtry, conſidered as a ſcience, muſt finally reſt; and though much has been already done, and many general obſervations laid down on this head, yet ſo many exceptions have occurred, even to ſuch of theſe obſervations as ſeem to have been moſt firmly eſtabliſhed, that not only a variety of tables of affinity have been formed, but many very eminent chemiſts have been induced to doubt whether any general law whatſoever could be traced" †.

"The diſcovery of the quantity of real acid in each of the mineral acid liquors, and the proportion of real acid taken up by a given quantity of each baſis at the point of ſaturation, led me unexpectedly to what ſeems to me the true method of inveſtigating the quantity of attraction which each acid bears to the ſeveral baſes to which it is capable of uniting. For it was impoſſible not to perceive,

1ſt, That the quantity of real acid neceſſary to ſaturate a given weight of each baſe, is inverſely as the affinity of each baſe to ſuch acid.

2dly, That the quantity of each baſe requiſite to ſaturate a given quantity of each acid, is directly as the affinity of ſuch acid to each baſe.

Thus, 100 grs. of each of the acids require for their ſaturation, a greater quantity of fixed alkali than of calcareous

---

* *Phil. Tranſ.* vol. lxxiii.

† *Ibid.* p 34.

calcareous earths, more of this earth than of volatile alkali, more of this alkali than of magneſia, and more of magneſia, than of earth of alum; as may be ſeen in the following table.

Quantity of baſe taken up by 100 grs. of each of the three acids.

	Potaſh.	Soda.	Lime.	Ammonia	Magneſia.	Alum.
	grs.	grs.	grs.	grs.	grs.	grs.
Sulphuric acid.	215	165	110	90	80	75
Nitric acid.	215	165	96	87	75	65
Muriatic acid.	215	158	89	79	71	55

"As theſe numbers," Mr Kirwan obſerves, "agree with what common experience teaches us concerning the affinity of theſe acids with their reſpective baſes, they may be conſidered as adequate expreſſions of the quantity of that affinity. Thus, the affinity of the ſulphuric acid to potaſh, that is, the force with which they unite to each other, is to the affinity with which that ſame acid unites to lime, as 215 grs. to 110; and to that which the nitric acid bears to lime, as 215 to 96."

111 Objections. But to this method of Mr Kirwan objections have been made by Morveau and Berthollet. It is ſtated that the eſſential principle of the force of affinity being in the direct ratio to the quantity of baſe, is not fully eſtabliſhed. According to the experiments of Morveau, a quantity of ſulphuric acid containing 100 grs. of real acid, required for ſaturation 201 grs. of cryſtallized carbonate of potaſh: a quantity of nitric acid which contained 100 grs. of real acid, required 302 grs. for ſaturation; and a quantity of muriatic acid containing 100. grs of real acid, required no leſs than 905 grs. of the ſame ſalt for ſaturation. From theſe experiments it appears, that Mr Kirwan's calculations are erroneous, or that the principle on which he has proceeded is falſe; for equal quantities of real acids require for ſaturation different quantities of potaſh; and beſides, the quantity of baſe required is in the inverſe ratio to the force of affinity, which is the reverſe of Mr Kirwan's principle.

Mr Kirwan, however, has acknowledged the force of theſe objections, and has deduced the proportion of real acid in the nitric and ſulphuric acids, from leſs exceptionable principles. His table, therefore, which expreſſes in numbers the ſtrength of affinities, is conſidered as the moſt correct which has yet been publiſhed; and his general principle, that the quantity of baſe required to ſaturate a given quantity of real acid, is the expreſſion of the force of affinity between the acid and the baſe, ſeems to receive additional confirmation in proportion to the progreſs of chemical knowledge.

Mr Kirwan has corrected the quantity of baſe taken up by 100 parts of ſulphuric, nitric, muriatic, and carbonic acids, as will be ſeen in the following table*.

100pts.	Potaſh.	Soda.	Ammonia.	Barytes.	Strontites.	Lime.	Magneſia.
Sulphuric.	121.48	78.32	26.05	200.	138.	70.	57.92
Nitric.	117.7	73.43	40.35	178.12	116.86	55.7	47.64
Muriatic.	177.6	136.2	58.48	314.46	216.21	118.3	89.8
Carbonic.	95.1	149.6		354.5	231.+	122.	50.

But according to the experiments and obſervations of Berthollet, as the force of affinity varies in proportion to the maſs of any body, no method, however accurate in other reſpects, will afford a certain rule for eſtimating the force of chemical affinity.

Eighth Law.

112 Different affinities among bodies. *Bodies have different degrees of affinity for each other.*

On the different force of affinity which exiſts between different bodies, depend many of the moſt important operations in chemiſtry; and it is by multiplying the objects of this law, that chemical ſcience can be improved and extended.

113 Two kinds. Affinities have been divided into two kinds, *ſimple* affinity, and *compound* affinity; or ſimple elective attractions, and double elective attractions.

114 Between two bodies. *Simple affinity.*—The firſt of theſe includes all thoſe combinations which directly take place between two bodies, as when muriatic acid and lime are combined together. It is alſo a caſe of ſimple affinity, or ſingle elective attraction, when to a ſolution which contains two ſubſtances, there is added a third which produces the ſeparation of one of the diſſolved bodies. This takes place when potaſh is added to the ſolution of lime in muriatic acid. The potaſh has a ſtronger affinity for the muriatic acid than the lime; it therefore ſeparates the acid from the lime, combines with it, and remains in the ſolution. The lime thus ſeparated from its combination, appears in the ſolid form, and falls to the bottom. This is called a precipitate.

115 Precipitates. In practical chemiſtry precipitates are diſtinguiſhed into ſeveral kinds. It is ſaid to be a real or true precipitate when the body which is diſengaged from the combination falls to the bottom, as in the caſe above where the lime fell to the bottom, after being ſeparated from the muriatic acid. A falſe precipitate is when the new compound which is formed falls down, as when ſulphuric acid is added to any ſolution of lime; for the compound being inſoluble, it appears in the form of a precipitate. A precipitate is ſaid to be pure when the body which has been decompoſed, can be formed again from the ſeparated conſtituent parts; and impure when

---

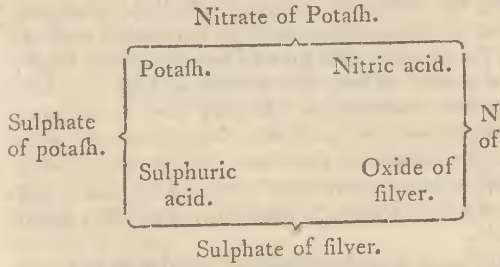
* *Anal. of Min. Waters.*

when this cannot be effected; that is, probably, when the decompoſition has not been complete. It ſometimes happens when a body which conſiſts of two ſubſtances, is decompoſed by means of a third, that the diſengaged ſubſtance aſſumes the elaſtic form. This is the caſe when muriate of ammonia is decompoſed by quicklime. The muriatic acid which is in combination with the ammonia, unites with the lime for which it has the greater attraction; and the ammonia is ſet free, and is inſtantly volatilized.

116 Between more than two.

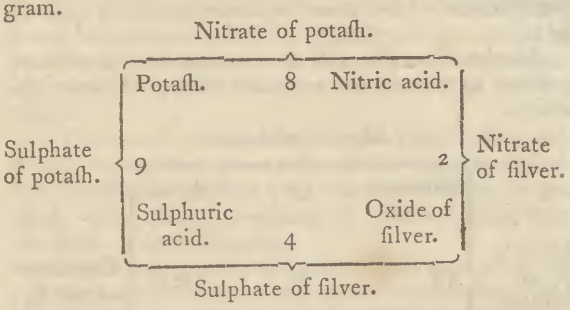
Compound affinity.—But there are ſubſtances which cannot be decompoſed when a third ſubſtance is preſented. The affinity of the two ſubſtances A and B in combination, may be ſo much ſtronger than the affinity of a third C for either A or B, that no decompoſition will take place when the body C is preſented to the compound of A and B. Suppoſe the two ſubſtances A and B are held united with a force equal to 12, and the force of affinity between the body C and B is equal only to 8, it is obvious that no change can be effected, becauſe the force of affinity between C and B cannot overcome the coheſive force that exiſts between A and B. But if a fourth body D is preſented to the compound A and B, and acts with a force on the body A equal to 6, while the body C acts on B with a force equal to 8, it is evident that the combined action of theſe two forces will overcome the force of affinity between A and B, which was ſuppoſed to be equal to 12, becauſe the meaſure of a force equal to 14 is greater than one equal to 12; and in this way the decompoſition of the body A and B is effected by the united action of two other bodies which would not have ſucceeded, had any one been preſented to it ſingly. From this double action a decompoſition of this kind is called a *double elective attraction*, a name given by Bergman, or a caſe of compound or complex affinity, as it has been propoſed to be denominated by later chemiſts.

Bergman invented a method of exhibiting theſe attractions, as in the following diagram.



In this example the ſubſtances to be decompoſed are placed on the right and left ſides of the diagram. Theſe are the ſulphate of potaſh compoſed of ſulphuric acid, and potaſh on the left ſide; and the nitrate of ſilver, which conſiſts of nitric acid and the oxide of ſilver. When theſe compounds are combined together, a decompoſition is effected by the mutual affinities between the conſtituent parts of the compounds. Thus the ſulphuric acid in combination with the potaſh, forms a new compound with the oxide of ſilver; and the nitric acid in combination with the ſilver, forms a new compound with the potaſh; becauſe the ſum of the force of affinities between the nitric acid and the potaſh, and the ſulphuric acid and the oxide of ſilver, is greater than the ſum of the affinities between the ſulphuric acid and the potaſh, and the nitric acid and the oxide of ſilver; and thus an exchange of principles takes place, and the new compounds are repreſented at the top and bottom of the diagram, namely the nitrate of potaſh and the ſulphate of ſilver.

Mr Elliot in the year 1782 propoſed, as an improvement on Bergman's method, to repreſent the force of theſe attractions by numbers. The ſame caſe in Mr Elliot's method is repreſented in the following diagram.

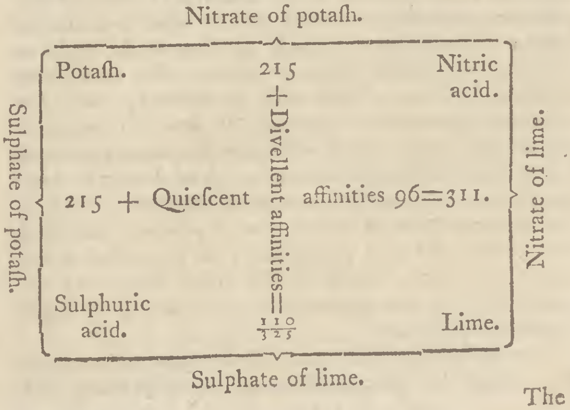


As it is thus repreſented, the ſulphuric acid and the potaſh are ſuppoſed to act with a force equal to 9; and the nitric acid and the oxide of ſilver attract with a force equal to 2. The affinity of the potaſh for the nitric acid is equal to 8; and the affinity between the ſulphuric acid and the oxide of ſilver is equal to 4. But 9+2=11, and 8+4=12, conſequently the ſum of the affinities between the nitric acid and the potaſh, and the ſulphuric acid and the oxide of ſilver, exceeds the ſum of the affinities between the nitric acid and the oxide of ſilver, and the ſulphuric acid and the potaſh, and thus a decompoſition is effected.

117 Two forces to be conſidered.

But "in all decompoſitions," ſays Mr Kirwan, "we muſt conſider, firſt, the powers which reſiſt any decompoſition, and tend to keep the bodies in their preſent ſtate; and 2dly, the powers which tend to effect a decompoſition and a new union. The firſt I ſhall call quieſcent affinities, and the ſecond, divellent.

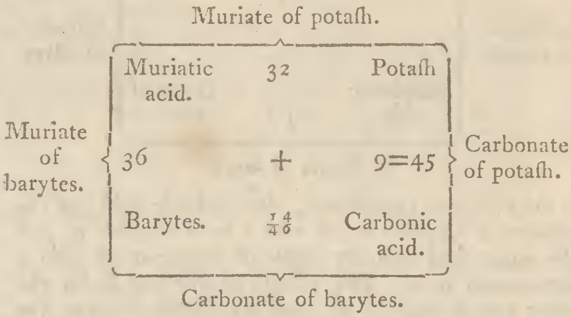
"A decompoſition will always take place when the ſum of the divellent affinities is greater than that of the quieſcent; and on the contrary no decompoſition will happen when the ſum of the quieſcent affinities is ſuperior to, or equal to that of the divellent: all we have to do, therefore, is to compare the ſums of each of theſe powers. Thus, if the ſolutions of ſulphate of potaſh and nitrate of lime be mixed together, a double decompoſition will take place" * This may be illuſtrated by the following diagram.



The

The affinities between the nitric acid and lime, and between the ſulphuric acid and the potaſh, which taken together amount to 311, are the quieſcent affinities. The affinities of the ſulphuric acid and the lime, and of the nitric acid and the potaſh, are the divellent affinities which are oppoſed to the firſt. But the amount of the latter is equal to 325, that is, the combined affinities of the ſubſtances which tend to form a new combination, and thus they overcome the force of the reſiſtance of the quieſcent affinities, as 325 exceeds 311.

Another example will ſerve to make this decompoſition by double or compound affinity ſtill more familiar.



In this caſe a ſolution of muriate of barytes is mixed with a ſolution of the carbonate of potaſh. The affinity of the muriatic acid for the barytes, and that of the potaſh for the carbonic acid, are the quieſcent affinities which are oppoſed to any decompoſing force. But on the contrary, the affinity of the muriatic acid for the potaſh, and that of the barytes for the carbonic acid, are the divellent affinities. The quieſcent affinities are only equal to 45, while the ſum of the divellent affinities is equal to 46; the latter muſt therefore prevail. The former combinations are broken, and inſtead of muriate of barytes, and carbonate of potaſh, we obtain muriate of potaſh and carbonate of barytes, which latter is inſoluble, and is therefore precipitated.

118 This force not conſtant.

But Berthollet has ſhown that the force of affinity is not conſtant and uniform, but is greatly influenced by the quantity and the ſtate of ſaturation. As, for inſtance, when two baſes act in oppoſition on an acid, the acid divides its action in proportion to their reſpective maſſes. If there be two acids inſtead of one, and no ſeparation take place, either by precipitation or cryſtallization, both acids will act equally on both baſes, in proportion to their maſſes. If each of the acids be previouſly combined with a baſe, and the ſolutions of their ſalts be mixed, the ſum of the reciprocal forces will be the ſame as before. No muriate of potaſh or ſulphate of lime will be formed; but there will be a combination of potaſh, of lime, of ſulphuric and muriatic acid, which will have the ſame degree of ſaturation as before the mixture. And hence it happens, that when two ſalts are mixed together, the mutual decompoſition of which would produce combinations of very different proportions, the ſeparation of the component parts, which ſhould reſult from ſuch decompoſition, is not perceptible. No change of baſes therefore takes place.

The force of coheſion cauſes the ſeparation which takes place by precipitation or cryſtallization. A ſimilar effect is produced by the ſame cauſe, in the action of complex affinities. If a ſolution of ſulphate of potaſh be mixed with muriate of lime, diſſolved in a ſmall quantity of water, the lime brought into contact with the ſulphuric acid, will be more powerfully influenced by the force of coheſion, than the potaſh. This is therefore to be conſidered as an additional force to thoſe which pre-exiſted, and determines the combination of the ſulphuric acid with the lime, and the precipitation of the new compound.

In all decompoſitions effected by compound affinity, the prevailing affinity has been aſcribed to thoſe ſubſtances which have the property of precipitating, or of forming a ſalt which can be ſeparated by cryſtallization. Thus the knowledge of the ſolubility of ſalts which may be formed in a liquid, will point out thoſe ſubſtances which are leaſt ſoluble, and therefore moſt apt to precipitate. To theſe ſubſtances chemiſts formerly aſcribed the ſtrongeſt affinity.

119 Moſt inſoluble compounds precipitate.

Lime, magneſia, ſtrontites, and barytes, form inſoluble ſalts with carbonic acid. When therefore, any of the ſoluble ſalts of theſe earths are mixed with alkaline carbonates, an exchange is produced, from which reſult the formation and precipitation of an earthy carbonate. The compound of ſulphuric acid and barytes forms an inſoluble ſalt. When, therefore, a ſolution of a ſulphate is mixed with that of a ſalt of barytes, a precipitation of ſulphate of barytes, which is inſoluble, will be effected. The ſulphate of lime has alſo but little ſolubility, and conſequently it is much diſpoſed to precipitate. Lime therefore decompoſes all the ſoluble ſulphates. But the ſulphate of lime being much more ſoluble than the ſulphate of barytes, the ſalts of barytes, which are more ſoluble than the ſulphate of lime, decompoſe it.

120 Temperature to be conſidered.

There are other circumſtances which tend to change the action of compound affinities. This action is greatly influenced by the greater or leſs ſolubility of ſalts. But the ſolubility of ſalts is varied by temperature. In eſtimating the reſult of compound affinities, therefore, the degree of temperature muſt be conſidered and taken into the account. To give an inſtance of this effect, nitrate of potaſh mixed with muriate of ſoda, cryſtallizes at a low temperature. During the evaporation the muriate of ſoda is ſeparated. No change of baſes will take place, becauſe the nitrate of ſoda is ſomewhat more ſoluble when cold, than nitrate of potaſh; and muriate of potaſh is more ſoluble when hot, than muriate of ſoda.

The action of complex affinities may alſo be changed by the formation of a triple ſalt which precipitates; but if the ſolubility of the combination be known, the decompoſition which is effected, and the reſulting compounds, may alſo be foreſeen.*

121 Reciprocal action.

According to the theory of Berthollet, all ſubſtances in the liquid ſtate exert a reciprocal action. In a ſolution of ſulphate of potaſh and muriate of ſoda, theſe two ſalts are not diſtinct, nor do they become ſo, until ſome extraneous cauſe produces their ſeparation. Sulphuric and muriatic acids, potaſh and ſoda, are contained in the liquid. To aſcertain what combinations are produced by the force of cryſtallization, he made the following experiments.

122 Force of cryſtallization.

"*Experiment* 1.—A mixture was made of equal parts of nitrate of lime and ſulphate of potaſh: after the ſeparation

---

* *Berthollet's Reſearches*, art. 13.

paration of the ſulphate of lime formed in the commencement, and of which no further mention ſhall be made in the following experiments, the liquid was evaporated, and nitrate of potaſh and ſulphate of lime were alone obtained by ſucceſſive operations. Yet, after the laſt evaporation, ſome cryſtals of ſulphate of potaſh were obtained : there was but a ſmall reſidue of uncryſtallizable liquid, in which carbonate of ſoda and nitrate of barytes produced precipitations ; whence it appears that it conſiſted of a ſmall quantity of ſulphuric acid and lime, and very probably of a larger portion of nitrate of potaſh.

" The quantity of ſulphate of lime which precipitated during this evaporation, was much greater than what could be diſſolved in an equal quantity of water ; whence it appears that its ſolubility was augmented by the action of the other ſubſtances.

" *Experiment* 2.—Two parts of ſulphate of potaſh, and one of nitrate of lime, yielded, by the firſt evaporation, ſulphate of potaſh and ſulphate of lime ; and by the following, nitrate of potaſh with the two ſulphates, the proportions of which continued to diminiſh until the ſalts ceaſed to cryſtallize : only a few drops of uncryſtallized liquid remained, in which no precipitate was formed on adding to it ſome carbonate of ſoda, but this effect was produced by the nitrate of barytes ; whence it appears probable that the liquid conſiſted of ſulphate of potaſh, and a ſmall proportion of nitrate of potaſh.

" *Experiment* 3.—Two parts of nitrate of lime, and one of ſulphate of potaſh, yielded by the firſt evaporation a ſmall quantity of ſulphate of lime, and on cooling, ſome nitrate of potaſh ; by the ſucceeding evaporations nothing but nitrate of potaſh was obtained. After the laſt, however, ſome cryſtals of ſulphate of lime were perceivable on the ſurface of the liquid. Though the reſidue, which was abundant, was repeatedly put to evaporate and cool, no cryſtallization was effected. This uncryſtallizable reſidue, treated with alcohol, yielded an abundant precipitate, in the ſolution of which in water no precipitate could be produced by nitrate of barytes ; whence it appears that it contained no ſulphuric acid, and that it was compoſed of pure nitrate of potaſh. What had been diſſolved in the alcohol was nitrate of lime, with a ſmall proportion of nitrate of potaſh : the uncryſtallizable reſidue conſiſted, therefore, of nitrate of potaſh and nitrate of lime.

" It appears that the ſulphate of lime was rendered much leſs ſoluble in this than in the preceding experiments ; and that the action of nitrate of lime prevented a conſiderable quantity of the nitrate of potaſh from cryſtallizing.

" Sulphate of lime was neceſſarily formed in theſe three experiments, becauſe its component parts were in contact ; and the inſolubility of the compound formed by them, occaſioned its precipitation to a certain extent.

" In the firſt and ſecond experiments, the ſulphate of lime was rendered much more ſoluble than it naturally is, by the action of the ſubſtances in ſolution ; but in the third experiment, its ſolubility was not perceptibly increaſed, for this reaſon, probably, that the nitrate of lime and nitrate of potaſh, which exiſted in the uncryſtallizable liquid, had mutually ſaturated each other ſo much as to diminiſh their action on the ſulphate of lime [*].

From theſe conſiderations, he deduces the theory of uncryſtallizable reſidues : which the ſucceeding obſervations tend to confirm.

" Saline ſubſtances exert a mutual action, which augments their ſolibility ; as has been proved by the experiments publiſhed by my learned colleague Vauquelin. This reciprocal action varies in different ſalts ; it was once ſuppoſed that the ſolubility of the nitrate of potaſh was not augmented by the action of earthy ſalts ; and yet it is augmented more by them than by any others.

" There muſt be, doubtleſs, in this reſpect, ſome difference ariſing from the nature of the ſalts, in the effect which they produce ; but this difference is, in general, very trifling, compared to that reſulting from the force of cryſtallization.

" *Experiment* 4.—A mixture of equal parts of nitrate and ſulphate of potaſh, yielded by evaporation, and ſucceſſively, according to their ſolubility, ſulphate of potaſh and nitrate of potaſh, without leaving any uncryſtallizable reſidue ; but having made a ſimilar experiment with a mixture of nitrate and ſulphate of ſoda, each of which has but a feeble tendency to cryſtallize, and nearly an equal degree of ſolubility, there was ſeparated by cryſtallization but a ſmall portion of the ſulphate of ſoda, the other parts of the mixture continuing in the liquid ſtate, incapable of being cryſtallized by any means. Muriate of ſoda and ſulphate of alumine, ſubmitted to the ſame treatment, were perceived to become more ſoluble ; but they were totally ſeparated in the end by alternate evaporation and cooling.

" It appears, then, that ſubſtances which are endued with an active tendency to cryſtallize, though rendered more ſoluble than they naturally are, ſeparate however in the order of their inſolubility, without leaving any, or but very little, uncryſtallizable reſidue.

" But when a mixture conſiſts of ſalts which have but a weak tendency to cryſtallize, their mutual action counteracts that tendency, ſo that a large portion of uncryſtallizable liquid remains : this effect is ſtill more complete when the mixture contains a ſubſtance naturally uncryſtallizable, as in the third experiment, in which there was an exceſs of nitrate of lime, the action of which exceſs on the nitrate of potaſh rendered a great portion of it uncryſtallizable."[†]

From this it appears, Berthollet obſerves, that the formation of ſalts obtained by cryſtallization, depends on the proportions of the ſubſtances which act on each other ; and combinations may be formed which vary from the proportions of the ſubſtances employed, or the ſtage of the operation ; that is, from the proportions which continue in action, when the combinations which might take place are not endued with a force of coheſion ſufficient to withdraw them from the ſphere of action.

Ninth Law.

123 Affinity diminiſhes towards the point of ſaturation.

Affinity is in the inverſe ratio of ſaturation.

In moſt of the combinations which take place between bodies, there exiſts a certain determinate proportion of the quantity of the ſubſtances which form the compound. On this indeed depend the conſtancy

and

---

[*] Berthollet's Reſearches, art. 13.

[†] Ibid.

and permanency, both of natural and artificial compounds. It is to this uniformity and permanency that their characteriſtic properties are owing; for when the proportions in compound bodies vary, although the conſtituent parts be of the ſame nature, yet the properties of the compound are greatly changed. Thus, in a caſe already mentioned, the different proportions of oxygen with lead, different compounds are produced; with a ſmaller proportion of oxygen, the reſulting compound is yellow, but with a greater it is red.

124 Saturation. As there are certain limits to the proportions in which bodies combine together, beyond which they cannot paſs, theſe are called the points of *ſaturation*; and when two bodies, in uniting together, have reached this point, they are ſaid to be ſaturated, or the one body is ſaid to be ſaturated with the other: in other words, the change has taken place, and a new compound is formed. When, for inſtance, a ſalt is diſſolved in water, as common ſalt, the water combines only with a certain proportion; and whatever quantity of ſalt is added beyond this proportion, it falls to the bottom undiſſolved. The reaſon of this is, that the particles of the ſalt are held together by their affinity for each other; that is, by the force of coheſion. Now, before any combination can be effected between the particles of the ſalt and the water, this force muſt be overcome. The force of affinity, therefore, between the water and the particles of ſalt, is greater than that between the particles of ſalt themſelves, and thus they are ſeparated and diſſolve in the water: but this force of affinity between the water and the ſalt is limited; and when it has arrived at its utmoſt limit, the action between the two bodies ceaſes. The two forces which were oppoſed to each other; that is, the force of affinity between the water and the ſalt on the one hand, and the force of coheſion between the particles of the ſalt on the other, are balanced. The water in this caſe is ſaid to be ſaturated with ſalt.

In a ſenſe ſomewhat ſimilar, the word *neutralization* has been employed. When to an acid there is added the ſolution of an alkali to a certain point, they combine together, and form a compound, in which the properties of the acid and of the alkali totally diſappear. They are then ſaid to have neutralized each other; and hence the name of *neutral ſalts*, which has been given to theſe compounds.

125 in different proportions. Some bodies, it would appear, enter into combination with others, only in one determinate proportion, and ſome in two proportions, and theſe proportions are denominated their *maximum* and *minimum* of ſaturation; that is, the ſmalleſt and greateſt proportions in which they combine with each other. There is another ſet of bodies which combine in any proportion between the higheſt and the loweſt point, while a fourth ſet combine only in certain determinate proportions between theſe points.

Now, from theſe obſervations, let us endeavour to illuſtrate the meaning of this law, by attending to what takes place in the different combinations of bodies with each other. A ſmaller quantity of ſalt diſſolved in a given quantity of water, is held in combination by a greater force of affinity, than a greater quantity; becauſe this force is to be eſtimated by the affinity which exiſts between the ſalt and the water, and its maſs. The nearer, therefore, it comes to the maximum or higheſt point of ſaturation, the weaker is the affinity between the water and the ſalt; and in approximating to this point, this force is gradually diminiſhed, till at laſt it entirely vaniſhes.

When two bodies combine together in two different proportions, or what are called the maximum and minimum points of ſaturation, the force of affinity is greateſt between the two bodies at the loweſt point. Suppoſe that two bodies, A and B, can enter into combination with each other, in two different proportions. Suppoſe the quantity of A is = 20 grs. and the firſt portion of B which combines with it is = 10 grs.: it is evident from this combination, that part of the force of the affinity of A is exhauſted, but ſtill it combines with another portion of B; ſuppoſe this is = 5 grs. and then it has reached its higheſt point of ſaturation, or the maximum. But as the laſt portion of B, which combined with A, is retained in the compound by the force of affinity in A, which remained after its combination with the firſt portion of B, it is obvious that this force muſt be greatly diminiſhed, and therefore the laſt portion of B will be moſt eaſily ſeparated from its combination with A; and this accordingly is found to hold in all caſes.

Tenth Law.

Between two compound bodies which are not acted on by compound affinity, decompoſition may take place, if the affinity of two of the principles for a third be greater than that which unites this third to one of the two firſt, although, at the moment of action, the union between the two firſt does not exiſt.

126 Diſpoſing affinity. This is called *diſpoſing* or *prediſpoſing* affinity, becauſe no change takes place without the influence or action of a third body on ſome of the compounds; for it is this action which operates the formation of the compound, and the decompoſition of another compound, without the formation of the firſt. To have a clear conception of this diſpoſing affinity, let us ſuppoſe that there are two compounds AB and CD; the affinity of whoſe conſtituent parts, that is, the affinity between A and C, and the affinity between B and D, is not greater than the affinity which exiſts between AB and CD. In this caſe, it is obvious that no decompoſition can be effected by compound affinity, becauſe the ſum of the quieſcent affinities exceeds the ſum of the divellent; but if the force which tends to combine B and C together, added to that which tends to unite the compound BC to D, be greater than the force of coheſion between the compounds AB and CD, the reſult of this action will be a decompoſition, the formation of a new compound BCD, and the ſeparation of the firſt component part A.

Water is compoſed of two ſubſtances, which have received the names of oxygen and hydrogen. Sulphur has no direct action on water. This ſhews that the affinity between ſulphur and any of the conſtituent parts of the water, is not ſo great as the affinity of the oxygen and hydrogen for each other; but if ſulphur be united with an alkali, the water is decompoſed by this combination, although there is no affinity between the alkali and the oxygen. The ſulphur combines with the oxygen of the water, and forms ſulphuric acid. It

is

is this attraction which favours the decompoſition of the water, and is therefore called a *prediſpoſing affinity*.

Such then are the phenomena of chemical action, which have been obſerved and claſſed together. The knowledge of the laws of affinity, and the knowledge of chemiſtry, may be regarded as ſynonymous terms, becauſe it is by the obſervation of the laws by which the changes that take place among bodies by chemical affinity are produced, that this ſcience can be improved and extended. The detail of chemical ſcience, therefore, may be regarded as the hiſtory of affinities. We therefore proceed in the following chapters, to examine the properties of thoſe bodies, the knowledge of which belongs to chemical ſcience; the changes which take place by the action of affinity, and the new compounds which are the reſult of theſe changes; and, at the ſame time, to point out ſome of their applications and uſes.

Chap. II. Of LIGHT.

Light and heat, which are to be treated of in this and the ſucceeding chapters, are highly intereſting, not only as curious ſubjects of ſpeculation, but as acting a very important part in the changes which are conſtantly going on among natural bodies. Indeed no change happens, in which the one or the other, and ſometimes both, is not either abſorbed or extricated.

Light, of which we are now to treat, is the principal agent in many chemical proceſſes; and this, as well as the aſtoniſhing velocity of its motions, and the properties which it has of penetrating and traverſing ſubſtances with which it comes in contact, render it an object worthy of great attention.

Light, if it could be defined, is too familiar to every one to require any definition. It is by the light of the ſun, or that which proceeds from burning bodies, that we are informed of the preſence of objects; or the rays of light proceeding from theſe bodies, and entering the eye, produce the ſenſation of viſion. 127 Opinions of the nature of light. We have no certain knowledge concerning the nature of light. Various conjectures, however, have been made, and various theories have been propoſed, with regard to it. Two of theſe we ſhall only mention. 128 An undulating fluid. According to Des Cartes, Huygens, and ſome other philoſophers, all ſpace is filled up with a very ſubtile fluid, and this fluid is agitated or put in motion by the ſun, or burning bodies. This motion conſiſts of vibrations or undulations, which, extending themſelves and reaching the eye, render the bodies which have produced theſe motions, viſible.

The other theory is that of Newton and his followers. 129 Material. According to this theory, light is ſuppoſed to be a real emanation from luminous bodies, that is, a ſubtile fluid, conſiſting of peculiar particles of matter which are conſtantly ſeparating from luminous bodies, and by entering the eye, excite the ſenſation of light, or the perception of the objects from which it proceeds, or thoſe from which it is reflected. This theory, which has been deduced from a great number of facts and obſervations, was eſtabliſhed by Newton by mathematical demonſtration. If then it be admitted, that light is a ſubtile fluid, conſiſting of minute particles, ſeveral conſequences follow, which require explanation, with regard to the ſize, the velocity, and the momentum of theſe particles. In what follows, we ſhall conſider light with regard to its phyſical properties, its chemical properties, or the effects it produces on bodies with which it enters into combination; and, laſtly, the ſources from which it is obtained.

Sect. I. *Of the* Physical Properties *of* Light.

130 Velocity

1. One of the moſt aſtoniſhing properties of light is its velocity. It has been obſerved by aſtronomers, that the eclipſes of the ſatellites of the planet Jupiter appear to take place ſooner, when that planet is neareſt to the earth, and later when Jupiter is on the oppoſite ſide of his orbit from the earth. 131 diſcovered. Roemer, a Daniſh aſtronomer, in attempting to account for this apparent anomaly, proved that it was owing to the difference of time which the particles of light required, to paſs through the ſemidiameter of Jupiter's orbit; and from this he demonſtrated, that the particles of light move through one half of the diameter of the earth's orbit in about eight minutes. 132 Confirmed. This diſcovery of Roemer has been fully confirmed by the theory propoſed by Dr Bradley, to account for the aberration of the light of the fixed ſtars. From theſe data it has been computed, that light moves with the velocity of 200,000 miles in a ſecond;—a velocity of which the human mind can form no diſtinct conception. But in comparing this velocity with that of a cannon ball, it may be obſerved, that light paſſes through a ſpace in about eight minutes, which a cannon ball with its ordinary velocity could not traverſe in leſs than thirty-two years!

133 Particles very minute.

2. From the remarkable velocity of light, may be inferred the extreme minuteneſs of its particles. The force with which moving bodies ſtrike, is in proportion to their maſſes, multiplied by their velocities. If, therefore, the one or the other, or both, be increaſed, the ſtriking force is proportionally augmented; and conſequently, if the particles of light were not extremely ſmall, their exceſſive velocity would be highly deſtructive. Indeed, were they equal in bulk to the two millionth part of a grain of ſand, this impulſe would not be leſs than that of ſand ſhot from the mouth of a cannon.

The minuteneſs of the rays of light may be alſo demonſtrated from the great facility with which they penetrate and paſs through tranſparent ſolid bodies. In moving through ſuch bodies, light ſeems not to ſuffer the ſmalleſt diminution of its velocity. If there is nothing to obſtruct the rays of light which proceed from a candle, it will fill the whole ſpace within two miles around, almoſt inſtantaneouſly, before it has loſt any ſenſible part of its ſubſtance.

134 Reflection.

3. When a ray of light falls on a poliſhed ſubſtance in a perpendicular direction, it is thrown back in the ſame direction; but when a ray of light falls on the ſame body obliquely, it returns from the ſurface on the oppoſite ſide of a perpendicular line drawn from the point on which the ray falls, and at an equal diſtance from that perpendicular. The angle which the ray of light forms with the perpendicular as it falls, is equal to the angle which it forms with the ſame line, when it is thrown back. The firſt angle is called the *angle of incidence*, and the ſecond the *angle of reflection*.

Hence the optical law, that the angle of incidence is equal to the angle of reflection. When the rays of light fall obliquely on poliſhed ſurfaces, they are reflected before they touch theſe ſurfaces, which is ſuppoſed to be owing to a repulſion between the particles of light and the particles of the poliſhed body. But when rays of light fall obliquely on a tranſparent ſubſtance, as a plate of glaſs, they paſs through to the other ſide, and then return to the ſame ſurface, and are reflected.

135 Inflection. 4. When a ray of light is admitted into a dark room, through a ſmall hole, it forms a luminous ſpot on any object oppoſite to that from which the light proceeds; and if the blades of two knives are placed on oppoſite ſides of the hole, having their planes parallel to the plane of the window ſhutter or paſteboard through which the ray paſſes, when the edges of the knives are brought near each other, the rays of light are drawn from their former direction towards the edges of the knives, and the luminous ſpot appears enlarged. This is called the *inflection* of light. A ſimilar effect is produced by nearly ſhutting the eyes, and looking at a candle. The rays of light appear to proceed from it in various directions; for the light, in paſſing through the eye-laſhes, is inflected, and is divided into ſeparate beams, diverging from the luminous object.

136 Refraction. 5. A ray of light paſſing from one medium to another, moves on in the ſame direction; as for inſtance, when light paſſes from air to water, or from water into air; but if a ray of light paſſes in an oblique direction from one medium to another, it is bent from its former courſe, and then moves on in a new direction: this is called the *refraction* of light. A ſtraight rod, which is introduced obliquely into a veſſel of water, appears bent at the place where it touches the ſurface of the water. This is owing to the refraction of the rays of light paſſing from the rarer medium of the air to the denſer medium of the water.

When the light paſſes into a medium of greater denſity, as for inſtance from air into water, it is refracted or bent towards the perpendicular; but when it paſſes from a denſer into a rarer medium, as from water into air, it is refracted from the perpendicular. The meaſure of the quantity of this refraction is eſtimated by the denſity of the medium; with this exception, however, that if the medium be a combuſtible ſubſtance, the refractive power is then found to be greater. It was from the obſervation of this law of the refraction of light, that the conjecture which was thrown out by Newton, of the combuſtible nature of water and the diamond, which has been verified by the diſcoveries of modern chemiſtry, occurred to the mind of that ſagacious philoſopher.

137 Spectrum 6. When a ray of light is admitted through a ſmall hole, and received on a white ſurface, it forms a luminous ſpot. If a denſe tranſparent body be interpoſed, the light will be refracted, in proportion to the denſity of the medium; but if a triangular glaſs priſm be interpoſed, the light is not merely refracted, but it is divided into ſeven different rays. The ray of light no longer forms a luminous ſpot, but has aſſumed an oblong ſhape, terminating in ſemicircular arches, and exhibiting ſeven different colours. This image is called the ſpectrum, and, from being produced by the priſm, the *priſmatic ſpectrum*. Theſe different coloured rays appearing in different places of the ſpectrum, ſhew that their refractive power is different. 138 of ſeven colours. Thoſe which are neareſt the middle are the leaſt refracted, and thoſe which are the moſt diſtant, the greateſt. The order of the ſeven rays of the ſpectrum is the following: RED, ORANGE, YELLOW, GREEN, BLUE, INDIGO, VIOLET. The red, which is at one end of the ſpectrum, is the leaſt, and the violet, which is at the other end, is the moſt refracted.

Sir Iſaac Newton found, if the whole ſpectrum was divided into 360 parts, the number of the parts occupied by each of the colours to be the following:

Red,	45 parts.
Orange,	27
Yellow,	48
Green,	60
Blue,	60
Indigo,	40
Violet,	80

139 Not farther diviſible. Theſe different coloured rays are not ſubject to farther diviſion. No change is effected upon any of them by being farther refracted or reflected; and, as they differ in refrangibility, ſo alſo do they differ in the power of inflection and reflection. The violet rays are found to be the moſt reflexible and inflexible, and the red the leaſt.

7. Light, it is well known, ſeems to ſuffer no interruption in paſſing through ſome bodies; ſuch are glaſs or water, but it is interrupted in its paſſage through other bodies, as a piece of wood or ſtone. The firſt ſet of bodies are called *tranſparent*, and the other *opaque*. The denſity of water or of glaſs is greater than that of a piece of wood. It cannot therefore be owing to the denſity of the latter, or the cloſeneſs of the particles which compoſe it, that the tranſmiſſion of light is prevented. 140 Tranſparency. In the explanation which has been given by Newton, it is ſuppoſed that the particles which compoſe tranſparent bodies, are of equal denſity, and are uniformly arranged; but in opaque bodies he ſuppoſes the particles are of unequal denſity, or are not uniformly arranged. From the uniform arrangement and equal denſity which, according to this explanation, are ſuppoſed to exiſt in tranſparent bodies, the light paſſing through them, moves in a ſtraight line, becauſe it is equally attracted by the particles of the body. 141 Opacity. But in the latter (the opaque bodies) the attraction between light and the particles of the body is unequal; its direction is conſtantly changing, till at laſt it is entirely interrupted.

142 Illuminating power. 8. Dr Herſchel, who has made ſome intereſting diſcoveries concerning light and heat, found that the illuminating power of the different rays was different. From the obſervations which he made on this ſubject, he ſays, that "with reſpect to the illuminating power aſſigned to each colour, we may conclude, that the red-making rays are very far from having it in any eminent degree. The orange poſſeſs more of it than the red, and the yellow rays illuminate objects ſtill more perfectly. The maximum of illumination lies in the brighteſt yellow, or paleſt green. The green itſelf is nearly equally bright with the yellow; but from the full deep green the illuminating power decreaſes

creaſes very ſenſibly; that of the blue is nearly upon a par with that of the red; the indigo has much leſs than the blue; and the violet is very deficient *."

Sect. II. *Of the Chemical Properties of Light.*

143 Light enters bodies.

1. From the properties of light which have now been detailed, it appears that it is ſubject to the univerſal law of attraction, as well as other bodies; but it is alſo found to enter into chemical combination with many ſubſtances. Theſe ſubſtances, it has been diſcovered by experiment, after being for ſome time expoſed to the light, and carried into a dark place, appear luminous. It is found, however, that this property is loſt when they are kept in the dark, and they do not recover it till after they have been again expoſed to the light. Some ſubſtances poſſeſs this property in a greater degree than others. One, which was diſcovered by Mr Canton, who made a number of experiments on this phoſphoreſcent light, as it has been called, is prepared by the following proceſs.

144 Canton's pyrophorus.

He took ſome oyster-ſhells and calcined them, after which they were reduced to powder, and the pureſt part of them was put through a fine ſieve. Three parts of this powder were mixed together with one part of the flower of ſulphur; the mixture was put into a crucible, and firmly preſſed to the bottom, which was then expoſed for an hour to a red heat. It was then removed from the fire, and when it cooled, the pureſt parts of the mixture were ſcraped off, and put up in a well-cloſed phial. This is called Canton's pyrophorus. When this is expoſed to the light for a ſhort time, it becomes ſo luminous that objects may be diſtinctly perceived in the dark, by the light which it emits. It loſes this property, however, by being kept in the dark, but recovers it again when it is expoſed to the light. And after being kept in the dark for ſome time, the light from the pyrophorus becomes feeble, or is nearly extinct, but it may be revived or increaſed by plunging the phial into hot water. But if the whole of the light has been ſeparated previous to the application of heat, no farther application can cauſe it to emit light, till it has been expoſed to a luminous body.

145 From which it is emitted again.

Thus it appears that light enters into combination with other bodies, and that it afterwards leaves them without having undergone any perceptible change.

2. If a quantity of purple-coloured fluate of lime (Derbyſhire ſpar) be reduced to coarſe powder, and expoſed to heat in a dark place, it emits a great quantity of coloured light; but when this light which has been in combination with the ſpar is once expelled, it does not recover its property of ſhining in the dark, as in the caſe of Canton's pyrophorus.

146 Suppoſed to be ſlow combuſtion.

It has been ſuppoſed by ſome, that the light emitted by theſe ſubſtances is the conſequence of ſlow combuſtion; but many of the ſubſtances which have this property are not combuſtible, and none of the changes which take place during this proceſs have been obſerved. In ſome caſes it would appear that the light which is given out is different from that to which they were expoſed, and which they muſt have abſorbed. In ſome of the pyrophori, the blue rays were obſerved to have a greater effect, and the light which was emitted was of a red colour.

147 Emitted by animal matters, &c.

3. Light, it is well known, is given out by a number of animal and vegetable matters, when the proceſs of putrefaction commences. In this caſe it ſeems to conſtitute one of their component parts. This particularly happens to fiſh of different kinds, as the herring and the mackerel, and to this is ſuppoſed to be owing the phoſphoreſcent light of the ſea, which appears when the water is broken and agitated. Theſe phenomena were obſerved by Mr Boyle and Dr Beale, both in the fleſh of quadrupeds and fiſhes, and earlier by Fabricius ab Aquapendente and Bartholin in the fleſh of quadrupeds. Experiments were made on the ſame ſubject by Mr Canton, whom we have already mentioned, and more lately by Dr Hulme.

148 A conſtituent principle.

From the experiments of the latter he concludes, that this light is a conſtituent principle of marine fiſhes; that it is incorporated with their whole ſubſtance, making a part of it, in the ſame manner as any other conſtituent principle; that when this ſpontaneous light is extinguiſhed by ſome ſubſtances, it may be again revived; that the quantity of light emitted is not in proportion to the degree of putrefaction, but on the contrary the greater the putreſcence, the leſs is the quantity of light emitted.

For the ſake of thoſe who may wiſh to repeat theſe experiments, we ſhall detail the following made on the herring and the mackerel, in the words of the author.

The Fleſh of Herring (G).

149 Dr Hulme's experiments.

(1.) "A freſh herring was ſplit, or divided longitudinally by a knife, into two parts. Then, about four drams of it, being cut acroſs, were put into a ſolution, compoſed of two drams of Epſom ſalt or vitriolated magneſia, and two ounces of cold ſpring water drawn up by the pump. The liquid was contained in a wide-mouthed three-ounce phial, which was placed in the laboratory. Upon carefully examining the liquid, on the ſecond evening after the proceſs was begun, I could plainly perceive a lucid ring (for the phial was round) floating at the top of the liquid, the part below it being dark; but, on ſhaking the phial, the whole at once became beautifully luminous, and continued in that ſtate. On the third evening, the light had again riſen to the top; but the lucid ring appeared leſs vivid, and, on ſhaking the phial as before, the liquid was not ſo luminous as on the preceding night.

(2.) The ſame experiment was repeated. On the ſecond night, the liquid, being agitated, was very luminous; on the third, not ſo lucid; and on the fourth the light was extinguiſhed.

(3.) With ſea ſalt or muriated natron half a dram, and two ounces of water. On the ſecond night, the liquid, when agitated, was dark; on the third, lucid; on the fourth, very luminous; on the fifth, it began to loſe light; on the ſixth, it continued to decreaſe; and on the ſeventh it was quite gone. Neither the liquid, nor the herring, had contracted any putrid ſmell.

---

* *Phil. Trans.* vol. xc. p. 26.

(G) The quantity uſed in each experiment was about four drams.

(4.) With ſea water two ounces. On the ſecond night, dark : on the third, fourth, and fifth, luminous ; on the ſixth, nearly extinct ; and on the ſeventh, totally. The piece of herring, when taken out and examined, was remarkably ſweet.

Roe of Herring (H).

(5.) With Epſom ſalt two drams, and water two ounces. On the ſecond night, the liquid was pretty luminous ; on the third and fourth, ſtill luminous ; and on the fifth its light was extinct.

(6.) With Glauber's ſalt or vitriolated natron, two drams to two ounces of water. On the ſecond night, when the phial was ſhaken, as uſual in all theſe experiments, the liquid was pretty luminous ; on the third, leſs ſo ; and on the fourth the light was ſcarcely viſible.

(7.) With ſea water two ounces. On the ſecond night, dark ; on the third, the liquid was moderately luminous ; on the fourth and fifth, it had extracted much light ; and on the ſeventh it was ſtill ſhining. After this proceſs, both the roe and the ſea water remained perfectly ſweet.

The Fleſh of Mackerel.

(8.) With Epſom ſalt two drams, and water two ounces. On the ſecond night, the liquid was finely illuminated ; on the third, a ſimilar appearance ; on the fourth, a diminution of light ; on the fifth, it continued lucid in a ſmall degree ; and on the ſixth the light was extinguiſhed.

Roe of Mackerel.

(9.) With Epſom ſalt two drams, and water two ounces. On the ſecond night, the liquid, when agitated, was exceedingly bright ; on the third, the ſame ; and on the fourth and fifth, ſtill lucid †.

† *Phil. Tranſ.* 1800. p. 168.

Dr Hulme found that ſome ſubſtances have the power of extinguiſhing this light. It was quickly extinguiſhed when mixed with water alone, with water impregnated with lime, carbonic acid gas, or ſulphurated hydrogen gas ; by fermented liquors and ardent ſpirits ; by the acids, both concentrated and diluted ; by the alkalies when diſſolved in water ; by many of the neutral ſalts, as the ſolutions of common ſalt, Epſom ſalt, and ſal ammoniac. It was alſo extinguiſhed by infuſions of chamomile flowers, of long pepper and of camphor made with boiling hot water, but not uſed till quite cool.

When the ſubſtances emitting this light were placed in a freezing medium, the light was in a ſhort time quite extinguiſhed ; but when expoſed to a moderate degree of temperature, it was revived. A moderate degree of heat increaſed this light, but it was extinguiſhed by a high temperature, and no luminous appearance could again be diſcovered.

150 Colour.

4. When all the rays of light are reflected from any body, that body is ſaid to be white ; but when all the rays are abſorbed, the body which abſorbs them is ſaid to be black : but experience informs us, that different bodies abſorb and reflect different rays. Thus, if a body abſorb all the rays excepting the yellow, that body is ſaid to be of a yellow colour ; or if a body reflect the red rays, while the others are abſorbed, it is ſaid to be red. Thus the colour of the body is characterized by the colour of the ray which is reflected ; or, which is the ſame thing, this is the cauſe of colouring bodies.

151 Effects of light on metallic oxides and ſalts.

5. One of the moſt ſingular effects which is obſerved in the combination of light with bodies, is its power of reducing the oxides of the metals. Some of theſe, as for inſtance, the red oxide of lead, when expoſed to the light of the ſun, loſe ſome of their weight. The oxide of gold may alſo be reduced in the ſame way, and the white ſalts of ſilver become black, and the oxide is reduced ; and when that proceſs is going on, oxygen gas is emitted, which, it would appear, has been ſeparated by the action of light. Some of the rays are found to have a greater effect than others. Scheele, who made a ſet of experiments to aſcertain the difference of effect of the different-coloured rays in blackening the muriate of ſilver, diſcovered that the violet ray was the moſt powerful in reducing the oxide of ſilver.

152 Peculiar rays.

It was formerly the general opinion, that the colorific rays of light were the cauſe of the reduction of the oxides of the metals, but the experiments and obſervations of Meſſrs Bockman and Ritter in Germany, and of Dr Wollaſton in England, prove that the muriate of ſilver is more ſtrongly and rapidly darkened by rays of the ſun which have been more refracted than the violet rays ; for it appeared that the muriate was affected in a ſpace lying beyond the violet light. Theſe rays, therefore, have not the property of giving light, nor do they produce any ſenſible degree of heat ; and thus it appears that there are three different ſets of rays ; namely, rays which illuminate, rays which warm without giving any light (I), and rays which produce a chemical action on bodies, but which give neither light nor heat. From the conſideration of theſe curious and intereſting experiments, it has been very naturally ſuppoſed, that the chemical actions dependent on ſolar light are owing to the inviſible rays which were refracted beyond the violet rays ; and that the colorific rays have no ſhare in theſe actions : for it has been obſerved, that the effect of the different colours increaſes with their refrangibility ; and that the whole is owing to the inviſible rays, which increaſe in number or quantity as they approach to the violet ray, and are in greateſt quantity at a certain diſtance beyond it.

153 Light abſorbed by plants.

6. The abſorption of light by plants produces another remarkable effect. It has been long known, that the green colour of the leaves of plants is produced by the light of the ſun. Experiments were firſt made to aſcertain this fact by M. Dufay and ſome others of the French academicians. The ſubject has been farther proſecuted and extended by Senebier of Geneva. When ſeeds are ſown in a dark place, they vegetate,

---

(H) The quantity uſed in each experiment was about four drams.

(I) Theſe will be particularly mentioned in the next chapter.

getate, and the plant grows with conſiderable luxuriance; but it never has any green colour as long as the light is excluded, the leaves continue white; and this happens although air be freely admitted. When the plant in this ſtate is expoſed to the light, the green colour begins to appear, and the plant aſſumes its ordinary habit. It may be added, that while the plant remains white, it contains but a ſmall quantity of combuſtible matter, and it has but little taſte. When it aſſumes the green colour after its expoſure to the light, it acquires its natural taſte, and the ordinary quantity of combuſtible matter. It is upon this principle that the art of blanching celery and other garden plants depends; by heaping up the earth about the ſtems the light is excluded, and thus they are deprived of any pungent taſte, and become white and tender (K).

SECT. III. *Of the* SOURCES *of* LIGHT.

154 The ſun. 1. The principal ſource of light is the ſun. It has been a queſtion of more curioſity than utility, what is the cauſe of the ſun conſtantly emitting light, and what are the means of repairing that waſte? By calculations it is ſuppoſed, that there ought to iſſue from one ſquare foot of the ſun's ſurface in one ſecond, $\frac{1}{40000}$th part of a grain of matter, to ſupply the conſumption of light; that is, at the rate of little more than two grains a-day, or about 4,752,000 grains, or 670lb. in 6000 years, which would have ſhortened the ſun's diameter about 10 feet, if it was formed of matter of the denſity of water only.*

But at the time this calculation was made, the diſcoveries of Herſchel, of the conſtitution of the ſun, were not known. The body of the ſun, according to the obſervations of this philoſopher, is not luminous, but opaque; and the light which was ſuppoſed to come from his ſurface, proceeds from a luminous atmoſphere which ſurrounds that body; and there are probably ſome means by which the waſte that is conſtantly going on, is repaired. The light which comes from the ſtars is of the ſame nature with that of the ſun.

155 Combuſtion. 2. Another ſource of light is burning bodies. In all caſes of burning, light is emitted. This light, therefore, muſt have been in combination with ſome of the ſubſtances which are employed in theſe proceſſes.

156 Heat. 3. But when bodies, without undergoing the proceſs of combuſtion, are heated to a certain temperature, they emit light; and it would appear, from experiments which have been made upon the ſubject, that all bodies which are not decompoſed before they arrive at the proper temperature, begin to give out light, exactly at the ſame degree of heat. Iron heated to 635°, according to Sir Iſaac Newton's experiments, becomes viſible in the dark; at 752° it ſhines brightly; and becomes luminous in the twilight at 884°. The temperature is above 1000° when it ſhines in broad day light. A red heat, according to the experiments of others, commences at the temperature of 800°, and when a body reaches the proper degree of heat, it appears luminous, independent of the air. Mr T. Wedgwood, who made a number of experiments on this ſubject, found that a piece of iron wire became red hot when immerſed in melted glaſs. Air, therefore, is not neceſſary to the ſhining of ignited bodies.

It was alſo aſcertained by Mr Wedgwood, that a piece of red-hot metal continues to ſhine for ſome time after it has been removed from the fire, which proves that conſtant acceſſions of light or heat are not neceſſary for the ſhining of ignited bodies. But if the red-hot metal be ſtrongly blown upon, it inſtantly ceaſes to ſhine, and thus, it appears, when the temperature is diminiſhed, it ceaſes to give out light †.

* *Prieſtley's Optics*, p. 389.

† *Phil. Tranſ.* vol. lxxxii. p. 279.

(K) This is remarkably illuſtrated by the following obſervations of Profeſſor Robiſon. "Having occaſion in autumn 1774, to go down and inſpect a drain in a coalwork, where an embankment had been made to keep off a lateral run of water, and, crawling along, I laid my hand on a very luxuriant plant, having a copious, deep-indented, white foliage, quite unknown to me. I inquired of the colliers what it was. None of them could tell me. It being curious, I made a ſod be carried up to the daylight, to learn from the workmen what ſort of a plant it was. But nobody had ever ſeen any like it. A few days after, looking at the ſod, as it lay at the mouth of the pit, I obſerved that the plant had languiſhed and died, for want of water, as I imagined. But looking at it more attentively, I obſerved that a new vegetation was beginning, with little ſproutings from the ſame ſtem, and that this new growth was of a green colour. This inſtantly brought to my recollection the curious obſervations of M. Dufay; and I cauſed the ſod to be ſet in the ground and carefully watered. I was the more incited to this, becauſe I thought that my fingers had contracted a ſenſible aromatic ſmell by handling the plant at this time. After about a week, this root ſet out ſeveral ſtems and leaves of common tanſy. The workmen now recollected that the ſods had been taken from an old cottage garden hard by, where a great deal of tanſy was ſtill growing among the graſs. I now ſent down for more of the ſame ſtuff, and ſeveral ſods were brought up, having the ſame luxuriant white foliage. This, when bruiſed between the fingers, gave no aromatic ſmell whatever. All theſe plants withered and died down, though carefully watered, and, in each, there ſprouted from the ſame ſtocks freſh ſtems, and a copious foliage, and produced, among others, common tanſy, fully impregnated with the ordinary juices of that plant, and of a full green colour. I have repeated the ſame experiment with great care on lovage (*leviſticum vulgare*), mint, and caraways. As theſe plants throve very well below, in the dark, but with a blanched foliage, which did not ſpread upwards, but lay flat on the ground; in all of them there was no reſemblance of ſhape to the ordinary foliage of the plant; all of them died down when brought into daylight; and the ſtocks then produced the proper plants in their uſual dreſs, and having all their diſtinguiſhing ſmells.

From ſuch experiments, I thought myſelf entitled to ſay that the ſun's rays not only produced the green fæcula of plants, but alſo the diſtinguiſhing juices, and particularly the eſſential oils. The improvements which have been made in chemical ſcience ſince that time, have, I think, fully confirmed my conjecture." *Black's Lect.* i. 533.

157 Gaſes not luminous.

From the experiments of Mr Wedgwood, it appears that the gaſes do not become luminous, even at a higher temperature. He took an earthen-ware pipe of a zig-zag form, and placed it in a crucible filled up with ſand. The ends of the pipe were left uncovered. To one end was attached a pair of bellows, and to the other a globular veſſel with a lateral bent pipe, to let out air, but exclude the external light, and having a neck in which was inſerted a circular plate of glaſs. The crucible, with the ſand and the part of the pipe contained in it, was heated to redneſs. The eye was fixed in the neck of the veſſel, which was then obſerved to be perfectly dark within. A ſtream of air was then directed through the tube from the bellows, but this air which paſſed through the red-hot tube, was not luminous. A ſmall ſtrip of gold was then fixed into the orifice of the tube oppoſite to the eye, and after two or three blaſts, it became faintly red; which ſhows that though the air was not luminous, it was equal in temperature to what is called red heat. Dr Darwin made an experiment of the ſame kind, and with a ſimilar reſult. The heated air was altogether inviſible; but when a bit of gold was introduced, it acquired a bright glow in a few ſeconds *.

158 Attrition and percuſſion.

4. Light is alſo emitted by attrition and percuſſion. In the experiments which were made by Mr Wedgwood, on the attrition of bodies, he found that different coloured rays were emitted; ſometimes it was a pure white light, as from the diamond; ſometimes of a faint red, as from blackiſh gun flint; and ſometimes of a deep red, as from unglazed white biſcuit earthen ware. But this effect produced by attrition, may perhaps be conſidered as the ſame with that of percuſſion. It is a familiar circumſtance, that ſparks of light are emitted, when two hard bodies, as for inſtance, two quartz ſtones, are ſmartly ſtruck againſt each other; and it appears that light is emitted, or ſparks given out, when theſe bodies are treated by percuſſion or attrition, even under water; and they ſeem equally luminous in atmoſpheric air, oxygen gas, carbonic acid, or hydrogen gaſes. The emiſſion of this light is accompanied with a peculiar ſmell, which varies in different bodies. The ſmell appears to be ſtrongeſt where the friction is greateſt; it has no dependence on the light produced by attrition, becauſe it is often very ſtrong when no light is emitted. Rock cryſtal, quartz, and other hard bodies, alſo emit this ſmell under water †.

When flint and ſteel are ſtruck ſmartly together, a ſpark is produced which will communicate fire to combuſtible ſubſtances. This ſpark has been found to be a particle of the iron which is driven off, and which catches fire as it paſſes through the air. It is to be conſidered as a caſe of combuſtion, and quite different from what happens when two ſtones are rubbed or ſtruck againſt each other.

The matter driven off, when ſtones of quartz are ſtruck againſt each other, conſiſts of ſmall, black, friable bodies, which leave a black ſtain when rubbed on paper, and when examined with a magnifying glaſs, have the appearance of being fuſed. The light is produced in theſe caſes, by the ſubſtances ſtruck together having been red hot. Some have ſuppoſed that they are a combination with oxygen; while others, who have probably examined them more accurately, aſſert that they are pieces of the quartz ſurrounded with a quantity of black powder; and having been raiſed to a very high temperature, ſet fire, in their paſſage through the air, to the combuſtible bodies that are floating in it.

Chap. III. Of CALORIC.

159 Term explained.

The word *heat* in common language has two different meanings. When we ſay that we feel heat, it muſt mean the ſenſation of heat excited in the body; but when we ſay that the fire or a ſtone is hot, it means that the power of exciting the ſenſation of heat in us, exiſts in the ſtone or fire. The one is the cauſe, and the other is to be conſidered as the effect. The heat of the ſtone or fire is therefore the cauſe of the ſenſation of heat in the body. Thus the word *heat* is generally employed to expreſs both the ſenſation, and the cauſe of that ſenſation. To prevent any ambiguity in the uſe of theſe terms, the word *caloric* has been adopted in the new chemical nomenclature, to ſignify that ſtate or condition of matter by which it excites in us the ſenſation of heat; and in this ſenſe it is now to be employed.

The nature and effects of caloric or heat are highly intereſting, as curious ſubjects of ſpeculation; but the knowledge of them is of the utmoſt importance in the ſtudy of chemical phenomena, becauſe no change takes place, no decompoſition is effected, and no new compound is formed, without the agency of caloric.

Sect. I. *Of the Nature and Properties of Caloric.*

160 Two opinions.

Two opinions have been maintained by philoſophers concerning the nature of caloric. According to one, it is ſuppoſed to be a peculiar ſubtile fluid, of a highly elaſtic and penetrating nature, which is univerſally diffuſed. According to the other opinion, it depends on a peculiar tremor or vibration which exiſts among the particles of heated bodies.

161 Bacon's.

Among the firſt who ſeem to have adopted the latter opinion, was the celebrated Bacon. In his treatiſe, *De forma calidi*, which he propoſed as a model of ſcientific inveſtigation, he enumerates all the facts which were then known concerning heat; and after a

162 That heat is motion.

cautious conſideration of theſe facts, he concludes, that heat is motion. The facts on which he founded this opinion, were derived from ſome of the moſt familiar methods by which heat is produced in bodies. A blackſmith can make a rod of iron red hot by ſtriking it ſmartly with a hammer; the heavy parts of machinery, by friction upon each other, and the axles of the wheels of carriages when heavily loaded, ſometimes take fire. A fire may be kindled by the friction of two pieces of dry wood, and the branches of trees ſtrongly rubbed againſt each other by the violence of a ſtorm, have ſet fire to thick foreſts. From the obſervation and conſideration of theſe facts, this eminent philoſopher was led to conclude, that heat is the effect of mechanical impulſe. Since the time of Bacon, this theory has had many followers, and even at the preſent day it is maintained by ſome philoſophers.

163 Diſtinct ſubſtances.

But the theory which ſuppoſes caloric or heat to be a diſtinct material ſubſtance, is now more generally adopted. It was firſt ſuppoſed by thoſe who favoured this theory, that this peculiar matter was chiefly characterized by the great elaſticity, or repulſive

---

* *Phil. Tranſ.* vol. lxxxii. p. 271.

† *Ibid.* p. 42.

power, of the particles among each other; but beſides this property, Dr Cleghorn ſuppoſed that it poſſeſſed another, namely, that while its particles have a ſtrong repulſion for one another, they are attracted by other kinds of matter, with different degrees of force. 164 Is attracted. But whatever opinion may be formed of the nature of caloric, after we have inveſtigated its properties and effects, we ſhall probably find, that the phenomena which it exhibits will be eaſier underſtood, and more ſatisfactorily accounted for, on the ſuppoſition that it is a diſtinct ſubſtance.

165 Velocity.

1. The rays of light and caloric accompany each other as they proceed from the ſun, or from burning bodies. It is therefore ſuppoſed that they move with the ſame degree of velocity; and if this be the caſe, the velocity of the rays of caloric muſt be equal to 200,000 miles in a ſecond. An experiment made by Mr Pictet proves the great velocity of the rays of caloric. Two concave mirrors, the one of tin, and the other of gilt plaſter, 18 inches in diameter, were placed at the diſtance of 69 feet from each other. A thermometer was placed in the focus of the latter, and a heated bullet of iron in the former. When the bullet was placed in the focus, a thick ſcreen, which was a few inches from the face of the metallic mirror, was removed. The thermometer inſtantly roſe, ſo that the time which caloric requires to move through the ſpace of 69 feet, cannot be eſtimated. And indeed, if caloric, as is moſt probable, moves with the velocity of light, the time that it paſſes the diſtance of 69 feet, or even 69,000 feet, is by far too minute to be meaſured by our inſtruments; ſo that no concluſion whatever with regard to the meaſurement of its velocity, can be drawn from this experiment.

166 Minute particles.

2. From the extreme velocity of caloric, and from its being equal to that of light, it is concluded that its particles are equally minute. From the accumulation of caloric in bodies, and particularly from one ſtriking effect which this accumulation produces, namely, expanſion, it was natural to ſuppoſe that bodies having received this addition, acquired an increaſe of weight. Experiments have therefore been made to aſcertain this effect. Boerhaave weighed a maſs of iron of 5lb. weight, while it was red hot, and afterwards repeated the ſame experiment with other metals, but found no variation, either in the hot or cold bodies, but what he could account for from the errors of the balance. 167 Experiments to aſcertain the weight of caloric, Muſchenbroeck ſuppoſed that heat is ponderous, or produced by a ponderous ſubſtance; and Buffon thought he had proved, by his own experiments, that a body is heavier when it is hot than when it is cold; but when ſimilar experiments were repeated, particularly by Dr Roebuck and Mr Whitehurſt, with very nice and delicate balances, the bodies which were weighed appeared heavier cold, than when they were hot. This ſeems to be owing to the rarefaction of the air ſurrounding that ſcale in which the heated body is placed; the preſſure of which is therefore leſs than that of the air over the other ſcale. From more recent experiments, and particularly one made by Dr Fordyce, it appears that bodies become heavier, but in a very ſmall degree only, not by the increaſe, but by the diminution of temperature. When the whole quantity of 1700 grs. of water was frozen, it was found to be, when carefully weighed, $\frac{3}{10}$ths of a grain heavier than it had been when fluid. At this time the thermometer applied to the veſſel which contained the frozen water, ſtood at 10°; but when it was allowed to remain till the thermometer roſe to 32°, it weighed only $\frac{2}{10}$ths of a grain more than when fluid, and at the ſame temperature. 168 unſucceſsful. But other experiments prove, that the addition of caloric to bodies produces no ſenſible change on their weight. This ſeems to be placed beyond a doubt by the accurate experiments of Lavoiſier, which were made with a view of aſcertaining whether the weight of bodies is altered by heating or cooling them; but he found no difference.

In the year 1787, Count Rumford repeated the experiment of Dr Fordyce with the greateſt care; and varying it in every poſſible way to avoid error, the reſults led him to conclude, that there is no ſenſible difference in the weight of bodies, either by the addition or abſtraction of caloric.

169 Repulſion.

3. Caloric agrees with light in another of its peculiar properties; this is its *repulſive* power, or that tendency of its particles to ſeparate from each other. The particles of caloric, therefore, can never be ſuppoſed to cohere.

170 Reflection.

4. As the rays of light are reflected by poliſhed ſurfaces, ſo it is found that the rays of caloric have the ſame property. The Swediſh chemiſt Scheele diſcovered, that the angle of reflection of the rays of caloric is equal to the angle of incidence. This has been more fully eſtabliſhed by Dr Herſchel. Some very intereſting experiments were made by Profeſſor Pictet of Geneva, which proved the ſame thing. Theſe experiments were conducted in the following manner. Two concave mirrors of tin, of nine inches focus, were placed at the diſtance of twelve feet two inches from each other. In the focus of the one was placed the bulb of a thermometer, and in that of the other a ball of iron two inches in diameter, which was juſt heated ſo as not to be viſible in the dark. In the ſpace of ſix minutes the thermometer roſe 22°. A ſimilar effect was produced by ſubſtituting a lighted candle in place of the ball of iron. Suppoſing that both the light and heat acted in the laſt experiment, he interpoſed between the two mirrors a plate of glaſs, with the view of ſeparating the rays of light from thoſe of caloric. The rays of caloric were thus interrupted by the plate of glaſs, but the rays of light were not perceptibly diminiſhed. In nine minutes the thermometer ſunk 14°; and in ſeven minutes after the glaſs was removed, it roſe about 12°. He therefore juſtly concluded, that the caloric reflected by the mirror, was the cauſe of the riſe of the thermometer. He made another experiment, ſubſtituting boiling water in a glaſs veſſel in place of the iron ball; and when the apparatus was adjuſted, and a ſcreen of ſilk which had been placed between the two mirrors removed, the thermometer roſe 3°; namely, from 47° to 50°.

The experiments were varied by removing the tin mirrors to the diſtance of 90 inches from each other. The glaſs veſſel, with boiling water, was placed in one focus, and a ſenſible thermometer in the other. In the middle ſpace between the mirrors, there was ſuſpended a common glaſs mirror, ſo that either ſide could be turned towards the glaſs veſſel. When the poliſhed ſide of this mirror was turned towards the glaſs veſſel, the thermometer roſe only $\frac{5}{10}$ths of a degree; but when the other ſide, which was darkened, was turned towards the glaſs veſſel, the thermometer roſe 3°.5. And in another experiment performed in the ſame way, the thermometer roſe 3° when the poliſhed ſide of the mirror was turned to the glaſs veſſel, and 9° when the other ſide was turned. Theſe experiments ſhew clearly, that the rays of caloric are reflected from poliſhed ſurfaces, as well as the rays of light.

171 Refraction. 5. Tranſparent bodies have the power of refracting the rays of caloric, as well as thoſe of light. They differ alſo in their refrangibility. So far as experiment goes, the moſt of the rays of caloric are leſs refrangible than the red rays of light. The experiments of Dr Herſchel ſhew, that the rays of caloric, from hot or burning bodies, as hot iron, hot water, fires and candles, are refrangible, as well as the rays of caloric which are emitted by the ſun. Whether all tranſparent bodies have the power of tranſmitting theſe rays, or what is the difference in the refractive power of theſe bodies, is not yet known.

172 Three ſets of rays, 6. The light which proceeds from the ſun ſeems to be compoſed of three diſtinct ſubſtances. Scheele diſcovered, that a glaſs mirror held before the fire, reflected the rays of light, but not the rays of caloric; but when a metallic mirror was placed in the ſame ſituation, both heat and light were reflected. The mirror of glaſs became hot in a ſhort time, but no change of temperature took place on the metallic mirror. This experiment ſhews that the glaſs mirror abſorbed the rays of caloric, and reflected thoſe of light; while the metallic mirror, ſuffering no change of temperature, reflected both. And if a plate of glaſs be held before a burning body, the rays of light are not ſenſibly interrupted, but the rays of caloric are intercepted; for no ſenſible heat is obſerved on the oppoſite ſide of the glaſs; but when the glaſs has reached a proper degree of temperature, the rays of caloric are tranſmitted with the ſame facility as thoſe of light. And thus the rays of light and caloric may be ſeparated.

173 coloured and heating.

174 Inviſible have the greateſt heating power. But the curious experiments of Dr Herſchel have clearly proved, that the inviſible rays which are emitted by the ſun, have the greateſt heating power. In theſe experiments, the different coloured rays were thrown on the bulb of a very delicate thermometer, and their heating power was obſerved. The heating power of the violet, green, and red rays, were found to be to each other as the following numbers:

Violet,	16.
Green,	22.4
Red,	55.

The heating power of the moſt refrangible rays was leaſt, and this power increaſes as the refrangibility diminiſhes. The red ray, therefore, has the greateſt heating power, and the violet, which is the moſt refrangible, the leaſt. The illuminating power, it has been already obſerved, is greateſt in the middle of the ſpectrum, and it diminiſhes towards both extremities; but the heating power, which is leaſt at the violet end, increaſes from that to the red extremity: and when the thermometer was placed beyond the limit of the red ray, it roſe ſtill higher than in the red ray, which has the greateſt heating power in the ſpectrum. The heating power of theſe inviſible rays was greateſt at the diſtance of ½ inch beyond the red ray, but it was ſenſible at the diſtance of 1½ inch.

Dr Herſchel's experiments have been varied, and ſtill farther confirmed by a ſet of experiments by Sir H. Englefield, the reſults of which were the following:

Therm.	in the blue ray roſe	in 3′	from 55° to 56°
	in the green	in 3′	from 54° to 58°
	in the yellow	in 3′	from 56° to 62°
	in the full red	in 2½′	from 56° to 72°
	in confines of the red	in 2½′	from 58° to 73½°
	quite out of viſible light	in 2½′	from 61° to 79°

The thermometer uſed in theſe experiments had its bulb blackened with Indian ink.

In the following experiments, three thermometers were employed; one had a naked ball, one was whitened, and the other was blackened. They were expoſed to the ſun's rays till they became ſtationary, when the thermometer with the

Naked ball ſtood at	58½°
Whitened ball	58½°
Blackened ball	63°

In the full-red ray	the blackened thermom. roſe	in 3′ from 58°	to 61°
	whitened -	in 3′ from 55°	to 58°
In quite dark -	blackened thermom.	in 3′ from 59°	to 64°
	whitened -	in 3′ from 58°	to 58½°
In confines of the red	black thermom. -	in 3′ from 59°	to 71°
	white - -	in 3′ from 57½°	to 60½°

In other experiments which were made afterwards, the reſults were,

In the full-red ray	the black thermom. roſe	in 3′ from 66° to 82°
	white -	in 3′ from 66° to 69½°
In quite dark ½ inch out of the red, the black thermom. roſe -	- - -	in 3′ from 70° to 84°

In this laſt experiment, when the thermometer was carried into the faint-red light, it ſunk quickly, and roſe again as quickly, when carried into the dark focus; but when carried into the dark on the other ſide of the red light, it ſunk very rapidly, and did not appear to receive any heat at all. †.

Thus it appears, that the rays of caloric and the rays of light are different; for theſe experiments clearly ſhew, that there are rays which produce heat, but give no light, and rays which give light, but produce no heat. It was formerly mentioned, that there is another ſet of rays which give neither light nor heat, but whoſe exiſtence has been fully demonſtrated by the remarkable effect which they produce in reducing the metallic ſalts and oxides. The light which is emitted from the ſun then conſiſts of three diſtinct ſets of rays which

---

† *Jour. Roy. Inſt.* vol. i. p. 206.

which have been fully recognized by their different degrees of refrangibility and their different effects. The heating rays are in the ſmalleſt degree refrangible; the rays which have the greateſt effect on the metallic oxides are the moſt refrangible, and the coloured rays are in an intermediate degree. The inviſible rays beyond the red extremity of the ſpectrum, which are leaſt refracted, have the greateſt heating power; the inviſible rays beyond the violet end, which are moſt refracted, have the greateſt power in reducing the metallic ſalts or oxides, and the rays in the middle of the ſpectrum have the greateſt illuminating power.

Sect. II. *Of the Effects of Caloric.*

175 Effects of caloric different in different bodies.

The effects of ſo powerful an agent as heat muſt be very conſiderable, and theſe effects are found to be different in different bodies, or as it is more or leſs accumulated in theſe bodies. One general effect is, that the accumulation of heat enlarges, and its abſtraction proportionally diminiſhes, the bulk of all bodies. When this accumulation is continued in ſome bodies, they change their condition from the ſtate of ſolid to that of liquid; and, when the accumulation is ſtill greater, liquid bodies are reduced to the form of vapour. Theſe effects, certainly curious and intereſting of themſelves, are of the utmoſt importance in the phenomena of nature and in the proceſſes of art; and the knowledge of the laws which have been deduced from theſe remarkable changes, enables us to explain many natural appearances, and to improve many of the arts of life.

1. Of Expansion.

176 Caloric expands all bodies.

1. One of the moſt general effects of heat, it has been obſerved, is the expanſion of bodies; that is, when caloric is accumulated in any body, it is enlarged in bulk; and, when that quantity of caloric is abſtracted, there is a correſponding contraction. Experience teaches us, that this effect of caloric is invariable and uniform in all the ſimpler kinds of matter. In ſome bodies, however, there are ſeeming exceptions to this general rule. In theſe bodies, when the temperature riſes a little above, or falls a little below a certain point, they are ſubject to irregular variations of their bulk; but theſe irregularities are limited to a few bodies, and to certain ſtates of temperature of theſe bodies: for when they are expoſed to equal variations of heat, above or below the temperature at which theſe irregularities are obſerved, the general law of expanſion uniformly holds. The expanſion of all bodies by heat, therefore, and their correſponding contraction by the abſtraction of caloric or by cold, may be conſidered as one of the moſt general facts in chemical ſcience.

177 Exceptions.

178 Expanſion proved.

2. There are many familiar inſtances of the expanſion of bodies by means of caloric, and this can be proved by very ſimple experiments. We ſhall mention an example of this effect on bodies in the ſolid, the liquid, and the gaſeous ſtate.

179 In a ſolid body.

(1.) If a rod of metal, as of iron, of an inch in diameter, and ſix or eight inches long, and the ſame thickneſs through its whole length, be exactly fitted to paſs through a hole in a plate of the ſame metal, and to be admitted lengthwiſe within the projecting edges of a ruler while it is cold; the ſame rod when it is made red hot, will be found to have enlarged in bulk ſo much, that it will not fall between the projecting parts of the ruler, nor will it paſs through the hole; but when it is cooled, or reduced to its former temperature, it again contracts, and returns preciſely to its former dimenſions.

180 In a liquid.

(2.) As an example of a liquid, whoſe bulk is enlarged by the accumulation of caloric, fill the body of a glaſs veſſel which has a long ſlender neck with ſpirit of wine. On the application of heat the liquid in the body of the veſſel is expanded, and riſes in the neck; and when the heat is abſtracted, and the liquid returns to its former temperature, it is again contracted, and returns to its former bulk. This experiment is moſt conveniently performed by immerſing the body of the veſſel in hot water.

181 In an elaſtic fluid.

(3.) The expanſion of a body in the gaſeous ſtate by the accumulation of caloric, is ſhewn by the following experiment. Let a quantity of air be confined in a bladder, but not in ſuch quantity as that the bladder ſhall be fully diſtended with it. If the bladder is expoſed to heat, the confined air expands, and the bladder is fully diſtended; but when it is again cooled, the air reſumes its former bulk, and the bladder its original flaccid ſtate.

182 Uniform in the ſame bodies.

3. Thus it appears, that all bodies expand by heat, and contract by cold, and the quantity of this expanſion is uniformly the ſame in the ſame bodies, when expoſed to the ſame temperature. But this quantity is found to differ greatly in different kinds of matter, by the ſame increaſe or diminution of their heat. In ſolid bodies it is leaſt, in liquids it is greater, but in elaſtic fluids greateſt of all; and in different kinds of ſolids, liquids, and elaſtic fluids, this difference is very conſiderable. The ratio at which this expanſion takes place in different bodies, can only be aſcertained by experiment; and, as the knowledge of this is a matter of great conſequence in many of the arts, experiments have been made with this view by different philoſophers (L).

183 But very different in ſolids, liquids, and elaſtic fluids.

The expanſion of gaſeous bodies, we have ſaid, is greateſt, that of liquids leſs, and that of ſolids leaſt of all, by being expoſed to the ſame degree of heat, which will appear from the following proportions.

100 cubic inches of	Atmoſpheric air,	from 32° to 212° increaſed to	137.5 cubic inches.
	Water,		104.5
	Iron,		100.1

(L) See experiments on this ſubject by Mr Elliot, Phil. Tranſ. vol. xxxix. and by Mr Smeaton, ibid. vol. xlviii.

184 Effects of expanſion on brittle ſubſtances.

4. This expanſive effect of heat will enable us to account for the cracking or breaking of veſſels which are made of brittle ſubſtances, by its ſudden application or abſtraction. This is particularly the caſe with thoſe ſubſtances which have little flexibility, as caſt iron, glaſs, or earthen ware; and accidents of this kind moſt frequently happen in veſſels made of theſe materials. If, for inſtance, heat be ſuddenly applied to a glaſs veſſel of conſiderable thickneſs, its external ſurface to which it is firſt applied expands more than the internal parts; the conſequence muſt therefore be, that they are ſeparated or drawn aſunder, and the veſſel is ſplit or broken.

185 In fitting iron hoops to carriage wheels.

5. One of the beſt illuſtrations of this expanſion by heat and contraction by cold on ſolid bodies, is in the application of iron hoops to carriage wheels. The hoop which has been intended for the wheel is made of rather ſmaller dimenſions than exactly to fit it. It is then made red hot, and while it is thus expanded, it is applied to the wheel. It is ſuddenly cooled by throwing cold water upon it, when it contracts, and returning to its former dimenſions, is ſtrongly faſtened on the wheel.

186 Different metals unequally affected.

The unequal contraction at the ſame degree of temperature, which is obſerved among ſolids, liquids, and aeriform ſubſtances, alſo takes place among ſolids themſelves. Thus, different metallic ſubſtances, at the ſame temperature, are found to expand and contract very unequally.

6. Advantage has been taken of this unequal contraction of metallic ſubſtances, to remedy thoſe defects and imperfections of delicate inſtruments, which are occaſioned by the contraction and expanſion of the ſubſtances employed in their conſtruction, when expoſed to different temperatures. Theſe inconveniences were moſt felt in inſtruments which were employed for the meaſurement of time, where great accuracy was required. The ſpring of a watch and the pendulum of a clock being ſubject to the ſame law of contraction and expanſion by heat and cold, in theſe changes, neceſſarily cauſed variations, in proportion to the extent of the effect. But as different metals were obſerved to expand unequally by the ſame temperature, this was applied to the conſtruction of thoſe parts of the inſtrument on which the accuracy of its indications depends. The equable meaſurement of time, for inſtance, by a clock, depends on the length of the pendulum always continuing the ſame. If it is ſubject to variations in length by expanſion or contraction, there will alſo be variations in the rate of its motions; for when the pendulum is lengthened by heat, the clock goes ſlower; and when it is ſhortened by cold, it goes faſter. It becomes therefore an object of great importance, that theſe inſtruments ſhould go at an equable rate in all temperatures; but this can only be effected by having the pendulum ſo conſtructed, that it ſhall neither lengthen by heat, nor contract by cold. This is done by conſtructing a pendulum in the following manner.

187 Uſe of this in conſtructing the pendulum.

"From the point of expanſion A (fig. 1. Plate CXLII.) a rod or thick wire, AB, of the leſs expanſible metal, muſt hang down a certain length. At the lower end it muſt have a ſtud, or croſs piece, BC, ſtrongly faſtened, and projecting a little to one ſide. On the projecting part, C, of this croſs piece, muſt be erected a pillar, CD, of the more expanſive metal. To the top of this pillar, another croſs and projecting piece, DE, muſt be ſtrongly faſtened; and, from this laſt, muſt again hang down another rod or wire, EF, of the firſt metal, having the ball of the pendulum at its extremity. And now, if the height of the pillar CD be one-third of the length of the two rods taken together, the pendulum can neither be lengthened by heat nor ſhortened by cold. For by the expanſion of the pillar, the pendulum is ſhortened, or the ball is raiſed nearer to the point of ſuſpenſion, becauſe the upper end D of the pillar is more raiſed by its expanſion, than the lower end C is depreſſed by the expanſion of AB; and, on the other hand, by its contraction, the pendulum is lengthened, or the ball is lowered; but, while this happens, the two rods, by their expanſion or contraction, produce a contrary effect; and the quantity of expanſion or contraction is the ſame in the rods that it is in the pillar, the greater length in the rods compenſating for the greater expanſibility in the pillar. The conſequence therefore muſt be, that the length of the pendulum, that is, the diſtance between the point of ſuſpenſion and the ball, cannot be varied by heat or cold. Accordingly, the clocks made for the uſe of aſtronomers, have pendulums conſtructed upon this principle, in which pillars of the more expanſible metals are employed to counteract the expanſion of the other parts of the pendulum-rod."

188 The bulk of water when frozen is increaſed,

7. There are, however, ſome remarkable inſtances which are ſeeming exceptions to this general law of expanſion. This is the caſe with thoſe bodies which paſs from the liquid to the ſolid ſtate; as for inſtance, water, when it aſſumes the ſolid form. Cloſe veſſels which are filled with water, are burſt when it freezes. In an experiment made by Mr Boyle, a braſs tube three inches in diameter, which was cloſed with a moveable ſtopper, was filled with water; when the water was frozen, it raiſed a weight equal to 74 lb. with which the ſtopper was loaded. In an experiment by the Florentine academicians, a hollow braſs globe, the diameter of whoſe cavity was an inch, was burſt by freezing the water with which it was filled. Muſchenbroeck has computed the force neceſſary to produce this effect, by eſtimating it equal to a preſſure of 27,720 lbs. weight. But the moſt remarkable experiments to prove the expanſive force of ice, were made by Major Williams in Canada, in the years 1784 and 1785. The iron plugs with which iron bombſhells filled with water were cloſed up by driving them in ſtrongly with a hammer, were thrown out to a great diſtance by the force of the congelation of the water; and when the plugs were ſo firmly ſecured as to reſiſt this force, the ſhell itſelf was burſt *.

189 and acts with prodigious force.

190 Other effects.

8. To the ſame expanſive force in the congelation of water, the burſting of water-pipes, the ſplitting of trees and of rocks, is to be aſcribed, which not unfrequently happens when the water which has been collected in their cavities or fiſſures, is frozen. The ſtones of the pavement are alſo raiſed and looſened by the freezing of the water in the earth in which they are imbedded, which is thus increaſed in bulk, and exerts its expanſive force.

9. Attempts have been made to diſcover the cauſe of this aſtoniſhing effect. According to ſome, it is owing

---

* *Edin. Tranſ.* vol. ii. p 23.

owing to the extrication of the air which water holds in combination in a denſe, nonelaſtic ſtate. When the 191 Accounted for water is freezing, part of the air aſſumes the elaſtic form, and ſeparates from it; but when the ſurface of the water is covered with ice, no more air can make its eſcape. It is then confined, and forms thoſe numerous cavities which are obſerved in ice. In conſequence of theſe cavities, a maſs of ice muſt be of greater bulk than the water previous to congelation, and cannot therefore be contained in the ſame ſpace: But another cauſe, which is perhaps the moſt probable, has been aſſigned for this increaſe of bulk, and conſequent expanſive force. Liquids which on cooling become 192 from the new arrangement of the particles. ſolid, and aſſume a regular form, are always found to increaſe in bulk. Water, when it paſſes from the liquid to the ſolid ſtate, has a ſtrong tendency among its parts to arrange themſelves in a determinate manner. They aſſume the form of priſmatic cryſtals, which croſs each other at angles of 60° and 120°. In this way the increaſe of bulk, and the expanſive force of water when it is conſolidated, are accounted for.

10. Some metallic ſubſtances, particularly caſt-iron, are obſerved to enlarge in bulk, when they paſs from the fluid to the ſolid ſtate, in the ſame way as water. To this increaſe of bulk in caſt-iron when it cools, are owing the ſharpneſs and diſtinctneſs of the lines in the ornamental figures on grates and furnaces which 193 In caſt iron. are made of this metal. The metal is introduced into the mould while it is fluid, or in the ſtate of fuſion, and increaſing in bulk as it cools, the minute cavities of the mould are more accurately filled. This increaſe of bulk, as in the caſe of water when it becomes ſolid, is alſo aſcribed to a determinate arrangement of the parts of the metal, or to cryſtallization.

11. On the expanſive property of bodies depends the conſtruction of the thermometer, which is employed for the meaſurement of the relative temperatures 194 The thermometer invented. of bodies. The invention of this inſtrument is generally aſcribed to Sanctorio, an Italian phyſician, who lived about the beginning of the 17th century, although it is ſaid by ſome, that thermometers were made by Drebel, a Dutch phyſician, and that they were common in Holland, and even in England, before Sanctorio was known in theſe countries.

195 Firſt conſtruction. In the thermometer of Sanctorio, the expanſive power of air was employed to meaſure the temperature. His thermometer is conſtructed in the following manner. A tube of glaſs of 18 inches or two feet in length, open at one end, is blown into a ball at the other. When the ball is heated, the air within is expanded, and while the air is thus expanded, if the open end of the tube be immerſed in a veſſel filled with any coloured fluid; as the internal air cools, and is diminiſhed in bulk, the liquid will riſe in the tube by the preſſure of the external air on the ſurface of the liquid in the veſſel. A ſcale of equal degrees was then applied to the whole length of the tube, and the thermometer was conſtructed. To aſcertain the heat of any body, as for inſtance the hand, it was applied to the ball, and if this temperature was greater than the medium in which the apparatus was placed, the internal air was rarefied, and conſequently depreſſed the ſurface of the coloured liquid in the tube. The number of degrees of this depreſſion was obſerved and compared in different experiments. 196 Imperfect. As for inſtance, the difference of temperature of the body at different periods, to aſcertain which, it is ſaid, it was employed by the inventor. But the inaccuracy of this inſtrument will be obvious; when we conſider that it depended, not only on the preſſure, but alſo on the temperature of the atmoſphere.

197 Improved. This defect in the air thermometer was remedied by Mr Boyle, and by the Florentine academicians, nearly at the ſame time; and they thought of employing other fluids. The firſt that was uſed was ſpirit of wine, which contracting and expanding more than water at the ſame temperature, and not liable to be frozen by cold, was found to be much more convenient. Quickſilver was ſome time afterwards employed in the ſame way. The ball of the glaſs, and part of the tube, was filled with the fluid, when the open extremity of the tube was cloſed. When heat was applied to the ball, the fluid within expanded, and contracted by cold, without being influenced by the preſſure of the atmoſphere, as in Sanctorio's thermometer. But ſtill this thermometer was very imperfect, for want of determinate points in the ſcale, by which different thermometers might be compared together. This was firſt pointed out by Sir Iſaac Newton, and after various improvements, it was brought to its preſent ſtate of perfection.

198 Fahrenheit's thermometer. The method of conſtructing Fahrenheit's thermometer, which is now in general uſe in this country, is the following: A ſmall ball is blown on the end of a glaſs tube, of a uniform width throughout. The ball and part of the tube are then to be filled with quickſilver which has been previouſly boiled to expel the air. The open end of the tube is then to be hermetically ſealed (M). The next object is to conſtruct the ſcale. It is found by experiment, that melting ſnow or freezing water, is always at the ſame temperature. If therefore, a thermometer be immerſed in the one or the other, the quickſilver will always ſtand at the ſame point. It has been obſerved, too, that water boils under the ſame preſſure of the atmoſphere at the ſame temperature. A thermometer therefore, immerſed in boiling water, will uniformly ſtand at the ſame point. Here then are two fixed points from which a ſcale may be conſtructed, by dividing the intermediate ſpace into equal parts, and carrying the ſame diviſions as far above and below the two fixed points as may be wanted. Thus, thermometers conſtructed in this way may be compared together; for if they are accurately made, and placed in the ſame temperature, they will always point to the ſame degree on the ſcale.

The fluid that is now generally employed is quickſilver, and it is found to anſwer beſt, becauſe its expanſions are moſt equable. The freezing point of Fahrenheit's thermometer is marked 32°, and the reaſon of this is ſaid to have been, that this artiſt thought

---

(M) This is done by heating the end of the tube with the flame of a lamp, and by cloſing it while the glaſs is ſoftened.

thought that he had produced the greateſt degree of cold by a mixture of ſnow and ſalt; and the point at which the thermometer then ſtood in this temperature, was marked zero. The boiling point in this thermometer is 212°, and the intermediate ſpace between the boiling and freezing points is therefore divided into 180°. This is the thermometer that is commonly uſed in Britain.

There are three other thermometers employed in different countries of Europe, which differ from each other in the number of degrees between the freezing and boiling points.

199 Reaumur's. Reaumur's thermometer was generally uſed in France before the revolution, and is ſtill employed in different countries on the continent. The freezing point in this thermometer is marked zero, and the boiling point 80°. To convert the degrees of Reaumur's thermometer to thoſe of Fahrenheit, the following is the formula. Reaum. $\frac{\times 9}{4}+32=$ Fahr. that is multiply the degrees of Reaumur by 9, divide by 4 and add 32. This gives the correſponding degrees on Fahrenheit's ſcale.

200 Celſius. The thermometer of Celſius has the ſpace between the freezing and boiling points divided into 100°. The boiling point is 100°, and the freezing point zero. This thermometer is uſed in Sweden. The *thermometre centigrade*, now uſed in France, has the ſcale divided in the ſame way. To convert the degrees of this thermometer into thoſe of Fahrenheit; Cel. $\frac{\times 9}{5}+32=$ Fahr.

201 Deliſle's. In Deliſle's thermometer, which is uſed in Ruſſia, the ſpace between the boiling and freezing points is divided into 150°; but the degrees are reckoned downwards. The boiling point is marked zero, and the freezing point 150°. To reduce the degrees of this thermometer under the boiling point to thoſe of Fahrenheit. Del. $\frac{\times 6}{5}-212=$ Fahr. and above the boiling point. Del. $\frac{\times 6}{5}+212=$ Fahr.

Such then are the principles and mode of conſtruction of the thermometer; an inſtrument which has been of the utmoſt importance in enabling us to diſcover many of the properties and effects of caloric, as by it only we can aſcertain with accuracy the relative temperatures (N).

202 Quantity of expanſion. 12. It has been an object of conſiderable intereſt and importance to aſcertain the quantity and rate of expanſion in bodies. Among ſolid bodies the quantity of expanſion is very ſmall, ſo that a nice apparatus is neceſſary to aſcertain it. But it appears that the ratio of this expanſion is equable, or nearly ſo. The reſults of experiments made by Mr Smeaton and ſome other philoſophers upon this ſubject, will be ſeen in the following table.

203 Of different metals.

Temperature.	Platina.	Antimony.	Steel	Iron.	Caſt Iron.	Biſmuth	Copper.	Caſt Braſs.	Braſs Wire
32°	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
212	120,104	120,130	120,147	120,151		120,167	120,204	120,000	120,232
White heat			123,428	121,500	122,571				

Temperature.	Tin.	Lead.	Zinc.	Hammered Zinc.	Zinc 8. Tin 1.	Lead 2. Tin 1.	Braſs 2. Zinc 1.	Pewter	Copper 3. Tin 1.
32°	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
212	120,298	120,344	120,355	120,373	120,123	120,301	120,247	120,274	120,218

204 Of glaſs. The rate of the expanſion of glaſs, which is a matter of conſiderable importance, has been aſcertained by M. de Luc, and is exhibited in the following table:

Temperature.	
32	100,000
50°	100,006
70°	100,014
100	100,023
120	100,033
150	100,044
167	100,056
190	100,069
212	100,083

205 Of liquids. 13. The expanſion of liquid bodies is greater than that of ſolids, but it is not equable with equal additions of temperature. It has been obſerved, that thoſe liquids which are moſt readily brought to the ſtate of vapour, or whoſe boiling point is loweſt, expand moſt. With the ſame given temperature, the expanſion of water is greater than that of mercury, and the expanſion of alcohol is greater than that of water. The boiling point of water, is lower than that of mercury, and the boiling point of alcohol is lower than that of water; from which it would appear, that the expanſion of liquids is nearly in the inverſe ratio of their boiling temperatures, and this expanſion ſeems to increaſe with the temperature; that is, the nearer a liquid is to that point of temperature at which it boils, the greater is the degree of expanſion by the addition of caloric; and the farther it is from the boiling temperature, the ſmaller is the increaſe of bulk by the addition of caloric. The following table exhibits the ratio of expanſion of ſeveral liquids, as they have been aſcertained by different philoſophers.

Table

(N) For meaſuring high degrees of temperature, the pyrometer of Wedgwood is employed, which will be deſcribed under the earth *alumina*.

Table of the Rate of Expanſion of different Liquids from 32° to 212°.

Temp.	Mercury.	Linſeed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpent.	Alcohol.
32°	100000	100000	—	—	—	—	100000
40	100081	—	99752	99514	—	—	100539
50	100183	—	100000	100000	100023	100000	101105
60	100304	—	100279	100486	100091	100460	101688
70	100406	—	100558	100990	100197	100993	102281
80	100508	—	100806	101530	100332	101471	102890
90	100610	—	101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104162
110	100813	—	101540	103196	—	102943	—
120	100915	—	101834	103776	101404	103421	—
130	101017	—	102097	104352	—	103954	—
140	101119	—	102320	105132	—	104573	—
150	101220	—	102614	—	102017	—	—
160	101322	—	102893	—	—	—	—
170	101424	—	103116	—	—	—	—
180	101526	—	103339	—	—	—	—
190	101628	—	103587	—	103617	—	—
200	101730	—	103911	—	—	—	—
212	101835	107250	—	—	104577	—	—

206 All gaſes expand equably.

14. It has been proved by experiment that all gaſeous bodies undergo the ſame expanſion, with the ſame addition of heat. This has been aſcertained by the ingenious experiments of Mr Dalton and M. Gay-Luſſac. The increaſe of bulk of ſome elaſtic fluids from 32° to 212°, as determined by the latter, will be ſeen in the following table :

Atmoſpheric air 100 parts, increaſed	37.50		
Hydrogen gas	37.52	difference	+0.2
Oxygen gas	37.48	———	—0.02
Azotic gas	37.49	———	—0.01 *

In other experiments he found, that the expanſion of the vapour of water and of ether correſponded with the expanſion of other gaſes ; and he remarks, that this property of the equable dilatation of the vapour of ether and water, and the gaſes, with the ſame degrees of temperature, depends not on the peculiar nature of the vapours and gaſes, but ſolely on their elaſtic ſtate.

Mr Dalton's experiments ſhew that the expanſion of air is very nearly equable. It appears, however, that the rate of expanſion diminiſhed as the temperature increaſed. The expanſion from 55° to 132½°, which includes 77½°, was 167 parts ; but the expanſion from 132½° to 212°, the next 77½° was only 158 parts, which was nine parts leſs than the firſt. The ſame philoſopher obſerves, that the reſults of ſeveral experiments which he made upon hydrogen gas, oxygen gas, carbonic acid gas, and nitrous gas, correſpond with thoſe on atmoſpherical air, not only in the total expanſion, but in the gradual diminution of it in aſcending. Small differences were obſerved, but they never exceeded ſix or eight parts in the whole amount 325 ; and differences to this amount, he adds, will take place in common air, when not freed from aqueous vapour, which, he ſays, was the ſituation of his factitious gaſes.

2. Of Fluidity.

207 Change of ſtate.

1. We have now ſeen the effects of caloric in expanding bodies, when it is accumulated in them. When a ſolid body, as a piece of iron, is expoſed to a high temperature, it is enlarged in bulk ; and when the additional quantity of caloric with which it had combined is withdrawn, it returns to its former dimenſions ; but when ſtill greater additions are made to moſt bodies, it is not merely a change of bulk that takes place, but a total change of their properties.

All matter exiſts, either in the ſtate of ſolid, of liquid, or in the ſtate of vapour. Moſt bodies, by the addition or the abſtraction of caloric, are convertible from one of theſe ſtates into another. Let us take water for an example. Ice is water in the ſolid ſtate. When a maſs of ice has received a proper quantity of caloric, it aſſumes the liquid ſtate ; and, when this liquid has received another portion of caloric, it is changed into the ſtate of vapour. But if this vapour is deprived of a certain portion of caloric, it returns to the ſtate of liquid or that of water ; and when this water is deprived of another portion of caloric, it becomes ſolid, or is converted into ice.

Thus it appears, that a ſolid body may be converted into a liquid by means of caloric ; and that a liquid may be converted into an elaſtic fluid by the ſame means. This ſeems to be a general law, to which there are but few exceptions. Some bodies may be converted into all the three ſtates, as water ; others, as ſpirit of wine, exiſt only in the fluid ſtate, and there are ſome ſolid bodies which are not convertible into the ſtate of liquid ; but theſe exceptions are ſo few, that it has been ſuppoſed the ſame effect would follow, were

---

* Ann. de Chim. vol. xliii. p. 167.

were theſe bodies expoſed to a proper degree of temperature.

208 Bodies become fluid at the ſame degree of temperature.

2. The temperature at which theſe changes are effected, is invariably the ſame in the ſame body. Thus, a maſs of ice is converted into the ſtate of liquid or of water, when it is expoſed to a temperature above 32°; and water, when it is raiſed to the temperature of 212°, aſſumes the ſtate of vapour or of ſteam. But although this temperature is conſtant in the ſame bodies, it varies greatly in different bodies. Thus, ſpirit of wine and ether are converted into vapour at a very low temperature, while mercury and the fixed oils, to undergo this change, require a temperature far above that which is neceſſary for the converſion of water.

209 In ſome inſtantaneouſly.

3. Some bodies are inſtantaneouſly converted from the ſolid to the liquid ſtate. Thus ice, when the temperature is raiſed, paſſes immediately from the ſolid to the fluid ſtate. Other bodies undergo a gradual change. They firſt become ſoft, as in the inſtance of melting wax, and paſs through the different degrees of ſoftneſs, till at laſt they become perfectly fluid.

210 In others gradually.

4. It may perhaps now ſeem ſurpriſing, that phenomena which were ſo familiar ſhould have exiſted ſo long without the true explanation of the changes which bodies undergo, in paſſing from the ſolid to the liquid or vaporous ſtate, or from the fluid to the ſolid ſtate. The want of inſtruments to meaſure accurately the relative degrees of temperature at which theſe changes take place, might perhaps be one cauſe of the unſucceſsful inveſtigations of philoſophers on this ſubject. But even after the invention and improvement of the thermometer, it was long before the ſecret, and we may add, ſimple cauſe of theſe wonderful effects, was fully aſcertained. It was reſerved for the ſagacity of Dr Black to give the true explanation. The era of the diſcovery of this law, of ſuch univerſal application to the phenomena of nature, may be regarded as one of the moſt important in the hiſtory of chemical ſcience. Dr Black was always diſtinguiſhed for caution and preciſion in all his views; and as the progreſſive ſteps by which this celebrated philoſopher was led to aſcertain the true cauſe of fluidity afford us a fine example of ſimple and elegant inveſtigation, we ſhall detail the experiments by which it was eſtabliſhed in his own words.

211 Great diſcovery of Dr Black.

5. After ſtating that the cauſe of fluidity which had been formerly given was unſatisfactory, and inconſiſtent with the phenomena, he obſerves that "theſe phenomena, when attentively conſidered, ſhew that fluidity is produced by heat, in a very different manner from that which was commonly imagined; a manner, however, which, when underſtood, enables us to explain many particulars relating to heat or cold, which appeared in the former view of the ſubject, quite perplexing and unaccountable.

212 Fluidity ſuppoſed to be owing to a ſmall addition of caloric.

"Fluidity was univerſally conſidered as produced by a ſmall addition to the quantity of heat which a body contains, when it is once heated up to its melting point; and the returning of ſuch body to a ſolid ſtate, as depending on a very ſmall diminution of the quantity of its heat, after it is cooled to the ſame degree; that a ſolid body, when it is changed into a fluid, receives no greater addition to the heat within it than what is meaſured by the elevation of temperature indicated after fuſion by the thermometer; and that, when the melted body is again made to congeal, by a diminution of its heat, it ſuffers no greater loſs of heat than what is indicated alſo by the ſimple application to it of the ſame inſtrument.

213 Inconſiſtent with facts.

"This was the univerſal opinion on this ſubject, ſo far as I know, when I began to read my lectures in the univerſity of Glaſgow, in the year 1757. But I ſoon found reaſon to object to it, as inconſiſtent with many remarkable facts, when attentively conſidered; and I endeavoured to ſhew, that theſe facts are convincing proofs that fluidity is produced by heat in a very different manner.

"I ſhall now deſcribe the manner in which fluidity appeared to me to be produced by heat, and we ſhall then compare the former and my view of the ſubject with the phenomena.

214 Caloric is abſorbed by ſolids becoming fluid.

"The opinion I formed from attentive obſervation of the facts and phenomena, is as follows. When ice, for example, or any other ſolid ſubſtance, is changing into a fluid by heat, I am of opinion that it receives a much greater quantity of heat than what is perceptible in it immediately after by the thermometer. A great quantity of heat enters into it, on this occaſion, without making it apparently warmer, when tried by that inſtrument. This heat, however, muſt be thrown into it, in order to give it the form of a fluid; and I affirm, that this great addition of heat is the principal, and moſt immediate cauſe of the fluidity induced.

215 Fluids becoming ſolid give out caloric.

"And, on the other hand, when we deprive ſuch a body of its fluidity again, by a diminution of its heat, a very great quantity of heat comes out of it, while it is aſſuming a ſolid form, the loſs of which heat is not to be perceived by the common manner of uſing the thermometer. The apparent heat of the body, as meaſured by that inſtrument, is not diminiſhed, or not in proportion to the loſs of heat which the body actually gives out on this occaſion; and it appears from a number of facts, that the ſtate of ſolidity cannot be induced without the abſtraction of this great quantity of heat. And this confirms the opinion, that this quantity of heat, abſorbed, and, as it were, concealed in the compoſition of fluids, is the moſt neceſſary and immediate cauſe of their fluidity.

"To perceive the foundation of this opinion, and the inconſiſtency of the former with many obvious facts, we muſt conſider, in the firſt place, the appearances obſervable in the melting of ice, and the freezing of water.

216 Proved by the melting of ice and freezing of water.

If we attend to the manner in which ice and ſnow melt, when expoſed to the air of a warm room, or when a thaw ſucceeds to froſt, we can eaſily pereceive, that however cold they might be at the firſt, they are ſoon heated up to their melting point, or begin ſoon at their ſurface to be changed into water. And if the common opinion had been well founded, if the complete change of them into water required only the further addition of a very ſmall quantity of heat, the maſs, though of a conſiderable ſize, ought all to be melted in a very few minutes or ſeconds more, the heat continuing inceſſantly to be communicated from the air around. Were this really the caſe, the conſequences of it would be dreadful in many caſes; for, even as things are at preſent, the melting of great quantities of ſnow and ice occaſions violent torrents, and

and great inundations in the cold countries, or in the rivers that come from them. But, were the ice and ſnow to melt as ſuddenly as they muſt neceſſarily do, were the former opinion of the action of heat in melting them well founded, the torrents and inundations would be incomparably more irreſiſtible and dreadful. They would tear up and ſweep away every thing, and that ſo ſuddenly, that mankind ſhould have great difficulty to eſcape from their ravages. This ſudden liquefaction does not actually happen; the maſſes of ice or ſnow melt with a very ſlow progreſs, and require a long time, eſpecially if they be of a large ſize, ſuch as are the collections of ice, and wreaths of ſnow, formed in ſome places during the winter. Theſe, after they begin to melt, often require many weeks of warm weather, before they are totally diſſolved into water. This remarkable ſlowneſs with which ice is melted, enables us to preſerve it eaſily during the ſummer, in the ſtructures called ice-houſes. It begins to melt in theſe, as ſoon as it is put into them; but, as the building expoſes only a ſmall ſurface to the air, and has a very thick covering of thatch, and the acceſs of the external air to the inſide of it is prevented as much as poſſible, the heat penetrates the ice-houſe with a ſlow progreſs, and this, added to the ſlowneſs with which the ice itſelf is diſpoſed to melt, protracts the total liquefaction of it ſo long, that ſome of it remains to the end of ſummer. In the ſame manner does ſnow continue on many mountains during the whole ſummer, in a melting ſtate, but melting ſo ſlowly, that the whole of that ſeaſou is not a ſufficient time for its complete liquefaction.

217 Melting of ice a very ſlow proceſs.

"This remarkable ſlowneſs with which ice and ſnow melt, ſtruck me as quite inconſiſtent with the common opinion of the modification of heat, in the liquefaction of bodies.

218 Foundation of the diſcovery.

"And this very phenomenon is partly the foundation of the opinion I have propoſed; for if we examine what happens, we may perceive that a great quantity of heat enters the melting ice, to form the water into which it is changed, and that the length of time neceſſary for the collection of ſo much heat from the ſurrounding bodies, is the reaſon of the ſlowneſs with which the ice is liquefied. If any perſon entertain doubts of the entrance and abſorption of heat in the melting ice, he needs only to touch it; he will inſtantly feel that it rapidly draws heat from his warm hand. He may alſo examine the bodies that ſurround it, or are in contact with it, all of which he will find deprived by it of a great part of their heat; or if he ſuſpend it by a thread, in the air of a warm room, he may perceive with his hand, or by a thermometer, a ſtream of cold air deſcending conſtantly from the ice; for the air in contact is deprived of a part of its heat, and thereby condenſed and made heavier than the warmer air of the reſt of the room; it therefore falls downwards, and its place round the ice is immediately ſupplied by ſome of the warmer air; but this, in its turn, is ſoon deprived of ſome heat, and prepared to deſcend in like manner; and thus there is a conſtant flow of warm air from around, to the ſides of the ice, and a deſcent of the ſame in a cold ſtate, from the lower part of the maſs, during which operation the ice muſt neceſſarily receive a great quantity of heat.

"It is, therefore, evident that the melting ice receives heat very faſt, but the only effect of this heat is to change it into water, which is not in the leaſt ſenſibly warmer than the ice was before. A thermometer, applied to drops or ſmall ſtreams of water, immediately as it comes from the melting ice, will point to the ſame degree as when it is applied to the ice itſelf, or if there is any difference, it is too ſmall to deſerve notice. A great quantity, therefore, of the heat, or of the matter of heat, which enters into the melting ice, produces no other effect but to give it fluidity, without augmenting its ſenſible heat; it appears to be abſorbed and concealed within the water, ſo as not to be diſcoverable by the application of a thermometer.

219 Thermometer does not indicate the caloric abſorbed.

"In order to underſtand this abſorption of heat into the melting ice, and concealment of it in the water, more diſtinctly, I made the following experiments.

220 Proved by experiments.

"The plan of the firſt was, to take a maſs of ice, and an equal quantity of water, in ſeparate veſſels, of the ſame ſize and ſhape, and as nearly as poſſible of the ſame heat, to ſuſpend them in the air of a warm room, and, by obſerving with a thermometer the celerity with which the water is heated, or receives heat, to learn the celerity with which it enters the ice; and the time neceſſary for melting the ice being alſo attended to, to form an eſtimate, from theſe two data, of the quantity of heat which enters the ice during its liquefaction.

221 Firſt experiment.

"In order to prepare for this experiment, I choſe two thin globular glaſſes, four inches diameter, and very nearly of the ſame weight: I poured into one of them five ounces of pure water, and then ſet it in a mixture of ſnow and ſalt, that the water might be frozen into a ſmall maſs of ice. As ſoon as frozen, it was carried into a large empty hall, in which the air was not diſturbed or varied in its temperature during the progreſs of the experiment; and in this room the glaſs was ſupported, as it were, in mid air, by being ſet on a ring of ſtrong wire, which had a tail iſſuing from the ſide of it five inches long, and the end of this tail was fixed in the moſt projecting part of a reading deſk or pulpit: And in this ſituation the glaſs remained until the ice was completely melted.

"When the ice was thus placed, I ſet up the other globular glaſs preciſely in the ſame ſituation, and at the diſtance of 18 inches to one ſide, and into this I poured five ounces of water, previouſly cooled, as near to the coldneſs of melting ice as poſſible, viz. to 33°, and ſuſpended in it a very delicate thermometer, the bulb of which being in the centre of the water, and the tube being ſo placed, that without touching the thermometer, I could ſee the degree to which it pointed. I then began to obſerve the aſcent of this thermometer, at proper intervals, in order to learn with what celerity the water received heat, ſtirring the water gently with the end of a feather about a minute before each obſervation. The heat of the air, examined at a little diſtance from the glaſſes, was 47° of Fahrenheit's ſcale.

"The thermometer aſſumed the temperature of the water in leſs than half a minute, after which, the riſe of it was obſerved every five or ten minutes, during half an hour. At the end of that time, the water was grown warmer than at firſt, by 7° degrees; and the temperature

temperature of it had riſen to the 40th degree of Fahrenheit's ſcale.

"The glaſs with the ice was, when firſt taken out of the freezing mixture, four or five degrees colder than melting ſnow, which I learned by applying the bulb of the thermometer to the bottom of it; but after ſome minutes, it had gained from the air thoſe four or five degrees, and was juſt beginning to melt, which point of time was then noted, and the glaſs left undiſturbed ten hours and a half. At the end of this time, I found only a very ſmall and ſpongy maſs of the ice remaining unmelted, in the centre of the upper ſurface of the water, but this alſo was totally melted in a few minutes more; and, introducing the bulb of the thermometer into the water, near the ſides of the glaſs, I found the water there was warmed to the 40th degree of Fahrenheit. From this it appears, that when a conſiderable part of the ice was melted, and the quantity of water around it was increaſing, the heat was not tranſmitted through this water to the remaining ice altogether ſo faſt as it was received by the water; which is eaſily underſtood, if we conſider that the diſtance between the remaining ice and the external ſurface of the veſſel through which the heat entered, was gradually increaſing, and that heat always requires time to paſs through bodies, or to be communicated from one part of them to another.

"It appears, therefore, from this experiment, that it was neceſſary that the glaſs with the ice receive heat from the air of the room during 21 half-hours, in order to melt the ice into water, and to heat that water to the 40th degree of Fahrenheit. During all this time, it was receiving the heat, or matter of heat, with the ſame celerity (very nearly) with which the water-glaſs received it during the ſingle half-hour in the firſt part of the experiment. For, as the water received it with a celerity which was diminiſhing gradually during that half-hour, in conſequence of the diminution of difference between its degrees of heat and that of air; ſo the glaſs with the ice alſo received heat with a diminiſhing celerity, which correſponded exactly with that of the water-glaſs, only that the progreſſion of this diminution was much more ſlow, and correſponded to the whole time which the water ſurrounding the ice required to become warmed to the 40th degree of Fahrenheit. The whole quantity of heat, therefore, received by the ice-glaſs during the 21 half-hours, was 21 times the quantity received by the water-glaſs during the ſingle half-hour. It was, therefore, a quantity of heat, which, had it been added to liquid water, would have made it warmer by $\overline{40-33}\times 21$, or 7×21, or 147 degrees. No part of this heat, however, appeared in the ice water, except 8 degrees; the remaining 139 or 140 degrees had been abſorbed by the melting ice, and were concealed in the water into which it was changed.

"The communication of heat to the melting ice was eaſily perceived, during the whole time of its expoſition, by feeling the ſtream of cold air which deſcended from the glaſs.

"This experiment was an analyſis of the manner in which ice is melted by the heat of the air in ordinary circumſtances.

"But another obvious method of melting ice occurred to me, in which it would be ſtill more eaſy to perceive the abſorption and concealment of heat, and this was the action of warm water.

222 Second experiment. "When hot and cold water are mixed together, the exceſs of heat contained in the hot water is equally diſtributed in an inſtant through the whole mixture, and raiſes the temperature of it according to the greatneſs of the exceſs of temperature, and the proportion which the hot water bore to the cold. If the quantities of hot and cold water are equal, the temperature is the middle degree between that of the hot and that of the cold. No part of the heat diſappears on this occaſion, ſo far as we can perceive, but the intenſity of it only is diminiſhed, by its being diffuſed through a larger quantity of matter. It was, therefore, obvious, that if a quantity of heat is abſorbed, and diſappears in the melting of ice, this would eaſily be perceived when the ice is melted with warm water.

"To make this experiment, I firſt froze a quantity of water in the neck of a broken retort, in order to have a maſs of ice of an oblong form.

"At the ſame time I heated a quantity of water, nearly equal in weight to the ice, in a very thin globular glaſs, the mouth of which was ſufficiently wide to take in the piece of ice. The water was heated by a ſmall ſpirit of wine lamp applied to the bottom of the glaſs; it was alſo ſtirred with the end of a feather, and a thermometer hung in it.

"While the water was heating, the maſs of ice was taken out of the mould in which it had been formed, and was expoſed to the air of a temperate room, until it was perceived to be beginning to melt over the whole of its ſurface.

"I then put a woollen glove on my left hand, and taking hold of the ice, I wiped it quite dry with a linen towel, laid it in the ſcale of a balance on a piece of flannel, and haſtily counterpoiſed it with ſand in the oppoſite ſcale, that I might examine the weight of it afterwards; and I immediately plunged it into the hot water, and extinguiſhed the lamp at the ſame time. The lamp being ſmall, the heat of the water had been increaſing very ſlowly, and had almoſt ceaſed to increaſe; and being examined immediately before I put the ice into it, the temperature was found to be juſt 190 degrees. The ice was all melted in a few ſeconds, and produced a mixture, the temperature of which was 53 degrees.

"The weight of the ice, when put into the hot water, was ſeven ounces three drams and a half. The weight of the glaſs, with the whole mixture in it, was 16 ounces, ſeven drams, and ſeven grains. The weight of the glaſs alone was nearly one ounce.

"In conſidering this experiment, we may overlook quantities leſs than half a dram, or 30 grains, and reckon the quantities of the different articles, by the number of half-drams in each.

Thus the weight of the ice was 119 half-drams.
——— Hot water 135
——— Mixture 254
——— Glaſs alone 16

"The melting of the ice was effected, not only by the heat of the hot water, but alſo by that of the glaſs. And, by other experiments, I learned that 16 parts of hot glaſs have no more power in heating cold bodies,

bodies, than eight parts of equally hot water; we may therefore ſubſtitute, in place of the 16 half-drams of warm glaſs, eight half-drams of warm water, which, added to the above quantity of warm water, make up 143 half-drams.

“ The heat of this warm water was 190 degrees, that is 158 hotter than the ice; and if this heat had abated in the mixture only in conſequence of the quantity and coldneſs of the ice, and if nothing had happened when the ice was put in, but merely a communication of this heat, and an equal diſtribution of it through the mixture, the temperature of the mixture ſhould have been 158, viz. the exceſs of heat in the warm water, multiplied by 143, the quantity of the warm matter, and divided by 262, the quantity of the whole, which gives 86.

223
Caloric is abſorbed.

“ The mixture ſhould have been 86 degrees warmer than melting ice; but it was found only 21 degrees warmer. Therefore a quantity of heat has diſappeared, which, if it had remained in a ſenſible ſtate, would have made the whole mixture and glaſs warmer by 65 degrees than they were actually found to be. But this quantity of heat would be ſufficient for increaſing, by 143 degrees, the heat of a quantity of water, equal in weight to the ice alone. It was, however, abſorbed by the ice, without in the leaſt increaſing its ſenſible heat (o).

“ The reſult of this experiment coincides ſufficiently with that of the former; the difference is not greater than what may be expected in ſimilar experiments, and might ariſe from the accident of the central parts of the maſs of ice being colder than the ſurface, by one or two degrees.

“ I have, in the ſame manner, put a lump of ice into an equal quantity of water, heated to the temperature 176, and the reſult was, that the fluid was no hotter than water juſt ready to freeze. Nay, if a little ſea ſalt be added to the water, and it be heated only to 166 or 170, we ſhall produce a fluid ſenſibly colder than the ice was in the beginning, which has appeared a curious and puzzling thing to thoſe unacquainted with the general fact.

“ It is, therefore, proved that the phenomena which attend the melting of ice in different circumſtances, are inconſiſtent with the common opinion which was eſtabliſhed upon this ſubject, and that they ſupport the one which I have propoſed *.”

* *Black's Lect.* vol. i. p. 125.

224
Called *latent heat*.

6. Theſe experiments ſhew clearly and incontrovertibly, that the converſion of ice into water is owing to the abſorption of a certain portion of caloric; and that the quantity of caloric abſorbed is equal to what would have raiſed the temperature of a body which remained unchanged, for inſtance as water, 140°. Theſe 140° therefore, have diſappeared, (for no increaſe of temperature is indicated by the thermometer), have been abſorbed by the ice, and are neceſſary to reduce it to the liquid ſtate. This portion of caloric which had thus diſappeared, Dr Black called *latent heat*, becauſe in this ſtate of combination its preſence was not indicated by the thermometer. By others this has been called *the caloric of fluidity*.

225
Experiments on other bodies prove the ſame thing.

7. In the progreſs of theſe inveſtigations, experiments were made on other ſubſtances, which clearly ſhewed that their fluidity is owing to the ſame cauſe. Theſe experiments were made on wax, tallow, ſpermaceti, ſulphur, alum, nitre, and ſome of the metals. The late ingenious Dr Irvine, the pupil of Dr Black, and who eſſentially aſſiſted him in many of his experiments, aſcertained the quantity of caloric which was neceſſary for the fluidity of the following ſubſtances; which, when compared with that of ice, will ſhew that the quantity of the caloric of fluidity increaſes with the temperature at which the body is converted into the liquid ſtate.

Spermaceti,	148°.
Bees wax,	175.
Tin,	500 *.

* *Black's Lect.* vol. i. p. 137.

226
Softneſs and malleability owing to the ſame cauſe.

8. Dr Black farther obſerves on the operation of this cauſe, that there is reaſon to think, that not only the fluidity of bodies, but even the ſoftneſs of ſuch as are rendered plaſtic by heat, depends on a quantity of heat combined with them, in the form of latent heat; and that the malleability and ductility of metals depend upon the ſame cauſe. For, while they are extended under the hammer, they become warm, and in ſome caſes very hot; but at the ſame time they become rigid, and are no longer malleable. They have loſt their toughneſs and ſoftneſs. To reſtore this, they muſt be annealed or made hot in the fire, and allowed to cool. Thus, they recover their malleability, of which they may be again deprived by a ſecond hammering.

227
Temperature at which bodies become fluid conſtant.

9. The temperature at which ſolid bodies begin to be converted into the liquid ſtate, is always conſtant; and till they are raiſed to this temperature, no change takes place. Water in the ſolid ſtate, or ice, always remains unchanged till it is placed in a temperature above 32°. This point, which is called the *melting point*, is conſtant in the ſame body, but is very different in different bodies. The following table exhibits the melting point of a number of ſolid bodies.

Lead,	594°
Biſmuth,	576
Tin,	442
Sulphur,	212
Wax,	142
Spermaceti,	133
Phoſphorus,	100
Tallow,	92
Oil of aniſe,	50
Olive oil,	36
Ice,	32
Milk,	30
Vinegar,	28
Blood,	25
Oil of bergamot,	23
Wines,	20

(o) “ Theſe two experiments, and the reaſoning which accompanies them, were read by me in the Philoſophical Club, or Society of Profeſſors and others in the Univerſity of Glaſgow, in the year 1762.”

Oil of turpentine,	14°
Sulphuric acid,	36
Mercury,	39
Liquid ammonia,	46
Ether,	46
Nitric acid,	66

3. Of Vapour.

228 Water changed into vapour.

1. If, after a maſs of ice is converted into water or the liquid ſtate, the application of heat be continued to that water, it undergoes other changes, and exhibits very different phenomena. If the temperature be raiſed ſufficiently high, the water becomes agitated with an inteſtine motion, and if it is ſupplied with a ſufficient quantity of caloric, the whole of the water is diſſipated. This agitation of the water, it is well known, is called in common language, *boiling*.

229 Boiling, what.

230 Boiling point conſtant;

2. As ſolid bodies which are capable of being converted into the liquid ſtate by an increaſe of caloric, have a certain determinate temperature, ſo, many of thoſe bodies which are capable of aſſuming the form of an elaſtic fluid, undergo this change, only when they are raiſed to a certain temperature. Some liquids, indeed, aſſume the form of vapour at all temperatures, which is the caſe with water, with volatile oils, ſpirits of wine and ether. This change is called *ſpontaneous evaporation;* but there are others which remain fixed and unchanged till the temperature is raiſed to that point at which they boil. Boiling is nothing elſe but the rapid converſion of the liquid into vapour. The heat being applied to the bottom of the veſſel, which contains the liquid, the particles at the bottom firſt aſſume the elaſtic form; and as they riſe through the liquid, cauſe it to be violently agitated. This boiling point, under the ſame preſſure, is always the ſame in the ſame liquid; and however ſtrong the heat that may be applied, or however long it may be continued, the temperature of the liquid, in open veſſels, never riſes above this point. The boiling point of water, for inſtance, is 212°, and it never becomes hotter; on the contrary, if the ſame heat be continued, the whole is diſſipated, and converted into vapour.

Table ſhewing the boiling point of ſeveral liquids.

Ether,	98°
Ammonia,	140
Alcohol,	176
Water,	212
Muriate of lime,	230
Nitric acid,	248
Phoſphorus,	554
Oil of turpentine,	560
Sulphur,	570
Sulphuric acid,	590
Linſeed oil,	600
Mercury,	660

231 but varies with preſſure.

3. But this boiling point is found to vary conſiderably, and this variation depends on the preſſure on the ſurface of the liquid. When the preſſure is diminiſhed, liquids boil at a lower temperature; but when this preſſure is increaſed, they require a higher temperature to produce boiling. Water boils at a low temperature on the top of a high mountain, or in the vacuum of an air pump, where the preſſure is greatly diminiſhed; but when it is confined in cloſe veſſels, as in Papin's digeſter, the temperature may be raiſed to 300° or 400° without boiling.

232 Law of latent heat extended.

4. The general law which was diſcovered by Dr Black, of the converſion of ſolids into liquids, was alſo applied by him to account for the change of liquids into elaſtic fluids. This was proved by the following experiments.

"*Experiment* 1.—I procured (ſays Dr Black) ſome cylindrical tin-plate veſſels, about four or five inches diameter, and flat-bottomed. Putting a ſmall quantity of water into them, of the temperature 50°, I ſet them upon a red-hot kitchen table, that is, a caſt-iron plate, having a furnace of burning fuel below it, taking care that the fire ſhould be pretty regular. After four minutes, the water began ſenſibly to boil, and in 20 minutes more, it was all boiled off. This experiment was made 4th October 1762.

"*Experiment* 2.—Two flat-bottomed veſſels, like the former, were ſet on the iron plate, with eight ounces of water in each, of the temperature 50°. They both began to boil at the end of three and a half minutes, and in eighteen minutes more, all the water was boiled off.

"*Experiment* 3.—The ſame veſſels were again ſupplied with 12 ounces of water in each, alſo of the temperature 50°. Both began to boil at the end of ſix and a quarter minutes, and the water was all boiled off, from the one in 28 minutes, and from the other in ſomething more than 29.

"I reaſoned from theſe experiments in the following manner: The veſſels in the firſt experiment received 162 degrees of heat in four minutes, or 40½ degrees each minute. If we, threfore, ſuppoſe that the heat enters equally faſt during the whole ebullition, we muſt ſuppoſe that 810 degrees of heat have been abſorbed by the water, and are contained in its vapour. Since this vapour is no hotter than boiling water, the heat is contained in it in a latent ſtate, if we conſider it only as the cauſe of warmth. Its preſence is ſufficiently indicated, however, by the vaporous or expanſive form which the water has now acquired.

233 Quantity of caloric in vapour.

"In experiment ſecond, the heat abſorbed, and rendered latent, ſeems to be about 830.

"In the third experiment, the heat abſorbed ſeems to be ſomewhat leſs, viz. about 750. The time of riſing to the boiling heat, in experiment third, has nearly the ſame proportion to that in experiment firſt, that the quantities of water have. The deficiency, therefore, in the heat abſorbed, has been probably only apparent, and ariſing from irregularity in the fire. Upon the whole, the conformity of their reſults with my conjecture was ſufficient to confirm me in my opinion of its juſtice. In the courſe of further experiments made both by myſelf and by ſome friends, and in which the utmoſt care was taken to procure a perfect uniformity in the heat applied, the abſorption was found extremely regular, and amounted at an average to about 810 degrees.

234 Other proofs of caloric abſorbed in vapour.

"There are other caſes where this abſorption appears in a much more ſingular manner. I put into a very ſtrong phial, about as much water as half filled it, and I corked it cloſe. The phial was placed in a ſand-pot, which was gradually heated, until the ſand and phial were ſeveral degrees above the common vaporific

porific point of water. I was curious to know what would be the effect of ſuddenly removing the preſſure of the air, which is well known to prevent water from boiling. The water boiled a very ſhort while, but the ebullition gradually decreaſed, till it was almoſt inſenſible. Here the formation of more vapour was oppoſed by a very ſtrong preſſure, proceeding from the quantity of vapour already accumulated, and confined in the upper part of the phial, and from the increaſed elaſticity of this vapour, by the increaſe of its heat. When matters were in this ſtate, I drew out the cork. Now, according to the common opinion of the formation of vapour by heat, it was to be expected that the whole of the water would ſuddenly aſſume the vaporous form, becauſe it was all heated above the vaporific point. But I was beginning by this time to expect a different event, becauſe I could not ſee whence the heat was to be ſupplied, which the water muſt contain when in the form of vapour. Accordingly, it happened as I expected; a portion only of the water was converted into vapour, which ruſhed out of the phial with a conſiderable exploſion, carrying along with it ſome drops of water. But, what was moſt intereſting to me in this experiment was, that the heat of what remained was reduced in an inſtant to the ordinary boiling point. Here, therefore, it was evident, that all that exceſs of heat which the water had contained above the boiling point, was ſpent in converting only a portion of it into vapour. This is plainly inconſiſtent with the common opinion, that nothing more is neceſſary for water's exiſting in a vaporous form under the preſſure of the atmoſphere, than its being raiſed to a certain temperature. The experiment makes it more probable, that if the influx of heat could at that inſtant have been prevented, it would have remained in the form of water, although raiſed, in a very ſenſible degree, above the boiling temperature.

" I was anxious to learn whether the heat which diſappeared in this experiment was in an accurate proportion to the quantity of vapour produced, or the quantity of water that had diſappeared. But the drops of water that were hurried along by the exploſion without being converted into vapour, made it impoſſible for me to aſcertain this with any tolerable accuracy, although I repeated the experiment ſeveral times.

235 The caloric abſorbed in proportion to the quantity of vapour.

" This experiment was afterwards made by my friend Mr Watt, in a very ſatisfactory manner. His ſtudies for the improvement of his ſteam-engine, gave him a great intereſt in every thing relating to the production of ſteam. He put three inches of water into a ſmall copper digeſter, and, ſcrewing on the lid, he left the ſafety-valve open. He then ſet it on a clear fire of coaks, and after it began to boil and produce ſteam, he allowed it to remain on the fire half an hour, with the valve open. Then, taking it off the fire, he found that an inch of water had boiled away. In the next place, he reſtored that inch of water, ſcrewed on the lid, and ſet it on the fire; and as ſoon as it began to boil, he ſhut the ſafety-valve, and allowed it to remain on the fire half an hour as before. The temperature of the whole was many degrees above the boiling point. He took it off the fire, and ſet it upon aſhes, and opened the valve a very ſmall matter. The ſteam ruſhed out with great violence, making a ſhrieking noiſe for about two minutes. When this had ceaſed, he ſhut the valve, and allowed all to cool. When he opened it, he found that an inch of water was conſumed.

" It is reaſonable to conclude from this experiment, that nearly as much heat was expended during the blowing of the ſteam-pipe, as had been formerly expended in boiling off the inch of water. For, before opening the valve, the temperature was many degrees above the boiling point, and all this diſappeared with the vapour. The ſame inference may be drawn from the time that the digeſter continued upon the fire with the valve ſhut, becauſe we may conclude that the heat was entering nearly at the ſame rate during the whole time. It is plain, however, that the experiment is not of ſuch a kind as to admit of nice calculation; but it is abundantly ſufficient to ſhew that a prodigious quantity of heat had eſcaped along with the particles of vapour produced from an inch of water. The water that remained could not be hotter than the boiling point, nor could the veſſel be hotter, otherwiſe it would have heated the water, and converted it into vapour. The heat, therefore, did not eſcape along with the vapour, but *in* it, probably united to every particle, as one of the ingredients of its vaporous conſtitution. And as ice, united with a certain quantity of heat, is water; ſo water, united with another quantity of heat, is ſteam or vapour *."

236 Confirmed by Dr Irvine.

The following experiment made by the late Dr Irvine of Glaſgow, at the deſire of Dr Black, and recorded by the latter, is a ſtill farther confirmation of the general fact of the converſion of liquids into elaſtic fluids, by combining with caloric.

" Five meaſures (each containing 4 lb. 5 oz. and 6 dr. avoirdupois) of water, of the temperature 52°, were poured into a ſmall ſtill in the laboratory. The fire had been kindled about 40 minutes before, and was come to a clear and uniform ſtate. The ſtill was ſet into the furnace, and, in an hour and 20 minutes, the firſt drop came from the worm; and in three hours and 45 minutes more, three meaſures of water were diſtilled, and the experiment ended. The refrigeratory contained 38 meaſures of water, of which the temperature, at the beginning of the experiment, was 52°. When one meaſure had come over, the water in the refrigeratory was at 76°. When two had come over, it was at 100°; and when three had come over, it was at 123°.

" In this experiment, the heat, which emerged from three meaſures of water, had raiſed the temperature of the water in the refrigeratory from 52° to 123°, or 71°. Now 3 is to 38 as 71 to $899\frac{1}{3}$, and the heat would have raiſed the three meaſures $899\frac{1}{3}$ degrees in its temperature, if this had been poſſible without converting it into vapour. The heat of the vapour from which this emerged, was 212°, or 160° more than that of the water. Taking this from 899°, there remains 739°, the heat contained in the vapour in a latent ſtate.

" But this muſt be ſenſibly leſs than the truth. During the experiment, the veſſels were very warm—the head of the ſtill as hot as boiling water, and the refrigeratory gradually riſing from 52°, which was within a degree or two of the temperature of the air of the laboratory, to 123°. A very conſiderable portion of the latent heat of the ſteam muſt have been carried off by the

---

* *Black's Lect.* vol. i. p. 161.

the air in contact with a conſiderable ſurface, ſome of which was exceedingly hot. A great deal muſt alſo have been carried off in the ſteam which aroſe very ſenſibly from the water in the refrigeratory, towards the end of the experiment. Mr Irvine alſo obſerved, that, during the diſtillation, the temperature of the water which ran from the worm was about 11° hotter than the water in the refrigeratory. The ſteam, therefore, at a medium, was not 160° hotter than the water which ran from the worm, but 125°, its mean temperature being about 87°. This conſideration alone will make the latent heat of the ſteam not leſs than 774 degrees, without any allowance for waſte.

"Some compariſon may alſo be made between the heat expended in the production of the ſteam, and that which emerges during its condenſation. The time which elapſed during the raiſing of the temperature of the five meaſures of water from 52° to 212°, that is 160°, was one hour and 20 minutes, or 80′,—and 225′ elapſed during the boiling off of three meaſures. Therefore, ſince 80 is to 225 as 160 to 450, as much heat was expended as would have raiſed the five meaſures 450° in temperature. This would have raiſed three meaſures 750° above the boiling heat already produced. This gives 750 for the latent heat of the ſteam, beſides what was unavoidably loſt by communication to the ambient air, and what was expended in heating the veſſels *."

237 Caloric of ſteam eſtimated by Watt.

In ſome experiments made by Mr Watt, who alſo aſſiſted Dr Black in conducting theſe invaluable experiments, it appears that the latent heat of ſteam is from 900° to 950°. This he diſcovered by obſerving the quantity of caloric which was abſorbed by the water in its converſion into ſteam or vapour, and the quantity given out, when that vapour returned to the ſtate of water.

238 By Lavoiſier.

The value of the latent heat of ſteam, eſtimated by the experiments of M. Lavoiſier, amounts to more than 1000°.

5. Thus is this general law eſtabliſhed, that all liquids are converted into elaſtic fluids, by combining with a certain portion of caloric. This portion of caloric is not indicated by the thermometer, and is therefore ſaid to be latent heat, as we already mentioned; but when the elaſtic fluid returns to the liquid ſtate, it again becomes ſenſible, and preciſely the ſame quantity is extricated which was abſorbed.

239 Elaſticity of all vapour the ſame as that of water with the ſame increaſe of temperature.

6. It is an object of ſome importance to aſcertain the elaſtic force of vapour, and the ratio of the increaſe of this elaſticity by increaſe of temperature. The elaſticity of vapour which is formed by a liquid boiling in the open air, is equal to the preſſure of the atmoſphere; and it has been aſcertained by the experiments of Mr Dalton and of M. Gay-Luſſac, that the elaſticity of all elaſtic fluids is the ſame with that of the vapour of water, with the ſame increaſe or diminution of temperature from the boiling point. If then, the boiling point of any liquid be known, the elaſticity of its vapour may be diſcovered, by comparing it with the elaſticity of the ſteam of water, the ſame number of degrees above or below the boiling point. In the following table, conſtructed by Mr Dalton from his experiments and calculations, the elaſticity of the vapour of water is given for every temperature from 40° to 325°. To find the elaſticity of the vapour of ether at 40° below its boiling point, which is 98°, take 40° from 98°, there remains 58°, and the ſame number from 212° the boiling point of water, there remains 172°, oppoſite to which number in the table is 12.73, which is the elaſticity of the ſteam of water at 172°, and alſo the elaſticity of the vapour of ether at 58°.

Table of the Force of Vapour from Water in every temperature, from that of Congelation of Mercury, or 40° below Zero of Fahrenheit, to 325° †.

Temperature.	Force of Vap. in inches of Mercury.	Temperatue.	Force of Vap. in inches of Mercury.	Temperature.	Force of Vap. in inches of Mercury.
-40°	.013	41°	.273	88°	1.28
-30	.020	42	.283	89	1.32
-20	.030	43	.294	90	1.36
-10	.040	44	.305	91	1.40
0	.064	45	.316	92	1.44
1	.066	46	.328	93	1.48
2	.068	47	.339	94	1.53
3	.071	48	.351	95	1.58
4	.074	49	.363	96	1.63
5	.076	50	.375	97	1.68
6	.079	51	.388	98	1.74
7	.082	52	.401	99	1.80
8	.085	53	.415	100	1.86
9	.087	54	.429	101	1.92
10	.090	55	.443	102	1.98
11	.093	56	.458	103	2.04
12	.096	57	.474	104	2.11
13	.100	58	.490	105	2.18
14	.104	59	.507	106	2.25
15	.108	60	.524	107	2.32
16	.112	61	.542	108	2.39
17	.116	62	.560	109	2.46
18	.120	63	.578	110	2.53
19	.124	64	.597	111	2.60
20	.129	65	.616	112	2.68
21	.134	66	.635	113	2.76
22	.139	67	.655	114	2.84
23	.144	68	.676	115	2.92
24	.150	69	.698	116	3.00
25	.156	70	.721	117	3.06
26	.162	71	.745	118	3.16
27	.168	72	.770	119	3.25
28	.174	73	.796	120	3.33
29	.180	74	.823	121	3.42
30	.186	75	.851	122	3.50
31	.193	76	.880	123	3.59
32	.200	77	.910	124	3.69
33	.207	78	.940	125	3.79
34	.214	79	.971	126	3.89
35	.221	80	1.00	127	4.00
36	.229	81	1.04	128	4.11
37	.237	82	1.07	129	4.22
38	.245	83	1.10	130	4.34
39	.254	84	1.14	131	4.47
40	.263	85	1.17	132	4.60
		86	1.21	133	4.73
		87	1.24	134	4.86

---

* *Lect.* vol. i. p. 173.

† *Manch. Mem.* vol. v. p. 559.

Table Continued.

Temperature.	Force of Vap. in inches of Mercury.	Temperature.	Force of Vap. in inches of Mercury.	Temperature.	Force of Vap. in inches of Mercury.
135°	5.00	190	19.00	244°	53.03
136	5.14	191	19.42	245	53.88
137	5.29	192	19.86	246	54.68
138	5.44	193	20.32	247	55.54
139	5.59	194	20.77	248	56.42
140	5.74	195	21.22	249	57.31
141	5.90	196	21.68	250	58.21
142	6.05	197	22.13	251	59.12
143	6.21	198	22.69	252	60.05
144	6.37	199	23.16	253	61.00
145	6.53	200	23.64	254	61.92
146	6.70	201	24.12	255	62.85
147	6.87	202	24.61	256	63.76
148	7.05	203	25.10	257	64.82
149	7.23	204	25.61	258	65.78
150	7.42	205	26.13	259	66.75
151	7.61	206	26.66	260	67.73
152	7.81	207	27.20	261	68.72
153	8.01	208	27.74	262	69.72
154	8.20	209	28.29	263	70.73
155	8.40	210	28.84	264	71.74
156	8.60	211	29.41	265	72.76
157	8.81	212	30.00	266	73.77
158	9.02			267	74.79
159	9.24	213	30.60	268	75.80
160	9.46	214	31.21	269	76.82
161	9.68	215	31.83	270	77.85
162	9.91	216	32.46	271	78.89
163	10.15	217	33.09	272	79.94
164	10.41	218	33.72	273	80.98
165	10. 8	219	34.35	274	82.01
166	10.96	220	34.99	275	83.13
167	11.25	221	35.63	276	84.35
168	11.54	222	36.25	277	85.47
169	11.83	223	36.88	278	86.50
170	12.13	224	37.53	279	87.63
171	12.43	225	38.20	280	88.75
172	12.73	226	38.89	281	89.87
173	13.02	227	39.59	282	90.99
174	13.32	228	40.30	283	92.11
175	13.62	229	41.02	284	93.23
176	13.92	230	41.75	285	94.35
177	14.22	231	42.49	286	95.48
178	14.52	232	43.24	287	96.64
179	14.83	233	44.00	288	97.80
180	15.15	234	44.78	289	98.96
181	15.50	235	45.58	290	100.12
182	15.86	236	46.39	291	101.28
183	16.23	237	47.20	292	102.45
184	16.61	238	48.02	293	103.63
185	17.00	239	48.84	294	104.80
186	17.40	240	49.67	295	105.97
187	17.80	241	50.50	296	107.14
188	18.20	242	51.34	297	108.31
189	18.60	243	52.18	298	109.48

Table Continued.

Temperature.	Force of Vap. in inches of Mercury.	Temperature.	Force of Vap. in inches of Mercury.	Temperature.	Force of Vap. in inches of Mercury.
299°	110.64	308°	121.20	317°	131.57
300	111.81	309	122.37	318	132.72
301	112.98	310	123.53	319	133.86
302	114.15	311	124.69	320	135.00
303	115.32	312	125.85	321	136.14
304	116.50	313	127.00	322	137.28
305	117.68	314	128.15	323	138.42
306	118.86	315	129.29	324	139.56
307	120.03	316	130.43	325	140.70

Sect. III. *Of the Motion of Caloric.*

240 Velocity of caloric equal to that of light.

1. It appears that the motion of caloric, when it is not interrupted, is equal in velocity to that of light. When therefore it is emitted by one body, it moves on with this velocity till it is received by another. This has been called the *tranſmiſſion* or *radiation* of heat. This radiation or ſeparation of heat from any body, ariſes from the force with which it is connected with that body being diminiſhed; that is, when a greater quantity of caloric is accumulated in that body than it can contain. The experiments of Dr Herſchel ſhew, that heat is radiated, refracted and reflected, in the ſame manner as light. The reflection of caloric has alſo been proved by the experiments of Mr Pictet formerly mentioned. But caloric is communicated from one body to another by direct contact of theſe bodies.

241 Radiated.

242 Refracted

243 and reflected.

244 Is communicated by contact.

2. It is well known that a cold body brought into contact with a warm body, in a certain time becomes hot; but this does not take place inſtantaneouſly; and the time neceſſary for one body to receive caloric from another, or for the different parts of the ſame body to acquire the ſame temperature, varies according to the nature and ſtate of theſe bodies. This is called the *conducting* power of bodies.

245 More rapidly in ſome bodies.

3. But as different bodies have different degrees of affinity for caloric, or contain different proportions of it, it muſt be ſeparated or abſorbed with greater or leſs facility. The motion of caloric therefore, in theſe different circumſtances, will be conſiderably varied in its celerity. This may be proved by direct experiment. If one extremity of two ſubſtances of different properties, as for inſtance, a rod of iron and another of wood, be put into the fire, and the hand brought into contact with the other extremity, the rod of iron will ſoon be heated too much for the hand to bear, while the rod of wood will not have its temperature greatly increaſed. This ſhews, that there is a ſmaller quantity of caloric carried through the wood; or, in other words, the iron is a better conductor than the wood.

246 Good conductors.

4. All ſolid bodies are conductors of caloric, but they poſſeſs this power in very different degrees. Thoſe bodies which conduct caloric with facility are called *good* conductors, but thoſe through which it

paſſes

247 Bad conductors. paſſes with difficulty or very ſlowly, are ſaid to be *bad* conductors. The motion of caloric from one body to another, or through the ſame body, is not altogether in proportion to their denſities, as might be ſuppoſed from the inſtance of the communication of caloric through wood and iron, juſt mentioned. Caloric is conducted very ſlowly through a more porous ſubſtance, ſuch as a maſs of cork, of wool, of feathers, or furs. It is on account of the ſlowneſs with which heat is conducted in theſe ſubſtances, that ſome of them are employed in the colder ſeaſons of the year, or in cold countries, as materials for clothing. The heat being ſlowly conducted through ſuch ſubſtances, they prevent the heat of the body from being diſſipated, or cut off the communication between the warm body and

248 Their uſe. the cold air. And thus we ſee a wiſe proviſion of nature, in furniſhing all animals which are inhabitants of the colder regions of the earth, with a thick covering of fur or feathers. According to the experiments of Count Rumford, the conducting power of fur, feathers, ſilk, and wool, diminiſhes in proportion to the fineneſs of their texture.

249 Metals the beſt conductors. Metallic ſubſtances are the beſt conductors of caloric; but among the metals it would appear that there is conſiderable variety in their conducting power, and this is not in proportion to their denſity, as appears from the experiments of Dr Ingenhouſz on the following metals, which are ſet down in the order of their conducting power *,

Silver,
Gold,
Copper,
Tin,
Platina,
Iron,
Steel,
Lead.

250 Conducting power of woods. A ſet of experiments were made on the conducting power of different woods, by Profeſſor Mayer of Erlangen, of which the following are the reſults, compared with the conducting power of water †.

Water,	10.0
Ebony,	21.7
Crab apple,	27.4
Aſh,	38.0
Beech,	32.1
Hornbeam,	32.3
Plum tree,	32.5
Female oak,	32.6
Pear tree,	33.2
Birch,	34.1
Oak,	36.3
Pitch pine,	37.5
Alder,	38.4
Pine,	38.6
Fir,	38.9
Lime tree,	39.0

The experiments of Guyton ſhew, that the conducting power of charcoal is to that of fine ſand nearly in the proportion of 2 to 3 ‡.

5. Fluid bodies, as well as ſolids, are conductors of caloric; but they are found to conduct it ſo ſlowly, that it was at firſt ſuppoſed, they did not poſſeſs this power at all; that is, that the caloric was not conducted from particle to particle in fluids, ſimilar to what happens in ſolid bodies. This opinion ſeemed to be ſupported by the nature and conſtitution of fluids, in which the particles have free motion among each other, ſo that when one ſet of particles acquire an additional quantity of caloric, their ſpecific gravity is neceſſarily diminiſhed, and they naturally change place with thoſe other particles of the fluid which have been leſs heated and are conſequently heavier. Theſe different appearances which were obſerved in the heating of fluids led Count Rumford, who made many ingenious experiments on this ſubject, to conclude, that fluids are heated, or conduct caloric, in a different manner from ſolids. In a ſpirit of wine thermometer, which was placed in a window to cool, he obſerved the fluid in the tube in rapid motion. There were two currents going in different directions, the one aſcending, and the other deſcending. The deſcending current occupied the ſides of the tube, and the aſcending current the middle. The currents were owing to the change in the ſpecific gravity of the particles, which being heated became lighter, and roſe to the top; the heavier particles at the ſame time deſcending. The particles which aſcended having reached the ſides or top of the tube, gave out their caloric, became ſpecifically heavier, and again fell to the bottom. The motion of the currents was conſiderably increaſed by the application of a cold body to the ſides of the tube. The count alſo repeated the experiment with linſeed oil, and alſo with water, in the latter of which he diſſolved potaſh, to bring its ſpecific gravity to that of amber, ſmall pieces of which he introduced, to obſerve the currents more diſtinctly. Theſe experiments were followed with the ſame reſult. When the temperature was increaſed or diminiſhed, the currents were ſet in motion, and only ceaſed when the temperature became equal to the ſurrounding bodies.

251 Fluids are conductors;

In proſecuting this ſubject, the count made other experiments, to aſcertain how far the heating or cooling of fluids is affected by a difference of fluidity. The thermometer which he employed in theſe experiments, has a copper bulb and a glaſs tube, and it was filled with linſeed oil. This was placed in the centre of a braſs cylinder, and the ſpace between the ſides of the cylinder and the thermometer, was 0.25175. The thermometer being ſecured, the cylinder was filled with 2276 grs. of pure water, and held in melting ſnow, till the thermometer fell to 32°. It was then immerſed in boiling water, and the thermometer roſe from 32° to 200° in 597″. The caloric which raiſed the thermometer muſt have been communicated to it through the water in the cylinder. The experiment was then varied, by boiling 192 grs. of ſtarch in the water in the cylinder. The thermometer now required 1109″ to riſe from 32° to 200°. The ſame experiment was repeated by mixing 192 grs. eider down with the ſame quantity of water, and alſo with a quantity of ſtewed apples. The reſults of theſe experiments will be ſeen in the following tables §.

---

* *Journ. de Phyſ.* 1789.

† *Annal. de Chim.* vol. xxx. p. 43.

‡ *Ibid.* vol. xxvi. p. 227.

§ *Rumford*, Eſſay 7.

Time the Caloric was in paſſing into the Thermometer.

Tempera-ture.	Through the water and Starch.	Through the Water and Eiderdown.	Through ſtewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
Therm. roſe from 32° to 200° in	1109	949	1096½	597
Therm. roſe 80°, viz. from 80° to 160°, in	341	269	335	172

Time the Caloric was in paſſing out of the Thermometer.

Tempera-ture.	Through the Water and Starch.	Through the Water and Eiderdown.	Through ſtewed Apples.	Through pure Water.
	Seconds.	Seconds.	Seconds.	Seconds.
Therm. fell from 200° to 40° in	1548	1541	1749½	1032
Therm. fell 80°, viz. from 160° to 80°, in	468	460	520	277

The ſubſtances which were added to the water in theſe experiments, by diminiſhing its fluidity, had the effect of retarding the internal motions or currents by which the caloric is conducted through fluids. Thus, when ſtarch was mixed with water, it required nearly double the time to raiſe the thermometer to the ſame degree, as with pure water. From theſe, and from ſome other experiments, Count Rumford concluded, that fluid bodies are heated in a different manner from ſolids; that caloric is not communicated through fluids from particle to particle, but that all the particles individually come in contact with the heating body, and this is ſuppoſed to be the cauſe of the currents which are obſerved during the heating of fluids.

252 but worſe than ſolids.

5. Fluids no doubt acquire great part of their temperature in this manner; but it has been clearly proved by the experiments of others, that they are alſo conductors of caloric exactly the ſame way as ſolid bodies, but in an inferior degree. This has been eſtabliſhed in the moſt ſatisfactory manner by the experiments of Dr Thomſon * and Mr Murray †, which were publiſhed in Nicholſon's Journal; and alſo by another ſet of experiments by Mr Dalton, which were publiſhed in the Mancheſter Memoirs ‡. By theſe experiments it is demonſtrated, that fluids conduct caloric from the ſurface downwards; which could not be the caſe, were it only communicated through them by the aſcending currents of particles, in the way Count Rumford ſuppoſed: but they are worſe conductors of caloric than ſolids; that is, it paſſes through them much more ſlowly.

SECT. IV. *Of the* DISTRIBUTION *of* CALORIC.

253 All bodies acquire the ſame temperature in the ſame medium.

If a number of bodies be expoſed to different temperatures, and then be all placed in the ſame temperature, or brought into contact with each other, they acquire in a certain time the ſame temperature. Thus, if one body be raiſed to the temperature of 200°, another to that of 100°, and a third to the temperature of 60°; and if theſe three bodies be placed in the temperature of 80°, they all indicate, in a ſhort time, the ſame temperature. The bodies which were at the temperature of 200° and 100° are reduced to 80°, and the temperature of the body at 60° riſes to the ſame. This is called the *diſtribution*, or the *equilibrium* of caloric. To whatever degree bodies are heated or cooled, they all acquire in time, the temperature of the ſurrounding medium, as it is indicated by the thermometer. It may therefore be received as a general law, *that all bodies which communicate freely with each other, and are ſubject to no inequality of external action, acquire the ſame temperature.*

254 Radiation not the ſole cauſe of cooling.

1. Bodies are deprived of caloric, not only by radiation from their ſurfaces, but it is alſo conducted by thoſe bodies with which the heated body comes in contact, and this depends greatly on the nature of the ſurrounding cold body. The experiments of Profeſſor Pictet and Count Rumford, however, ſhew, that radiation is not the only cauſe. By thoſe of the former it appeared, that hot bodies ſuſpended in the vacuum of an air-pump, cooled more ſlowly than in the open air; and by thoſe of the latter, the cooling was ſtill ſlower in the Torricellian vacuum.

255 Good conductors cool moſt rapidly.

2. The time requiſite for the heating or cooling of bodies depends much on their conducting power. A ſubſtance which is a good conductor of caloric cools much more rapidly than a bad conductor. Mercury and water heated to the ſame temperature cool in very different times; the mercury cools more than twice as faſt as the water in the ſame circumſtances. The time of the cooling of fluids has been conſidered as nearly in the inverſe ratio of their conducting power.

256 Diſtribution of caloric explained by Boerhaave, &c.

3. This equal diſtribution of caloric was attempted to be explained by Boerhaave, Muſchenbroeck, and others, by ſuppoſing that there is an equal quantity of caloric in every equal meaſure of ſpace, however that ſpace might be filled up with different bodies, and that theſe bodies floated, as it were, in this caloric. From this equal diſtribution of caloric in ſpace, they concluded that there was an equal quantity of caloric in all bodies, becauſe, whatever was the denſity or different circumſtances of bodies, they always indicated the ſame temperature to the thermometer. A cubic foot of gold, and a cubic foot of air, according to this theory, contained the ſame quantity of caloric.

257 By Pictet.

Profeſſor Pictet gave another explanation of this phenomenon. He ſuppoſed that the accumulation of caloric in a body increaſed the repulſive force between its particles, by the diminution of the diſtance between them. By the action of this repulſive force, the particles are driven off in all directions. This repulſion continues to act till it is oppoſed by a new force, which is the force of repulſion between the particles of caloric ſeparated from another body; and, till theſe two forces acquire the ſame intenſity, the particles of caloric continue to ſeparate from the hotter body. When the two forces are balanced, the bodies are of the ſame temperature. Thus, if two bodies of different

---

* Vol. iv. p. 529.

† Ibid, octavo, vol. i. p. 165.

‡ Vol. v. p. 373.

temperatures are brought into contact with each other, the repulſive force of the particles of caloric in the hotter body is the greateſt, and therefore the particles tend to ſeparate from each other; but the repulſion between the particles of the colder body being leſs, they come nearer each other. The caloric from the hotter body continues to ſeparate, and to enter the colder body, till the two forces exactly balance each other, and then the temperature is the ſame *. But this theory, with all its ſimplicity and ingenuity, being unſatisfactory in accounting for the equilibrium of temperature, has been given up, even by its author.

258 His theory unſatisfactory.

259 Prevoſt's theory

4. Another theory has been propoſed by M. Prevoſt, profeſſor of philoſophy at Geneva. "Accuſtomed," ſays he, "for a long time, to conſider this ſubject in a different view from what had been formerly taken of it, I endeavoured to draw the attention of naturaliſts to this inveſtigation, in a memoir on the equilibrium of caloric †, and in my *reſearches on heat* ‡. In theſe works, I believe it was firſt propoſed to ſubſtitute a moveable equilibrium in place of the immoveable equilibrium, the exiſtence of which had been generally admitted.

"On this hypotheſis, it is equally eaſy and ſatisfactory to account for the reflection of cold, as for that of heat. I conſider it indeed a characteriſtic of its truth; for theſe two facts being of the ſame kind, the theory that will account for the one, is applicable to the other. Before I proceed to ſtate in a few words the principle of this theory, I may premiſe, that I had the ſatisfaction of ſeeing it adopted by M. Pictet and others, who are well qualified to judge of it.

"Caloric is a diſcrete, agitated fluid: each particle of free caloric moves with immenſe velocity; one particle moves in one direction, and another particle moves in another, ſo that a heated body gives out calorific rays in all directions; and theſe particles are ſo far ſeparated from each other, that two or more currents may croſs each other, as is the caſe with light, without mutual diſturbance in their courſe. Conceiving this to be the conſtitution of caloric, if we ſuppoſe two contiguous ſpaces in which it abounds, there will be continual changes between theſe ſpaces. If in the two ſpaces caloric abounds equally, the exchanges will be equal; there will be an equilibrium. If one of the ſpaces contain more caloric than the other, the exchanges will be unequal. The cooleſt will receive more particles of caloric than it gives out, and after a ſufficient time, the continual repetition of theſe changes will reſtore the equilibrium §.

"From theſe principles may be deduced all the laws of the increaſe and diminution of temperature. Let us ſuppoſe a body placed in a medium hotter than itſelf, and that this medium has a conſtant temperature. We may conſider the caloric of the medium as compoſed of two parts, the one equal to that of the body, and the other equal to the difference of the two. With regard to the firſt, the exchanges are equal; between the body and the medium there is an equilibrium. The exceſs of the heat of the medium may then only be conſidered; and relatively to this exceſs the body is abſolutely cold. Let us ſuppoſe that in one ſecond the body receives $\frac{1}{10}$ of this caloric; at the end of the firſt ſecond the exceſs will be no more than $\frac{9}{10}$: the $\frac{1}{10}$ of this new exceſs will paſs into the body during the next ſecond; and the exceſs will be reduced to $\frac{9}{10}$ of $\frac{9}{10}$; and in purſuing this, at the end of the third ſecond, the exceſs will be $(\frac{9}{10})^3$, and ſo on: ſo that, conformably to the obſerved law, the times increaſe in arithmetical progreſſion, and the differences decreaſe in geometrical progreſſion. In the ſame way may be eaſily deduced the law of the cooling of a body placed in a medium colder than itſelf. And thus the true theory of heat, founded on facts totally different from thoſe by which Richmann eſtabliſhed this law, neceſſarily leads us to it *.

SECT. V. *Of the* QUANTITY *of* CALORIC *in Bodies.*

We have now treated in the former ſections of the effects of caloric, of its motion, and of its diffuſion in bodies; we are next to conſider the *quantity* of caloric which theſe bodies contain. This ſubject has occupied the attention and ſpeculations of many philoſophers. In theſe ſpeculations, two objects were kept in view, the one to aſcertain the whole quantity of caloric which a body contains, and the other the quantity of caloric neceſſary to raiſe different bodies to the ſame temperature. This laſt is uſually called *ſpecific caloric.*

1. OF SPECIFIC CALORIC.

260 explained.

1. If one lb. of water at the temperature of 100° be mixed with another lb. of water at the temperature of 50°, they will very ſoon acquire the ſame temperature, which will be the mean of the two temperatures. The pound of water at 100° will give out 25°, and the pound of water at 50° will receive 25°, which brings both to the temperature of 75°.

2. But if we take one pound of water at 100°, and one pound of mercury at 50°, the temperature, after mixing the water and the mercury, will not be 75°, the medium temperature in the former caſe. On the contrary, when the mixture is made, the temperature will be found to be 88°. The water, therefore, has loſt only 12°, and the mercury has gained 38°. If this experiment be reverſed, and one pound of water at 50° be mixed with a pound of mercury at 100, the temperature of the mixture will be found to be only 62°; ſo that in this caſe the mercury has given out 38°, and the water has received only 12°. In this experiment, therefore, it appears clearly, that different quantities of caloric are neceſſary to increaſe or diminiſh the temperature of different bodies; for, the quantity of caloric which raiſes water 12°, raiſes mercury no leſs than 38°. This quantity of caloric which bodies require to raiſe them to the ſame temperature, is called *ſpecific* caloric.

3. "It was formerly a common ſuppoſition," ſays Dr Black, "that the quantities of caloric required to increaſe the heat of different bodies by the ſame number of degrees, were directly in proportion to the quantity of matter in each; and therefore, when the bodies were of equal ſize, the quantities of caloric were in proportion to their denſity. But very ſoon after I began to think of this ſubject, in the year 1760, I perceived that this opinion was a miſtake, and that the quantities of heat which different kinds of matter muſt receive, to reduce them to an equilibrium with one another, or to raiſe their temperature by an equal num-

---

* *Eſſai ſur le Feu*, chap. i.

† *Journ. de Phyſ.* April 1791.

‡ Geneva, 1792.

§ *Phil. Tranſ.* 1802.

* *Phil. Tranſ.* 1802, p. 444.

ber of degrees, are not in proportion to the quantity of matter in each, but in proportions widely different to this, and for which no general principle or reaſon can yet be aſſigned *." This difference was firſt pointed out by Dr Black, which he ſtates in the above obſervations, and he diſtinguiſhed it by the term *capacity of bodies for heat.* Dr Black's method, which is given by Profeſſor Robiſon, is the following.

* *Black's Lect.* v. i. p. 79.

261 Dr Black's method.

"Dr Black eſtimated the capacities, by mixing the two bodies in equal maſſes, but of different temperatures; and then ſtated *their capacities as inverſely proportional to the changes of temperature of each by the mixture.* Thus, a pound of gold, of the temperature 150°, being ſuddenly mixed with a pound of water, of the temperature 50°, raiſes it to 55° nearly: Therefore the capacity of gold is to that of an equal weight of water as 5 to 95, or as 1 to 19; for the gold loſes 95°, and the water gains 5°.

"It will be moſt convenient to compare all bodies with water, and to expreſs the capacity of water by unity, or to call it 1. Let the quantity of the water be W, and its temperature w. Let the quantity of the other body be B, and its temperature b. Let the temperature of the mixture be m. The capacity of B is $\frac{W \times \overline{m - w}}{B \times \overline{b - m}}$, or, when the water has been the hotter of the two, the capacity of B is $\frac{W \times \overline{w - m}}{B \times \overline{m - b}}$. In other words, *multiply the weight of the water by its change of temperature. Do the ſame for the other ſubſtance. Divide the firſt product by the ſecond. The quotient is the capacity of the other ſubſtance, that of water being accounted* 1 † (P)."

† *Lect.* v. i. p. 506.

4. This ſubject was ſtill farther proſecuted by other philoſophers, particularly by Dr Irvine of Glaſgow, Dr Crawford of London, and Profeſſor Wilcke of Stockholm.

262 Dr Crawford's

The method which was employed by Dr Crawford was ſimilar to that of Dr Black. Two ſubſtances which were of different temperatures, were uniformly mixed; the change of temperature produced on each was obſerved, and this was conſidered as inverſely proportional to its ſpecific caloric.

263 Mr Wilcke's

Mr Wilcke has aſcertained the ſpecific caloric of many metals, by a ſet of very ingenious experiments, which were conducted in the following manner. The metal which was the ſubject of the experiment, was firſt accurately weighed. The quantity employed was generally a pound. It was then ſuſpended by a thread, plunged into a veſſel of tin plate filled with boiling water, and allowed to remain till it reached a certain temperature indicated by the thermometer. A quantity of water at the temperature of 32°, exactly equal in weight to the metal, was put into another veſſel of tin plate. The metal was then immerſed in this veſſel, and ſuſpended in it ſo as to be kept free from the ſides and bottom. The temperature, at the moment when the metal and water were reduced to the ſame, was obſerved. The ſpecific caloric of the metal was then deduced by calculation from the change of temperature. He firſt calculated what the temperature would have been, if a quantity of water of equal weight with the metal, and of the ſame temperature, had been added to the ice-cold water. The following is the proceſs.

Let M be a quantity of water at the temperature C, m another quantity at the temperature c, and let their common temperature after mixture be x; according to a rule demonſtrated long ago by Richman, $x = \frac{MC + mc}{M + m}$. In the preſent caſe the quantities of water are equal, therefore M and m are each $= 1$; C, the temperature of the ice-cold water, $= 32$: therefore $\frac{MC + mc}{M + m} = \frac{32 + c}{2}$. Now c is the temperature of the metal. Therefore if 32 be added to the temperature of the metal, and the whole be divided by 2, the quotient will expreſs the temperature of the mixture, if an equal weight of water with the metal, and of the ſame temperature with it, had been added to the ice-cold water inſtead of the metal.

He then calculated what the temperature of the mixture would have been, if, inſtead of the metal, a quantity of water of the ſame temperature with it, and equal to the metal in bulk, had been added to the ice-cold water. As the weights of the ice-cold water and the metal are equal, their volumes are inverſely as their ſpecific gravities. Therefore the volume of ice-cold water is to a quantity of hot water equal in volume to the metal, as the ſpecific gravity of the metal to that of the water. Let M $=$ volume of cold water, $m =$ volume of hot water, $g =$ ſpecific gravity of the metal, $1 =$ ſpecific gravity of water; then $m : M :: 1 : g$; hence $m = \frac{M}{g} =$ (M being made $= 1$) $\frac{1}{g}$.

(P) "Theſe experiments require the moſt ſcrupulous attention to many circumſtances which may affect the reſult. 1. The mixture muſt be made in a very extended ſurface, that it may quickly attain the medium temperature. 2. The ſtuff which is poured into the other ſhould have the temperature of the room, that no change may happen in the pouring it out of its containing veſſel. 3. The effect of the veſſel in which the mixture is made muſt be conſidered. 4. Leſs chance of error will be incurred when the ſubſtances are of equal bulk. 5. The change of temperature of the mixture, during a few ſucceſſive moments, muſt be obſerved, in order to obtain the real temperature at the beginning. 6. No ſubſtances ſhould be mixed which produce any change of temperature by their chemical action, or which change their temperature, if mixed when of the ſame temperature. 7. Each ſubſtance muſt be compared in a variety of temperatures, leſt the ratio of the capacities ſhould be different in different temperatures.

"When all theſe circumſtances have been duly attended to, we obtain the meaſure of the *capacities* of different ſubſtances for heat." *Black's Lect.* v. i. p. 506.

$\frac{1}{g}$. Subſtituting this value of m in the formula, $\frac{MC+mc}{M+m}=x$, in which $M=1$ and $C=32$, x will be $=\frac{32g+c}{g+1}$. Therefore if the ſpecific gravity of the metal be multiplied by 32, and the temperature of the metal be added, and the ſum be divided by the ſpecific gravity of the metal +1, the quotient will expreſs the temperature to which the ice-cold water would be raiſed by adding to it a volume of water equal to that of the metal, and of the ſame temperature with it.

He then calculated how much water at the temperature of the metal it would take to raiſe the ice-cold water the ſame number of degrees which the metal had raiſed it. Let the temperature to which the metal had raiſed the ice-cold water be $=N$, if in the formula $\frac{MC+mc}{M+m}=x$, x be made $=N$, $M=1$, $C=32$, m will be $=\frac{N-32}{c-N}$. Therefore if from the temperature to which the ice-cold water was raiſed by the metal 32 be ſubtracted, and if from the temperature of the metal be ſubtracted the temperature to which it raiſed the water, and the firſt remainder be divided by the laſt, the quotient will expreſs the quantity of water of the temperature of the metal which would have raiſed the ice-cold water the ſame number of degrees that the metal did.

Now $\frac{N-32}{c-N}$ expreſſes the ſpecific caloric of the metal, that of water being $=1$. For (neglecting the ſmall difference occaſioned by the difference of temperature) the weight and volume of the ice-cold water are to the weight and volume of the hot water as 1 to $\frac{N-32}{c-N}$, and the number of particles of water in each are in the ſame proportion. But the metal is equal in weight to the ice-cold water, it muſt therefore contain as many particles of matter; therefore the quantity of matter in the metal muſt be to that in the hot water as 1 to $\frac{N-32}{c-N}$. But they gave out the ſame quantity of caloric; which, being divided equally among their particles, gives to each particle a quantity of caloric inverſely as the bulks of the metal and water; that is, the ſpecific caloric of the water is to that of the metal as 1 to $\frac{N-32}{c-N}$ (R).

It will now be proper to give a ſpecimen or two of his experiments, and the calculations founded on them, as above deſcribed.

GOLD. *Specific Gravity* 19.040.

Number of experiments.	Temperature of the metal.	Temper. to which the metal raiſed the water at 32°.	Temper. to which it would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temper. to which it would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{N-32}{c-N}=\frac{1}{\frac{c-N}{N-32}}$, the numerator being 1.
1	163.4°	38.3°	97.7°	38.555°	19.857
2	144.5	37.4	88.25	37.58	19.833
3	127.4	36.5	79.7	36.68	20.500
4	118.4	36.05	75.2	36.15	20.333
5	103.1	35.6	65.75	35.42	18.750
6	95	34.45	63.5	35.06	19.000

Mean 19.712

LEAD.

(R) All theſe formulas have been altered to make them correſpond with Fahrenheit's thermometer. They are a good deal ſimpler when the experiments are made with Celſius's thermometer, as Mr Wilcke did. In it the freezing point is zero; and conſequently inſtead of 32 in the formula, 0 is always ſubſtituted.

LEAD. *Specific Gravity* 11.456.

Number of experiments.	Temperature of the metal.	Temper. to which the metal raiſed the water at 32°.	Temper. to which the water would have been raiſed by a quantity of water equal in weight and heat to the metal.	Temper to which the water would have been raiſed by water equal in bulk and temperature to the metal.	Denominator of the fraction. $\frac{1}{\frac{c-N}{N-32}}$
1	186.8	38.3	109.4	44.425	23.571
2	181.40	37.85	106.7	43.473	24.538
3	165.2	37.4	98.6	42.692	23.666
4	163.4	37.4	97.7	42.548	23.333
5	136.4	36.5	84.2	40.344	22.200
6	131	36.05	81.5	39.947	24.700
7	126.5	36.05	79.25	39.585	22.333
8	107.6	35.15	69.8	38.339	23.000
9	94.1	34.7	63.05	36.985	22.000

Mean 23.515

It is needleſs to add, that the laſt column marks the denominator of the ſpecific caloric of the metal; the numerator being always 1, and the ſpecific caloric of water being 1. Thus the ſpecific caloric of gold is $\frac{1}{19.712}$. In exactly the ſame manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke aſcertain the ſpecific caloric of a number of other bodies.*

* *Thomſon's Chemiſtry,* v. i. 314.

5. With the ſame view, to aſcertain the ſpecific caloric of bodies, a ſimple and ingenious apparatus was contrived by Lavoiſier and La Place. This inſtrument is called a *calorimeter*, or meaſurer of heat. Its principles and conſtruction are the following:

264 Lavoiſier's method.

"If, after having cooled, ſays Lavoiſier, any body to the freezing point, it be expoſed in an atmoſphere of 88.25° the body will gradually become heated, from the ſurface inwards, till at laſt it acquire the ſame temperature with the ſurrounding air. But, if a piece of ice be placed in the ſame ſituation, the circumſtances are quite different; it does not approach in the ſmalleſt degree towards the temperature of the circumambient air, but remains conſtantly at 32°, or the temperature of melting ice, till the laſt portion of ice be completely melted.

"This phenomenon is readily explained; as, to melt ice, or reduce it to water, it requires to be combined with a certain portion of caloric, the whole caloric attracted from the ſurrounding bodies, is arreſted or fixed at the ſurface or external layer of ice which it is employed to diſſolve, and combines with it to form water; the next quantity of caloric combines with the ſecond layer to diſſolve it into water, and ſo on ſucceſſively till the whole ice be diſſolved, or converted into water, by combination with caloric; the very laſt atom ſtill remaining at its former temperature, becauſe the caloric could never penetrate ſo far, while any intermediate ice remained to melt, or to combine with.

"Upon theſe principles, if we conceive a hollow ſphere of ice at the temperature of 32° placed in an atmoſphere of 54.5°, and containing a ſubſtance at any degree of temperature above freezing; it follows, That the heat of the external atmoſphere cannot penetrate into the internal hollow of the ſphere of ice; and, That the heat of the body which is placed in the hollow of the ſphere cannot penetrate outwards beyond it, but will be ſtopped at the internal ſurface, being continually employed to melt ſucceſſive layers of ice, until the temperature of the body be reduced to 32° by having all its ſuperabundant caloric above that temperature carried off to melt the ice. If the whole water, formed within the ſphere of ice during the reduction of the temperature of the included body to 32°, be carefully collected, the weight of the water will be exactly proportional to the quantity of caloric loſt by the body, in paſſing from its original temperature to that of melting ice; for it is evident that a double quantity of caloric would have melted twice the quantity of ice. Hence the quantity of ice melted is a very exact meaſure of the proportional quantity of caloric employed to produce that effect, and conſequently of the quantity loſt by the only ſubſtance that could poſſibly have ſupplied it.

"I have made this ſuppoſition, of what would take place in a hollow ſphere of ice, for the purpoſe of more readily explaining the method uſed in this ſpecies of experiment, which was firſt conceived by M. de la

Place. It would be difficult to procure ſuch ſpheres of ice, and inconvenient to make uſe of them when got; but, by means of the following apparatus, we have remedied that defect.

"The calorimeter is repreſented in Plate CXLII. fig. 2. The capacity or cavity is divided into three parts, which, for better diſtinction, I ſhall name the interior, middle, and external cavities. 265 Apparatus deſcribed. The interior cavity *f f f f*, into which the ſubſtances ſubmitted to experiment are put, is compoſed of a grating or cage of iron wire, ſupported by ſeveral iron bars; its opening or mouth LM, is covered by the lid HG, fig. 3. which is compoſed of the ſame materials. The middle cavity *b b b b*, fig. 2. contains the ice which ſurrounds the interior cavity, and which is intended to be melted by the caloric of the ſubſtances employed in the experiment. The ice is ſupported by the grate *m m* at the bottom of the cavity, under which is placed the ſieve *n n*.

"In proportion as the ice contained in the middle cavity is melted, by the caloric diſengaged from the body placed in the interior cavity, the water runs through the grate and ſieve, and falls through the conical funnel *c c d*, fig. 2. and the tube *x y*, into a receiver. This water may be retained or let out at pleaſure, by means of the ſtop-cock *u*. The external cavity *a a a a*, fig. 2. is filled with ice, to prevent any effect upon the ice in the middle cavity from the heat of the ſurrounding air, and the water produced from it is carried off through the pipe ST, which ſhuts by means of the ſtop-cock *r*. The whole machine is covered by a lid made of tin, and painted with oil colour, to prevent ruſt.

"When this machine is employed. the middle cavity *b b b b*, fig. 2. and the lid GH, fig. 3. of the interior cavity, the external cavity *a a a a*, fig. 2. and the lid which covers the whole, are all filled with pounded ice, well rammed, ſo that no void ſpaces remain, and the ice of the middle cavity is allowed to drain. The machine is then opened, and the ſubſtance ſubmitted to experiment being placed in the interior cavity, it is inſtantly cloſed. After waiting till the included body is completely cooled to the freezing point, and the whole melted ice has drained from the middle cavity, the water collected in the receiver is accurately weighed. The weight of the water produced during the experiment is an exact meaſure of the caloric diſengaged during the cooling of the included body, as this ſubſtance is evidently in a ſimilar ſituation with the one formerly mentioned as included in a hollow ſphere of ice. The whole caloric diſengaged from the included body is ſtopped by the ice in the middle cavity, and that ice is preſerved from being affected by any other heat by means of the ice contained in the cover and in the external cavity. Experiments of this kind generally laſt from 15 to 20 hours, but they are ſometimes accelerated by covering up the ſubſtance in the interior cavity with well drained ice, which haſtens its cooling.

"It is abſolutely requiſite that there be no communication between the external and middle cavities of the calorimeter, otherwiſe the ice melted by the influence of the ſurrounding air, in the external cavity, would mix with the water produced from the ice of the middle cavity, which would no longer be a meaſure of the caloric loſt by the ſubſtance ſubmitted to experiment.

"When the temperature of the atmoſphere is only a few degrees above the freezing point, its heat can hardly reach the middle cavity, being arreſted by the ice of the cover, and of the external cavity; but, if the temperature of the air be under the degree of freezing, it might cool the ice contained in the middle cavity, by cauſing the ice in the external cavity to fall, in the firſt place, below 32°. It is therefore eſſential that this experiment be carried on in a temperature ſomewhat above freezing: Hence, in time of froſt, the calorimeter muſt be kept in an apartment carefully heated. It is likewiſe neceſſary that the ice employed be not under 32°, for which purpoſe it muſt be pounded, and ſpread out thin for ſome time, in a place where the temperature is higher. *Elem. of Chem.*

6. Tables of the ſpecific caloric of bodies have been given by Dr Crawford, Mr Kirwan, Bergman, Gadolin, and Meyer. The following are the reſults of their inveſtigations.

Table of the Specific Caloric of various Bodies, that of Water being = 1.0000.

Bodies.	Specific Gravity.	Specific Caloric.
I. Gases.		
Hydrogen gas -	0.000094	21.4000
Oxygen gas -	0.0034	4.7490
Common air -	0.00122	1.7900
Carbonic acid gas -	0.00183	1.0459
Steam - - -		1.5500
Azotic gas -	0.00120	0.7036
II. Liquids.		
Water - -	1.0000	1.0000
Carbonate of ammonia		1.851
Arterial blood -		1.030
Cows milk -	1.0324	0.9999
Sulphuret of ammonia	0.818	0.9940
Venous blood -		0.8928
Solution of brown ſugar		0.8600
Nitric acid -		0.844
Sulphate of magneſia 1 Water - 8		0.844
Common ſalt 1 Water - 8 -		0.832
Nitre 1 Water 8 -		0.8167
Muriate of ammonia 1 Water - -		0.779
Tartar 1 Water 237.3 -		0.765
Solution of potaſs -	1.346	0.759
Sulphate of iron 1 Water - 2.5 -		0.734
Sulphate of ſoda 1 Water 2.9 -		0.728
Oil of olives -	0.9153	0.710
Ammonia - -	0.997	0.7080

TABLE *Contiuued.*

Bodies.	Specific Gravity.	Specific Caloric.
Muriatic acid	1.122	0.6800
Sulphuric acid 4 Water 5		0.6631
Alum 1 Water 4.45		0.649
Nitric acid $9\frac{1}{3}$ Lime 1		0.6181
Nitre 1 Water 3		0.646
Alcohol	0.8371	0.6021
Sulphuric acid	1.840	0.5968
Nitrous acid	1.355	0.576
Linſeed oil	0.9403	0.528
Spermaceti oil		0.5000
Oil of turpentine	0.9910	0.472
Vinegar		0.3870
Lime 9 Water 16		0.3346
Mercury	13.568	0.3100
Diſtilled vinegar		0.1030
III. SOLIDS.		
Ice		0.9000
Ox-hide with the hair		0.787
Lungs of a ſheep		0.769
Lean of ox-beef		0.7400
Pine	0.408	0.65
Fir	0.447	0.60
Lime	0.408	0.62
Pitch-pine	0.495	0.58
Apple tree	0.639	0.57
Alder	0.484	0.53
Oak	0.531	0.51
Aſh	0.631	0.51
Crab-apple	0.603	0.50
Rice		0.5050
Horſe beans		0.5020
Duſt of the pine tree		0.5000
Peaſe		0.4920
Beech	0.692	0.49
Hornbeam	0.690	0.48
Birch	0.608	0.48
Wheat		0.4770
Elm	0.646	0.47
Female oak	0.668	0.45
Plum tree	0.687	0.44
Ebony	1.054	0.43
Barley		0.4210
Oats		0.4160
Pitcoal		0.2777
Charcoal		0.2631
Chalk		0.2564
Ruſt of iron		0.2500
White oxide of antimony waſhed		0.2270
Oxide of copper nearly freed from air		0.2272
Quicklime		0.2199

TABLE *continued.*

Bodies.	Specific. Gravity.	Specific Caloric.
Stoneware		0.195
Agate	2.648	0.195
Cryſtal	3.189?	0.1929
Cinders		0.1923
Swediſh glaſs	2.386	0.187
Aſhes of cinders		0.1885
Sulphur	1.99	0.183
Flint glaſs	3.3293	0.174
Ruſt of iron nearly freed from air		0.1666
White oxide of antimony ditto		0.1666
Aſhes of the elm		0.1402
Oxide of zinc nearly free from air		0.1369
Iron	7.876	0.1264
Braſs	8.358	0.1141
Copper	8.784	0.1121
Sheet iron		0.1099
Oxide of lead and tin		0.102
Gun-metal		0.1100
White oxide of tin nearly free from air		0.0990
Zinc	7.154	0.0981
Aſhes of charcoal		0.0909
Silver	10.001	0.082
Yellow oxide of lead nearly freed from air		0.0680
Tin	7.380	0.0661
Antimony	6.107	0.0637
Gold	19.040	0.050
Lead	11.456	0.0424
Biſmuth	9.861	0.043

2. Of the ABSOLUTE QUANTITY of CALORIC.

1. Such then are the different methods which have been propoſed, to aſcertain the relative quantities of caloric which are neceſſary to reduce bodies to the ſame temperature. Attempts have alſo been made to diſcover the temperature of abſolute privation, and thus to aſcertain the whole quantity of caloric which a body contains.

266 Dr Irvine's method.

The firſt attempt made with this view, was by the late Dr Irvine of Glaſgow. The theorem which he invented to aſcertain the real zero, or the abſolute quantity of caloric which a body contains, is founded on the uniformity of the ſpecific caloric of bodies at all temperatures. And taking it for granted that the ſpecific caloric of bodies is always the ſame whatever be the temperature, the whole quantity, or the abſolute quantity, will be proportional to the ſpecific caloric. Having diſcovered the ratio between the abſolute calorics of bodies, and the difference between two abſolute calorics, the whole quantity in any body might be found by calculation. But either the data on which the theorem proceeds are wrong, or the experiments which have been made with the view of applying it to the

267 founded on the uniformity of ſpecific caloric.

268 Reſults very different.

the eſtimation of the abſolute quantity of caloric have been very inaccurately conducted, the reſults varying ſo much from each other. According to Dr Irvine's own experiments and calculation, the real zero with regard to ice would be 1228° below 0°; but according to Dr Crawford's it is 1500°, Mr Kirwan makes it 1318° below 0° in a compariſon of the ſpecific caloric of water and ice. Lavoiſier and La Place fix it at 3426° below 0°, from the reſult of experiments on a mixture of water and quicklime. But in other experiments by the ſame philoſophers, there is a great variation in the reſult. Four parts of ſulphuric acid, and three parts of water mixed together, give a reſult for the real zero equal to 7260° below 0°; and four parts of ſulphuric acid, and five of water, give it only equal to 2598° below 0°. Profeſſor Robiſon, ſpeaking of the ſpecific and abſolute quantities of heat in bodies being ſuppoſed to be proportional, obſerves that "this opinion is juſt, only on the ſuppoſition that the meaſures, obtained by experiments and calculation, are conſtantly the ſame, whatever the temperatures may be in which the experiments are made. Dr Irvine's ingenious method of diſcovering the temperature of abſolute privation, evidently preſuppoſes this conſtancy of ſpecific heat; or, if they are not conſtant, it ſuppoſes that we know the whole law of variation. Now both of theſe aſſumptions are highly improbable. In none of the progreſſions of natural operations that we are acquainted with do we find this conſtancy. It is much more analogous to other phenomena, to ſuppoſe that, in the temperatures near to that of abſolute privation, the quantities of heat neceſſary for producing equal elevation gradually diminiſh, and this, perhaps, without end, like the diſtance of the hyperbola from its aſſymptote. It is equally probable that the law of diminution may be different in different ſubſtances. This will cauſe the meaſures of ſpecific heats to change their proportions continually; and therefore the ſpecific capacities obſerved in temperatures, all of which are far removed from that of the entire abſence of heat, give us no means of obtaining the proportions of the accumulated ſum of all the heats which have been received into the ſubſtances. It follows from this, that even although it ſhould be granted to Dr Irvine, that the heat which emerges, in mixing vitriolic acid and water, or in the freezing of water, is the difference between the abſolute heat of the mixture, or the ice, and the abſolute heats of the ſubſtances before mixture, or of the water before freezing, ſtill we cannot aſcertain thoſe abſolute heats, or the temperature of no heat.

Accordingly, it appears that it has been only in a very few caſes that Dr Irvine found a tolerable coincidence of his determination of this extreme cold; and the determination by means of mixtures differed enormouſly from thoſe obtained by means of congelation; and ſtill more from thoſe obtained by means of the condenſation of vapour *."

269 Mr Dalton's method.

2. Mr Dalton has propoſed another hypotheſis for determining the real zero, or the abſolute quantity of caloric in bodies. He obſerves that the remarkable fact of the quantity of expanſion of elaſtic fluids being the ſame in the ſame circumſtances, ſhews, that it depends ſolely upon heat: "whereas the expanſion in ſolid and liquid bodies ſeems to depend upon an adjuſtment of the two oppoſite forces of heat and chemical affinity, the one a *conſtant* force in the ſame temperature, the other a *variable* one, according to the nature of the body; hence the unequal expanſion of ſuch bodies. It ſeems therefore that general laws reſpecting the abſolute quantity and the nature of heat, are more likely to be derived from elaſtic fluids than from other ſubſtances.

In order to explain the manner in which elaſtic fluids expand by heat, let us aſſume an hypotheſis that the repulſive force of each particle is exactly proportional to the whole quantity of heat combined with it, or in other words to its temperature reckoned from the point of total privation: then, ſince the diameter of each particle's ſphere of influence is as the cube root of the ſpace occupied by the maſs, we ſhall have $\sqrt[3]{1000} : \sqrt[3]{1325}$ (10 : 11, nearly) : : the abſolute quantity of heat in air of 55°: the abſolute quantity in air of 212°. This gives the point of total privation of heat, or abſolute cold, at 1547° below the point at which water freezes. Dr Crawford deduces the ſaid point by a method wholly different to be 1532°. So near a coincidence is certainly more than fortuitous.

The only objection I ſee to this hypotheſis is, that it neceſſarily requires the augmentation of elaſtic fluids for a given quantity of heat to be greater in the higher temperatures than in the lower, becauſe the cubes of a ſeries of numbers in arithmetical progreſſion differ more the larger the numbers or roots: but it has juſt been ſhewn that in fact an augmentation of a contrary kind is obſerved. This refers us to the conſideration whether the mercurial thermometer is an accurate meaſure of the increments of heat; if it be, the hypotheſis fails; but if equal increments of heat cauſe a greater expanſion in mercury in the higher than in the lower temperatures, and that in a ſmall degree, the fact noticed above, inſtead of being an objection, will corroborate the hypotheſis. Dr Crawford determines the expanſions of mercury to be very nearly in proportion to the increments of heat: M. De Luc makes them to be leſs for a given quantity of heat in the lower than in the higher part of the ſcale; and in a ratio that agrees with this hypotheſis. Now as every other liquid we are acquainted with is found to expand more in the higher than in the lower temperatures; analogy is in favour of the concluſions of De Luc, that mercury does the ſame." *Manch. Mem.* v. 602.

The different methods which have been propoſed by philoſophers to determine the real zero, or the abſolute quantity of caloric in bodies, and the want of coincidence between the reſults of the experiments and calculations, founded on theſe methods, ſhew us at leaſt, that the ſubject is attended with great difficulty and uncertainty. Perhaps the preſent ſtate of our knowledge does not furniſh us with the means of removing the difficulty. Some fortunate diſcovery is ſtill needed, to guide our ſteps in the ſolution of this problem.

270 Cold.

3. Having thus conſidered the relative and abſolute quantities of caloric in bodies, and the methods which have been propoſed for aſcertaining theſe quantities, it may be neceſſary to ſtate in what ſenſe, or with what limitations, the term *cold* is to be employed. When we leave a room at the temperature of 60°, and go into the air in a froſty day at the temperature of 32°,

---

* *Black's Lect.* v. i. p. 508.

32°, we ſay that it is cold; or when the hand is held in water at the temperature of 100° for a few minutes, and then ſuddenly plunged into water at the temperature of 40°, the latter is ſaid to be cold. This, however, is merely an expreſſion of the ſenſation excited in the body, which depends ſolely on the abſtraction of its heat. This may be proved by the following experiment. If three quantities of water are taken, the firſt at the temperature of 32°, the ſecond at the temperature of 50°, and the third at the temperature of 100°. Immerſe the right hand into the water at the temperature of 100°, and the left into the water at the temperature of 32°. Let them remain for a minute, and then ſuddenly plunge both hands into the water at the intermediate temperature of 50°; the right hand will feel cold, and the left hand warm; and thus different ſenſations are produced by the ſame body at the ſame time and at the ſame temperature. But this depends entirely on the previous ſtate of the hands, and on the abſorption or abſtraction of caloric; and this ſeeming paradox is eaſily explained by what has been ſaid on the equal diſtribution of caloric. The right hand which was placed in the water at the temperature of 100° abſorbed caloric, becauſe the temperature of the water is above that of the body. This excites the ſenſation of heat; but when the ſame hand is placed in the water at the temperature of 50° it is deprived of caloric, becauſe the ſurrounding medium is far below its temperature; and thus the ſenſation of cold is produced. But from the left hand, placed in the water at 32° caloric is abſtracted, which gives the ſenſation of cold, and the ſame hand placed in the water at 50° receives caloric, and this entering the body, excites the ſenſation of heat.

Thus then, the term *cold* is merely expreſſive of the relative temperature of two bodies. In common language, the word *cold* is ſufficiently intelligible, but in the preſent view of the doctrine of caloric, it can have no other preciſe meaning, than to expreſs the abſence of a quantity of heat.

271
Frigorific particles.

Obſerving the remarkable effects which were produced on fluids by the abſtraction of caloric, it is not at all ſurpriſing that the phenomena which were not obſerved with great accuracy, ſhould be aſcribed rather to the addition of ſome new body, than to the abſtraction of one which was formerly in combination. Hence originated the hypotheſis which ſuppoſed the exiſtence of the frigorific particles of De Mairan and Muſchenbroeck, which prevailed till the effects of caloric were developed by the diſcoveries of modern chemiſtry. They were led to this hypotheſis of the entrance of extraneous matter into water when it is converted from the fluid into the ſolid ſtate, from obſerving the increaſe of bulk which takes place. Theſe frigorific particles, to which all the effects of cold were aſcribed, it was imagined, had ſome reſemblance to nitre. This opinion probably aroſe from the circumſtance of a great degree of cold, or diminution of temperature, being produced by diſſolving nitre in water. The frigorific particles were ſuppoſed to be conſtantly floating in the air, and by mixing with liquid bodies, as water, converted them into ſolids, by acting the part of wedges, which prevented the free motion of the particles among each other.

272
Cold ſeems to be reflected.

The experiments of Profeſſor Pictet, in which cold ſeems to be reflected, ſtill give ſome ſupport to this opinion. Two concave mirrors of tin were placed at the diſtance of 10½ feet from each other; a glaſs veſſel full of ſnow was placed in the focus of the one, and an air thermometer in that of the other. The thermometer ſunk ſeveral degrees, but when the ſnow was removed, it roſe again; and when a greater degree of cold was produced on the ſnow, by pouring an acid upon it which diſſolved it rapidly, the thermometer fell ſeveral degrees lower. At firſt ſight it appears, that cold has been given out by the ſnow, and this cold reflected by the mirrors occaſioned the fall of the thermometer. The explanation of this fact is not without difficulty. As the rays of caloric are emitted by all ſurrounding bodies, the temperature of the thermometer is probably kept up by ſome of theſe rays.

273
Accounted for.

Suppoſe when the thermometer is placed in the focus of one of the mirrors, that it ſtands at the ſame temperature that it would do when brought into contact with any other of the ſurrounding bodies; and that this temperature is partly owing to the rays of caloric which are paſſing off from theſe bodies: if then there is any interruption of theſe rays, the temperature of that body, as the thermometer, muſt be diminiſhed. This is probably what takes place when the temperature of the thermometer in the focus of one of the mirrors falls, by placing a cold body in the focus of the other. To make this a little plainer, ſuppoſe the temperature of the thermometer is kept up by 100 rays of caloric; when a cold body is placed in a proper ſituation, as in the focus of the oppoſite mirror; if any number of theſe rays be abſorbed by the cold body, it muſt conſequently fall in temperature.

But although the explanation be not altogether ſatisfactory, it affords no proof of the exiſtence of frigorific particles. Were we even to admit this hypotheſis, it would not probably aſſiſt us much in the explanation.

274
To produce great cold.

4. Great degrees of cold are produced, by mixing together thoſe ſubſtances which diſſolve rapidly. The reaſon of this will appear by recollecting what has been ſaid of the abſorption of caloric when a ſolid body is converted into a fluid. Mixtures to produce artificial cold, are generally made of the neutral ſalts diſſolved in water; of diluted acids and ſome of the neutral ſalts, and of ſnow or pounded ice with ſome of theſe ſalts. A great number of experiments were made upon this ſubject by Mr Walker[*]; alſo by Profeſſor Lowitz of Peterſburgh[†]; by Fourcroy and Vauquelin[‡]; and by Guyton[§]. The following table exhibits the reſults of theſe experiments.

TABLE of Freezing Mixtures.

	Mixtures.	Parts.	Thermometer ſinks.
1.	Muriate of ammonia	5	From 50° to 10°
	Nitre	5	
	Water	16	
2.	Muriate of ammonia	5	From 50° to 4°
	Nitre	5	
	Sulphate of ſoda	8	
	Water	16	

---

[*] *Phil. Tranſ.* 1795, p. 270 1801, p. 120

[†] *Ann. de Chim.* vol. xxvi. p. 297.

[‡] *Ibid.* vol. xxix. p. 281.

[§] *Ibid.* 290.

Table of Freezing Mixtures continued.

	Mixtures.	Parts.	Thermometer ſinks.
3.	Nitrate of ammonia Water	1 1	From 50° to 4°
4.	Nitrate of ammonia Carbonate of ſoda Water	1 1 1	From 50° to 7°
5.	Sulphate of ſoda Diluted nitric acid	3 2	From 50 to 3°
6.	Sulphate of ſoda Muriate of ammonia Nitre Diluted nitric acid	6 4 2 4	From 50° to 10°
7.	Sulphate of ſoda Nitrate of ammonia Diluted nitric acid	6 5 4	From 50° to 14°
8.	Phoſphate of ſoda Diluted nitric acid	9 4	From 50° to 12°
9.	Phoſphate of ſoda, Nitrate of ammonia Diluted nitric acid	9 6 4	From 50° to 21°
10.	Sulphate of ſoda Muriatic acid	8 5	From 50° to 0°
11.	Sulphate of ſoda Diluted ſulphuric acid	5 4	From 50° to 3°
12.	Snow Common ſalt	1 1	From 32° to 0°
13.	Snow or pounded ice Common ſalt	2 1	From 0° to —5°
14.	Snow or pounded ice Common ſalt Muriate of ammonia and nitre	1 5 5	From —5° to —18°
15.	Snow or pounded ice Common ſalt Nitrate of ammonia	12 5 5	From —18° to —25°
16.	Snow and diluted nitric acid.		From 0° to —46°
17.	Potaſh Snow	4 3	From 32° to —51°
18.	Snow Diluted ſulphuric acid Diluted nitric acid	2 1 1	From —10° to —56°
19.	Snow Diluted ſulphuric acid	1 1	From 20° to —60°
20.	Muriate of lime Snow	3 2	From 32° to —50°
21.	Muriate of lime Snow	2 1	From 0° to —66°
22.	Muriate of lime Snow	3 1	From —40° to —73°
23.	Diluted ſulphuric acid Snow	10 8	From —68° to —91°

275 How to uſe the freezing mixtures.

When any of theſe ſubſtances are to be employed as freezing mixtures, the ſalts ſhould be uſed freſh cryſtallized, and reduced to fine powder; and it will perhaps be found moſt convenient to obſerve the proportions which are ſet down in the table. Suppoſe it is wanted to produce a degree of artificial cold equal to —50°, which is the temperature produced from 32° by the 20th freezing mixture. The ſubſtances employed, namely, the muriate of lime and the ſnow, muſt be previouſly cooled down to the temperature of 32°, or any degree below it. This may be done by placing them ſeparately in the 11th freezing mixture, the ſulphate of ſoda and diluted ſulphuric acid, which reduces the temperature from 50° to 3°; or in the 12th freezing mixture of ſnow and common ſalt, which reduces the temperature from 32° to 0. The materials thus cooled down, are then to be mixed together as quickly as poſſible, when, if the experiment ſucceed, the temperature will fall from 32° to —50°, as in the 20th freezing mixture.

276 Veſſels.

The veſſels which are employed for theſe proceſſes ſhould be very thin, and made of the beſt conductors of heat. Veſſels of tin plate anſwer the purpoſe, and when acids are to be uſed, they may be lined with wax, which will ſecure them ſufficiently againſt their action. They ſhould be of no larger dimenſions than juſt to contain the materials.

SECT. VI. *Of the Sources of Caloric.*

We are now to conſider the means by which caloric may be evolved, or rendered ſenſible. This is a ſubject of great importance, both as a curious inveſtigation, and as a uſeful and neceſſary application in chemiſtry and the arts of life. According to the different ſources from which caloric is derived, or the means which are employed for its evolution, theſe may be reckoned five in number; namely, percuſſion, friction, mixture, the ſun, combuſtion: and we ſhall conſider them in the order in which they have been named.

Firſt

Firſt Source of Caloric,

Percuſſion.

277 Flint and ſteel. The production of heat by ſtriking together flint and ſteel, is a well known fact. The ſame thing alſo takes place when many other hard bodies are ſtruck againſt each other. Fires are frequently kindled by making a piece of iron red-hot by percuſſion, which is effected by ſtriking it ſmartly with a hammer. 278 Heat produced owing to condenſation. In moſt of the caſes in which caloric is evolved by percuſſion, this evolution is aſcribed to the condenſation of the particles of the body ſtruck. This has been obſerved to take place, both in elaſtic fluids and liquids.

279 in airs. 1. The ſudden condenſation of air alone, has been found to produce a change of ſeveral degrees in the thermometer. In ſome experiments by Dr Darwin, the condenſed air from an air-gun, thrown on the bulb of a thermometer, uniformly ſunk it about 2°. This ſhews that the condenſed air had given out ſome of its caloric; for during the operation of condenſing it, the apparatus became ſenſibly hot *.

Mr Dalton's experiments on the condenſation and rarefaction of air, ſhew that an increaſe of temperature of 50° is produced, by admitting air into an exhauſted receiver; and when the equilibrium is reſtored to condenſed air, 50° of cold is produced. The ſuddenneſs of the fall and riſe of the thermometer is very remarkable in theſe caſes; and from this circumſtance, Mr Dalton conjectures, that the real change of temperature of the air or medium, was much greater than the thermometer indicated; but that the inequality exiſted only for a few ſeconds †. From theſe experiments, therefore, it appears, that caloric is evolved during the condenſation, and abſorbed during the rarefaction of air.

A conſiderable riſe in temperature takes place, when different gaſes unite together, and are condenſed. Muriatic acid gas and ammoniacal gas, when combined together, form a ſolid ſalt; and during this combination a great quantity of caloric is evolved.

280 in hard bodies. 2. To the ſame cauſe is aſcribed the caloric which is evolved by the percuſſion of hard bodies. This is particularly the caſe with metallic ſubſtances. They acquire a conſiderable increaſe of denſity by hammering; and during this proceſs caloric is evolved. A piece of iron, it has been obſerved, becomes red-hot when it is ſmartly ſtruck with a hammer on an anvil; and it acquires a conſiderable increaſe of denſity. Before hammering the ſpecific gravity of iron is 7.788; after it is hammered it increaſes to 7.840. In ſome other metals the increaſe of denſity is ſtill more remarkable. Before hammering, platina is only 19.5; and after hammering, its ſpecific gravity is increaſed to 23.0. As a proof that the heat is evolved by condenſation, iron, which has been once heated by hammering, cannot be ſubjected to the ſame proceſs till it has been again expoſed to heat. It has become ſo brittle that it flies to pieces under the ſtrokes of the hammer.

281 Difficult to account for incombuſtibles giving out heat when ſtruck. 3. It is perhaps more difficult to account for the caloric and light which are emitted by incombuſtible ſubſtances; as, for inſtance, in the caſe of two quartz ſtones ſtruck againſt each other, which has been already alluded to in treating of light. The particles of theſe bodies which were ſtruck off by percuſſion, are found, on examination, to be in a ſtate of fuſion; and it would appear that this is a caſe in which light and caloric are emitted without oxygen having any ſhare in the action, as is ſuppoſed to happen in all caſes of combuſtion.

In ſome obſervations on the appearances produced by the colliſion of ſteel with hard bodies, made by Mr Davy, he mentions that Mr Hawkſbee ſhewed *, that no ſparks could be produced *in vacuo;* a faint light was only perceived. Mr Davy thinks that the vivid ſparks obtained from ſteel in the atmoſphere, are owing to the combination of the ſmall abraded and heated metallic particles with oxygen; but it has been doubted, he obſerves, whether the faint luminous appearance, when the experiment is made *in vacuo*, be owing to the light produced by the fracture and abraſion of the particles of the flint, or only partly to this cauſe, and partly to the ignition of the minute filaments ſeparated from the ſteel. When a fine and thin flint, which is eaſily broken, is uſed for the colliſion *in vacuo*, the light is more vivid, than when a thick one is employed. From this he concludes that the particles of ſteel are rendered luminous in conſequence of combuſtion. This opinion was proved by the following experiment.

A thin piece of iron pyrites (ſulphuret of iron) was inſerted in a gun-lock in place of the flint. By colliſion in the atmoſphere it gave vivid ſparks, chiefly white, but ſometimes mixed with a few red ſparks. The ſame experiment was repeated when the apparatus was introduced into the exhauſted receiver of an air-pump; but no light whatever appeared.

282 Suppoſed to be electric. Mr Davy farther obſerves, that bodies which become luminous by being ſtruck or rubbed together *in vacuo*, under water, or in gaſes that do not contain oxygen; ſuch bodies, for inſtance, as fluate and carbonate of lime, ſiliceous ſtones, glaſs, ſugar, and many of the compound ſalts, are both electrics *per ſe* and phoſphoreſcent ſubſtances; ſo that the flaſhes they produce are probably occaſioned, partly by electricity and partly by phoſphoreſcence. In ſome caſes, however, by the colliſion of very hard, ſtony bodies, which are bad conductors of heat, there may be an actual ignition of the particles. This ſeems to be countenanced by various facts. Mr T. Wedgwood found, that a piece of window-glaſs, when brought into contact with a revolving wheel of grit, became red hot at its point of friction, and gave off luminous particles, which were capable of inflaming gunpowder and hydrogen gas †; and we are informed, Mr Davy adds, by a late voyager (s), that the natives of Oonalaſhka light their fires by ſtriking together two pieces of quartz over dry

* *Phil. Tranſ.* 1789, p. 44.

† *Manch. Mem.* vol. v. p. 515.

* *Phil. Tranſ.* vol. xxxiv. p. 2165.

† *Ibid.* 179 p. 45.

(s) Sauer's account of this fact is the following. "I obſerved in all the huts a baſket containing two large pieces of quartz, a large piece of native ſulphur, and ſome dry graſs or moſs. This ſerves them in kindling fires; for which purpoſe they rub the native ſulphur on the ſtones over the dry graſs, ſtrewed lightly with a graſs, their ſurfaces being previouſly rubbed with ſulphur *.

* *Jour. Roy. Inſt.* vol. i. p. 264.

Second Source of Caloric,

Friction.

283 Combuſtible bodies inflamed.

284 Heat by friction not owing to diminiſhed ſpecific caloric

285 proved by Count Rumford.

1. A great quantity of caloric is alſo given out by friction. The intenſity of the heat produced by friction depends on many circumſtances, and varies chiefly in the ratio of the time employed and the nature and ſurface of the bodies which are rubbed together. When the bodies rubbed are combuſtible, as two pieces of dry wood, they may be inflamed; but when they poſſeſs combuſtibility in a low degree, or are altogether incombuſtible, the temperature may be raiſed ſo high as to communicate a degree of heat ſufficient to ſet fire to combuſtible bodies. Greater difficulty ſtill attends the explanation of the phenomena of the evolution of caloric by friction than by the percuſſion of hard, incombuſtible bodies. In this caſe there can be no increaſe of denſity by the friction in many inſtances, for caloric is evolved by rubbing together two pieces of wood, or by rubbing the hand on a piece of ſoft cloth where increaſe of denſity can ſcarcely be ſuppoſed. Nor can the increaſe of temperature by friction be accounted for by the diminution of the ſpecific caloric of the bodies which are rubbed together; for Count Rumford, who made ſome intereſting experiments on this ſubject, could not diſcover any change in this reſpect, and ſuppoſing that this change had taken place, it would not be ſufficiently great to account for all the heat produced. In one of theſe experiments he took a braſs ſix-pounder, caſt ſolid, and rough as it came from the foundery; fixed it horizontally on the machine fixed for boring, and cauſed its extremity to be cut off; and by turning round the metal in that part, a ſolid cylinder was formed $7\frac{3}{4}$ inches in diameter, and $9\frac{8}{10}$ inches long. This when finiſhed remained joined to the reſt of the metal by a ſmall cylindrical neck $2\frac{1}{5}$ inches in diameter, and $2\frac{8}{10}$ inches long. This ſhort cylinder was bored with a horizontal borer uſed in boring cannon. Its bore which was $3\frac{7}{10}$ inches in diameter, inſtead of being continued through its whole length $9\frac{8}{10}$ inches, was only $7\frac{2}{10}$ inches in length. A ſolid bottom of $2\frac{6}{10}$ inches in length was thus left. A blunt ſteel borer was preſſed againſt the bottom of the bore of the cylinder with a force equal to 10,000 lb. avoirdupois; and the cylinder was turned round by horſes at the rate of about 32 times in a minute. To prevent the diſſipation of the heat, the cylinder was covered up with thick flannel. At the beginning of the experiment the temperature of the air and of the cylinder was 60°. At the end of 30′, when it had made 960 revolutions, a mercurial thermometer was introduced into the hole made to receive it in the ſide of the cylinder, and the mercury roſe to 130°. When the borer was removed, and the metallic duſt or ſcales taken out of the bottom of the cylinder, it was found to amount to 837 grs. As the weight of this duſt amounts to no more than $\frac{1}{948}$th part of that of the cylinder, it muſt have given off 948° to raiſe the temperature of the cylinder 1°, and conſequently it muſt have given out 66,360° of heat in the courſe of the experiment.

286 Nor to the air.

2. But to determine whether the air of the atmoſphere had any part or not in the generation of this heat, by one deciſive experiment, he contrived the following, in which it was impoſſible for it to produce any effect whatever. The apparatus was incloſed in a wooden box, which was made water-tight, and being filled with water, completely excluded the external air. The quantity of water employed was 18.77 lb. avoirdupois or $2\frac{1}{4}$ wine gallons, and the temperature at the commencement of the experiment was 60°. The machine was put in motion, and moved at the ſame rate as in the former experiment. At the end of an hour the temperature was 107°; in half an hour more, it roſe to 178°, and at the end of two hours and 30′ from the beginning of the experiment the water actually boiled. By Count Rumford's calculation the caloric generated by friction in this experiment, and accumulated in two hours and 30′, would have heated ice-cold water 180°, or cauſed it to boil. From the reſults of his computation it appears, that the quantity of caloric thus generated equably, was greater than that produced equably in the combuſtion of nine wax-candles, each $\frac{3}{4}$ of an inch in diameter, burning with clear bright flames for the ſame length of time.

287 Count Rumford concludes that heat is motion.

Reflecting on theſe experiments, Count Rumford recurs to the queſtion, What is heat? Is there any ſuch thing as an igneous fluid? And after ſtating that the quantity of caloric thus generated could neither be furniſhed by the particles of the metal, detached from the ſolid maſſes, nor by the air, nor by the water, becauſe it muſt have received its heat from the apparatus, he concludes, that caloric is not a material ſubſtance, but only a peculiar kind of motion produced among the particles of matter †.

† *Phil. Tranſ.* 1798, p. 80.

288 Nor to combination with oxygen.

3. The experiments of Profeſſor Pictet alſo prove, that the caloric generated by friction is not owing to the combination of oxygen with any of the bodies. He contrived an apparatus which could be introduced into the receiver of an air-pump. By means of this apparatus, a piece of adamantine ſpar was rubbed againſt a ſteel cup in the open air. A thermometer which was fixed in the inſide of the cup, did not riſe when the apparatus was ſet in motion, although abundance of ſparks were produced. When the apparatus was placed in an exhauſted receiver, and the experiment repeated, a phoſphoric light, but no ſparks, appeared, nor was the thermometer any way affected; but when a ſmaller braſs cup was employed; and a piece of braſs rubbed againſt it in the open air, the thermometer was not affected till the motion ceaſed, and then it roſe 0.3°. The caloric, it would appear, was carried off as it was generated, by the motion of the air. When the ſame experiment was repeated in

---

few feathers in the top where the ſulphur falls; then they ſtrike the two ſtones one againſt the other; the fine particles of ſulphur immediately blaze like a flaſh of lightning, and communicating with the ſtraw ſet the whole in a flame. *Sauer's Account of Billings' Expedition to the northern parts of Ruſſia*, p. 159.

in vacuo, the thermometer roſe 1.2°, and it began to riſe as ſoon as the friction commenced. When a piece of wood was made to rub on a wooden cup, the thermometer roſe 2.1°, and *in vacuo* 2.4° †.

These experiments, therefore, are ſufficiently concluſive to prove that the caloric evolved by friction is not derived from the atmoſphere; but ſtill the queſtion recurs, What is its origin? No ſatisfactory anſwer can be given to this queſtion, if it cannot be reſolved, as ſome have ſuppoſed, by having recourſe to the agency of electricity; and, conſidering the ſimilarity of the effects of caloric and electricity in heating and cooling bodies, in producing the expanſion and fuſion of metallic ſubſtances, in effecting the actual combuſtion of inflammable matters, and that in other reſpects the one can be ſubſtituted for the other, it is not at all improbable that electric matter, which is generated in great abundance by friction, may be the chief agent in the evolution of caloric by the friction of bodies on each other.

289 Probably owing to electricity.

290 Choice of wood in machines important on account of the friction.

4. In ſome obſervations on ſpontaneous inflammations by Berthollet, he mentions the experiments which were repeated by D. Palcani, for obtaining fire by the friction of two pieces of wood, in which he gave to one of the rubbing pieces the form of a tablet, and to the other that of a ſpindle or cylinder; and as the reſults of ſome of theſe experiments are of importance to ſhew what attention ought to be paid to the choice of wood, in the conſtruction of machines and inſtruments where there is conſiderable friction, we ſhall ſtate the following.

Cylinders.	Tablet.	Duration.	Effect.
Boxwood,	Box,	5′	Senſible heat.
do.	Poplar,	5	do.
do.	Oak,	5	do.
do.	Mulberry,	3	Conſiderable heat and ſmoke,
do.	Laurel,	3	do.
Laurel,	Poplar,	2	do.
do.	Ivy,	2	do.
Ivy,	Box,	3	do.
do.	Walnut,	3	do.
Olive,	Olive,	3	do.
Mulberry,	Laurel,	2	Conſiderable heat, ſmoke, and blackneſs.
Aſh,	Oak,	5	Senſible heat.
do.	Fir,	5	do.
Peartree,	Oak,	5	do.
Cherry,	Elm,	5	do.
Plumtree,	Appletree,	5	do.
Oak,	Fir,	5	do.

When the experiment was changed, and a cylinder of one of the kinds of wood was rubbed between two tablets of the other; as for example, a cylinder of poplar between two tablets of mulberry wood, the increaſe of the rubbed ſurfaces which were in contact with the air, produced a temperature much more conſiderable; and almoſt the whole of the kinds of wood enumerated above, took fire.

The effect of friction alſo varies according as the woods employed of the ſame kind are rubbed in the direction of the fibres, or when the fibres croſs each other. In the firſt caſe the friction and heat generated are much more conſiderable than in the ſecond †.

Third Source of Caloric,

Mixture.

291 Change of temperature by combination.

1. It is one of the characteriſtics of chemical action to produce a change of temperature. This happens in conſequence of the increaſe or diminution of bulk of the bodies which have been the ſubject of combination, or a total change of their ſtate and properties. Thus it has been eſtabliſhed as a general law in chemical ſcience, that all bodies which paſs from the ſolid to the fluid ſtate, abſorb a quantity of caloric: and all bodies which paſs from the fluid to the ſolid ſtate, give out caloric. This law, therefore, will enable us to account for thoſe changes which take place by the mixture of different bodies. In the courſe of the detail of chemical ſcience on which we are about to enter, we ſhall have frequent opportunities of pointing out the effects of this law. At preſent we ſhall only mention a few inſtances in which caloric is evolved by mixture, or chemical action.

292 Gaſeous bodies forming ſolids or liquids.

2. When two ſubſtances in the ſtate of gas enter into union, and form a ſolid or liquid body, caloric is evolved.

a. Ammoniacal gas and muriatic acid gas, when they are mixed together, inſtantly combine, and form a ſolid ſalt, at the ſame time giving out a quantity of caloric.

b. When oxygen gas and nitrous gas are mixed together, they combine and form a liquid, and at the moment of union, give out caloric.

3. When two liquids are mixed together, and if the denſity of the mixture be greater than the mean of the two liquids, caloric is evolved during the combination.

a. When alcohol or ſpirits of wine and water are mixed together, the denſity is greater than the mean of the two liquids; caloric therefore is given out during the mixture.

b. A much greater degree of heat is produced by mixing together ſulphuric acid and water. If four parts of ſulphuric acid be combined with one part of water, the denſity of the mixture is much greater than the medium denſity of the two liquids, and accordingly the quantity of caloric evolved is ſufficient to boil water.

4. A great quantity of caloric is alſo given out when a fluid body combines with a ſolid. We have an inſtance of this in the ſlacking of lime.

a. When water is thrown upon quicklime, it inſtantly diſappears; for part of it combines with the lime, and becomes ſolid; and thus paſſing from the liquid to the ſolid ſtate, it gives out caloric.

b. If a quantity of ſulphuric acid be poured upon quicklime, the caloric evolved is ſufficient to raiſe part of the ſulphuric acid into vapour.

293 Cold produced by water becoming ſuddenly fluid.

5. Were we to reverſe theſe experiments, and ſtate inſtances of caloric being abſorbed during the mixture of bodies, we ſhould obſerve the operation of the ſame law, in the caſe of ſolid bodies becoming fluid, producing a great degree of cold. But it appears that the production of cold by the ſolution of ſalts in water is owing to the water which is in a previous ſtate of

---

† *Eſſai ſur le Feu*, chap. ix.

† *Annal. de Chim.* vol. xlviii. p. 252.

of combination with one of the ſalts; and thus water paſſing from the ſolid to the liquid ſtate, muſt abſorb caloric, and therefore produce cold. The ſalts which are moſt proper for this purpoſe, contain a great proportion of water in their compoſition; for if the ſame ſalts are deprived of water by expoſing them to heat, the ſame effect by no means follows. On the contrary, when they are diſſolved in water in this ſtate, heat is produced, becauſe they combine with a portion of the water for which they have a ſtrong affinity, and this water paſſing from the liquid to the ſolid ſtate, gives out its caloric.

294 Heat evolved in fermentation, &c.

6. A conſiderable quantity of caloric is alſo generated in other mixtures, in which the fermentation and putrefaction of animal and vegetable ſubſtances takes place. During theſe proceſſes the ſubſtances which are held in ſolution enter into new combinations, and their chemical properties are totally changed. While this change is going on, there is a gradual and conſtant evolution of caloric.

It is an artificial heat of this kind, which is generated by animal and vegetable matters, and on account of its uniformity and conſtancy is employed for promoting of vegetation; as when horſe dung and tanner's bark are uſed in making hot beds; or for the hatching of eggs, a practice which has been long in uſe in Egypt.

Fourth Source of Caloric,

The Sun.

1. But the great ſource of light and heat in the planetary ſyſtem is the ſun. When treating of light we mentioned a ſpeculation of philoſophers about the great and conſtant waſte of light, which the ſun, although a body of immenſe magnitude, muſt ſuſtain. But ſince the nature and conſtitution of the ſun were diſcovered by Dr Herſchel, theſe ſpeculations fall to the ground. According to theſe diſcoveries, the ſun is not, as was formerly ſuppoſed, an immenſe globe of fire, in which the materials compoſing it were continually waſting by combuſtion; but a ſolid opaque body, ſimilar to the other planets, and ſurrounded by a very denſe atmoſphere, in which are obſerved two kinds of clouds. The lower region of clouds is ſimilar to thoſe in the atmoſphere of the earth. The uppermoſt region of clouds is luminous, and from this proceed the light and heat which were ſuppoſed to come from the body of the ſun. This luminous region, it appears from Dr Herſchel's obſervations, in conſequence of changes which ſeem to be conſtantly going on in it, exhibits different degrees of ſplendour, diminiſhing greatly the quantity of light and heat which are emitted at other times. To theſe variations he aſcribes the difference of temperature in different ſeaſons, and the conſequent abundance or deficiency of crops.

295 The ſun an opake body.

296 Dark colours abſorb heat.

2. It is a familiar obſervation, that dark-coloured clothes, as black for inſtance, are much warmer than thoſe which are of a lighter colour. The obſervation and the practice founded upon it are correct, although the reaſon is only obvious to the philoſopher. The rays of light, and alſo probably thoſe of caloric, are reflected in greater proportion by white bodies, than by thoſe which are of a deeper colour. The ſun's rays enter the opaque body, and combine with it, and thus increaſe the temperature. Theſe rays are permitted to paſs through tranſparent bodies, which are very little affected by them; but combining with opaque bodies they heat them, and the deeper the colour of the body, the greater is the increaſe of temperature.

297 Hooke and Franklin's experiments.

3. But this has not been left to the uncertainty of common obſervation. Experiments were made by Dr Franklin, and before him by Dr Hooke, to aſcertain this curious point. Pieces of cloth of different colours were placed upon ſnow, and expoſed to the light of the ſun. The colours were white, red, blue, black; and it was found that the darkeſt coloured pieces acquired moſt heat, becauſe they ſunk deepeſt in the ſnow, and this was in proportion to the darkneſs of the colour.

298 Mr Davy's;

Mr Davy made a ſimilar experiment, to determine the correſpondence between the increaſe of repulſive motion in bodies from the action of light and dark colours.

"Six ſimilar pieces of copper, (T) of equal weight, ſize, and denſity, were thus coloured, one white, one yellow, one red, one green, one blue, and one black. A portion of a mixture of oil and wax, which became fluid at about 76°, was placed on the centre of each on the inferior ſide. They were then attached to a board painted white, and ſo placed with regard to the ſun, that their upper ſurfaces were equally expoſed to the light. Their inferior ſurfaces, to which the cerate was attached, were equally deprived of light and heat, that is, they were ſo expoſed, that there could be no miſtake with regard to the repulſive motion generated in them by the action of light. The changes of temperature in them, from the action of light, took place in the following order. The cerate on the black plate began to melt perceptibly before the reſt, the blue next in order, then the green and the red, and laſtly the yellow. The white was ſcarcely at all affected; the black was in a complete ſtate of fuſion *. It appears, therefore, from theſe experiments, that caloric enters bodies in different proportions; and in the greateſt proportion in the darkeſt coloured bodies.

299 Bodies which abſorb moſt light become warmeſt.

It appears too, that thoſe bodies which abſorb moſt light, acquire the greateſt degree of temperature when expoſed to the ſun's rays. This has been demonſtrated by the experiments of Wedgwood, Cavallo, and Pictet.

The former took two pieces of phoſphoreſcent marble, one of which was blackened, and placed them on a hot iron. No light appeared from the blackened marble, but the other exhibited its uſual phoſphoreſcence. Upon a ſecond expoſure, the piece which was not blackened gave a faint light; the blackened one, as before, gave none at all. When the black was wiped off, and both pieces were again placed upon the heater, no light appeared either from the one or the other. This experiment ſhows, that the phoſphoreſcent property was nearly deſtroyed without any viſible light having appeared. But both pieces of marble before being heated, muſt have contained the ſame quantity of

* *Beddoes' Contributions*, p. 44.

(T) Each an inch ſquare, and two lines thick.

of light and heat, and therefore the light from the blackened piece muſt have been abſorbed by the black colour *.

* *Phil. Tranſ.* 1792, p. 278.

In Cavallo's experiments (u), the bulb of a thermometer was painted black, and expoſed along with other thermometers to the ſun's rays. The difference of temperature between the blackened thermometer and the other, ſometimes amounted to 10°; that is, the blackened thermometer indicated a temperature 10° higher than the other. But this difference was not conſtant, for it varied according to the brightneſs of the ſun, and the denſity and temperature of the atmoſphere. Conſiderable variations were alſo obſerved from the difference of colours which were employed, and from the difference of poliſh of the ſurface of the plate.

The ſame thing was obſerved when the thermometers were expoſed to ſtrong day light. The thermometer whoſe bulb was blackened indicated the higheſt temperature †.

† *Ibid.* 1780, p. 587.

In an experiment by Profeſſor Pictet, two thermometers, one of which had its bulb blackened, when they were kept in a dark place, indicated the ſame temperature. Theſe experiments prove the cloſe connection between light and caloric; for the greater the proportion of light abſorbed by any body, the higher is the temperature of that body. And when the light is totally excluded, as in the laſt-mentioned experiment of Pictet, the temperature is the ſame ‡.

‡ *Eſſai ſur le Feu*, ch. iv.

300 Different heating power of the rays.

4. But it has been ſhown that there is a very great difference in the heating power of the different rays of light. It appears from the experiments of Dr Herſchel, that this heating power increaſes from the middle of the ſpectrum to the red ray, and is greateſt beyond it, where the rays are inviſible. Hence it is inferred that the rays of light and caloric nearly accompany each other, and that the latter are in different proportions in the different coloured rays. They are eaſily ſeparated from each other, as when the ſun's rays are tranſmitted through a tranſparent body, the rays of light paſs on ſeemingly undiminiſhed, but the rays of caloric are intercepted. When the ſun's rays are directed to an opaque body, the rays of light are reflected, and the rays of caloric are abſorbed and retained. This is the caſe with the light of the moon which, however much it be concentrated, gives no indication of being accompanied with heat.

It has alſo been ſhown, that the different rays of light produce different chemical effects on metallic ſalts and oxides. Theſe effects increaſe on the oppoſite direction of the ſpectrum, from the heating power of the rays. From the middle of the ſpectrum towards the violet end, they become more powerful, and produce the greateſt effect beyond the viſible rays.

301 Solar rays of three kinds.

5. From theſe diſcoveries it appears, that the ſolar rays are of three kinds. 1. Rays which produce heat; 2. Rays which produce colour, and 3. Rays which deprive metallic ſubſtances of their oxygen. The firſt ſet of rays is in greateſt abundance, or are moſt powerful towards the red end of the ſpectrum, and are leaſt refracted. The ſecond ſet, or thoſe which illuminate objects, are moſt powerful in the middle of the ſpectrum; and the third ſet produce the greateſt effect towards the violet end, where the rays are moſt refracted.

302 Tranſparent bodies not heated by the ſolar rays.

6. The ſolar rays paſs through tranſparent bodies without increaſing their temperature. The atmoſphere, for inſtance, receives no increaſe of temperature by tranſmitting the ſun's rays, till theſe rays are reflected from other bodies, or are communicated to it by bodies which have abſorbed them. This is alſo proved by the ſun's rays being tranſmitted through convex lenſes, producing a high degree of temperature when they are concentrated, but giving no increaſe of temperature to the glaſs itſelf. By this method, the heat which proceeds from the ſun can be greatly increaſed. Indeed, the intenſity of temperature produced in this way is equal to that of the hotteſt furnace. This is done, either by reflecting the ſun's rays from a concave poliſhed mirror, or by concentrating or collecting them by the refractive power of convex lenſes, and directing the rays thus concentrated, on the combuſtible body. See *Burning-Glass*.

Fifth Source of Caloric,

Combuſtion.

303 Effects of combuſtion ſtriking.

It was impoſſible for men whoſe attention was directed to the phenomena of nature, long to let paſs unobſerved the ſingular appearances which are exhibited in the combuſtion or burning of bodies. Indeed the changes produced on bodies by this proceſs, the aſtoniſhing effects which follow, and the importance of the proceſs itſelf, could not fail to excite great intereſt and attention.

304 Important,

As combuſtion is one of the principal ſources of heat, it has long occupied the attention of men in general, both as to the means of its improvement, and application in the arts of life, and in the diſcovery of a theory or explanation which will account for the phenomena. But the want of ſucceſs in this branch of philoſophical inveſtigation, even at the preſent day, ſhews that the ſubject is attended with great difficulty.

305 but of difficult explanation.

306 Difference between increaſe of temperature and burning.

When a piece of iron is expoſed to a high temperature, it becomes red hot, and when it is removed from the heating body, it continues for ſome time to give out light and heat. But when it is ſuffered to cool, it returns to the ſame ſtate in which it was before it was heated, having undergone no perceptible change. When a piece of wood is burnt, it alſo gives out light and heat, but during this proceſs it is totally changed. Great part is diſſipated, and nothing remains but a ſmall quantity of aſhes.

When a piece of ſulphur is expoſed to a temperature between 300° and 400°, it takes fire and burns; gives out

---

(u) The hint of theſe experiments, he ſays, was taken from the account of an experiment in a volume of the Philoſophical Tranſactions, made with a thermometer whoſe bulb was painted black, and expoſed to the rays of the ſun. The experiment alluded to was made by Dr Watſon, biſhop of Landaff. *Philoſophical Tranſactions*, 1763, p. 40.

out heat and light, and during this proceſs the ſulphur has acquired new properties, or has entered into new combinations.

307 Bodies totally changed by combuſtion.

When a metallic ſubſtance, zinc, for inſtance, is expoſed to a certain temperature, it alſo undergoes a very great change, during which heat and light are alſo given out. The zinc is changed to a light, flocculent ſubſtance, but moſt other metals are reduced to the form of powder (x).

308 Oxygen gas neceſſary in this proceſs.

Now, none of theſe changes can be effected without the preſence of atmoſpherical air, or rather without the preſence of oxygen gas, which is one of its conſtituent parts, and that part of it which is neceſſary for the proceſs of combuſtion. In all caſes where combuſtion takes place, oxygen gas diſappears or changes its ſtate; light and heat are emitted, and the combuſtible body has changed its properties. Such are the phenomena of combuſtion, ſo far as obſervation and experiment have gone; but ſtill the difficulty remains, to diſcover what ſhare is to be aſcribed to the different agents which are neceſſarily concerned in this proceſs, in the changes which are effected. It is now univerſally agreed, that oxygen gas, or its baſe, is fixed in the combuſtible body during the proceſs of combuſtion, and that the caloric which is neceſſary to retain the oxygen in the ſtate of an elaſtic fluid being emitted during the change, is the ſource of the heat which is given out by burning bodies. But what is the ſource of the light? Is it emitted by the oxygen gas along with the caloric in its change from the fluid to the ſolid ſtate? Or has it been a conſtituent part of the combuſtible body which is ſeparated during combuſtion? Of this, different opinions have been entertained by philoſophers, and the queſtion in a great meaſure ſtill remains undecided. Let us now conſider the different theories which have been propoſed to account for theſe phenomena.

309 Source of the light not aſcertained.

310 Theories.

1. In the early dawn of chemiſtry, when the ſcattered facts were firſt collected, and it began to aſſume a ſcientific form, attempts to explain this proceſs were ſoon made. Becher was the firſt who gave any conſiſtent form to a theory of combuſtion. Before his time, ſulphur was conſidered as the univerſal inflammable principle; but he rejected this opinion, conſidering ſulphur as an inflammable ſubſtance, containing the principle of inflammability, but not that principle itſelf. This theory was improved and extended by Stahl, who gave this principle the name of *phlogiſton* (y), from which the theory was called the phlogiſtic, and from his own name the *Stahlian* theory. This principle was ſuppoſed to exiſt in all inflammable bodies, and to be the ſame in them all. The diverſity which is obſerved among them, in external appearance and other properties, is owing to the other principles or elements of which they are compoſed, and with which the common principle of inflammability, or phlogiſton, is combined. Inflammation or combuſtion, with the ſeveral phenomena that attend it, is ſuppoſed to depend on a gradual ſeparation and diſſipation of this principle; and this being once ſeparated, what remains of the body is no longer combuſtible, but is ſimilar to other kinds of matter. This principle is repreſented as a dry ſubſtance, of an earthy nature, compoſed of particles which more than all others are diſpoſed to be affected with a very ſwift whirling motion. When the particles of a body are agitated with this motion, the body becomes hot, is ignited, or undergoes combuſtion, according to its violence. The heat and the light which are emitted during combuſtion, depend upon a peculiar motion of the particles of matter; phlogiſton, which is ſuppoſed to be contained in all combuſtible ſubſtances, being moſt diſpoſed to aſſume this motion *.

311 Stahlian.

312 Hooke's

2. But before this time, a different theory was propoſed by Dr Hooke, who publiſhed an account of it in 1665, in a work entitled *Micrographia*; and, in the year 1676, in another work called *Lampas*. According to this theory, the air of the atmoſphere is the univerſal ſolvent of all combuſtibles. This ſolution takes place when the temperature of the combuſtible body is ſufficiently raiſed, and during the violence of its action the heat is emitted. This diſſolution of inflammable bodies is a ſubſtance inherent in the air, which is like, if not the very ſame with, that which is fixed in ſaltpetre. During this diſſolution of bodies, part unites with the air and eſcapes; and part, after being mixed with it, forms a coagulum or precipitation, ſome of which being light, is carried away, while another part which is heavier, remains behind.

313 and Mayow's.

Some time after, an account of the ſame theory was publiſhed by Dr Mayow, with ſome additional experiments, in a work entitled *De Sal-nitro et Spiritu Nitro-aëreo.* The nitro-aerial particles, or the ſpiritus nitro-aereus of Mayow, was the ſame as the univerſal ſolvent of Hooke. According to Mayow, this ſpiritus nitro-aereus conſiſts of minute particles, from the motion of which it is produced, and when the motion is more rapid, not only heat, but light alſo, is extricated. The following abſtract of the theory of Dr Hooke, with Profeſſor Robiſon's obſervations, will not, we hope, be unacceptable to our readers.

314 Abſtract of Hooke's theory.

“ This theory, ſo oppoſite, as Dr Black obſerves, to the theory of Stahl, is not ſo recent as is generally imagined. It was ſeen, in all its extent and importance, by Dr Robert Hooke, one of the greateſt geniuſes and moſt ardent inquirers into the operations of nature, who figured during the latter half of the 17th century, a period full of great diſcoveries.

“ Dr Hooke propoſed this theory in conſiderable detail in his *Micrographia*, publiſhed in 1665; and in his *Lampas*, publiſhed in 1676; and he makes it an important doctrine in his treatiſe on Comets, and in many paſſages of his Cutlerian Lectures. He promiſes to take it into ſerious conſideration, and to publiſh a full exhibition of it. The alluſions made to it in his lectures make it evident that he had continued to make ſome deſultory additions to his firſt conceptions. His *Lampas* contains a moſt accurate explanation of flame, which

---

* *Black's Lect.* vol. i. p. 231, 232.

(x) To theſe ſubſtances was formerly given the name of *calx* or *calces*, but in the preſent chemical nomenclature they are denominated *oxides*.

(y) This principle was alſo called *terra ſecunda* or *terra inflammabilis*.

which cannot be ſurpaſſed by any performance of the preſent day.

“ In the Micrographia he ſtates the theory in the following words :

“ 1. The air in which we live, and breathe, and move, and which encompaſſes and cheriſhes all bodies, is the univerſal ſolvent of all ſulphurous (ſynonymous, at that time, with inflammable) bodies.

“ 2. This action it performs not till the body be ſufficiently heated, as we obſerve in other ſolutions.

“ 3. *This action of diſſolution produces the great heat which we call fire.*

“ 4. It acts with ſuch violence as to agitate the particles of the diaphanous body air, and to produce that elaſtic pulſe called light.

“ 5. This action, or diſſolution of inflammable bodies, is performed by *a ſubſtance inherent in, and mixed with the air, that is like, if not the very ſame, with that which is fixed in ſaltpetre.*

“ 6. In this diſſolution of bodies by the air, a part of the body, uniting with the air, is diſſolved or turned into air, and eſcapes and flies about.

“ 7. As one part is thus turned into air, ſo another is mixed with it, but forms a coagulum, or precipitation, ſome of which is ſo light as to be carried away with the air, while other groſſer and heavier matters remain behind, &c. &c. This latter article is frequently employed in other parts of his writings, and is ſometimes called a groſſer *compound*, mixed with matters terrene, and originally inſoluble in air, and incombuſtible.

“ Can any thing more be wanting to prove that this is the ſame with the modern theory of combuſtion? Nothing but to ſhew that this coagulum contained the air which had formed it, by ſhewing an increaſe of its weight, or by ſeparating it again. But the eager mind of Hooke, attracted by every appearance of novelty, was ſatisfied with the general notion of a great ſubject, and immediately quitted it in chaſe of ſome other intereſting object. Had he not been thus led off by a new purſuit, this wonderful man would not only have anticipated, but completed many of the great diſcoveries of the laſt century. It was a bold conception, and only a vigorous mind could entertain it for a moment, that the vaſt heat of combuſtion was contained in a few grains of air. Yet this was his opinion, as appears by the explanation which he gives, in various meetings of the Royal Society, and in his lectures on comets, of the deflagration of combuſtible bodies with ſaltpetre, and of fiery motion.

“ In the treatiſe called Lampas, he obſerves that this his treatiſe, publiſhed eleven years before, had been very favourably received, and that he had not ſeen any valid objection offered to it. It was in this interval that Dr Mayow, at Oxford, publiſhed his book *De Sal-Nitro, et Spiritu Nitro-aëreo*, in which he holds preciſely the ſame doctrine; but his exhibition of it is obſcure, complicated, and wavering, mixed with much mechanical nonſenſe, of wedges, and darts, and motions, &c. according to the faſhion of the times. Hooke's conception of the ſubject, on the contrary, is clear, ſimple, and ſteady. The only addition made by Mayow are ſome obſervations on the increaſe of weight obſerved in the preparation of diaphoretic antimony, &c. Hooke, explaining at a meeting of the Royal Society, ſome tricks of the plumbers workmen, who called the litharge which formed on the ſurface of melted lead droſs, and took it with them as their perquiſite, ſays expreſsly, that they can make droſs of the whole, and that it is more than the lead by all the air which was its menſtruum. But Mayow wrote on the ſubject expreſsly, and it appears in the title of his book. He is remembered, while Hooke is forgotten, becauſe no one would think of looking into the Micrographia for chemical information. The theory comes in by chance, to explain the indeſtructibility of charcoal in cloſe veſſels by heat. Mayow alſo made many very ingenious experiments on the air which had contributed to inflammation, and has anticipated both the manipulations and the diſcoveries of modern pneumatic chemiſtry.”

315 Phlogiſton ſuppoſed to be light.

3. But in the progreſs of chemical ſcience, the exiſtence of the imaginary principle of phlogiſton began to be called in queſtion. It had been obſerved, and was proved by experiment, that ſubſtances became inflammable by merely being expoſed to the light of the ſun, and in this way having acquired the principle of inflammability, it was ſuppoſed to be the ſame as light. This opinion of phlogiſton being light fixed in bodies, which was the firſt improvement or modification of the theory of Stahl, was adopted by Macquer and other chemiſts.

316 Farther modified.

4. In the progreſs of diſcovery, this theory was ſtill farther modified. The introduction of pneumatic chemiſtry, and the accuracy and preciſion which it gave to the experiments and reſearches of chemiſts, enabled them to aſcertain, with greater certainty, the changes which take place on bodies after being ſubjected to combuſtion, as well as on the air in which they are burnt. Some of theſe changes were obſerved by Dr Prieſtley, whoſe indefatigable labours contributed eſſentially to the extenſion of chemical ſcience. He found by experiment, that the air in which combuſtibles had been burnt, was afterwards unfit for the ſupport of flame, and equally ſo for the breathing of animals. He aſcribed this change which the air had ſuffered to its combination with the phlogiſton which had ſeparated from the burning body during the proceſs of combuſtion. He conſidered air as neceſſary to combuſtion, becauſe, having a ſtrong affinity for phlogiſton, it attracted it during the proceſs, and combined with it; and by this combination the air was contaminated and rendered unfit for farther combuſtion, or for animal reſpiration. But ſtill the difficulty remained to account for the heat and light which are extricated during this proceſs.

317 Changes obſerved on the air by Prieſtley,

318 ſuppoſed that it combined with phlogiſton.

319 Caloric and light exiſt in the air.

According to Dr Crawford, the caloric and light which appear during combuſtion, exiſt in the air in which the body is burnt, and during the proceſs the phlogiſton combines with the air, from which at the ſame time the light and caloric are ſeparated.

320 Phlogiſton the ſame with hydrogen.

5. Soon after Mr Kirwan propoſed another opinion, which was pretty generally adopted by chemical philoſophers. According to this opinion, hydrogen and phlogiſton are the ſame; that it exiſts as a conſtituent part in all combuſtibles, ſeparating from them during combuſtion, and combining with the oxygen of the air.

321 Scheele's hypotheſis.

6. In the year 1777, Scheele publiſhed a work which was entitled, *Chemical Experiments on Air and Fire.* Heat according to him, conſiſts of a certain

quantity of oxygen united with phlogiſton. Radiant heat, which moves in ſtraight lines, is compoſed of oxygen combined with a greater proportion of phlogiſton; and light, of oxygen combined with a ſtill greater quantity.

322 Diſcovery of Lavoiſier.

7. But the labours and diſcoveries of the French chemiſts gave a new turn to chemical ſcience. The unfortunate Lavoiſier, who had devoted his time and his fortune to chemical purſuits, had long directed his attention to the phenomena of combuſtion; and after an extenſive ſeries of experiments, diſtinguiſhed for their accuracy and preciſion, he eſtabliſhed the general law, that oxygen combines with the burning body in all caſes of combuſtion; and thus, he was enabled ſatisfactorily to account for the phenomena of combuſtion without phlogiſton, the exiſtence of which had never been proved.

323 His theory.

8. The principles of this theory are the following. No combuſtion can take place without the preſence of oxygen, for it is the combination of the combuſtible body with oxygen. The oxygen of the atmoſphere, which is in the ſtate of an elaſtic fluid, exiſts in combination with caloric and light; and during the combuſtion, that is, the combination of the oxygen with the combuſtible body, the caloric and light are ſeparated.

324 Accounts only for ſome of the phenomena.

9. This theory accounts for the phenomena of combuſtion in the more limited acceptation of this term, which is merely the combination of oxygen with a combuſtible body, without any extrication of caloric and light. Thus, oxygen combines with ſome metallic ſubſtances and other bodies, without any perceptible emiſſion of light or heat. This is called *oxidation*, and the product of this combination is denominated an *oxide*. In all caſes of combuſtion oxygen combines with the combuſtible body. Indeed this is ſo eſſentially neceſſary, that no combuſtion can take place without it; but in the more extenſive ſignification of the term combuſtion, it is underſtood, not merely to mean the combination of oxygen with the combuſtible body, but alſo to be accompanied with the extrication of heat and light. According to the theory of Lavoiſier, the caloric and light which appear during combuſtion, are given out by the oxygen gas. It is the ſeparation of that quantity of caloric which is neceſſary to retain the baſe of this gas, or oxygen, in the form of an elaſtic fluid. When, therefore, the temperature of a body is ſufficiently raiſed, the affinity between oxygen and this body becomes greater than that which exiſts between the oxygen, and the caloric and light. The oxygen therefore combines with the combuſtible body, and the caloric and light are ſeparated.

This theory is applicable to the explanation of the phenomena of combuſtion, in the more limited meaning of that term; and it is partially applicable to explain the phenomena in its more extenſive meaning. But when it is conſidered, that the proceſs of combuſtion goes on between two ſolids, one of which contains oxygen in its combination, as for inſtance, ſulphur and nitre, difficulties ariſe in accounting for the heat and light, when the oxygen which combines with the combuſtible body, is in the ſolid ſtate.

To remove theſe difficulties, and to explain the appearances, the theory of Lavoiſier has been greatly modified, or new theories propoſed.

325 Theory of Brugnatelli

10. With this view a theory has been propoſed by Brugnatelli. This theory ſuppoſes that oxygen exiſts in combination with bodies, in two ſtates. In the one it is entirely deprived of its caloric and light, and in the other, it retains great part of the caloric and light, even in its combined, concrete ſtate. It is ſimply called *oxygen* in the firſt caſe, when it is deprived of its caloric and light; in the latter it is denominated *thermoxygen*, when the caloric and light are combined with it in the concrete ſtate. Thermoxygen, then, is a compound of oxygen and caloric in the concrete ſtate. This caloric is different from that which holds the thermoxygen in the ſtate of gas, and it is in the ſame relation to thermoxygen gas, as water is to cryſtallized ſalts. This thermoxygen only enters into the compoſition of acids, when it is deprived of its concrete caloric. But it combines with the metals in the ſtate of thermoxygen; that is, united with the concrete part of caloric. Metallic ſubſtances, therefore, are denominated *thermoxides*.

In its union with metals, thermoxygen is either previouſly formed, or is in its naſcent ſtate, during the combination. In the latter caſe, the caloric which is diſengaged by the chemical action, or that which is applied to aſſiſt the combination, furniſhes the neceſſary portion for the formation of the thermoxide; that is, the combination of oxygen containing caloric in its concrete ſtate, with a metal. Thus it is, that ſome metals require the application of heat for their ſolution in concentrated acids.

The baſe of pure air is in the ſtate of thermoxygen, in its combination with water. The metals, therefore, which have a ſtronger affinity for it than for hydrogen, the other component part of water, readily combine with it, without the aid of external heat, in acids diluted with this fluid. Gaſeous thermoxygen always gives out caloric, when it paſſes from the elaſtic to the concrete ſtate; but as thermoxygen requires little caloric for its expanſion, little is ſeparated when it is condenſed. We ſhall only add the author's explanation of the difference between atmoſpherical air and thoſe ſubſtances which have the ſame conſtituent parts in different proportion. The difference between atmoſpherical air and nitrous gas, he ſuppoſes, is aſcribed to the proportion of the conſtituent principles, and conſequently, according to this hypotheſis, the atmoſpherical air might be converted into nitrous gas, by augmenting the proportion of oxygen gas, or by diminiſhing that of the azotic gas. But the difference between theſe two gaſes, according to the theory of Brugnatelli, conſiſts in this, that in atmoſpherical air the azotic gas is combined with thermoxygen gas; but in nitrous gas, the azotic gas is combined with ſimple oxygen*.

326 Theory which ſuppoſes the light to be given out by the combuſtible.

11. This theory, notwithſtanding its ingenuity, is regarded by ſome merely as a plauſible hypotheſis, which is little ſupported by facts. We ſhall therefore leave it to the conſideration of our readers, and proceed to ſtate the principles of another, which is propoſed to be ſubſtituted in place of the Lavoiſierian theory, in explaining the phenomena of combuſtion. In this theory, it is ſuppoſed that the oxygen gas which is abſorbed during combuſtion, furniſhes the caloric, while the combuſtible body gives out the light which previouſly exiſted in it as a component part. In proof of

---

* *Annal. de Chim.* vol. xxix. p. 182.

327 Light furniſhed by the combuſtible.

of this theory it is ſtated, that ſome bodies give out, during combuſtion, a greater quantity of light than others, even where the quantity of oxygen abſorbed is leſs; that the colour of this light varies according to the nature of the combuſtible; and that vegetables which grow in the dark contain no combuſtible matter, being deprived of the light which is eſſentially neceſſary for its formation. This theory, which Gren calls *the theory of fire and combuſtion*, is diſtinctly detailed by him in the following words.

"I take here the word *fire* in the uſual ſenſe of common language, and underſtand by it that light which is combined with free caloric. *Combuſtion* is the extrication of fire with and by the decompoſition of oxygen gas. Take the example of phoſphorus. On its combuſtion two new products, the phoſphoric acid and fire, ariſe from phoſphorus and oxygen gas.

328 A theory muſt explain all the phenomena.

"In order that the theory of combuſtion be admiſſible, it muſt explain every circumſtance by which this phenomenon is accompanied, and be in contradiction with none of them. It, beſides, muſt not be inconſiſtent with any other fixed invariable law of nature.

"According to the *antiphlogiſtic ſyſtem*, a combuſtible body is ſuch as is poſſeſſed of the power of attracting, in a certain temperature, the oxygen of vital air more ſtrongly than it is attracted by the caloric. Beſides, in that ſyſtem, oxygen gas does not merely conſiſt of oxygen and caloric, but it likewiſe contains light, in a fixed ſtate, as a conſtituent part.

"If, therefore, phoſphorus, at the temperature requiſite to its inflammation, be brought into oxygen gas, it robs the latter of its oxygen, and makes with it phoſphoric acid; whilſt the caloric and the baſis, or matter of light, previouſly *latent* in the gas, are reſtored to liberty; and, combining together, produce the fire which flies off. Thus the oxygen gas is decompoſed.

329 New body generated by combuſtion.

"A new body, the phoſphoric acid, is now generated; and, becauſe in many caſes an acid is produced by the combuſtion of inflammable matters, this circumſtance has induced modern chemiſts to denote the baſis of vital air by the words *acidifying principle*, or *oxygen;* not on the ground that it is ſuppoſed to be ſour of itſelf, but becauſe it forms an acid only when combined with an *acidifiable baſis*, as in our experiment with phoſphorus. And it is on this account that, in this ſyſtem, combuſtion has likewiſe received the name of *oxygenation*. But in the caſe (very often occurring) where the combuſtible matter imbibes oxygen, yet without becoming thereby an acid, the product is called *oxyd* (alſo denominated *half-acid*), and the proceſs is termed *oxydation*.

330 Acquires an increaſe of weight.

"Since the combuſtible ſubſtance takes up the ponderable baſis of oxygen gas, and ſince, according to this ſyſtem, both the caloric and light are imponderable, it is thereby accounted for, why the reſidue of burnt matters, the phoſphoric acid, for inſtance, acquires an increaſe of weight equal to that portion of vital air which was decompoſed.—If the inflammable ſubſtance be ſaturated with oxygen, it is rendered incapable of decompoſing more oxygen gas, and the combuſtion is ended.

"When the combuſtion is performed in atmoſpheric air, it is then the azotic, either mingled or mixed with the oxygen gas, that prevents theſe phenomena from going on with the ſame vivacity as in pure oxygen gas; and likewiſe, as the azotic gas is not affected or acted on by the inflammable body, it is left as the reſidue of the atmoſpheric air.

331 Combuſtion a caſe of ſimple affinity in the old theory.

"Hence, by that ſyſtem, the combuſtion of phoſphorus in oxygen gas is effected by a ſimple affinity, and the principle of fire is not in the combuſtible body, but in the oxygen gas.

332 Explained by double affinity.

"However, from what I have ſtated of the compoſition of light, I cannot help thinking, that in combuſtion a double affinity takes place; and to explain this theory I ſhall ſelect the example of phoſphorus. That ſubſtance conſiſts of the baſis of light, called by me *phlogiſton*, and making a conſtituent part of all combuſtible bodies united to a peculiar body, the *phoſphoric-radical*.—*Oxygen gas* is a compound of *oxygen* and *caloric*.

"Now, when phoſphorus is heated in this gas, and by this means the force of attraction between the phlogiſton and the phoſphoric-radical is ſufficiently weakened, ſo that the attractive power between the radical of phoſphorus and the oxygen may prevail, then the act of combuſtion enſues. The phoſphoric baſis attracts the oxygen, while the phlogiſton of the phoſphorus is attracted by the caloric of the oxygen gas. Thus, by virtue of this double affinity, two new compounds, the phoſphoric acid and fire, ariſe from the two former combinations, phoſphorus and oxygen gas.

"When the radical of phoſphorus, and in general of any combuſtible body, has abſorbed ſo much oxygen, that it is ſaturated with it, the combuſtion is arrived at its higheſt degree; and in the ſame manner it is ended, at the moment when all the quantity of oxygen gas, capable of being decompoſed, is exhauſted. By this it is explained, why, in a given volume of oxygen gas, only a certain quantity of phoſphorus, and in general of every other combuſtible matter, can be conſumed by fire.

"The increaſe of weight in the reſidue of the burnt ſubſtance is, in this phlogiſtic, or rather *eclectic ſyſtem*, likewiſe explained by the acceſs of oxygen; and the caloric and baſis of light are likewiſe ſuppoſed to be both imponderable. The remaining azotic gas, not being acted upon by the combuſtible matter, is merely the reſidue of the atmoſpheric air.

333 Light given out without oxygen.

"Thoſe that wiſh to be impartial, muſt allow that the light, in the *antiphlogiſtic ſyſtem*, acts a part quite ſuperfluous; that it may be thoroughly ſet aſide without impairing the ſyſtem; that by this ſyſtem thoſe phenomena cannot be explained, where light iſſues from combuſtible bodies without any acceſs of vital air, (ſome inſtances of which will hereafter be given (z); that the influence of light upon the growth and thriving of plants, upon the changes of their mixture during

---

(z) As in the caſe of the combination of ſulphur and iron or copper.

ing vegetation, and upon the alteration in the mixture of many other bodies, is by far too great, to allow oxygen gas to be conſidered as its only reſervoir. Finally, it muſt be granted (an important point) that the antiphlogiſtic ſyſtem does in no way explain the incidents preliminary to the proceſs of combuſtion; and that it affords no argument to ſhow why a certain degree of heat is neceſſary, in order that the combuſtible body be inflamed *."

* Gren's *Chemiſtry*, vol. i. p. 135.

11. Such then are the general facts with regard to combuſtion, and ſuch are the theories which have been propoſed, to account for the phenomena exhibited in this proceſs. 334 Three modifications. Three ſtates or modifications have been diſtinguiſhed in the act of combuſtion, namely, ignition, inflammation, and detonation.

335 Ignition. *a.* Ignition, properly ſpeaking, is rather a preliminary ſtep, than a part of the proceſs of combuſtion itſelf. A metallic ſubſtance, for inſtance, may become red hot when expoſed to a certain temperature; but when it is cooled, it returns without change to its former ſtate. In this caſe caloric and light are given out, but the body undergoes no farther change. There is no abſorption of oxygen, which is one of the ordinary phenomena of combuſtion. But, with an increaſe of temperature, this alſo is effected, and the whole phenomena of combuſtion are exhibited; namely, the union of oxygen with the combuſtible body, and the emiſſion of light and heat.

336 Inflammation. *b.* The ſecond ſtate or modification of combuſtion is called *inflammation*. This depends on the nature of the combuſtible body, owing partly to its ſtrong affinity for oxygen, and partly to the ſlight affinity which exiſts between the particles of the combuſtible body. We have examples of this in the burning of ſulphur or phoſphorus, or a candle in the open air, or in oxygen gas.

337 Detonation. *c.* Detonation is another modification of combuſtion. It is a rapid and inſtantaneous inflammation, accompanied with exploſion. This ariſes from the ſudden formation of a vacuum, by the change of elaſtic fluids into the liquid ſtate, or by the ſudden evolution of elaſtic fluids from the ſolid ſtate. Of the firſt we have an inſtance in the compoſition of water by the inflammation of oxygen and hydrogen gaſes, which is attended with a violent exploſion, great condenſation, and the extrication of light and heat. Of the evolution of elaſtic fluids from ſolid bodies, we have a good inſtance in common gunpowder, from which an immenſe volume of elaſtic vapour is inſtantaneouſly extricated, which, by its expanſive force being ſuddenly exerted, produces the exploſion, and the irreſiſtible effects of this powerful agent.

338 Combuſtible ſubſtances converted into acids, 339 or water, 340 or oxides

12. All inflammable ſubſtances, Dr Black obſerves, are changed, during combuſtion, into one or more principles. From the combuſtion of ſome ſubſtances, as ſulphur and phoſphorus, an acid is obtained. From the combuſtion of others, as hydrogen with oxygen, water is the product; and in the caſe of metals, they are reduced to the ſtate of oxide, or *calx*, as it was formerly called. After the combuſtible ſubſtance has been ſubjected to the proceſs of combuſtion, it is totally changed in its properties, and it can no longer exhibit the phenomena of combuſtion.

Such then are the general properties and effects of light and heat, two of the moſt powerful agents, and of the moſt extenſive influence, in all the changes and combinations which take place among bodies, by chemical action. In many properties they reſemble each other, but are totally different from all other kinds of matter. Theſe bodies, poſſeſſed of a repulſive power among the particles of each other, are attracted by other bodies, and combine with them; and theſe combinations produce the moſt aſtoniſhing effects, giving new forms to matter, and inducing innumerable changes, which may be conſidered as conſtituting the principle and eſſence of ſome of the moſt ſublime operations of nature, and many of the moſt important proceſſes of art.

Connected with light and heat in many of their obvious properties, and alſo in many of the changes which they produce upon bodies, are electricity and galvaniſm; and with electricity at leaſt, if not alſo with galvaniſm, the magnetic power poſſeſſes ſome common properties; and eſpecially if ſome of theſe are to be conſidered, as ſome have ſuppoſed, only as modifications of the ſame ſubſtances which we have treated of, the diſcuſſion of theſe ſubjects would be properly introduced here; but, according to the nature and arrangement of this work, each will be fully detailed under its proper head. See ELECTRICITY, GALVANISM, MAGNETISM.

CHAP. IV. OF OXYGEN, AND OXYGEN GAS.

341 Of great importance.

1. OXYGEN gas, or its baſe, oxygen, is one of the moſt important agents in the chemical phenomena of nature, or in the proceſſes of art. There is indeed ſcarcely a ſingle proceſs in which this ſubſtance has not ſome ſhare. Its nature and properties, therefore, ought to be early known.

342 A diſcovery of modern chemiſtry.

Oxygen gas is one of the diſcoveries of modern chemiſtry. It was diſcovered by Dr Prieſtley in the year 1774, and from him it received the name of *dephlogiſticated air*. It was afterwards denominated *highly reſpirable air*. From Scheele, who diſcovered it in 1775, it received the name of *empyreal air*. It was called *vital air* by Condorcet; and Lavoiſier gave it the name of *oxygen gas*, by which it has ſince been generally diſtinguiſhed.

343 Proceſſes for obtaining it.

2. Oxygen gas is moſt eaſily obtained by the following proceſs: *a.* Take a quantity of the ſubſtance called *mangane*ſ*e*; introduce it into the iron bottle A, fig. 3. to the neck of which apply the bent tube B, which is made to fit it exactly, and lute them together at the joining CD (A). The bottle thus prepared, is to be expoſed

---

(A) The lute which anſwers this purpoſe ſufficiently well, is compoſed of pipe clay and linſeed oil well beaten together, and reduced to the conſiſtence of glaziers putty. This is neatly applied to the joining, and if allowed to remain for eight or ten hours before it is expoſed to the heat, it will afterwards bear the higheſt temperature.

expoſed to the heat of a furnace, or to that of an open fire. As ſoon as the heat is applied, the atmoſpheric air within the bottle is driven off; and, as the bottle becomes red hot, the quantity of air which paſſes over, is greatly increaſed. Let the end of the tube connected with the bottle be introduced under the ſhelf in the pneumatic trough, and the bubbles of air will paſs through the water, and may be received in jars filled with water, and inverted over the opening in the ſhelf.

b. Oxygen gas may alſo be obtained by treating what is called in chemiſtry the *red oxide of mercury*, in a ſimilar manner.

c. This gas may be alſo readily procured byint roducing into a glaſs retort, a quantity of the ſame ſubſtance (manganeſe) reduced to powder, adding an equal weight of ſulphuric acid, and applying a moderate heat.

d. Or it may be obtained from the ſubſtance called *nitre* or ſaltpetre, expoſed to a red heat, in an earthen or coated glaſs retort.

344
Nature of the proceſs explained.

3. In all theſe methods of obtaining this gas, it is unneceſſary to mention, that it muſt be received in the pneumatic apparatus, in the ſame way as has been directed for procuring it from the manganeſe, expoſed to heat in the iron veſſel; and in whatever way it is obtained, the chemical change which takes place in theſe proceſſes, is thus explained. Oxygen gas conſiſts of two ingredients, the one, which is called its baſe, and the other *caloric*, or the matter of heat. In the manganeſe, this baſe is ſuppoſed to be combined with the metallic ſubſtance; and when this ſubſtance is expoſed to a ſufficient temperature, the oxygen, having a greater attraction for caloric than for the metal, combines with it, and paſſes off in the ſtate of gas. The ſame change takes place, when the proceſs for obtaining the gas, by means of the red oxide of mercury, is employed. When the ſulphuric acid, which is in the ſtate of liquid, is added to the manganeſe, it combines with it, and becomes ſolid. But no liquid ſubſtance can become ſolid, without being deprived of the caloric neceſſary to retain it in the ſtate of fluidity. The caloric which retained the ſulphuric acid in the liquid ſtate, combines with the oxygen of the manganeſe, aſſumes the fluid or gaſeous form, and makes its eſcape. This is an example of double affinity. The ſulphuric acid unites with the manganeſe, and forms a ſolid; while the caloric combines with the baſe of oxygen, and appears in the form of oxygen gas.

345
Properties.

4. Oxygen gas thus obtained, poſſeſſes many of the properties of common air. It is colourleſs, inviſible, elaſtic, and may be indefinitely expanded or compreſſed.

Oxygen gas poſſeſſes neither taſte nor ſmell; its ſpecific gravity, according to Mr Kirwan, is to that of water as 0.00135 to 1.0000. Being therefore 740 times lighter than its bulk of water, its weight to atmoſpherical air is in the proportion of 1103 to 1000; or 100 cubic inches of oxygen gas weigh 34 grs. while the ſame meaſure of atmoſpherical air weighs only 31 grs. the temperature being 60°, and the barometer being at 30 inches. According to Mr Davy's experiments, 100 cubic inches of oxygen gas weigh 35.05 grs.

Water does not ſenſibly abſorb oxygen gas. But by means of ſtrong preſſure, it may be made to combine with, and to retain in ſolution, half its bulk of the gas. The water thus impregnated, is not ſenſibly different from common water in taſte or ſmell, but it is ſaid to have proved an uſeful remedy in ſome diſeaſes.

346
Combuſtion more brilliant in oxygen gas.

Combuſtible ſubſtances burn with greater brilliancy and rapidity in oxygen gas than in common air. Indeed it is owing to a certain quantity of the former, that the proceſs of combuſtion goes on in the latter; and when the oxygen gas is exhauſted, the proceſs is interrupted. If a jar or phial is filled with this gas, and a lighted candle introduced into it, it burns with greater ſplendour, and produces a greater degree of heat, than in a ſimilar veſſel filled with common air. If the candle be blown out, and while the ſnuff is red hot, it is introduced into a veſſel filled with oxygen gas, it re-kindles with a ſlight exploſion, and burns with the ſame ſplendour. A candle in a veſſel filled oxygen gas burns much longer than in the ſame quantity of atmoſpherical air.

347
Animals live a longer time in it.

Oxygen gas is eſſentially neceſſary for reſpiration. No breathing animal can live in any air which does not contain ſome proportion of oxygen gas. And the experiments of Dr Prieſtley and others prove, that animals live a much longer time in oxygen gas than in an equal bulk of atmoſpherical air. The experiments of Count Morozzo fully eſtabliſh this fact. Into a veſſel filled with common air, and inverted over water, he introduced a number of ſparrows, and obſerved the effects. The following are the reſults of his experiments:

	H.	M.
The firſt ſparrow lived	3	0
The ſecond	0	3
The third	0	1

The experiments were repeated by filling the ſame veſſel with oxygen gas, and he obtained the following reſults:

	H.	M.
The firſt ſparrow lived	5	23
The ſecond	2	10
The third	1	30
The fourth	1	10
The fifth	0	30
The ſixth	0	47
The ſeventh	0	27
The eighth	0	30
The ninth	0	22
The tenth	0	21

Two ſparrows were then put in together; the one lived for an hour, but the other died in about 20 minutes.

348
Oxygen combines with bodies.

5. Oxygen combines with a great number of bodies, and forms compounds with them. It is always preſented to us in a ſtate of combination. In examining its properties, it is always as a compound; and theſe properties are only cognizable to our ſenſes in that ſtate.

When oxygen combines with metallic ſubſtances, they acquire new properties, and this combination in chemical language is denominated an *oxide*. Combined with many other ſubſtances, the nature of the ſubſtance is alſo changed, and the compound exhibits new properties. One of the moſt remarkable of theſe is the taſte of the compound ſubſtance, which is often ſour or acid; and becauſe this circumſtance was obſerved to be one of the moſt frequent and moſt remarkable which attend its combinations, the name of oxygen, or acidifying, was invented by Lavoiſier. Oxygen gas is alſo neceſſary for the germination of the ſeeds of plants; but as the proceſs of vegetation advances, it is given out in great abundance by the leaves during the day. By this means the great waſte of oxygen gas in the proceſſes of combuſtion and reſpiration is fully repaired, and the balance between its conſumption and ſupply is preſerved.

349 Origin of the name.

6. The following is the order of its affinity for the ſubſtances with which it enters into combination.

Oxygen.
Charcoal,
Titanium,
Manganeſe,
Zinc,
Iron,
Tin,
Uranium,
Molybdena,
Tungſten,
Cobalt,
Antimony,
Hydrogen,
Phoſphorus,
Sulphur,
Azote,
Nickel,
Arſenic,
Chromium,
Biſmuth,
Lead,
Copper,
Tellurium,
Platina,
Mercury,
Silver,
Oxide of arſenic,
Nitrous gas,
Gold,
Muriatic acid,
White oxide of manganeſe,
White oxide of lead.

CHAP. V. OF AZOTIC GAS.

350 Diſcovery.

1. Azotic gas was examined by Mr Scheele, the celebrated Swediſh chemiſt, in 1776; and his experiments proved, that it is a fluid poſſeſſed of peculiar properties. It ſeems, however, to have been known to Dr Rutherford of Edinburgh, as early as the year 1772, as appears from his theſis publiſhed in that year, in which he ſpeaks of the effects of combuſtion and reſpiration on the air of the atmoſphere.

351 Methods of procuring it.

2. There are various methods by which this gas may be obtained. *a.* The proceſs recommended by Berthollet is the following: Take a quantity of muſcular fleſh, or the fibrous part of the blood, which has been well waſhed. Cut the fleſh into ſmall bits; introduce it into a retort, or a matraſs to which a ground tube has been adapted. Pour over it diluted nitric acid, expoſe it to a heat of about 100°, and place the beak of the retort or the end of the tube in the pneumatic apparatus, that the gas which comes over may be received in proper veſſels. The gas thus obtained, is *azotic* gas. *b.* If ſulphuret of potaſh be expoſed to the air of the atmoſphere, incloſed in a bell-glaſs, over water; or, if ſulphuret of iron be formed into a paſte with water, and treated in the ſame way, and allowed to remain for ſome days, the quantity of air within the glaſs is greatly diminiſhed, in conſequence of part having been abſorbed, and what remains is azotic gas. *c.* When the air of the atmoſphere is incloſed in the ſame way, and expoſed to the action of phoſphorus, it alſo ſuffers diminution, part being abſorbed. Azotic gas only remains.

352 Properties.

3. Azotic gas, like common air, is inviſible and elaſtic, and may be indefinitely condenſed and dilated. Its ſpecific gravity is leſs than that of atmoſpheric air. It is eſtimated by Mr Kirwan at 0.00120, which is in the proportion of 985 to 1000; but according to Lavoiſier's experiments, it is to atmoſpheric air as 942.6 to 1000, which makes its ſpecific gravity only 0.00115.

This gas is unfit for combuſtion. If into a jar or phial, filled with azotic gas, a lighted candle be introduced, it is immediately extinguiſhed.

This gas is alſo extremely noxious to animals, and is therefore totally unfit for reſpiration.

353 Is a ſimple ſubſtance.

4. No attempts which have yet been made, have ſucceeded in decompoſing azote, or the baſe of azotic gas. It muſt therefore be admitted among the number of ſimple ſubſtances. It has never been obtained in a ſeparate ſtate. It is therefore when it is combined with caloric, that is, in a gaſeous ſtate, that we are acquainted with its properties; and from its being unfit for reſpiration, it derived its name. Some chemiſts have indeed conſidered it as a compound ſubſtance. Dr Prieſtley ſuppoſed that it conſiſted of phlogiſton and oxygen gas. On this account he called it *phlogiſticated air*. According to the Stahlian theory, the proceſs of combuſtion is the ſeparation of phlogiſton from the burning body. Oxygen gas, having a ſtrong affinity for phlogiſton, combines with it during the combuſtion, and is even ſuppoſed to contribute to the ſeparation of the phlogiſton, by its affinity for it. And when this air is ſaturated with phlogiſton, the proceſs of combuſtion is at an end. The air that remains after this proceſs is azotic gas. This theory, when firſt announced by Dr Prieſtley, was pretty generally received; but future experiments ſoon demonſtrated, that the quantity of air in which a combuſtible body was burnt, diminiſhed both in bulk and in weight; and therefore proved that the air, inſtead of receiving any addition, was on the contrary deprived of ſomething.

Achard, about the year 1784, concluded, from ſome experiments which he had made, that azotic gas conſiſts of water and fire. This theory has been ſupported by Weſtrumb, and more lately by Wiegleb. According to the experiments on which theſe chemiſts reſt the truth of their theory, azotic gas is always the reſult when ſteam is made to paſs through red hot earthen, or even metallic tubes; but a ſeries of very accurate experiments, inſtituted by the aſſociated Dutch chemiſts, clearly proved that no azotic gas was produced, when the inſtruments employed were impenetrable by air *. Dr Prieſtley had long before ſhown, that in ſimilar experiments, when he employed earthenware retorts, containing moiſt clay, and expoſed them to

---

* *Annal de Chim.* vol. xxvi. p. 310.

to a temperature above boiling heat; inſtead of vapour iſſuing from the beak of the retort, a quantity of air, which was nearly equal in weight to the quantity of water introduced, paſſed over. The concluſion which he drew from theſe experiments, was, that the water was converted into air; for he found that it poſſeſſed nearly the ſame properties as common air. But he proved afterwards by more accurate experiments, that water had made its way through the pores of the veſſel, and that its place was ſupplied by the external air which was forced in by the preſſure of the atmoſphere. For it was clearly aſcertained by the experiments of the Dutch chemiſts, that no gas was obtained, while perfectly ſound glaſs or metallic tubes were employed.

Another theory has been propoſed, of the compoſition of azotic gas, by Girtanner *. He ſuppoſes that azotic gas conſiſts of hydrogen and oxygen gas, having a ſmaller proportion of oxygen gas than what enters into the compoſition of water †. But the experiments of other chemiſts, as thoſe of Berthollet and Bouillon Lagrange, have afforded no ſuch reſult (B).

354 Combinations. 5. There is no perceptible action between light and azotic gas. 355 With caloric. Combined with caloric, we have already ſeen it may be indefinitely expanded, but without undergoing any change in its properties.

Azotic gas, from its being found in ſuch abundance in the air of the atmoſphere, no doubt acts ſome important part in the economy of nature. It is given out, or ſeems to be given out, in great quantity during the decompoſition of animal and vegetable matters; but during theſe proceſſes, it is the oxygen of the atmoſpherical air which is abſorbed, and thus the reſiduary air is azotic gas. The baſe of azotic gas is unknown, and chemiſts are ſtill unacquainted with its affinities.

356 With oxygen in different proportions. Azotic gas combines with oxygen in different proportions, and forms compounds very different in their nature and properties. In one proportion it conſtitutes the air of the atmoſphere, in another, what is called *nitrous oxide*, and in a third *nitrous gas*. Theſe we ſhall examine in their order in the following ſections.

SECT. I. *Of* ATMOSPHERIC AIR.

357 Properties. 1. The air of the atmoſphere is compoſed of azotic and oxygen gaſes. This is an inviſible elaſtic fluid, which may be indefinitely compreſſed and dilated. The ſpecific gravity of atmoſpheric air is 0.0012, or about 816 times lighter than water. This is to be underſtood when the temperature is between 50° and 60°, and when the barometer is at 30 inches. The preſſure of the air of the atmoſphere is nearly equal to 15lb. on every ſquare inch.

2. Till the diſcoveries of modern chemiſtry, atmoſpheric air was conſidered as one of the four ſimple elementary ſubſtances, of which all bodies are compoſed. But the experiments and reſearches of Prieſtley and of Scheele fully demonſtrated the exiſtence of two ſeparate ſubſtances, totally diſtinct from each other in their nature and properties. Oxygen gas, one of the component parts of atmoſpheric air, was, according to Dr Prieſtley, completely freed from phlogiſton; and hence he calls it dephlogiſticated air, which was in an eminent degree, fit for reſpiration and combuſtion; but azotic gas, the other component part, was ſuppoſed to be ſaturated with phlogiſton, and therefore unfit, as it was found to be, for theſe purpoſes. To the latter, the azotic gas, Scheele gave the name of *foul* air.

358 Proportions of azotic and oxygen gaſes. 3. According to the experiments of Lavoiſier, the proportions of the two gaſes which exiſt in atmoſpheric air, are 73 parts of azotic gas, and 27 of oxygen gas. But according to later experiments the proportions are found to be 78 of azotic gas, and 22 of oxygen gas by bulk; or by weight, 74 of azotic and 26 of oxygen gas.

359 Always conſtant. The proportions of theſe two gaſes in atmoſpheric air are uniform and conſtant. They have been found to be nearly the ſame in all parts of the world, and in all ſeaſons of the year, where experiments have been made.

360 Conſtitution of the atmoſphere. 4. A queſtion has ariſen among philoſophers concerning the conſtitution of the atmoſphere, whether its component parts are to be conſidered merely as a mechanical mixture, or as a chemical combination. To the latter opinion the greater number of chemiſts are inclined, 361 Suppoſed to be a chemical combination, from the conſtancy of the proportions of the component parts of the atmoſphere; theſe parts always being found in the ſame proportion at all heights, and never ſeparating according to their ſpecific gravities; from its poſſeſſing diſtinct properties, and from its continuing the ſame, whatever proceſſes are carried on in it; or whatever proportions of oxygen may be abſorbed during theſe proceſſes.

362 or a mechanical mixture. A contrary opinion has been adopted by Mr Dalton, which he has endeavoured to eſtabliſh by ſome very acute mathematical reaſoning. According to this ingenious hypotheſis, the elaſtic fluids which exiſt in the atmoſphere, have no mutual action whatever. The particles of one fluid are only attracted and repelled by each other, but are not acted upon by the particles of another fluid. The particles of the different fluids, with regard to each other, are ſubject to the laws of inelaſtic bodies *.

SECT. II. *Of* NITROUS OXIDE GAS.

363 Proceſs for obtaining this gas. 1. This gas is moſt readily obtained by decompoſing nitrate of ammonia, a ſalt compoſed of nitric acid and ammonia, the properties of which will be afterwards particularly detailed. The cryſtals of this ſalt are put into a retort, and expoſed to a temperature between 340° and 500°. It very ſoon melts after the heat is applied, and a great quantity of gas is emitted, at firſt in the form of white fumes, but afterwards tranſparent and colourleſs. This may be received in jars over water in the uſual way. This is the nitrous oxide gas, the gaſeous oxide of azote, or, as it has been called by ſome, from the pleaſurable ſenſations it excites on being reſpired, *the gas of paradiſe*. The firſt part of the gas which comes over is not quite ſo pure as when it is given out ſlowly, and when it is tranſparent. When therefore it is reſpired, care ſhould be taken to ſeparate what comes off firſt, from the reſt. This gas, as is obvious from the proceſs, is obtained by the decompoſition of the nitrate of ammonia; but the change which

---

* *Annal. de Chim.* vol. xxxiv. p. 3.

† *Ibid.* vol. xxxv. p. 23.

* *Mancheſter Mem.* vol. v. p. 535.

(B) The component parts of water are oxygen and hydrogen, as we ſhall find afterwards.

which takes place will be better underſtood, when we come to treat of the ſalt itſelf, being previouſly acquainted with its conſtituent parts.

364 Diſcovery. 2. This gas was called by Dr Prieſtley dephlogiſticated nitrous gas; and it was diſcovered by him in the year 1776. Its component parts were aſcertained by the aſſociated Dutch chemiſts; but its nature and properties were more fully and preciſely inveſtigated by Mr Davy *.

365 Properties. 3. In its phyſical properties, this gas reſembles common air. It is elaſtic, tranſparent, and colourleſs. The ſpecific gravity, as it has been eſtimated by Mr Davy, is 0.00197. One hundred cubic inches of it weigh 50.20 grs. The component parts of nitrous oxide gas are 63 of azote, and 37 of oxygen gas.

Some combuſtibles burn in this gas nearly as well as in oxygen gas, but with this difference, that they muſt be in a ſtate of ignition.

Pyrophorus, which ſpontaneouſly inflames ſo low as the temperature of 40° in atmoſpheric air, will not burn in nitrous oxide gas, till it is raiſed to a temperature above 212°. A burning taper introduced into pure nitrous oxide gas, burns at firſt with a brilliant white light, and ſparkles as in oxygen gas; but as the combuſtion goes on, the flame gradually lengthens, and is ſurrounded with a pale blue light. Phoſphorus burns in it with a brilliancy not much inferior to its combuſtion in oxygen gas.

366 Effects in reſpiring it. 4. It was at firſt ſuppoſed that this gas is unfit for reſpiration, but the experiments of Mr Davy have ſhewn the contrary; and the ſingular effects which it produces on the animal frame have excited much intereſt. From theſe experiments, and from many others which have been ſince repeated, it appears that it may be reſpired for ſome minutes without injury. In ſome caſes it produces no effect whatever; but, in general, the ſenſations it excites are ſimilar to thoſe of intoxication; but they are rarely followed by its unpleaſant effects. Mr Davy deſcribes his own feelings when he reſpired this gas, in the following words.

"Having previouſly cloſed my noſtrils and exhauſted my lungs, I breathed four quarts of nitrous oxide from and into a ſilk bag. The firſt feelings were giddineſs, ſenſe of fullneſs of the head, and indiſtinct ſenſation; but in leſs than half a minute, the reſpiration being continued, they diminiſhed gradually, and were ſucceeded by a ſenſation analogous to gentle preſſure on all the muſcles, attended by a highly pleaſurable thrilling, particularly in the cheſt and the extremities. The objects around me became dazzling, and my hearing more acute. Towards the laſt inſpirations, the thrilling increaſed, the ſenſe of muſcular power became greater, and at laſt an irreſiſtible propenſity to action was indulged in; I recollect but indiſtinctly what followed; I know that my motions were various and violent.

"Theſe effects very ſoon ceaſed after reſpiration. In ten minutes I had recovered my natural ſtate of mind. The thrilling in the extremities continued longer than the other ſenſations.

"This experiment was made in the morning; no languor or exhauſtion was conſequent, my feelings throughout the day were as uſual, and I paſſed the night in undiſturbed repoſe *."

But although it may be reſpired for a ſhort time with impunity, not more than 3 or 4 minutes, yet animals that are confined in it ſoon become reſtleſs and uneaſy, and at laſt expire. From this therefore it appears that it is unfit for the ſupport of animal life, and perhaps could not at all be reſpired, if the lungs were previouſly exhauſted of atmoſpheric air.

367 Taſte and ſmell. 5. The taſte of the nitrous oxide gas, when in a ſtate of purity, is diſtinctly ſweet to the tongue and palate; and it has an agreeable odour. Mr Davy obſerves, that he often thought it produced a feeling ſomewhat analogous, as he expreſſes it, to taſte in its application to the lungs; for in one or two experiments he perceived a diſtinct ſenſe of warmth in the cheſt †.

368 Is abſorbed by water. 6. Water abſorbs the nitrous oxide gas in conſiderable proportion. When the water is agitated, 0.54 parts of its bulk, or 0.27 of its weight, combine with it. The water becomes ſweetiſh, and the whole of the gas may be expelled from it unchanged, by boiling.

7. No change takes place upon this gas by the action of light, but when it is expoſed to a high temperature, as when the electric ſpark is ſent through it, or when it is made to paſs through a red-hot porcelain tube, it is decompoſed, and converted into common air and nitric acid.

Sect. III. *Of Nitrous Gas.*

369 How procured. 1. If a quantity of pure copper filings be put into a matraſs or retort, and diluted nitric acid be poured over them, a violent efferveſcence takes place, and a great quantity of gas is evolved. This is *nitrous gas*. It may be obtained alſo, by ſubſtituting for the copper other metals, as iron, ſilver, and mercury.

This gas is mentioned by Dr Hales, but it is to the labours of Dr Prieſtley that we are indebted for the knowledge of its nature and properties.

370 Properties. 2. This gas is an elaſtic, colourleſs fluid, which has no ſenſible taſte, and does not redden the tincture of turnſole (c).

According to Mr Kirwan, the ſpecific gravity of nitrous gas is 0.001458, but by Mr Davy's eſtimation it is 0.001343. The weight of 100 cubic inches of it is 34.26 grs. and it is compoſed of 55.95 oxygen, and 44.05 azote ‡. This gas is totally unfit for reſpiration. Animals that breathe it are inſtantly ſuffocated.

Some combuſtibles burn in this gas. Phoſphorus, when introduced into it in a ſtate of active inflammation, burns with almoſt as much vividneſs as in oxygen gas ||. Homberg's pyrophorus, a ſubſtance which takes fire when expoſed to the air, when introduced into this gas, inſtantly becomes red, and burns very vividly. In this experiment, and in the former with the phoſphorus, theſe ſubſtances combine with the oxygen of the nitrous gas, while heat and light are emitted and azotic gas is left behind.

371 Action of heat. 3. Nitrous gas, when expoſed to the action of heat, by being made to paſs through a red-hot porcelain tube, undergoes

---

* *Reſearches*, 1800.

* *Davy's Reſearches*, p. 457.

† *Ibid.* p. 460.

‡ *Ibid.* p. 565.

|| *Ibid.* p. 135.

(c) This is a teſt for acid ſubſtances, which will be mentioned particularly afterwards.

undergoes no change*. It is abſorbed by water. When the water is freed from air, it abſorbs about $\frac{1}{10}$ of its bulk of nitrous gas, at the common temperature, and when it is boiled or frozen, the gas ſeparates unchanged. The water thus impregnated with nitrous gas, has no peculiar taſte, nor does it alter the colour of vegetable blues.

372 Combines with oxygen.

4. When a quantity of atmoſpherical air is introduced into a jar containing nitrous gas, a red colour appears from the mixture of the two gaſes; they are diminiſhed in bulk, and heat is evolved. The product is nitrous acid. If oxygen gas be employed in place of atmoſpheric air, the whole of the two gaſes will be converted into a liquid. The diminution of bulk is owing to the condenſation of the elaſtic fluids, and the evolution of caloric muſt be aſcribed to the change of ſtate, from that of elaſtic fluid to that of liquid.

Azotic gas alſo enters into combination with oxygen in a different proportion from what has been ſtated above, forming nitrous and nitric acids; but theſe will come more properly to be treated of among the claſs of acids.

The following table exhibits at one view the different proportions of oxygen and azotic gaſes in the compounds formed by theſe two ſubſtances.

100 cubic inches.	Weight in grains.	In 100 grains, Proportions of	
		Azote.	Oxygen.
Atmoſpheric air	31.10	73.00	27.00
Nitrous oxide	50.20	63.30	36.70
Nitrous gas	34.26	44.05	55.95
Nitric acid	76.00	29.50	70.50

Chap. VI. Of HYDROGEN GAS.

373 Hiſtory.

1. This gas has been long known under the name of the *fire-damp* of the miners. Its combuſtible property is deſcribed in the works of Boyle and Hales, of Boerhaave, and of Stahl; but it was not till the year 1766 that its properties were particularly aſcertained, and the difference between it and atmoſpheric air pointed out by Mr Cavendiſh. Its properties and combinations were more fully inveſtigated by Prieſtley and Scheele, Senebier and Volta, under the name of *inflammable gas* or *air*. It is now diſtinguiſhed by the name of hydrogen gas, and its baſe by that of hydrogen.

Like the two former, oxygen and azote, it is never obtained in an uncombined ſtate. Its properties can only be examined in the ſtate of gas.

374 Method of procuring.

2. Hydrogen gas may be obtained in a ſtate of tolerable purity by the following proceſs. Take one part of clean iron filings, and introduce them into a tubulated retort, and add two parts of ſulphuric acid previouſly diluted with four times its bulk of water. A violent effervеſcence immediately takes place, and great abundance of air bubbles make their eſcape. Put in the ſtopper of the retort, and place the beak of it under the ſhelf in the pneumatic trough, and let the gas which comes over be received in proper veſſels. The gas which is thus obtained, is *hydrogen gas*, which is diſtinguiſhed by the following properties.

375 Properties.

3. In its phyſical properties it reſembles common air. It is inviſible and elaſtic, and may be indefinitely compreſſed and expanded.

Its ſpecific gravity has been variouſly eſtimated, owing, perhaps, to its different degrees of purity. According to Lavoiſier, it is 0.000094, which is nearly 12 times lighter than atmoſpherical air; but, according to Mr Kirwan, it is 0.00010.

Hydrogen gas is unfit for ſupporting combuſtion. If a lighted candle be ſuddenly plunged in a veſſel filled with hydrogen gas, it is immediately extinguiſhed; or if an inverted jar filled with hydrogen gas be ſuddenly brought over a lighted candle, it is extinguiſhed in the ſame way. The latter experiment is the moſt effectual, on account of the ſmall ſpecific gravity of the hydrogen gas, which is prevented from eſcaping by riſing upwards when the jar is inverted.

It is alſo unfit for reſpiration.

When ſmall animals are encloſed in a veſſel filled with this gas, they are ſoon thrown into convulſions, and expire. Scheele, however, who firſt made the attempt, breathed it ſeveral times without much injury. Fontana made the ſame experiment, and he ſuppoſes that this was owing to the common air in the lungs before reſpiration of the hydrogen gas; for when he made a full expiration, before he began to breathe the hydrogen gas, he could only inſpire it three times, and theſe three produced great languor and oppreſſion about the breaſt. This is confirmed by Mr Davy of the royal inſtitution, who, in ſome experiments on himſelf found, that after having exhauſted the lungs as much as poſſible, he could not reſpire this gas for half a minute. It produced uneaſy feelings in the cheſt, momentary loſs of muſcular power, and ſometimes a tranſient giddineſs *. From theſe experiments, therefore, it may be concluded, that hydrogen gas is totally incapable of ſupporting animal life.

376 Is combuſtible.

4. But although hydrogen gas be unfit for the ſupport of combuſtion, or for reſpiration, yet it is itſelf a highly combuſtible ſubſtance. If a jar be filled with hydrogen gas, and a burning taper be applied, the gas will take fire, and burn with a flame which is more or leſs coloured according to the purity of the gas. When the gas is in the pureſt ſtate that can be obtained, it is of a white colour; but when it holds charcoal in ſolution, it is of a reddiſh colour.

377 Combines with water only by preſſure.

5. Hydrogen gas, if other gaſes be entirely excluded, undergoes no change when it is kept in contact with water, nor is any part of it abſorbed by the water: But when artificial preſſure is employed, water is ſaid to abſorb a third part of its bulk of the gas.

378 A remedy in diſeaſe.

No perceptible change is obſerved in the taſte of the water thus impregnated with hydrogen gas; it is recommended by Mr Paul as beneficial in nervous diſorders, and in inflammatory fevers †.

379 Employed in balloons.

Hydrogen gas, on account of its being ſo much lighter than atmoſpherical air, has been employed for the purpoſe of filling air balloons. When perfectly pure, it is 12 or 13 times lighter than the ſame bulk of atmoſpherical air; but, in the uſual way of obtaining it, the ſpecific gravity of hydrogen gas is ſeven or eight times leſs than that of common air. See Aerostation.

380 Explodes.

6. If hydrogen gas and atmoſpherical air be mixed together, they remain unaltered; but if one part of oxygen

---

* *Lagrange*, vol. i. p. 122.

* *Davy's Reſearches*, p. 401.

† *Phil. Mag.* v. xv. p. 93.

381 With atmoſpheric air.

382 And with oxygen gas.

gen gas, and two parts of hydrogen gas, be introduced into a phial, and a burning taper be applied to its mouth, the mixed gaſes will explode with a loud noiſe, and the bulk will be greatly diminiſhed. The whole of the oxygen of the atmoſpheric air diſappears, and the azotic gas only remains. If one part of oxygen gas and 2½ parts of hydrogen gas be mixed together in a phial, and exploded in the ſame way, they both diſappear. This may be proved by mixing the two gaſes in a jar over water or mercury, and exploding them by means of the electric ſpark. The gaſes diſappear; a vacuum is conſequently formed in the jar, and the water or the mercury, by the preſſure of the air, is forced up. If the experiment has been made over mercury, and if the inſide of the jar was previouſly free from moiſture, drops of water will appear, which have been formed by the combination of the two gaſes. Water, therefore, is compoſed of oxygen and hydrogen gas. This is a caſe of true combuſtion. Oxygen combines with the combuſtible body; light and caloric are evolved, and the reſult of this action and combination is one of the products of combuſtion, namely water. The diſcovery of the compoſition of water, undoubtedly one of the moſt important in modern chemiſtry, will be the ſubject of the following ſection.

Sect. I. *Of Water.*

383 Importance in chemiſtry.

1. Water acts ſo important a part in many chemical actions and combinations, that its nature and properties ſhould be early known. Before the diſcoveries of modern chemiſtry, it was conſidered as a ſimple ſubſtance, and one of the four elements which enter into the conſtitution of all bodies in nature.

The fortunate diſcovery of the compoſition of water, is undoubtedly one of the moſt important which has been made in chemical ſcience. We have already mentioned, that the product of oxygen and hydrogen gaſes, when exploded together, is water (d): but in a ſubject of ſo much importance, it will be neceſſary to enter more into detail; and this we ſhall do, 1ſt, by ſtating the experiments on the baſis of which the proofs of its compoſition reſt; and 2dly, by giving a ſhort hiſtorical view of the progreſs of the diſcovery.

2. Various experiments have been made to aſcertain this fact; but thoſe which were made by Lavoiſier being on a larger ſcale, and performed with ſuch precautions as to inſure accuracy and preciſion, the following account of them will be the more ſatisfactory.

1. *Proof of the Compoſition of Water.*

384 Proof of the compoſition of water by analyſis.

Plate CXLII. Fig. 3.

Exper. a. Take a porcelain or glaſs tube from 8 to 12 lines diameter, and place it acroſs the furnace EFCD, with a gentle inclination from E to F (e). The higher extremity of the tube is then luted to the glaſs retort A, containing a known quantity of diſtilled water. To the lower extremity F is luted the worm SS, the lower end of which is fixed in the neck of the bottle H, which bottle has the bent tube KK fixed to a ſecond opening. This bent tube is intended to carry off any elaſtic fluids which may eſcape into the bottle H. A fire is then lighted in the furnace EFCD, ſufficient to keep the tube EF red hot, but not to melt it. The water in the retort A is kept boiling by a fire in the furnace VVXX. The water is gradually changed into ſteam by the heat of the two furnaces. It paſſes through the tube EF into the worm SS, where it is condenſed, and then drops into the bottle H. When the whole water is evaporated, and all the communicating veſſels are emptied into the bottle H, it is found to contain exactly the ſame quantity which was put into the retort. This experiment therefore is a ſimple diſtillation.

Exper. b. Every thing being diſpoſed as in the laſt experiment, let 28 grains of pure charcoal, broken into ſmall parts, and which has been expoſed to a red heat in a cloſe veſſel, be introduced into the tube EF. The experiment is then performed in the ſame manner as the former. The water is evaporated, and a portion of it is again condenſed in the worm SS, and then falls into the bottle H; but at the ſame time a conſiderable quantity of an elaſtic fluid eſcapes through the tube KK, which is received in veſſels. When the water is entirely evaporated, and the tube examined, the 28 grains of charcoal have wholly diſappeared.

When the water in the bottle H is examined, it is found to have loſt 85.7 grains of its weight; and when the elaſtic fluid which paſſed off by the tube KK is weighed, it is found to weigh 113.7 grains, which is exactly the weight which the water has loſt, added to the 28 grains of charcoal which had diſappeared. The elaſtic fluid, on examination, is diſcovered to be of two kinds; namely, 144 cubical inches of carbonic acid gas weighing 100 grains, and 380 cubical inches of a very light gas weighing only 13.7 grains. Now 100 grains of carbonic acid gas conſiſt of 72 grains of oxygen, combined with 28 grains of carbone. It is therefore evident, that the 28 grains of charcoal muſt have acquired 72 grains of oxygen from the water. It is alſo evident, that 85.7 grains of water are compoſed of 72 grains of oxygen, combined with 13.7 grains of a gas capable of being burned.

Exper. c. Every thing being put in the ſame order as in the two former experiments, with this difference, that inſtead of the 28 grains of charcoal, 274 grains of ſoft iron, in thin plates rolled up ſpirally, are introduced into the tube EF. The tube is kept red-hot while the water is evaporating from the retort. After

---

(d) Sir Iſaac Newton having diſcovered in the courſe of his optical inveſtigations, that combuſtible bodies poſſeſs the greateſt refractive power in proportion to their denſity, and obſerving the great refracting power of water, conjectured with aſtoniſhing ſagacity that it muſt contain a combuſtible ſubſtance. In the ſame way he was led to a ſimilar conjecture with regard to the diamond; both which have been verified.

(e) The tube EF, if of glaſs, ſhould be ſuch as can bear a ſtrong heat without melting. It ſhould alſo be coated over with a lute compoſed of clay and powdered ſtone-ware; and to prevent it from bending during the experiment, it muſt be ſupported about the middle by an iron bar.

After the water has been diſtilled, it is found to have loſt 100 grains. The gas or elaſtic fluid weighs 15 grains, and the iron has gained 85 grains additional weight, which put together make up 100 grains, the weight which the water has loſt. The iron has all the qualities which it would have received by being burned in oxygen gas. It is a true oxide (or calx) of iron. We have the ſame reſult as in the laſt experiment, and have therefore another proof for concluding, that 100 grains of water conſiſt of 85 grains of oxygen, and 15 of the baſe of inflammable gas.

385
Proved by ſyntheſis.

We have now exhibited two ſufficient proofs, that water is compoſed of oxygen and hydrogen; but as the compoſition of water is ſo intereſting and important a ſubject, M. Lavoiſier was not ſatisfied with theſe proofs alone. He juſtly concluded, that if water be a compound of two ſubſtances, it ought to follow, that by reuniting theſe two ſubſtances, water would be produced. He accordingly proved the truth of this concluſion by the following experiment.

Exper. d. He took a large cryſtal balloon A, fig. 4. containing about 30 pints, and having a large mouth; round which was cemented the plate of copper BC, pierced with four holes, through which four tubes paſs. The firſt tube H*h* is intended to exhauſt the balloon of its air, by adapting it to an air pump. The ſecond tube *gg* communicates with a reſervoir of oxygen gas placed at MM. The third tube *d*D∂ is connected with a reſervoir of hydrogenous gas at NN. The fourth tube contains a metallic wire GL, having a knob at its lower extremity L, from which an electric ſpark is paſſed to ∂, in order to ſet fire to the hydrogen gas. The metallic wire is moveable in the tube, that the knob L may be either turned towards ∂, or away from it, as there is occaſion. We muſt alſo add, that the three tubes H*h*, *gg*, *d*D∂ are furniſhed with ſtopcocks.

It is neceſſary that the oxygen gas, before being put into the reſervoir, ſhould be completely purified from carbonic acid. This may be done by keeping it for a long time in contact with a ſolution of cauſtic potaſh. The hydrogen gas ought to be purified in the ſame manner. The quantity employed ought to be double the bulk of the oxygen gas. It is beſt procured from water by means of iron, as was deſcribed in Experiment Third.

Great care muſt alſo be taken to deprive the oxygen and hydrogen gas of every particle of water. For this purpoſe they are made to paſs in their way to the balloon A, through ſalts which have a ſtrong attraction for water; as the acetite of potaſh (a compound of vinegar and vegetable alkali), or the muriate or nitrate of lime (the muriatic or nitric acid combined with lime). Theſe ſalts are diſpoſed in the tubes MM and NN of one inch diameter, and are reduced only to a coarſe powder, that they may not unite into lumps, and interrupt the paſſage of the gaſes.

Every thing being thus prepared for the experiment, the balloon is exhauſted of its air by the tube H*h*, and is filled with oxygen gas. The hydrogen gas is alſo preſſed in through the tube *d*D∂ by a weight of one or two inches of water. As ſoon as the hydrogen gas enters the balloon, it is ſet fire to by an electric ſpark. The combuſtion can be kept up as long as we pleaſe, by ſupplying the balloon with freſh quantities of theſe two gaſes. As the combuſtion advances, a quantity of water is collected on the ſides of the balloon, and trickles down in drops to the bottom of it. By knowing the weight of the gaſes conſumed, and the weight of the water produced, we ſhall find that they are preciſely equal. M. Lavoiſier and M. Meuſnier found that it required 85 parts by weight of oxygen gas, and 15 parts of hydrogen gas, to produce 100 parts of water.

Thus we have complete proofs, both analytical and ſynthetical, that water is not a ſimple elementary ſubſtance, as it has been long ſuppoſed, but is compounded of two elements, oxygen and hydrogen.

But although the knowledge of the component parts of water was finally confirmed by Lavoiſier and his friends, we ſhall find that ſcience is indebted for its origin and progreſs, chiefly, if not entirely, to the Engliſh philoſopers.

2. *Hiſtory of the Diſcovery of the Compoſition of Water.*

386
Combuſtion of hydrogen yields water.

387
Conjectures.

1. So early as the year 1776, an experiment was made by Macquer, to aſcertain what would be the product of the combuſtion of hydrogen gas. He accordingly ſet fire to a bottle full of it, and held a ſaucer over the flame, but no ſoot appeared upon it as he expected, for it remained quite clean; and was bedewed with drops which were found to be pure water. Various conjectures were now formed about the nature of the product of the combuſtion of oxygen and hydrogen gaſes. By ſome it was ſuppoſed the carbonic acid gas; by others it was conjectured it would be the ſulphurous or ſulphuric acid. The latter was the opinion of M. Lavoiſier. Such were the experiments and opinions of the French chemiſts, previous to the year 1781.

388
Experiment by Warltire and Prieſtley.

2. About the beginning of that year, Mr Warltire, a lecturer in natural philoſophy, had long entertained an opinion that the combuſtion of hydrogen gas with atmoſpheric air might determine the queſtion, whether heat be a heavy body. Apprehenſive of danger in making the experiment, he had for ſome time declined it; but was at laſt encouraged by Dr Prieſtley, and accordingly prepared an apparatus for the purpoſe. This was a copper veſſel properly fitted, and filled with atmoſpherical air and hydrogen gas, which was exploded by making the electric ſpark paſs through it. A loſs of weight of two grs. was obſerved after the combuſtion. A ſimilar experiment was repeated in cloſe glaſs veſſels, which, though clean and dry before the combuſtion, became immediately wet with moiſture, and lined with a ſooty matter. This ſooty matter, Dr Prieſtley afterwards ſuppoſed, proceeded from the mercury which had been employed in filling the veſſel.

389
By Cavendiſh.

3. During the ſame year, Mr Cavendiſh repeated the experiments of Mr Warltire and Dr Prieſtley. He performed them ſeveral times with atmoſpheric air and hydrogen gas, in a veſſel which held 24,000 grs. of water, and he never could perceive a loſs of weight more than $\frac{1}{5}$ gr. and often none at all. In all theſe experiments, not the leaſt ſooty matter appeared in the inſide of the glaſs. To examine the nature of the dew which appeared in the inſide of the glaſs, he burnt 500,000 grain meaſures of hydrogen gas with about $2\frac{1}{2}$ times that quantity of common air; and in this combuſtion

buſtion he obtained 135 grs. of water, which had neither taſte nor ſmell; and when it was evaporated, left no ſenſible ſediment. It ſeemed to be pure water.

In another experiment, he exploded in a glaſs globe, 19,500 grain meaſures of oxygen gas, and 37,000 of hydrogen gas, by means of the electric ſpark. The reſult of the experiment was 30 grains of water, which contained a ſmall quantity of nitric acid. The experiments of Mr Cavendiſh were made in the year 1781, and they are undoubtedly concluſive with regard to the compoſition of water.

390 Mr Watt's views. 4. It would appear, that Mr Watt entertained the ſame ideas on this ſubject. When he was informed by Dr Prieſtley of the reſult of theſe experiments, he obſerves; "Let us conſider what obviouſly happens in the deflagration of hydrogen and oxygen gaſes. Theſe two kinds of air unite with violence, they become red hot, and when cooling totally diſappear. When the veſſel is cooled, a quantity of water is found in it equal to the weight of the air employed. The water is then the only remaining product of the proceſs; and water, light, and heat, are all the products, unleſs there be ſome other matter ſet free, which eſcapes our ſenſes. Are we not then authorized to conclude, that water is compoſed of oxygen and hydrogen gaſes, deprived of part of their latent or elementary heat; that oxygen gas is compoſed of water, deprived of its hydrogen, and united to elementary heat and light; and that the latter are contained in it in a latent ſtate, ſo as not to be ſenſible to the thermometer or to the eye. And if light be only a modification of heat, or a circumſtance attending it, or a component part of the hydrogen gas, then oxygen gas is compoſed of water deprived of its hydrogen, and united to elementary heat."

Phil. Tranſ. 1784, p. 383.

Thus it appears that Mr Watt had a juſt view of the compoſition of water, and of the nature of the proceſs by which its component parts paſs to a liquid ſtate from that of an elaſtic fluid.

391 Lavoiſier's experiments. 5. Towards the end of the ſame year, M. Lavoiſier had made ſome experiments, the reſult of which ſurpriſed him; for the product of the combuſtion of the oxygen and hydrogen gaſes, inſtead of being ſulphuric or ſulphurous acid, as he expected it, was pure water. This led him to procure an apparatus, with which the experiment might be performed on a large ſcale, and with more accuracy and preciſion. Accordingly the experiments which we have already detailed were performed on the 24th of June 1783, in preſence of ſeveral academicians, and alſo of Sir Charles Blagden, who was at that time in Paris. A ſimilar experiment was afterwards performed by M. Monge, with the ſame reſult; and it was repeated again by Lavoiſier and Meuſnier, on a ſcale ſo large as to put the matter beyond a doubt. The concluſion, therefore, from the whole was (as has been ſtated in detailing the experiments themſelves), that water is compoſed of oxygen and hydrogen; and this fact, we believe, ſince Dr Prieſtley's death, is univerſally admitted.

392 Fourcroy's, &c. 6. If farther proofs were neceſſary to eſtabliſh the fact, we might refer the reader to an elaborate memoir on the combuſtion of hydrogen gas in cloſe veſſels by the celebrated chemiſts Fourcroy, Vauquelin, and Seguin, which was read at the academy of ſciences in the year 1790*.

393 Water in three ſtates. 7. Water exiſts in three different ſtates; in the ſolid ſtate or ſtate of ice; in the liquid, and in the ſtate of vapour or ſteam. Its principal properties have already been detailed, in treating of the effects of caloric. It aſſumes the ſolid form when it is cooled down to the temperature of 32°. In this ſtate it increaſes in bulk, by which it exerts a prodigious expanſive force, which is owing to the new arrangement of its particles, which aſſume a cryſtalline form, the cryſtals croſſing each other at angles of 60° or 120°. 394 Ice. The ſpecific gravity of ice is leſs than that of water.

395 Water or liquid. When ice is expoſed to a temperature above 32°, it abſorbs caloric, which then becomes latent, and is converted into the liquid ſtate, or that of water. At the temperature of 42½°, water has reached its maximum of denſity. According to the experiments of Lefevre Gineau †, a French cubic foot of diſtilled water, taken at its maximum of denſity, is equal to 70lb. 223 grs. French, =529,452.9492 troy grains. An Engliſh cubic foot at the ſame temperature weighs 437,102.4946 grains troy. By Profeſſor Robiſon's experiments it is aſcertained, that a cubic foot of water at the temperature of 55° weighs 998.74 avoirdupois ounces, of 437.5 grains troy each, or about 1¼ ounce leſs than 1000 avoirdupois ounces.

396 Vapour. When water is expoſed to the temperature of 212°, it boils, and if this temperature be continued, the whole is converted into an elaſtic inviſible fluid, called vapour or ſteam. This, as has been already ſhewn, is owing to the abſorption of a quantity of caloric, which is neceſſary to retain it in the fluid form. In this ſtate it is about 1800 times its bulk when in the ſtate of water. This ſhews what an expanſive force it muſt exert when it is confined, and hence its application in the ſteam engine, of which it is the moving power.

Sect. II. *Of Ammonia.*

Hydrogen alſo enters into combination with azote, and forms a compound of great importance. When hydrogen and azotic gaſes are mixed together, no change takes place, nor has any proceſs been yet diſcovered by which theſe two gaſes can be directly combined; but when theſe are in their naſcent ſtate, as it is called, or in the moment of evolution from the bodies with which they were formerly in combination, they unite together and form ammonia, or the volatile alkali. It is demonſtrated alſo by direct experiment, that this ſubſtance is compoſed of theſe two gaſes; but for the properties of it, we muſt refer to the chapter on alkalies, where they will be fully detailed.

Chap. VII. Of CARBONE.

397 The diamond combuſtible. 1. It may appear at firſt ſight ſurpriſing, that the diamond, one of the hardeſt and moſt indeſtructible ſubſtances in nature, ſhould be arranged among combuſtible bodies. This, however, was conjectured by Newton, when he conſidered its great refracting power, referring it to the general law, that combuſtible bodies have this power in greateſt perfection. The ſagacious conjecture

---

* *Annal. de Chim.* vol. viii. p. 230.

† *Journ. de Phyſ.* tom. xix. p. 171.

398
Proved by experiment.

conjecture of this great philoſopher has been fully verified. The firſt experiment to aſcertain the combuſtibility of the diamond, was made in the year 1694, in the preſence of Coſmo III. grand duke of Tuſcany, by the Florentine academicians. In this experiment, the diamond, expoſed to the heat of a burning-glaſs, firſt became dull and tarniſhed, loſt of its weight, and was at laſt entirely diſſipated, without the ſmalleſt reſidue. Some years afterwards, a ſeries of experiments was made before Francis I. emperor of Germany, in which diamonds were conſumed in the heat of a furnace. In the year 1771, Macquer firſt obſerved the diamond ſwell up and burn with a very ſenſible flame. Rouelle the younger, Cadet, Mitouart, and Darcet repeated the ſame experiments, all which tended to eſtabliſh the volatility and combuſtibility of the diamond.

But it is to the celebrated Lavoiſier that we are indebted for aſcertaining the nature and product of this combuſtion.

399
Found in the torrid zone.

400
Form.

2. But for the ſake of compariſon, we ſhall mention ſome of the general properties of the diamond. This precious ſtone is found in the warmer regions of the earth, and chiefly in the Eaſt Indies and the Brazils. It is found cryſtallized in regular octahedrons, which is its primitive form; that of the molecules is the regular tetrahedron. The moſt common form is the ſix-ſided priſm, terminating in a ſix-ſided pyramid. What are called ſpheroidal diamonds, have 48 curvilineal, triangular faces, which form of cryſtal is owing, according to Hauy, to a regular decrement, which may be determined by calculation. The lapidaries are well acquainted with the direction of the laminæ of the diamond, becauſe in that direction it is found to be moſt eaſily poliſhed. The hardeſt diamonds are found to have their fibres twiſted, which by the lapidaries are called *natural* diamonds.

401
Properties.

3. The diamond is the hardeſt body known. It can only be poliſhed with the powder of itſelf, which is procured by rubbing one diamond againſt another. The ſpecific gravity of the diamond is 3.5. One of its moſt remarkable properties is its brilliancy. When expoſed to the light of the ſun for ſome time, and afterwards carried into a dark place, it appears luminous, ſo that it has the property of abſorbing light. It becomes very ſenſibly electric by friction, and is therefore a non-conductor of electricity.

402
Product of its combuſtion.

4. As it was now aſcertained, that the diamond expoſed to a ſtrong heat was ſuſceptible of combuſtion, and might be entirely diſſipated, Lavoiſier directed his attention in the year 1772 to diſcover the product which was thus obtained; and he found by experiment, that the quantity of the diamond, expoſed to the heat of a burning-glaſs in oxygen gas, conſumed, was in exact proportion to the quantity of air which was abſorbed. This air was converted into carbonic acid gas (F). The quantity of the carbonic acid obtained being found proportional to the quantity of diamond conſumed, it was concluded that diamond was nothing elſe but pure carbone. This furniſhed a ſtriking analogy between the diamond and charcoal, from the combuſtion of which a ſimilar product is obtained. An experiment made by Guyton in the year 1785, and a ſimilar one repeated in 1797 by Mr Tennant, proved that the diamond is combuſtible, and that it burns like charcoal when thrown into melted nitre. The concluſion from which was, that the diamond and charcoal are compoſed of the ſame ſubſtance.

403
A ſimple ſubſtance.

404
Compared with charcoal, which is a compound.

5. We ſhall find in inveſtigating the properties of charcoal in the following ſection, that the one is a ſimple, the other a compound ſubſtance, which will enable us to explain the remarkable difference between many of the properties of the diamond and charcoal. Charcoal burns in the heat of an ordinary fire, but the diamond requires for its combuſtion a temperature not leſs than 5000°; nor is the difference between theſe two bodies in ſpecific gravity, hardneſs, and colour, leſs ſtriking. Lavoiſier had aſcertained that 100 parts of carbonic acid contained

28 charcoal,
72 oxygen.
100

In the experiments made by Guyton on the diamond, it appeared that carbonic acid gas is compoſed of

17.88 diamond,
82.12 oxygen.
100.00*.

If then 100 parts of carbonic acid gas, are compoſed of the ſame proportions of conſtituent parts, and theſe proportions are obtained both by the combuſtion of the diamond and charcoal, it muſt neceſſarily follow that the charcoal, which requires a ſmaller proportion of oxygen to make up the 100 parts of carbonic acid gas, muſt contain the difference of the quantity of oxygen between the quantity with which it combines, and the quantity neceſſary to ſaturate the diamond. Thus, diamond requires 82.12 of oxygen, and charcoal requires only 72, the difference between which is 10.12, which muſt have been previouſly combined with the charcoal before combuſtion. The 28 parts of charcoal, then, are compoſed of

17.88 diamond,
10.12 oxygen.
28.00

Hence it follows, that 100 parts of charcoal conſiſt of

63.86 diamond,
36.14 oxygen.
100.00

From this account, therefore, of the nature and properties of the diamond, it muſt be conſidered as a ſimple ſubſtance, and that ſubſtance which has received the name of carbone in the new chemical nomenclature; very different in its properties from charcoal, which is a compound ſubſtance, and has received the name of

---

* *Ann. de Chim.* tom. xxxi. p. 99.

(F) Carbonic acid gas, as will appear afterwards, is compoſed of carbone and oxygen.

oxide of carbone or diamond (G). But we ſhall conſider the properties of the compound more particularly in the following ſection.

Sect. I. *Of the* Combinations *of* Carbone *with* Oxygen.

Carbone enters into combinations with oxygen. 1. In the ſtate of charcoal or *oxide of carbone;* 2. In the form of gas, which has been denominated the *gaſeous oxide of carbone*, or *carbonic oxide;* and 3. In another proportion conſtituting *carbonic acid*, which alſo exiſts in the gaſeous ſtate. The nature and properties of the two firſt we are now to examine: the laſt will be treated of under the claſs of acids.

I. Of Charcoal.

405 Charcoal very abundant.

1. Charcoal exiſts in great abundance in animal and vegetable matters, and it is obtained by the partial decompoſition of theſe ſubſtances. It may be procured by burning wood in cloſe veſſels; and the matter that remains after this combuſtion, is a black, ſhining, brittle ſubſtance, which is well known under the name of charred wood, or charcoal. To obtain charcoal pure, it muſt be repeatedly waſhed with pure water, and be afterwards expoſed for ſome time to a ſtrong heat in cloſe veſſels. Thus prepared, if it be entirely deprived of moiſture and excluded from air, it may be expoſed to the ſtrongeſt heat without any change.

406 Method of preparing and purifying.

407 Properties.

2. Charcoal is a good conductor of electricity. When it is new made, it is found to have the property of removing the diſagreeable odour with which animal matters beginning to putrify, clothes and other ſubſtances, are tainted. On account of this property, perhaps, and alſo an account of its mechanical effects, it is greatly recommended as an excellent teeth powder. Charcoal ſeems to be quite indeſtructible. This is the beſt method of preſerving wood from decay, which is expoſed to the effects of air and moiſture. Stakes charred on the outſide, have remained in the ground for ſome thouſand years, and are ſtill in perfect preſervation. This ſeems to have been a common practice among the ancients.

3. Charcoal has neither taſte nor ſmell. It is inſoluble in water, but it abſorbs moiſture in conſiderable proportion. When it is well dried, charcoal attracts the air very greedily. A piece of charcoal well dried, placed under a jar over mercury, abſorbs the air, and the mercury aſcends rapidly; but if a little water be introduced into the jar, the charcoal abſorbs the moiſture, gives out the air, and the mercury deſcends. In ſome experiments made with this view, it appeared that charcoal abſorbed four times its bulk of air; and when the charcoal was plunged into water, a fifth part of this air was diſengaged, which being examined, a quantity of oxygen had diſappeared. In another experiment, the charcoal was introduced into a veſſel filled with oxygen gas, when it abſorbed eight times its bulk of the gas, and being plunged into water, gave out a fourth part. Theſe experiments were made by Delametherie ‡.

The experiments of Senebier ſeem to prove, that it was only the oxygen gas of the atmoſpheric air that was abſorbed by charcoal; but it has been ſince demonſtrated, that this only takes place when the charcoal is hot. The atmoſpheric air is abſorbed unchanged when the charcoal is cold.

4. When the temperature of pure charcoal is raiſed to redneſs, and is introduced into a jar of oxygen gas, it burns rapidly, giving out brilliant ſparks, but with little flame. The charcoal diſappears, and the oxygen gas is totally changed. By its combination with the charcoal during the combuſtion, it is converted into a peculiar gas which has received the name of *carbonic acid gas*, the component parts of which were diſcovered by M. Lavoiſier, to be

28 charcoal,
72 oxygen.

100

The properties of this acid will be fully deſcribed in its place among the claſs of acids.

408 Compoſition.

5. It is generally agreed among chemiſts, that charcoal conſiſts of oxygen and carbone; but a controverſy at preſent exiſts, whether hydrogen does not, in all caſes, enter into its compoſition? Charcoal prepared in the common way, always contains a portion of hydrogen. It is therefore to be conſidered as a triple compound, conſiſting of carbone, oxygen, and hydrogen. But according to the experiments of Deſormes and Clement, charcoal expoſed for ſome time in a cloſe veſſel to a very ſtrong heat, is entirely deprived of its hydrogen †. This, however, does not correſpond with the experiments of Mr Cruickſhank, in which the gaſes obtained from charcoal in all ſtates of preparation were always found to contain hydrogen.

6. There is no direct action between carbone and azotic gas; but by the action of a third ſubſtance. Compounds of azote, hydrogen and carbone, which are combined alſo with a greater or leſſer proportion of oxygen, frequently exiſt among vegetable and animal matters.

II. Of the Gaſeous Oxide of Carbone.

409 Hiſtory.

1. A peculiar inflammable gas, which has been conſidered of the ſame nature with the carbonated hydrogen gas to be deſcribed in the next ſection, was announced by Dr Prieſtley, from the manner of its production and properties, as a confirmation of the truth of the phlogiſtic theory. His experiments were ſoon repeated by many other chemiſts, and particularly by Mr Cruickſhank of Woolwich, who publiſhed a very ſatisfactory account of the nature, compoſition and properties of this gas. He gave it the name of the *gaſeous oxide of carbone.* He conſidered it as conſiſting of carbone united with oxygen; the oxygen and carbone exiſting in it being nearly in the proportion of two

---

(G) In the preſent nomenclature of chemiſtry, the word *oxide* is uſed to denote the combination of oxygen with a baſe, the product of which combination exhibits no acid properties, as in the preſent caſe, the combination of oxygen with carbone or diamond.

‡ *Journ. de Phyſ.* vol. xxv.

† *Ann. de Chim.* vol. xxxix. p. 29.

410 Methods of procuring.

two to one. Dr Prieſtley obtained it from the gray oxide, or forge ſcales of iron and charcoal. Mr Cruickſhank alſo obtained it by a ſimilar proceſs. He employed the oxides of zinc and copper; the black oxide of mangane*ſ*e and litharge. The gas which is obtained from theſe ſubſtances, is a mixture of carbonic acid and the gaſeous oxide of carbone. Mr Cruickſhank found, that the oxides which moſt readily part with their oxygen, afford the greateſt proportion of carbonic acid; but the oxides which retain their oxygen more ſtrongly, give the greateſt proportion of the gaſeous oxide of carbone. At the beginning of the proceſs, carbonic acid comes over in greateſt abundance; it then diminiſhes, and afterwards nothing but the gaſeous oxide is extricated.

It is alſo obtained by expoſing to a ſtrong heat one part of pure charcoal and three parts of carbonate of lime, ſtrontites, or barytes, in an iron retort. The carbonic acid which is in combination with the earths, is partly diſengaged unchanged, and partly decompoſed by the charcoal, and converted by the action of the charcoal into the gaſeous oxide of carbone. The gas which is obtained in this proceſs is compoſed of one part of carbonic acid and five parts of gaſeous oxide *.

The ſame gaſes are alſo obtained, by employing iron filings with the earthy carbonates, and the quantity is conſiderably increaſed when pure iron is uſed. Mr Cruickſhank and the French chemiſts alſo obtained it, by making carbonic acid gas paſs through red hot charcoal, in an iron or porcelain tube. The carbonic acid is decompoſed, and the gaſeous oxide is formed.

The carbonic acid which is mixed with the gaſeous oxide obtained in all theſe proceſſes, may be ſeparated by waſhing the gas with lime water, and the gaſeous oxide remains in a ſtate of purity.

411 Properties.

2. This gas is inviſible and elaſtic like common air. Its ſpecific gravity is 0.001167; 100 cubic inches weigh 30 grains.

It is unfit for reſpiration. Small animals introduced into it are inſtantaneouſly ſuffocated; and in ſome perſons who attempted to breathe it, it produced faintneſs and giddineſs. Delormes and Clement think that it is probably owing to this gas diſengaged from burning charcoal, that ſudden death is induced in cloſe apartments. It is not altered by paſſing it through a red-hot tube, nor does it undergo any change by being expoſed to light; and it is neither inflamed nor diminiſhed by paſſing the electric ſpark through it. This gas in contact with common air, when ſet fire to, burns with a blue flame. When it is made to traverſe a red-hot tube full of air, it produces ſlight detonations. The reſidue of theſe combuſtions is carbonic acid and azote.

3. With oxygen gas, if in conſiderable proportion, the combuſtion is very rapid; a red flame is produced, and the whole of the gas is conſumed. The reſidue in this combuſtion is carbonic acid †.

According to Mr Cruickſhank, the gaſeous oxide of carbone is a compound of carbone and oxygen. Thirty grains of it obtained from charcoal and metallic oxides, required 15 grains of oxygen to ſaturate it, and the quantity of carbonic acid produced was 35.5. Thirty grains obtained from iron filings and earthy carbonate, required 13.6 grains of oxygen, which gave 43.2 grains of carbonic acid.

4. But according to the experiments and concluſions of Berthollet, the gaſeous oxides of carbone contain a certain portion of hydrogen in their compoſition. This quantity, he thinks, amounts to about .04=$\frac{1}{25}$. He diſtinguiſhes two ſpecies of inflammable gas, which contain carbone; the one conſiſts entirely of hydrogen and carbone, which he propoſes to denominate *carbonated hydrogen gas*, which will be treated of in the next ſection. The other ſpecies of inflammable gas is alſo formed of hydrogen and carbone, but contains a certain portion of oxygen. To this he propoſes to give the name of oxycarbonated hydrogen gas. But the reſults of the experiments of Cruickſhank and others do not correſpond with the experiments and concluſions of Berthollet, in admitting any proportion of hydrogen as a component part of his oxycarbonated hydrogen gas, or of the gaſeous oxide of carbone. But for an account of his obſervations and reaſonings on this ſubject. See *Memoires de l'Inſtitut Nation.* tom. iv. p. 269, 319, and 325.

SECT. II. *Of CARBONATED HYDROGEN GAS.*

412 Method of procuring.

1. If a quantity of wet charcoal be introduced into a retort, and expoſed to a red-heat, a great quantity of gas paſſes over, which may be collected in jars in the pneumatic apparatus, in the uſual way. It may be alſo obtained by making the vapour of water paſs through red-hot charcoal in a porcelain or iron tube placed acroſs a furnace. The water is decompoſed; the hydrogen, one of its component parts, combines with the carbone of the charcoal. The gas obtained by theſe proceſſes has been called *light inflammable air*. A ſimilar gas may be procured from ether, ſpirits of wine or camphor, by making the vapour of theſe ſubſtances paſs through red-hot porcelain tubes. This gas, from its greater ſpecific gravity, has been called *heavy inflammable air*. The proportions of the ſubſtances which enter into the compoſition of this gas vary conſiderably according to the proceſs employed, or the materials from which it is obtained. It is the ſame gas which is given out in great abundance during hot weather, from ſtagnant waters.

413 Properties.

2. This gas is like common air, inviſible and elaſtic. When a candle is applied to it, it burns with a blue, lambent flame. If it be mixed with atmoſpheric air, the combuſtion is more rapid and brilliant, and ſtill more ſo when it is mixed with oxygen gas, but without any detonation. The product of this combuſtion is carbonic acid and water. The oxygen combines partly with the carbone, and forms carbonic acid; and partly with the hydrogen, and forms water.

3. It is totally unfit for reſpiration. Animals introduced in it are inſtantly ſuffocated. It is alſo unfit for ſupporting combuſtion.

One of the moſt remarkable properties of this gas is, when it is mixed in a tube with common air or oxygen gas, about $\frac{2}{3}$ds its bulk of the latter, and fired by the electric ſpark, there is a conſiderable increaſe of volume.

414 Compoſition.

The component parts of carbonated hydrogen gas obtained from different ſubſtances, as they have been aſcertained by Mr Cruickſhank, are the following. When it is procured from ether, camphor, or ſtagnated water, it contains the greateſt proportion of carbone. The ſpecific gravity is 0.000804, and it is to common air nearly

---

* *Ann. de Chim.* tom. xxxix. p. 45.

† *Ibid.* p. 58.

nearly as two to three. One part by weight of hydrogen gas holds in ſolution $5\frac{1}{2}$ parts of carbone;

100 parts contain 52.35 carbone,
9.60 hydrogen,
38.05 water inſtead of vapour.
100.00

When it is obtained from ether, the ſpecific gravity is 0.000787:

100 parts contain 45 carbone,
15 hydrogen,
40 water.
100

When it is obtained from ſpirit of wine, the ſpecific gravity is 0.00063:

100 parts contain 44.1 carbone,
11.8 hydrogen,
44.1 water.
100.0

The lighteſt is obtained from diſtilling wet charcoal, or paſſing the vapour of water through red-hot charcoal. It contains one part by weight of hydrogen gas, holding three parts of carbone in ſolution. The ſpecific gravity is 0.000554. It is to common air nearly as one to two;

100 parts contain 28 carbone,
9 hydrogen,
63 water †.
100

Mr Cruickſhank has diſcovered a very eaſy method of diſtinguiſhing the gaſeous oxide of carbone from the carbonated hydrogen gas. A mixture of the latter and oxymuriatic acid gas may be exploded by paſſing electric ſparks through it. But a mixture of oxymuriatic acid gas and the gaſeous oxide of carbone ſuffers no change by the action of electricity.

The following table, drawn up by Mr Cruickſhank, exhibits the reſults of his experiments on theſe two gaſes.

A Table, *ſhewing the Analyſis, &c. of the different Species of Carbonated Hydrogen Gas, or Hydrocarbonates, and of the Gaſeous Oxide of Carbone.*

Gaſes, and the different Subſtances from which the Gaſes are obtained, &c.	Weight of 100 Cubic Inches, or Grains.	Proportion of Oxygen neceſſary to ſaturate 100 Meaſures of the Gas.		Products when combined with Oxygen.				Hence the Gaſes conſiſt of			
				Carbonic Acid.		Water produced.	Water held in Solution by the Gas.	Oxyg.	Carbon.	Hydro	Water.
	Grains.	Meaſ.	Quan. of Grains.	In Vol. Meaſ.	In Quan. Grains.	Grains.	Grains.				
Pure carbonated hydrogen gas from camphor, &c.	21	176	59,8	116	54,5	18	8 or 9	none	11	2+	8 or 9
—— from ether	20	170	58	108	50,5	18	9	none	9	3	8
—— from alcohol	16	118	40	75	36	13	7	none	7	1,9	7
—— wet charcoal	14,5	66	22,4	40	19	9	9	none	4	1,3	9
Gaſeous oxide from charcoal and metallic oxides	30	44	15	76	35,5	about 8	prob^y none	about 15	nearly 15	1+	uncertain
—— from iron filings, and carbonate of lime, or barytes	30	40	13,6	92	43,2	none	none	21+	8,6	none	none

Chap. VIII. Of PHOSPHORUS.

415 History.

1. This ſingular ſubſtance was accidentally diſcovered in 1677 by an alchemiſt of Hamburg, named Brandt, when he was engaged in ſearching for the philoſopher's ſtone. Kunkel, another chemiſt, who had ſeen the new product, aſſociated himſelf with one of his friends named Krafft, to purchaſe the ſecret of its preparation; but the latter deceiving his friend, made the purchaſe for himſelf, and refuſed to communicate it. Kunkel, who at this time knew nothing farther of its preparation, than that it was obtained by certain proceſſes from urine, undertook the taſk, and ſucceeded. It is on this account that this ſubſtance long went under the name of Kunkel's phoſphorus. Mr Boyle is alſo conſidered as one of the diſcoverers of phoſphorus. He communicated the ſecret of the proceſs for preparing it to the Royal Society of London in 1680. It is aſſerted, indeed, by Krafft, that he diſcovered the ſecret to Mr Boyle, having in the year 1678 carried a ſmall piece of it to London, to ſhew it to the royal family; but there is little probability, that a man of ſuch integrity as Mr Boyle, would claim the diſcovery of the proceſs as his own, and communicate it to the Royal Society, if this had not been the caſe.

Mr Boyle communicated the proceſs to Godfrey Hankwitz, an apothecary of London, who for many years

---

† *Nicholſon's Journal*, vol. v. p. 1.

years ſupplied Europe with phoſphorus; and hence it went under the name of *Engliſh phoſphorus*. Many chemiſts now attempted to produce phoſphorus, and different proceſſes had been publiſhed for the purpoſe; but it would appear that they rarely ſucceeded.

In the year 1737, a ſtranger having ſold to the French government a proceſs for making phoſphorus, the Academy of Sciences charged Dufay, Geoffroy, Duhamel, and Hellot, to ſuperintend it. The latter publiſhed an account of the experiment, which ſucceeded. Rouelle the elder exhibited phoſphorus which he had prepared, in the courſe which he opened at Paris ſome years after. In the year 1743, Margraaf made a great improvement in the proceſs, but ſtill it continued to be obtained with difficulty, and in very ſmall quantity. It was not till 30 years after, that conſiderable improvement was made in the proceſs for procuring phoſphorus.

416 Exiſts in bones. In the year 1774, the Swediſh chemiſts, Gahn and Scheele, made the important diſcovery, that phoſphorus is contained in the bones of animals, and they improved the proceſſes for procuring it.

417 Proceſs for obtaining 2. The moſt convenient proceſs for obtaining phoſphorus ſeems to be that recommended by Fourcroy and Vauquelin *. Take a quantity of burnt bones and reduce them to powder. Put 100 parts of this powder into a porcelain or ſtone-ware baſon, and dilute it with four times its weight of water. Forty parts of ſulphuric acid are then to be added in ſmall portions, taking care to ſtir the mixture after the addition of every portion. A violent efferveſcence takes place, and a great quantity of air is diſengaged. Let the mixture remain for 24 hours, ſtirring it occaſionally, to expoſe every part of the powder to the action of the acid. The burnt bones conſiſt of the phoſphoric acid and lime; but the ſulphuric acid has a greater affinity for the lime than the phoſphoric acid. The action of the ſulphuric acid uniting with the lime, and the ſeparation of the phoſphoric acid, occaſion the efferveſcence. The ſulphuric acid and the lime combine together, being inſoluble, and fall to the bottom.

Pour the whole mixture on a cloth filter, ſo that the liquid part which is to be received in a porcelain veſſel may paſs through. A white powder, which is the inſoluble ſulphate of lime, remains on the filter. After this has been repeatedly waſhed with water, it may be thrown away, but the water is to be added to that part of the liquid which paſſed through the filter.

Take a ſolution of ſugar of lead in water, and pour it gradually into the liquid in the porcelain baſon. A white powder falls to the bottom, and the ſugar of lead muſt be added ſo long as any precipitation takes place. The whole is again to be poured upon a filter, and the white powder which remains is to be well waſhed and dried. The dried powder is then to be mixed with one-ſixth of its weight of charcoal powder. Put this mixture into an earthen-ware retort, and place it in a ſand bath with the beak plunged into a veſſel of water. Apply heat, and let it be gradually increaſed, till the retort becomes red hot. As the heat increaſes, air-bubbles ruſh in abundance through the beak of the retort, ſome of which are inflamed when they come in contact with the air at the ſurface of the water. A ſubſtance at laſt drops out ſimilar to melted wax, which congeals under the water. This is phoſphorus.

418 and purifying it. In this ſtate the phoſphorus is not quite pure. It is generally mixed with ſome charcoal powder, and a portion of half burnt phoſphorus, which give it a brown colour. To have it quite pure, melt it in warm water, and ſtrain it ſeveral times through a piece of ſhamoy leather under the ſurface of the water (H). To mould it into ſticks, take a glaſs funnel with a long tube, which muſt be ſtopped with a cork. Fill it with water, and put the phoſphorus into it. Immerſe the funnel in boiling water, and when the phoſphorus is melted and flows into the tube of the funnel, then plunge it into cold water, and when the phoſphorus has become ſolid, remove the cork, and puſh the phoſphorus from the mould with a piece of wood. Thus prepared, it muſt be preſerved in cloſe veſſels containing pure water.

419 Properties. 3. When phoſphorus is perfectly pure, it is ſemitranſparent, and has the conſiſtence of wax. It is ſo ſoft that it may be cut with a knife. Its ſpecific gravity is from 1.770 to 2.033. It has an acrid and diſagreeable taſte, and a peculiar ſmell ſomewhat reſembling garlic. When a ſtick of phoſphorus is broken, it exhibits ſome appearance of cryſtallization. The cryſtals are needle-ſhaped, or long octahedrons; but to obtain them in their moſt perfect ſtate, the ſurface of the phoſphorus, juſt when it becomes ſolid, ſhould be pierced, that the internal liquid phoſphorus may flow out, and leave a cavity for their formation.

420 Action of light. 4. When phoſphorus is expoſed to the light, it becomes of a reddiſh colour, which appears to be an incipient combuſtion. It is therefore neceſſary to preſerve it in a dark place. 421 Of heat. At the temperature of 99° it becomes liquid, and if air be entirely excluded, it evaporates at 219°, and boils at 554°. At the temperature of 43° or 44°, it gives out a white ſmoke, and is luminous in the dark. This is a ſlow combuſtion of the phoſphorus, which becomes more rapid as the temperature is raiſed. When phoſphorus is heated to the temperature of 148°, it takes fire, burns with a bright flame, and gives out a great quantity of white ſmoke.

Phoſphorus enters into combination with oxygen, azote, hydrogen, and carbone.

SECT. I. *Of the* COMBINATIONS *of* PHOSPHORUS *with* OXYGEN.

Phoſphorus enters into combinations with oxygen in different proportions.

I. Oxide of Phoſphorus.

When phoſphorus is expoſed to the light, or is kept in water that is not freed from air, it ſoon becomes of a white colour, having loſt its tranſparency, and afterwards

---

* *Mem. de l'Inſt.* tom. ii. p. 282.

(H) The leather ſhould only be employed once, for the phoſphorus which is ſtrained through it afterwards will be coloured.

422 To ſeparate the oxide.

wards changes to a brown. This is the firſt combination of oxygen with it, and being in the ſmalleſt proportion, and giving no acid properties to the compound, it has been denominated an *oxide of phoſphorus*. This ſhews that it is neceſſary to keep it excluded from air and light. But phoſphorus thus changed on the ſurface may be freed from that part which is oxidated by a very ſimple proceſs. Diſſolve the phoſphorus in warm water, the whole melts except the oxidated part, which remains at the ſurface, becauſe it is not ſoluble at the ſame temperature.

II. Acids.

423 Production.

1. When phoſphorus is burned in common air confined in a veſſel, the combuſtion is pretty rapid, and continues till the whole of the oxygen be conſumed. A great quantity of white fumes are produced, and when theſe fumes are mixed with water which abſorbs them, it is found to have acid properties. This is the *phoſphorous acid*, in which the oxygen is in ſmaller proportion than in the following, but greater than in the oxide.

424 Splendid combuſtion.

2. But when a ſmall bit of phoſphorus is introduced into a jar filled with oxygen gas at the temperature of 60°, it diſſolves ſlowly, but does not appear luminous till the temperature be raiſed to 80°, which ſhews that phoſphorus requires a higher temperature to burn in oxygen gas than in common air. And if the phoſphorus be introduced into the oxygen gas, which is perfectly pure at a lower temperature, it undergoes no change, gives out no ſmoke, and is not luminous in the dark. But when it is immerſed in a ſtate of ignition into oxygen gas, it exhibits the moſt brilliant combuſtion that can be conceived. The light which is emitted is almoſt as ſplendid as that of the ſun, and is too powerful for the eye to bear. During this combuſtion the oxygen gas diſappears, it loſes its gaſeous form, and becomes ſolid in combination with the phoſphorus. It is during this change from the fluid to the ſolid ſtate that the caloric is emitted; and the light, according to Gren's theory of combuſtion, is given out by the phoſphorus. The product is a concrete ſubſtance which adheres to the ſides of the jar. This is the *phoſphoric acid*, in which there is a greater proportion of oxygen in combination with the phoſphorus. Theſe acids will be treated of in the chapter on acids.

SECT. II. *Of* PHOSPHORATED AZOTIC GAS.

425 Phoſphorus combines with azotic gas without emitting light.

1. At firſt ſight it ſeems difficult to explain the reaſon that phoſphorus requires a higher temperature for its combuſtion in oxygen gas than in common air. But the cauſe of this ſingular phenomenon appears by examining the effects of azotic gas on phoſphorus. The phoſphorus, which is readily converted into vapour at a low temperature, combines with the azotic gas without combuſtion, and therefore without giving out any light. The azotic gas is thus ſaturated with the phoſphorus, and its bulk is increaſed about $\frac{1}{40}$. The combination is denominated *phoſphorated azotic gas*.

2. When oxygen gas is introduced into a jar filled with this gas, it becomes luminous, becauſe there is a combuſtion of the phoſphorus which is held in ſolution by the azotic gas. The combuſtion is more rapid and brilliant when the phoſphorated azotic gas is let up into the jar of oxygen gas.

SECT. III. *Of* PHOSPHORIZED *and* PHOSPHORATED HYDROGEN GAS.

426 Phoſphorus diſſolved in hydrogen gas.

1. When a piece of phoſphorus is put into a jar filled with hydrogen gas, it does not appear luminous in the dark. But, after having remained for ſeveral hours, part of the phoſphorus is diſſolved. When this gas, to which Fourcroy and Vauquelin have given the name of phoſphorized hydrogen gas, is introduced into a jar of oxygen gas, each bubble, as it paſſes up and comes in contact with the gas, produces a very brilliant bluiſh flame, which fills the whole veſſel. This effect does not take place in atmoſpheric air. This gas holds in ſolution only a ſmall proportion of phoſphorus; but it is owing to the combuſtion of this portion that the flame appears in the oxygen gas. This gas has a leſs fetid odour than that which is next to be deſcribed. It has, however, a ſlight ſmell of garlic *.

427 Hiſtory.

2. Phoſphorated hydrogen gas was diſcovered by M. Gengembre in 1783, by boiling a ſolution of potaſh on phoſphorus, and by Mr Kirwan in the following year. Its nature and properties have been more completely inveſtigated by M. Raymond in two papers in the *Annales de Chimie* for 1791 and 1800. It may be obtained by introducing a bit of phoſphorus into a jar of hydrogen gas ſtanding over mercury, and melting the phoſphorus by means of a burning glaſs. The phoſphorus is thus converted into the ſtate of vapour, when the hydrogen gas diſſolves a much greater proportion. But a more ſimple proceſs has been recommended by Raymond.

428 Proceſſes for obtaining it.

Take two ounces of quicklime, ſlaked in the air, about 60 grs. of phoſphorus, and half an ounce of water; reduce the whole to a paſte, and put it immediately into a ſmall glaſs or ſtone-ware retort, the body of which may be filled with the materials. Immerſe the beak of the retort under water in the pneumatic trough, and apply a moderate heat. As ſoon as the retort is heated, the gas begins to come over; and when the bubbles come to the ſurface of the water in contact with the air, they explode with flame and ſmoke. When the gas paſſes off ſlowly the bubbles are larger; and when they reach the ſurface they exhibit an elegant appearance, forming, after exploſion, a beautiful coronet of white ſmoke, which riſes with an undulatory motion to the cieling, when the air is ſtill. When this gas is brought into contact with oxygen gas, the combuſtion is more rapid and more brilliant.

429 Products by combuſtion.

The products of the combuſtion of this gas are phoſphoric acid and water. The phoſphorus which is held in ſolution by the hydrogen, combines with the oxygen, and forms phoſphoric acid; while the hydrogen unites with another portion of oxygen and forms water.

430 Properties.

This gas has a very fetid odour, which has ſome reſemblance to the ſmell of putrid fiſh. When pure water is agitated in contact with this gas, it abſorbs about one-fourth of its bulk at the temperature of 50°. The colour of the ſolution is not quite ſo deep as that of roll

---

* *Ann. de Chim.* vol. xxi. p. 203.

roll ſulphur. The ſmell is ſtrong and diſagreeable, and the taſte extremely bitter. It does not appear luminous in the dark. But when it is expoſed nearly to the temperature of boiling, the whole of the phoſphorated hydrogen gas is driven off unchanged, and the water remains behind perfectly pure. When the ſolution is expoſed to the air, the oxide of phoſphorus is depoſited, and the hydrogen gas eſcapes *.

Sect. IV. *Phosphuret of Carbone.*

Phoſphorus enters into combination with charcoal, 430 How produced. and forms what Prouſt, who diſcovered it, denominates *phoſphuret of carbone.* It is produced during the diſtillation of phoſphorus, and remains behind on the leather, when it is ſtrained through it to purify it from this ſubſtance. It is of a red colour, and does not melt like pure phoſphorus. If it be diſtilled with a gentle heat, there is ſeparated a ſmall portion of phoſphorus which it contains in exceſs. But the true compound of phoſphuret of carbone is not decompoſed 431 Action of heat. without a very ſtrong heat. When the veſſels have cooled there is found a light, flocculent powder, of a lively orange red, which M. Prouſt conſiders as the phoſphuret of carbone. If it be expoſed to a red heat in the retort in which it is formed, the whole of the phoſphorus is driven off, and the charcoal remains behind. When this phoſphuret is expoſed to the open air on a heated metallic plate, it burns rapidly; but the charcoal which abſorbs the phoſphoric acid, as it is formed, eſcapes the combuſtion. It loſes, in a ſhort time, the property of burning, by being expoſed to the air, and then it may be preſerved without any riſk of its catching fire ſpontaneouſly †.

Chap. IX. Of SULPHUR.

432 A ſimple ſubſtance. 1. Sulphur is a ſimple undecompounded combuſtible ſubſtance, which is univerſally diffuſed in nature; but moſt commonly in a ſtate of combination with mineral, vegetable, or animal matters. It is found in ſome mineral waters, but in greateſt abundance in volcanic countries, where it is a valuable article of commerce.

433 Properties. 2. Sulphur, as it is extracted from minerals and purified by art, is a hard brittle ſubſtance of a yellow colour, which can be eaſily reduced to powder. It is always opaque, has a lamellated fracture, and becomes electric by friction. The ſpecific gravity, after it is melted, does not exceed 1.9907. It has no ſmell, and very little perceptible taſte. When it is rubbed ſome time, it is volatilized, and diffuſes a peculiar and ſlightly fetid odour, by which it is eaſily diſtinguiſhed. It leaves on the ſkin which has been in contact with it, a very ſtrong ſmell, which remains for ſome hours. It is inſoluble in water.

434 Action of heat. 3. Light has no ſenſible effect on ſulphur. But if a roll of ſulphur be held in the hand for a little, it begins to crackle, and at laſt it breaks to pieces. When a temperature equal to that of boiling water is applied to ſulphur, it melts, becomes liquid and tranſparent, and changes to a brown red colour; but, on cooling, if the fuſion is not too long continued, it reſumes the yellow 435 Cryſtallizes. colour. If it be permitted to cool ſlowly, it cryſtallizes into priſmatic needles. The cryſtals are better formed by pouring out part of the liquid ſulphur as ſoon as the ſurface has become ſolid.

436 Becomes viſcid. 4. If the heat be continued it becomes thick and viſcid; and if it be then poured into cold water, it retains its ſoftneſs, ſo that it is employed for taking impreſſions of ſeals and medals. In this ſtate they are called *ſulphurs.* 437 Is ſublimed. When ſulphur is expoſed to heat in cloſe veſſels, it is volatilized or ſublimed in the form of a very fine powder, known under the name of flowers of sulphur.

Sulphur enters into combination with oxygen, azote, hydrogen, carbone, and phoſphorus.

438 With azotic gas. The combination of ſulphur with azotic gas has been little examined. Part of the ſulphur is diſſolved, when it is heated in a veſſel filled with the gas. This *ſulphurated azotic gas*, as it is called, has a fetid odour. When the temperature is diminiſhed, part of the ſulphur is depoſited. It has been lately diſcovered in the mineral waters of Aix-la-Chapelle.—We ſhall conſider the other combinations of ſulphur in the following ſections.

Sect. I. *Sulphur combined with Oxygen.*

439 Oxide. 1. When ſulphur is kept ſome time in fuſion in an open veſſel, it aſſumes a red colour, and becomes viſcid. After it is cooled, it retains its red colour, which is owing to the combination of oxygen in ſmall proportion with the ſulphur. In this ſtate it has been denominated the *oxide of ſulphur.* According to the experiments of Dr Thomſon, the oxide of ſulphur, formed by melting the ſubſtance in a deep veſſel, is of a dark violet colour, fibrous fracture, and tough conſiſtence; the ſpecific gravity is 2.325. It contained $2\frac{4}{10}$ per cent. of oxygen. Another oxide, containing 6.2 per cent. of oxygen, was formed by paſſing a current of oxy-muriatic acid gas through flowers of ſulphur *.

440 Burnt in common air. 2. When ſulphur is burnt in the open air, it emits a pale blue flame, with a great quantity of white ſmoke. When theſe fumes are mixed with water, it is found to poſſeſs acid properties. This is a combination of ſulphur with a greater proportion of oxygen than exiſts in the oxide, and is called *ſulphurous acid.*

441 In oxygen gas. 3. But when ſulphur is burnt in oxygen gas, a very rapid combuſtion takes place with a reddiſh white flame, and it combines with a greater proportion of oxygen. When the fumes which are copiouſly emitted during this combuſtion are collected and mixed with water, it exhibits the properties of an acid, which is the *ſulphuric acid.* Thus it appears, that ſulphur combines with oxygen in four different proportions. In two of theſe, in which the proportions are ſmalleſt, the compounds are denominated oxides; but in the two others, in which the proportion of oxygen is increaſed, the compounds are acids, the properties of which will be afterwards inveſtigated.

Sect. II. *Sulphurated Hydrogen Gas.*

442 Method of procuring. 1. This gas may be procured by various proceſſes. It may be obtained by making hydrogen gas paſs through melted ſulphur. In this way the hydrogen gas enters into combination with ſulphur. The ſame gas may alſo be obtained by melting together in a crucible

---

* *Ann. de Chim.* vol. xxxv. p. 234.

† *Ibid.* p. 44.

* *Ann. de Chim.* vol. xxi. p. 207.

equal parts of iron filings and ſulphur, by which means a black brittle maſs is formed, which is to be reduced to powder, and introduced into a glaſs veſſel (fig. 6.) with two mouths, the one of which has a ſtopper A and the other a bent tube B, accurately ground to fit the mouths C, D. When the mixture of iron filings and ſulphur has been introduced into the phial, the bent tube is to be fitted into the mouth, with the other end under the ſurface of the water in the trough E. The apparatus being thus prepared, pour in muriatic acid through the other opening, and immediately cloſe it with the ground ſtopper. The ſulphurated hydrogen gas is copiouſly diſengaged, and fills the glaſs jar F, which is previouſly placed on the ſhelf to receive it. This gas was formerly known by the name of *hepatic gas*.

443 Properties. 2. The odour is extremely fœtid, reſembling that from the waſhings of a gun, or from rotten eggs, which is owing to the extrication of the ſame gas. The ſpecific gravity of this gas is 0.00135.

It is unfit for reſpiration, and a taper immerſed in it is extinguiſhed, ſo that it is alſo unfit for ſupporting combuſtion. When it is inflamed in contact with atmoſpheric air or oxygen gas, it burns with a reddiſh blue flame, and depoſits a quantity of ſulphur. Sulphur alſo is depoſited by ſimple expoſure to the air. From this it appears, therefore, that the affinity of hydrogen for oxygen is ſtronger than for ſulphur. During the combuſtion, the hydrogen unites with the oxygen, and the ſulphur is depoſited. It is from this depoſition that the ſulphur found about mineral ſprings, the waters of which contain this gas, is derived.

444 Compoſition. 3 According to the experiments of Thenard, 100 parts by weight of ſulphurated hydrogen gas contain

70.857	ſulphur,
29.143	hydrogen.
100.000 *.	

445 Diſſolves phoſphorus. 4. Sulphurated hydrogen gas has the property of diſſolving phoſphorus. Fourcroy and Vauquelin introduced pieces of phoſphorus into a jar filled with this gas over mercury. After the phoſphorus had been expoſed to the gas for twelve hours, the atmoſpheric air was admitted, and there inſtantly appeared a bluiſh, voluminous flame. The bubbles of the gas diffuſed in the air, preſented by day light a white vapour, which ſeemed to adhere like viſcid matter to the ſurface of the mercury; but in the dark, exhibited a very brilliant light. The mercury in the trough in which the experiment was made, continued for ſome minutes to give out ſparks of light by agitation. The hands plunged into this gas, continued luminous for ſome minutes, and a ſponge introduced into it retained the ſame property for ſome time in the air †.

5. Sulphurated hydrogen gas is very readily abſorbed by water, and in this ſtate it poſſeſſes ſome of the properties of an acid. It changes vegetable blues to a red colour.

SECT. III. *Carburet of Sulphur.*

446 With carbone in different proportions. 1. Sulphur and carbone combine together at a high temperature, and probably in different proportions; one of theſe combinations is liquid, at the ordinary temperature and preſſure of the atmoſphere. This is the carburet of ſulphur. The following method of preparing it is given by Clement and Deſormes, who have particularly inveſtigated the action of ſulphur and charcoal.

447 Preparation. 2. Put a quantity of charcoal in ſmall pieces, or in powder previouſly dried, into a porcelain tube, which is to paſs through a furnace that it may be expoſed to a red heat. The gas from the charcoal is to be allowed to eſcape, before the other part of the apparatus is adjuſted. To that extremity of the porcelain tube which contains the charcoal, fit a long glaſs tube, ſufficiently wide to contain a number of ſmall pieces of ſulphur, which may be puſhed ſucceſſively into the porcelain tube with an iron rod paſſing through a cork which cloſes the end of the tube. To the other extremity there is to be fitted another glaſs tube, bent at the end, that it may be immerſed in a veſſel of water in the pneumatic trough. Heat is then to be applied till the porcelain tube and the charcoal become red-hot, when the pieces of ſulphur are to be puſhed ſlowly forward into the tube, and when it acts on the charcoal, a yellow liquid of an oily appearance paſſes through the tube. The heat being continued, it evaporates, and is condenſed in the water of the veſſel in which the tube terminates, traverſing it in globules which collect together at the bottom.

448 Precautions The ſucceſs of this experiment is ſomewhat doubtful. When ſulphur is expoſed ſuddenly to a ſtrong heat, in place of being ſublimed, it appears in ſome meaſure fixed, and becomes ſoft by fuſion. Sometimes it paſſes too rapidly through the charcoal to unite with it; the pieces of ſulphur, therefore, ſhould be ſlowly introduced, and the tube in paſſing through the furnace, ſhould be inclined from that extremity at which the ſulphur is introduced.

449 Properties. 3. When the carburet of ſulphur is pure, it is tranſparent and colourleſs, but frequently has a greeniſh-yellow tinge. It has a diſagreeable pungent odour. The taſte is at firſt cooling, but afterwards becomes extremely pungent. It is heavier than water, does not mix with it, and therefore remains at the bottom of the veſſel. The ſpecific gravity of this liquid is various. In one trial it was found to be 1.3.

450 Evaporates. 4. The carburet of ſulphur evaporates at the ordinary temperature of the atmoſphere, and increaſes its volume nearly as much as ether. When a quantity of this liquid in a veſſel of water is placed under the receiver of an air pump, and the air exhauſted, it riſes through the water in bubbles, and aſſumes the gaſeous form; and when the preſſure of the air is reſtored, the gas is inſtantly condenſed, and returns to the liquid ſtate.

451 Combuſtible. 5. The carburet of ſulphur burns with great facility, and during the combuſtion it emits a ſtrong odour of ſulphurous acid, depoſits a little ſulphur, which afterwards burns, and there remains ſome black charcoal in its uſual combuſtible ſtate. The air which holds carburet of ſulphur in ſolution, burns quietly, but when it is mixed with oxygen gas, and brought in contact with a burning body, it explodes with prodigious violence, and not without conſiderable danger.

6. This ſubſtance unites with phoſphorus, which it very readily diſſolves, but the ſolution is not more inflammable than the phoſphorus itſelf. It combines alſo

---

* *Ann. de Chim.* vol. xxxii. p. 267.

† *Ibid.* vol. xxi. p. 207.

alſo with a ſmall quantity of ſulphur, but without any other change in its properties than becoming a little deeper coloured. It ſeems to have no action on charcoal *.

* Ann. de Chim. vol. xlii. p. 134.

Sect. IV. *Sulphuret of Phosphorus.*

452 Preparations. 1. Sulphur and phoſphorus combine together in all proportions. If one part of phoſphorus with eight times its weight of ſulphur, be put into a matraſs, with 32 parts of diſtilled water; on the application of a gentle heat, the phoſphorus melts and diſſolves the ſulphur. The new compound aſſumes a yellow colour, and remains fluid, till it is cooled down to the temperature of 77°, when it becomes ſolid. This ſubſtance is the *ſulphuret of phoſphorus*. In other caſes, when the proportion of phoſphorus exceeds that of the ſulphur, it is called a *phoſphuret of ſulphur*.

453 Combined with ſulphur more fuſible. 2. The compounds of ſulphur and phoſphorus have been particularly inveſtigated by Pelletier, and he has found that the compound is always more fuſible than either of the uncombined conſtituents. The following table exhibits the reſults of his experiments†.

† Fourcroy Connaiſs. Chim. tom. i. p. 202.

8 Phoſphorus 1 Sulphur	remain fluid at 95°
4 Phoſphorus 1 Sulphur	59
1 Phoſphorus ½ Sulphur	50
1 Phoſphorus 1 Sulphur	41
1 Phoſphorus 2 Sulphur	72
1 Phoſphorus 3 Sulphur	99

All theſe compounds, therefore, it muſt appear, are more fuſible than the phoſphorus itſelf, and much more ſo than the ſulphur.

454 Danger in the proceſs. 3. In making theſe combinations, great caution ſhould be obſerved; for if the heat be applied ſuddenly, even when the ſubſtances are under water, a violent exploſion ſometimes takes places, from the ſudden formation and extrication of the ſulphurated and phoſphorated hydrogen gaſes.

Chap. X. Of ACIDS.

455 Oxides. 1. We have ſeen, in deſcribing the different ſubſtances which have been treated of in the five preceding chapters, that they all combine with oxygen in different proportions, excepting one. Hydrogen combines with oxygen only in one proportion, and this compound is water. The firſt portion of oxygen which combines with the other four ſubſtances, namely azote, carbone, phoſphorus, and ſulphur, forms with them compounds which, poſſeſſing no acid properties, have received the name of oxides (1).

456 Acids. 2. But when theſe ſubſtances combine with a greater proportion of oxygen, they exhibit very different properties; and poſſeſſed of theſe properties, they are ranked among the claſs of acids. The ſubſtances which poſſeſs the following properties are referred to this claſs.

457 Diſtinctive characters. *a*. They redden vegetable blue colours (k).

b. They poſſeſs a peculiar taſte, which is well known by the terms *acid* or *ſour*.

c. They combine with water in all proportions.

d. They enter into chemical combination with alkalies, with earths, and metallic oxides, and form with them compounds which have been denominated *ſalts*.

458 Importance of acids. 3. The acids are a very important claſs of bodies, and not merely on account of their peculiar properties, and the ſingular and uſeful compounds which they form with other ſubſtances, but alſo as they are the inſtruments of analyſis in the hands of the chemiſt for diſcovering the properties and combinations of the objects of his ſcience. Without their aid he can ſcarcely move a ſingle ſtep in his inveſtigations. It was therefore neceſſary to introduce the account of the acids in this place, that we might be early acquainted with the means of proſecuting our reſearches.

459 Nomenclature. 4. Acids which have the ſame baſe, combine with oxygen in different proportions. Thus, for inſtance, ſulphur combines with oxygen in two proportions. The 100 parts of one compound contain 32 of oxygen, and the 100 parts of the other contain 38 parts. The characteriſtic properties of theſe compounds are totally different. It is therefore neceſſary that they ſhould be diſtinguiſhed by ſome appropriate name, and this accordingly has been attended to in the conſtruction of the preſent chemical nomenclature. The name of the acid is derived from the baſe, and this name has a different termination according to the proportion of the oxygen combined with its baſe. With the ſmalleſt proportion the name terminates in the ſyllable *ous*; with the greater proportion, it terminates in the ſyllable *ic*. Thus, in the caſe of the acid formed with ſulphur, that compound in which there is the ſmaller proportion of oxygen is denominated the *ſulphurous acid*; the other, which has the greater proportion of oxygen is the *ſulphuric acid*. In the ſame way when phoſphorus combines with oxygen in the ſmalleſt proportion which gives it acid properties, it is called the *phoſphorous acid*; in the greater proportion, the *phoſphoric acid*. And thus by the ſimple change of the termination, the name is deſcriptive of the peculiar ſtate of the proportions in the compound.

---

(1) Perhaps the combination of oxygen and azote, as they exiſt in atmoſpheric air, ſhould be excepted. It is to the combination of oxygen in greater proportion with azote than exiſts in atmoſpheric air, that the name of oxide is given. But philoſophers are not agreed whether atmoſpheric air is to be conſidered as a chemical combination, or a mechanical mixture.

(k) Hence vegetable blue infuſions, or paper ſtained with them, are employed as teſts to diſcover acids. Theſe are ſometimes called re-agents. A great variety of ſubſtances are employed for this purpoſe, ſuch as the infuſion and tincture of litmus, and of turnſole the ſyrup of violets, the infuſion of the flowers of mallow or red cabbage.

Sect. I. Of Sulphuric Acid.

460 Names. 1. The name of ſulphuric acid is given to the combination of ſulphur and of oxygen, with the greateſt proportion of the latter. It was formerly called vitriolic acid, becauſe it was obtained from vitriol by diſtillation, which is a compound of ſulphuric acid and an oxide of iron. When it is ſtrongly concentrated, it has a ſluggiſh appearance; hence it was called, *oil of vitriol*. It has alſo been denominated *oleum ſulphuris per campanam*, becauſe it was obtained by burning ſulphur under a glaſs bell.

461 History. 2. The ancients were unacquainted with this acid. Pliny ſpeaks of vitriols, which were uſed for different purpoſes, in ſome of which it was probably decompoſed. Sulphur was burnt in ſacrifices, but in neither caſe was the product attended to. Baſil Valentine is the firſt who mentions this acid, about the end of the 15th century. Agricola and Paracelſus have alſo ſpoken of it, but Dornæus is the firſt who deſcribed it diſtinctly, in the year 1570.

3. If a quantity of flowers of ſulphur be expoſed to a degree of heat ſufficient to inflame it, and if, when it is in a ſtate of ignition, it be introduced into a jar filled with oxygen gas, it burns with great ſplendor, and emits a great quantity of white fumes. 462 Formation by experiment. Theſe fumes may be condenſed, by pouring a ſmall quantity of water into the jar, and when this is examined, it is found to poſſeſs acid properties. This is the *ſulphuric acid*. It is procured, as appears by this experiment, by burning ſulphur in oxygen gas.

463 And in the large way. 4. The proceſs for obtaining ſulphuric acid in the large way is the following. A mixture of ſulphur and nitre is burnt in leaden chambers. The uſe of the nitre is to ſupply a quantity of oxygen for the combuſtion of the ſulphur. There is a little water in the bottom of the veſſels, which ſerves to condenſe the vapours given out during the combuſtion. The acid which is obtained in this way is very weak, for it is diluted with the water in which it was condenſed, which water may be ſeparated by diſtillation. Even after this it is uſually contaminated with a little lead from the veſſels, ſome potaſh, and ſometimes nitric and ſulphurous acids. 464 Purification. To obtain it perfectly pure, the ſulphuric acid of commerce muſt be diſtilled. This proceſs is conducted by putting a quantity of the acid into a retort, and expoſing it to a degree of heat ſufficient to make it boil. The beak of the retort is put into a receiver, in which the acid, as it comes over, is condenſed.

465 Properties. 5. The acid thus purified, is a tranſparent colourleſs liquid, of an oily conſiſtence. It has no ſmell, but a ſtrong acid taſte. It deſtroys all animal and vegetable ſubſtances. It reddens all vegetable blues. It always contains water. When this is driven off by a moderate heat, the acid is ſaid to be concentrated. When as much concentrated as poſſible, the ſpecific gravity is 2, or double that of water; but it can rarely be obtained of greater denſity than 1.84.

466 Action of heat. 6. The ſulphuric acid ſuffers no change from being expoſed to the light. It boils at the temperature of 546°, or, according to Bergman, 540°. When this acid is deprived of its caloric, it is ſuſceptible of congelation, and even of cryſtallization, in flat, ſix-ſided priſms, terminating in a ſix-ſided pyramid. It cryſtallizes moſt readily, when it is neither too much concentrated, nor diluted with water. Of the ſpecific gravity of 1.65 it cryſtallizes at the temperature of a few degrees below the freezing point of water. Of the ſpecific gravity of 1.84 it reſiſts the greateſt degree of cold. Chaptal obſerved it cryſtallize at the temperature of 48°, and Mr Keir found that it froze at 45° of the ſpecific gravity of 1.78.

467 Attracts water strongly. 7. Sulphuric acid has a ſtrong attraction for water. In ſome experiments that have been made, ſulphuric acid, when expoſed to the atmoſphere, attracted above ſix times its weight of water. When four parts of concentrated ſulphuric acid, and one part of ice at the temperature of 32°, are mixed together, the moment they come in contact the ice melts, and the temperature riſes to 212°. A greater quantity of caloric is given out when the two bodies are mixed together in the liquid ſtate. If four parts of the acid and one of water are ſuddenly mixed together, the temperature of the mixture riſes to about 300°. This extrication of caloric, it is obvious, ariſes from the ſudden condenſation of the two liquids, the medium bulk of which is conſiderably leſs than the two taken together.

8. So great is the attraction of this acid for water, that the ſtrongeſt that can be prepared can ſcarcely be ſuppoſed to be entirely free from it. 468 Method of determining the quantity. It has therefore greatly occupied the attention of chemical philoſophers to determine the proportions of real acid and water, in ſulphuric acid of any given ſpecific gravity. This ſubject has been inveſtigated by Wenzel, Wiegleb, and Bergman, and more lately and ſucceſsfully by Mr Kirwan. 469 Mr Kirwan's. His method was the following. Eighty-ſix grains of potaſh, diſſolved in water, were ſaturated with ſulphuric acid of a known ſpecific gravity. The ſolution being turbid, water was added till the ſpecific gravity was 1.03 at temperature 60°. The whole weight was now equal to 3694 grains. Forty-five grs. of ſulphate of potaſh diſſolved in 1017 grs. of diſtilled water, had the ſame ſpecific gravity at the temperature 60°. Hence the proportion of ſalt in each ſolution was equal. But in the laſt, the quantity of ſalt was $\frac{1}{22.6}$, then the quantity of ſalt in the former was $\frac{3694}{22.6}=$ 163.45 grains. Of this quantity only 86 were alkali; the remainder, therefore, viz. 77.45 grains, were acid, or acid and water. The quantity of acid employed in the ſaturation amounted to 79 grs. ſtandard; but the quantity of acid taken up was only 77.45 grs. therefore 1.55 were rejected, and conſequently were mere water, therefore the acid taken up is ſtronger than ſtandard; and ſince 79 parts ſtandard loſe 1.55 by combining with pure potaſh, 100 parts ſtandard ſhould loſe 1.96, or 98.04 parts of acid of the ſtrength of what is found in ſulphate of potaſh, contains as much real acid as 100 parts ſtandard. Hence 100 parts of this ſtrong acid are nearly equivalent to 102 of ſtandard. Therefore, 100 parts of potaſh take up nearly 92 of ſtandard ſulphuric acid, or 82 of the ſtrongeſt, and afford 182 of ſulphate of potaſh. Mr Kirwan thinks there is no reaſon to ſuppoſe that the ſulphate of potaſh

potaſh contains any water of cryſtallization. One hundred grs. expoſed to a red heat for half an hour fell into powder, and loſt only a ſingle grain *.

It having been ſuggeſted by Guyton-Morveau, Mr Kirwan obſerves, that the denſities of mixtures of ſulphuric acid and water being greater than what is found by calculation, ſhould be aſcribed to the condenſation of the aqueous part, rather than to that of the acid; and this led him to conſider of a different method from what he had formerly employed in determining the quantity of real acid in ſulphuric acid of different denſities. Sulphuric acid of the ſpecific gravity of 2.000, which is the ſtrongeſt that can be produced by art, was taken as the ſtandard of the ſtrength of all other acids. He could not procure the acid of this ſtrength at the temperature of 60°. But from many experiments made with acids of inferior denſity, as 1.8846, 1.8689, 1.8042, 1.7500, he concludes, that the condenſation of equal weights of this ſtandard acid and water amounts to $\frac{1}{75}$th of the whole. Then by applying Mr Pouget's formulas (L) for inveſtigating the increaſed denſities of inferior proportions of acid and water, the ſucceſſive increments of denſity will be found as in the following table.

Parts.

* Iriſh Tranſ. vol. iv. p. 18.

(L) The formula here alluded to was invented by M. Pouget in the inveſtigation of the ſpecific gravity of alcohol mixed with water in different proportions; and he has given a detailed account of his method in a letter addreſſed to Mr Kirwan, which is inſerted in the Tranſactions of the Royal Iriſh Academy, vol. iii. p. 157.

Having purified alcohol by repeated diſtillations, the ſpecific gravity at the temperature 65.75° was found to be 0.8199. This he took for his ſtandard. And conſidering the ſpecific gravity as the means of diſcovering the increaſe of denſity, or the diminution of volume, he thought the quantities in the mixture would be beſt determined, not by the difference of weight, but of volume. He therefore took ten mixtures, the firſt containing nine meaſures of alcohol and one of water, the ſecond eight meaſures of alcohol and two of water, and ſo on to the laſt, which contained only one meaſure of alcohol and nine of water. But as the real meaſures are always uncertain, he weighed them to aſcertain the ſpecific gravity. Thus 10,000 grains of water and 8199 of alcohol formed a mixture of equal parts in bulk. Knowing the real ſpecific gravities of mixtures of alcohol and water, taking a mean of a great number of obſervations made at the ſame temperature, and comparing them with the ſpecific gravities found directly by calculation, he thus deduces the increaſe of denſity or the diminution of volume produced in the whole maſs by the mutual penetration of the fluids. For calling A the real ſpecific gravity, and B the ſpecific gravity found by calculation, n the number of meaſures which compoſe the whole maſs, $n-x$ that to which it is reduced by mutual penetration, it is evident, ſince this increaſe of denſity does not diminiſh the weight of the whole maſs, that $n\,B=\overline{n-x}\times A$. Then $x=\frac{A-B}{A}\times n$, or making $n=1\,\frac{A-B}{A}$, which expreſſes the diminutions of bulk, or the quantities of fluid abſorbed during the mixture.

The following table contains the reſult of Pouget's experiments, or the diminutions of volume which is ſuppoſed to be $=1$ of each of the mixtures, calculated according to the formula.

Number of meaſures of		Diminution of the whole volume = 1 by experiment.	By calculation.
Water.	Alcohol.		
1	9	0.0109	0.0103
2	8	0.0187	0.0184
3	7	0.0242	0.0242
4	6	0.0268	0.0276
5	5	0.0288	
6	4	0.0266	0.0276
7	3	0.0207	0.0242
8	2	0.0123	0.0184
9	1	0.0044	0.0103

From this table it appears that the numbers which expreſs the diminution of bulk follow a regular progreſſion. The greateſt correſpond to the mixtures of equal parts, and they decreaſe towards each end of the progreſſion. They muſt therefore be regulated by ſome general law. M. Pouget thinks that the alcohol may

Parts Water.	Standard.	Increments of Denſity.
5	95	,0252
10	90	,0479
15	85	,0679
20	80	,0856
25	75	,0699
30	70	,1119
35	65	,1213
40	60	,1279
45	55	,1319
50	50	,1333

" By adding, ſays Mr Kirwan, theſe increments to the ſpecific gravities found by calculation, and taking arithmetical mediums for the intermediate quantities of ſtandard, I made out the firſt 50 numbers of the following table; the remainder was formed by actual obſervation in the following manner, premiſing that the ſpecific gravities were always taken between 59,5° and 60°, or at moſt 60,5° of Fahrenheit.

" 1ſt, I found by the preceding part of the table that 100 parts of ſulphuric acid whoſe ſpecific gravity was 1.8472 contained 88,5 parts ſtandard; conſequently 400 grs. of this acid contain 354.

" 2dly, I then took ſix portions of this acid, each containing 400 grs. and added to them as much water as made them contain reſpectively 48. 46. 44. 42. 40. and 38. grains ſtandard. To find the proportion of water that

---

may be conceived as being diſſolved in the water which has abſorbed or retained part of it in its pores. The quantity abſorbed ought to be in the ratio of that of the ſolvent and the body diſſolved, and each meaſure of water will retain quantities of alcohol proportional to the number of meaſures of this fluid in the mixture. Thus for example, in a mixture formed of nine meaſures of alcohol and one of water, this meaſure of water will abſorb a quantity of alcohol $=9$: and in another mixture of eight meaſures of alcohol with two of water, each meaſure of water will contain a quantity of alcohol $=8$. Conſequently the diminutions of bulk of each mixture are in a ratio compounded of the number of meaſures of alcohol and of water which form it; and in the table above, as 1×9, 2×8, 3×7, 4×6, 5×5, &c. And in general taking for a conſtant quantity the diminution of bulk with equal meaſures, and calling it c; calling the whole number of meaſures n; the number of meaſures of alcohol in any mixture, x, and the increaſe of denſity or diminution of volume z, we ſhall have $c : z :: \frac{n}{2}\times\frac{n}{2} : \overline{n-x}\times x$: and $z=\frac{4c}{n2}\times\overline{nx-x^2}$: or making $n=1$, $4cx-4cx^2$. The increaſe of denſity, calculated according to the formula, correſponds pretty nearly with experiments; for all mixtures in which the alcohol is in greater quantity than water, but not in thoſe caſes in which the water is in greateſt proportion, the real increaſe of denſity is much leſs than by calculation, and the differences become more conſiderable as the quantity of water is increaſed. M. Pouget thinks, that when the quantity of water is greater than that of alcohol, the law of abſorption is diſturbed; and he conjectures that it is owing to the attraction of the particles of the water among themſelves, which conſequently oppoſe their union with any other ſubſtance. But when the alcohol forms at leaſt the half of the whole maſs, the diminutions of bulk are as the products of the numbers which expreſs the proportions of alcohol and water forming the mixture: they may be repreſented by the formula $z=\frac{4cnx-4cx^2}{n^2}$. By this formula may be determined the ſtrength of ſpirits of wine of commerce, or the number of parts of water and ſtandard alcohol of which they are compoſed.

The number of meaſures of the whole maſs or the bulk - $=1$
The number of meaſures of alcohol in any mixture - - $=x$;
The diminution of bulk of equal parts by experiment - - $=c$
The diminution of bulk of a mixture containing x meaſures of alcohol by hypotheſis $=4cx-4cx^2$
The ſpecific gravity of water - - - $=a$
Specific gravity of alcohol - - - $=b$
Specific gravity of the unknown mixture - - $=y$

Since the increaſe of denſity does not change the weight of the maſs, we ſhall have $\overline{1-x}\times a+bx=1-4cx+4cx^2\times y$.

By this equation may be found the value of x or the proportion of alcohol, having previouſly aſcertained the ſpecific gravity of the mixture, and to determine this ſpecific gravity, or the value of y, by knowing the proportions of alcohol and water. Hence

$$x=0.5-\frac{a-b}{8cy}+\sqrt[2]{\frac{a-y}{4cy}+\left(\frac{a-b}{8cy}-0.5\right)^2}$$

$$y=\frac{a-ax+bx}{1-4cx+4cx^2}$$

And making $a=1$, $b=0.8199$, $c=0.0288$

$$x=0\ 5\frac{0.1801}{0.2304y}+\sqrt[2]{\frac{1-y}{0.1152y}+\left(\frac{0.1801}{0.2304y}-0.5\right)}$$

$$y=\frac{1-0.1801x}{1-0.1152x+0.1152x^2}$$

that ſhould be added to each portion of acid, in order that it ſhould contain the given proportion of ſtandard, I uſed the following analogy: Let the quantity of water to be added to 400 parts of the acid that the mixture may contain 48 per cent. ſtandard be x.

Then $400+x.\ 354 :: 100.\ 48$, then $19200+48x=35400$.

And $48x=35400-19200=16200$. And $x=\frac{16200}{48}=337{,}5$.

"In this manner I found the quantities of water to be added to each of the other portions. The mixtures being made, they were ſet by for four days, ſtirring them with a glaſs rod (that remained in them) each day, and the 5th day they were tried; after which the half of each was taken out and as much water added to them, and then ſet by for three days, by which means the ſpecific gravities correſponding to 24. 23. 22. 21. 20. and 19. per cent. ſtandard were found, after which ſix more portions of 400 grs. each of the concentrated acid, whoſe ſpecific gravity was 1,8393, were taken, the proper proportion of water added to each, and after three days reſt and repeated agitation, their denſities in temperature 60° were examined as above, by which means the ſpecific gravities correſponding to 36. 34. 32. 30. 28. and 26. per cent. ſtandard were obtained, and half theſe portions mixed with half water exhibited, after three days reſt and agitation, the denſities correſponding to 18. 17. 16. 15. 14. and 13. per cent. ſtandard in the above temperature. The balance I uſed turned with $\frac{1}{15}$ of a grain when charged with two ounces, and the ſolid employed was a ſmall glaſs ball containing mercury which loſt 27,88 grs. of its weight when weighed in water in temperature 56°, ſuſpended commonly by a horſe-hair, but when dipped in ſtrong nitrous and marine acids it is ſuſpended by a fine gold wire, and then loſt 27,78 grs. of its weight in water.

"I alſo examined and rectified, in ſome inſtances, many parts of the firſt 50 numbers of the table in the ſame manner, but in general I found them juſt.

TABLE of the Quantity of the Standard Sulphuric Acid 2,000 in Sulphuric Acid of inferior Denſity.

100 Parts.	Standard Temp. 60°.	100 Parts.	Standard.	100 Parts.	Standard.
2,000	100	1,7959	84	1,6312	68
1,9859	99	1,7849	83	1,6217	67
1,9719	98	1,7738	82	1,6122	66
1,9579	97	1,7629	81	1,6027	65
1,9439	96	1,7519	80	1,5932	64
1,9299	95	1,7416	79	1,5840	63
1,9168	94	1,7312	78	1,5748	62
1,9041	93	1,7208	77	1,5656	61
1,8914	92	1,7104	76	1,5564	60
1,8787	91	1,7000	75	1,5473	59
1,8660	90	1,6899	74	1,5385	58
1,8542	89	1,6800	73	1,5292	57
1,8424	88	1,6701	72	1,5202	56
1,8306	87	1,6602	71	1,5112	55
1,8188	86	1,6503	70	1,5022	54
1,8070	85	1,6407	69	1,4933	53

TABLE Continued.

100 Parts.	Standard Temp. 60°.	100 Parts.	Standard.	100 Parts.	Standard.
1,4844	52	1,2951	35	1,1398	18
1,4755	51	1,2847	34	1,1309	17
1,4666	50	1,2757	33	1,1208	16
1,4427	49	2,2668	32	1,1129	15
1,4189	48	1,2589	31	1,1011	14
1,4099	47	1,2510	30	1,0955	13
1,4010	46	1,2415	29	1,0896	12
1,3875	45	1,2320	28	1,0833	11
1,3741	44	1,2210	27	1,0780	10
1,3663	43	1,2101	26	1,0725	9
1,3586	42	1,2009	25	1,0666	8
1,3473	41	1,1918	24	1,0610	7
1,3360	40	1,1836	23	1,0555	6
1,3254	39	1,1746	22	1,0492	5
1,3149	38	1,1678	21	1,0450	4
1,3102	37	1,1614	20	1,0396	3
1,3056	36	1,1531	19	1,0343	2

"The laſt eleven numbers were only found by analogy, obſerving the ſeries of decrements in the four preceding denſities, and therefore are to be conſidered barely as approximations.

"To reduce vitriolic acids of given denſities, at any degree of temperature between 49° and 70°, to that which they ſhould have at temperature 60°, in order that their proportion of ſtandard may be thereby inveſtigated, I made the following experiments:

Degrees of Temperature.	Sp. Gr. of A.	Sp. Gr. of B.	Sp. Gr. of C.
70°	1,8292	1,6969	1,3845
65	1,8317	1,6983	1,3866
60	1,8360	1,7005	1,3888
55	1,8382	1,7037	1,3898
50	1,8403	1,7062	- -
49	1,8403	- -	1,3926

"Hence we ſee that vitriolic acid, whoſe denſity at any degree between 49° and 70° reſembles or approaches the correſponding denſity in the column A, gains or loſes 0,00126 of its ſpecific gravity by *every two* degrees between 60° and 70° of Fahrenheit, and 0,00086 by *every two* degrees between 49° and 60°.

"Secondly, That any vitriolic acid, whoſe denſity at any degree between 50° and 70° reſembles or approaches to the correſponding denſity in the column B, gains or loſes 0,00158 for every two degrees between 60° and 70°; and 0.0017 by every two degrees between 50° and 60°. Whence it appears that the ſtronger acid is leſs altered by variation of temperature than the weaker, which formerly appeared to me an irregularity, but now ſeems to proceed from the increaſe of the accrued denſity, when larger proportions of water are mixed with the ſtronger acid.

"3dly, Sulphuric acid, whoſe denſity at any degree between 50° and 70° reſembles the correſponding at the ſame degree in the column C, gains or loſes 0.00086 for

for every two degrees between 60° and 70° incluſively, and 0.00076 between 50° and 60°. Between 45° and 50° I could perceive no difference *.

470 Compoſition.

9. Attempts have been made to determine the proportion of oxygen and ſulphur, which enter into the compoſition of ſulphuric acid. According to the experiments of Lavoiſier, in which he meaſured the quantity of oxygen abſorbed, by a given weight of ſulphur during combuſtion, the proportions are,

71 ſulphur,
29 oxygen.

100

But other methods have been adopted, which promiſe more accurate reſults. Theſe are, by decompoſing other ſubſtances which contain oxygen, by means of ſulphur. According to the experiments of Mr Chenevix, conducted in this way, the ſulphuric acid conſiſts of

61.5 ſulphur,
38.5 oxygen.

100.0

10. Sulphuric acid does not combine with oxygen, nor has it any action with azotic gas.

471 Action with hydrogen.

11. It appears that hydrogen has a greater affinity for oxygen, than the ſulphur has, and therefore the ſulphuric acid is decompoſed by means of hydrogen gas. In the cold there is no action between hydrogen gas and ſulphuric acid; but if they are made to paſs through a red-hot porcelain tube, the acid is decompoſed; water is formed, and ſulphur is precipitated. When hydrogen gas is employed in a greater proportion than the half of the acid, the ſuperabundant gas diſſolves the ſulphur, and is diſengaged in the form of ſulphurated hydrogen gas.

472 Charcoal.

12. Charcoal has no action on ſulphuric acid in the cold; but at the boiling temperature, it decompoſes it, and converts it into ſulphurous acid. If a piece of red-hot charcoal be immerſed in a quantity of concentrated ſulphuric acid, part of the acid is ſuddenly diſengaged under the form of thick white fumes, accompanied with ſulphurous acid gas. The ſulphuric acid is decompoſed; part of its oxygen is attracted by the charcoal, forming carbonic acid, and thus it is reduced to the loweſt proportion of oxygen, in the ſtate of ſulphurous acid.

473 Phoſphorus.

13. A ſimilar effect is produced by phoſphorus. Phoſphorus, with the aſſiſtance of heat, partially decompoſes the ſulphuric acid, by abſtracting part of its oxygen. Phoſphoric acid is formed, and ſulphurous acid driven off.

474 Sulphur.

14. In the cold, ſulphur has no action on ſulphuric acid; but, when they are boiled together, the ſulphur is partly diſſolved in the acid, and converts it into ſulphurous acid. The ſulphur which has been added combines with the oxygen, which is neceſſary for the conſtitution of ſulphuric acid, and thus the whole is converted into ſulphurous acid.

475 Sulphates.

15. Sulphuric acid combines with alkalies, the earths and the metals forming ſalts; which, in the preſent language of chemiſtry, are denominated *ſulphates*.

476 Uſes.

16. This acid is employed in great quantity in many arts and manufactures. It is employed alſo in medicine and pharmacy; the preparation of it, therefore, has long been an object of conſiderable importance.

477 Affinities.

17. The affinities of ſulphuric acid are the following:

Barytes,
Strontites,
Potaſh,
Soda,
Lime,
Magneſia,
Ammonia,
Glucina,
Yttria,
Alumina,
Zirconia,
Oxide of Zinc,
Iron,
Mangane ſe,
Cobalt,
Nickel,
Lead,
Tin,
Copper,
Biſmuth,
Antimony,
Arſenic
Mercury,
Silver,
Gold,
Platina.

SECT. II. *Of Sulphurous Acid.*

478 Names.

479 Hiſtory.

1. According to the explanation of the nomenclature of the acids, the term *ſulphurous* ſhows that this acid is in its diminiſhed ſtate of combination with oxygen. It was formerly called *ſpirit of ſulphur*, and *volatile ſulphurous acid.* Although the ancients muſt have been acquainted with ſome of its properties, as it is formed during the ſlow combuſtion of ſulphur, yet Stahl is the firſt chemiſt who examined it with attention. He ſuppoſed that it was the ſulphuric acid combined with his imaginary principle of phlogiſton. Hence he called it *phlogiſticated* ſulphuric acid. It was not till the year 1774 that its nature and compoſition were diſcovered by the labours of Prieſtley and Lavoiſier. Berthollet afterwards inveſtigated the formation, decompoſition, combinations, and uſes of this acid. Fourcroy and Vauquelin * alſo have examined many of its properties, eſpecially the ſaline compounds which it forms, ſo that now its properties are well known.

480 Abundant in nature.

481 Fatal to Pliny.

2. The ſulphurous acid exiſts in nature in great abundance, and particularly in the neighbourhood of volcanoes. It is diſengaged from ſome lavas in a ſtate of fuſion, and from the ſoil which is impregnated with ſulphur, when a ſufficient degree of heat is applied. It was by the vapours of ſulphurous acid that Pliny the naturaliſt was ſuffocated in the eruption of Mount Veſuvius, which deſtroyed Herculaneum, in the 79th year before the Chriſtian æra.

482 Formation.

3. When ſulphur is burnt in the open air, the fumes that are generated by this ſlow combuſtion, are ſulphurous acid. It was in this way that this acid was formerly

---

* *Iriſh Tranſ.* vol. iv. p. 7.

* *Ann. de Chim.* tom. xxiv. p. 229.

merly obtained. The method of procuring it, which is now followed, is to decompoſe the ſulphuric acid by means of any ſubſtance which deprives it of part of its oxygen. If one part of mercury and two parts of concentrated ſulphuric acid be expoſed to heat in a glaſs retort, the mixture efferveſces, and a gas is diſengaged, which may be collected in jars over mercury. In this proceſs the mercury attracts part of the oxygen of the ſulphuric acid, and leaves behind that portion which conſtitutes the ſulphurous acid.

483 In the ſtate of gas.

4. Sulphurous acid thus obtained is in the ſtate of gas, and it is an elaſtic, inviſible and colourleſs fluid, like common air. It is rather more than double the weight of atmoſpheric air. Its ſpecific gravity is 0.00246; 100 cubic inches weigh nearly 63 grains. It has a ſharp pungent ſmell; it is unfit for reſpiration, and for ſupporting combuſtion. It reddens vegetable blues, and then deſtroys the greater number of them. It is on account of this property that the fumes of ſulphur are employed to remove the ſtains of fruit from linen, and that the ſulphurous acid is often uſed in bleaching.

484 Properties.

485 Action with caloric.

5. The ſulphurous acid gas refracts the light ſtrongly without undergoing any change. When it is ſtrongly heated, as in a red-hot porcelain tube, it remains unaltered, according to the experiments of Fourcroy. But Dr Prieſtley and Berthollet found that it depoſited ſulphur, after long expoſure to heat. At the temperature of—31° it becomes liquid. This property, which diſtinguiſhes it from other gaſes, and which was diſcovered by Monge and Clouet, Fourcroy thinks is owing to the water it holds in ſolution.

486 With oxygen gas, &c.

6. When the ſulphurous acid is in the form of gas, it does not readily combine with oxygen. In its fluid form it unites more readily, and is converted into ſulphuric acid. In making a mixture of ſulphurous acid gas and oxygen gas paſs through a red-hot tube, they combine together, and are converted into ſulphuric acid. There ſeems to be no action between ſulphurous acid and azotic gas.

487 With hydrogen gas.

7. Hydrogen gas has no action on ſulphurous acid gas in the cold; but when a mixture of theſe gaſes is made to paſs through a red-hot tube, ſulphurous acid is decompoſed; the hydrogen combines with the oxygen and forms water, and ſulphur is depoſited. If the hydrogen gas be in greater proportion than the oxygen contained in the ſulphurous acid, it diſſolves part of the ſulphur, and paſſes off in the form of ſulphurated hydrogen gas.

488 With charcoal.

8. Its action with charcoal is ſomewhat ſimilar. In the cold there is no effect, but expoſed together to a red heat, carbonic acid is formed, by the union of carbone and oxygen, and ſulphur is depoſited.

489 With phoſphorated gas.

9. There is no action whatever between phoſphorus and ſulphurous acid gas; but phoſphorated hydrogen gas is decompoſed by this acid. When the two gaſes come in contact, a white thick vapour is produced; ſulphur combined with phoſphorus in the ſolid ſtate is depoſited, and water is formed.

490 Sulphurated hydrogen gas.

10. Sulphur has no action on this acid; but ſulphurated hydrogen gas, at the inſtant it comes in contact with ſulphurous acid gas, is condenſed; ſolid ſulphur is depoſited, and water is formed, with the extrication of caloric by the condenſation of the two gaſes.

491 With water.

11. Water has a ſtrong attraction for ſulphurous acid gas. A bit of ice brought in contact with it, is immediately melted without any perceptible change of temperature. When water is ſaturated with this gas, it is known by the name of *ſulphurous acid*, or *liquid ſulphurous acid*. The ſpecific gravity is 1.040. At the temperature of 43° water combines with $\frac{1}{3}$ of its weight of ſulphurous acid gas[†]; but as the temperature increaſes, it abſorbs it in ſmaller proportion. It freezes at a temperature a few degrees below 32°, and it paſſes into the ſolid ſtate without parting with any of its acid. The liquid ſulphurous acid has the ſmell, taſte, and other properties of the gas, and particularly that of deſtroying vegetable colours. When expoſed to the atmoſphere, it gradually abſorbs oxygen, and paſſes into the ſtate of ſulphuric acid. This change goes on more rapidly when it is diluted with water, and agitated in contact with the air.

492 With ſulphuric acid.

12. The ſulphuric acid ſeparates the ſulphurous acid in the gaſeous form from its combinations, and even from water. Concentrated ſulphuric acid abſorbs this gas, which imparts to it a yellowiſh brown colour, and renders it pungent and fuming. The two acids ſtrongly attract each other, ſo that when they are expoſed to the action of heat, the firſt vapour which riſes cryſtallizes in long, white, needle-ſhaped priſms. This is a compound of the two acids. It ſmokes in the air; diſſolves with efferveſcence in it, and when thrown into water produces a hiſſing noiſe, like a red-hot iron. It has the ſtrong ſmell of ſulphurous acid. This ſubſtance was formerly called *glacial ſulphuric acid*[*].

493 Glacial ſulphuric acid.

494 Uſes.

13. Sulphurous acid is very much employed in the arts, and ſometimes in medicine. In the ſtate of gas it is uſed for the bleaching of ſilk and wool, by extracting the colouring matter. It removes alſo the ſtains ariſing from vegetable juices, and ſpots of iron from linen.

495 Compoſition.

14. According to Fourcroy, 100 parts of this acid are compoſed of

85 ſulphur,
15 oxygen.
———
100

But according to the analyſis of Dr Thomſon,

68 ſulphur,
32 oxygen.
———
100

496 Affinities.

15. The compound ſalts formed by this acid are denominated *ſulphites*.

16. The following are the affinities of this acid.

Barytes,
Lime,
Potaſh,
Soda,
Strontites,
Magneſia,
Ammonia,
Glucina,
Alumina,
Zirconia.

[†] *Fourcroy, Connaiſs. Chim.* ii. 76.

[*] *Ibid.* ii. p. 78.

SECT. III. *Of Nitric Acid.*

497 Names. 498 Hiſtory. 1. This acid was formerly known by the name of aqua fortis, and ſpirit of nitre. Raymond Lully, who lived in the 13th century, ſeems to have been acquainted with it; and Baſil Valentine, who lived in the 15th, deſcribes the proceſs for preparing it. He calls it *water of nitre*. But till the diſcoveries of modern chemiſtry, little was known of the nature, properties, and compoſition of this acid. It is to the experiments and reſearches of Cavendiſh and Prieſtley, of Lavoiſier and Berthollet, that we are indebted for the knowledge we poſſeſs of this acid.

499 Abundant in nature. 2. The nitric acid exiſts in great abundance in nature. It is formed by the union of its conſtituent parts, which are evolved during the putrefactive proceſs of animal and vegetable matters; but it is never found, except in combination with ſome baſe, from which it muſt be extracted by art. The component parts of nitric acid, are azote and oxygen. The name in this caſe is not derived from the baſe, which is azote, but from nitre, from which it is generally obtained. This acid cannot be formed merely by bringing in contact the two gaſes which are its conſtituent parts; but if they are mixed together in certain proportions, and electric ſparks ſent through the mixture, the gaſes diſappear, and are converted into a liquid. This is the *nitric acid*. By a ſimilar experiment Mr Cavendiſh diſcovered the compoſition of this acid.

500 Method of procuring it. 3. This acid may be obtained by putting three parts of nitre or ſaltpetre with one of ſulphuric acid into a glaſs retort, and diſtilling with a ſtrong heat. The gas which comes over is condenſed in a glaſs receiver, to which the retort is to be luted. This gas which is condenſed is the nitric acid. Nitre is compoſed of nitric acid and potaſh, but potaſh has a ſtronger affinity for ſulphuric acid than for nitric acid; it therefore combines with the ſulphuric acid in the retort, and the nitric acid is diſengaged, and paſſes over in the gaſeous form.

501 Of purifying. 4. The acid thus obtained is impure, and is contaminated with muriatic, and ſometimes with ſulphurous acid. It is purified by diſtillation with a gentle heat. At firſt too it is of a yellow colour, which is owing to the fumes of the nitrous gas with which it is combined. Theſe fumes are driven off by heat, after which the acid remains pure, and is tranſparent and colourleſs.

502 Properties. 5. Thus prepared, it has a ſtrong acid taſte; a diſagreeable pungent odour, and gives a yellow colour to the ſkin. The ſpecific gravity of ſtrong nitric acid is 1.583, or, according to Mr Kirwan, at temperature 60°, 1.554.

503 Diſcovery of its compoſition. 6. Nitric acid and one of its compounds, nitre, have long been the ſubject of the experiments and reſearches of chemical philoſophers. In inveſtigating the nature of nitre, Mayow found that it poſſeſſed a common property with atmoſpheric air; namely, the property of giving a red colour to the blood. And, from obſerving that air was deprived of this property by the proceſs of combuſtion and reſpiration, he drew the ſingular concluſion, that nitre contained that part of the air which is neceſſary for reſpiration and combuſtion.

7. When nitric acid diſſolves metallic ſubſtances, a great quantity of a peculiar gas makes its eſcape, and the metal acquires conſiderable weight during this proceſs. According to the phlogiſtic theory, it was ſuppoſed that the metal was deprived of its phlogiſton, and that this phlogiſton had combined with the nitrous gas which had eſcaped. This was Dr Prieſtley's explanation. But it was differently explained by Lavoiſier. He took 1104 grs. of mercury, and added to it 945 grs. of nitric acid. Nitrous gas was emitted during the ſolution, and when he expoſed the mercury which had been converted into an oxide, to a red heat, oxygen gas was given out, and the mercury appeared in the metallic ſtate. He therefore concluded, that the nitric acid in this caſe was decompoſed, and that it conſiſted of oxygen which combined with the metal, and of nitrous gas which was driven off. The proportions, he ſuppoſed, were, 64 parts of nitrous gas by weight, and 36 of oxygen gas. He found, however, that the quantity of oxygen obtained in this proceſs, was ſometimes greater than what was neceſſary to ſaturate the nitrous gas; and he was at a loſs to account for this quantity. His own experiments, as well as ſome of Dr Prieſtley's, proved, that azote is a component part of nitre.

Mr Cavendiſh, who diſcovered the compoſition of water, in his experiments and reſearches on that ſubject, found, that nitric acid was produced during the exploſion of oxygen and hydrogen gaſes; and that he could increaſe this quantity by adding azotic gas to the mixture before combuſtion. From this he concluded, that the formation of the acid depended on the azotic gas. He proved this by paſſing electrical ſparks through common air in a glaſs tube. The air diminiſhed in bulk, and nitric acid was formed. Repeating a ſimilar experiment with oxygen and azotic gaſes in certain proportions, he found that the whole could be converted into nitric acid [*]. Mr Cavendiſh repeated the ſame experiments, with a view to remove ſome objections which had been made to his concluſions. They were followed by the ſame reſult, ſo that the fact of the compoſition of nitric acid was fully eſtabliſhed [†].

To perform this experiment, take a glaſs tube of about one-ſixth of an inch in diameter. Cloſe one end with a cork, through which let a metallic conductor with a ball at each extremity be paſſed. Fill the tube with mercury; immerſe the open end into the mercurial trough; introduce a mixture of .13 parts of azotic gas, and .87 of oxygen gas, occupying three inches of the tube, and a ſolution of potaſh filling one-half inch more. Let electrical exploſions be ſent through the tube till the air ceaſes to be diminiſhed in bulk. If the experiment ſucceed, the potaſh will be found converted into nitre, which ſhews that the nitric acid, which is a component part of nitre, has been formed during the proceſs.

8. Nitric acid, having a ſtrong affinity for water, is 504 Abſorbs water. never found entirely deprived of this liquid. When expoſed to the air, it attracts moiſture from it, and heat is given out when it is mixed with water. Mr Kirwan has endeavoured to aſcertain the relative 505 Method of determining the quantity. ſtrength of nitric acid of different denſities, or ſpecific gravities; and the method which he adopted is the following. He ſaturated 36 grs. of carbonate of ſoda with

with

---

[*] *Phil. Tranſ.* 1784.

[†] *Ibid.* 1788, p. 261.

with 147 grs. of nitric acid, of ſpecific gravity 1.2754, which contained 45.7 per cent. of ſtandard acid of ſpecific gravity 1.5543. The carbonic acid which eſcaped amounted to 14 grs.; and by adding 939 grs. of water, the ſpecific gravity of the ſolution at the temperature of 58.5°, was 1.0401. By a ſimilar teſt with that employed in aſcertaining the ſtrength of ſulphuric acid, namely, by comparing this ſolution with one of nitrate of ſoda of the ſame denſity, he found the quantity of ſalt amounted to $1.\frac{16}{901}$ parts. There was an exceſs of acid of about 2 grs. The whole weight was 1439 grains. The quantity of ſalt, therefore, was $\frac{1439}{16.901} = 85.142$ grs. The quantity of pure alkali was $.50 - 14 = 36.05$ grs. The quantity of ſtandard acid was 66.7; the ſum of both $= 102.75$. Of this quantity only 85.142 entered into combination with the ſalt; the remaining 17.608 were mere water, given out by the ſtandard acid. If then 66.7 parts ſtandard acid loſe 17.608 parts water combining with the alkali, 100 parts ſhould loſe 26.38. And, as Mr Kirwan has made it probable, that nitrate of ſoda contains very little water in its compoſition; 100 parts of ſtandard nitric acid is compoſed of 73.62 of pure acid, and 26.38 of water ‡.

The following table drawn up by Mr Kirwan ſhews the quantity of pure acid in nitric acid of different ſpecific gravities.

100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.
1.5543	73.54	1.4171	53.68
1.5295	69.86	1.4120	52.94
1.5183	69.12	1.4069	52.21
1.5070	68.39	1.4018	51.47
1.4957	67.65	1.3975	50.74
1.4844	66.92	1.3925	50.00
1.4731	66.18	1.3875	49.27
1.4719	65.45	1.3825	48.53
1.4707	64.71	1.3775	47.80
1.4695	63.98+	1.3721	47.06
1.4683	63.24	1.3671	46.33
1.4671	62.51	1.3621	45.59
1.4640	61.77	1.3571	44.86+
1.4611	61.03	1.3521	44.12
1.4582	60.30	1.3468	43.38
1.4553	59.56	1.3417	42.65
1.4524	58.83	1.3364	41.91
1.4471	58.09	1.3315	41.18
1.4422	57.36	1.3264	40.44
1.4373	56.62	1.3212	39.71
1.4324	55.89	1.3160	38.97
1.4275	55.15	1.3108	38.34
1.4222	54.12+	1.3056	37.50
1.3004	36.77	1.2015	25.00
1.2911	36.03	1.1963	24.26
1.2812	35.30+	1.1911	23.53
1.2795	34.56	1.1845	22.79
1.2779	33.82	1.1779	22.06
1.2687	33.09	1.1704	21.32
1.2586	32.35	1.1639	20.59
1.2500	31.62	1.1581	19.85
1.2464	30.88	1.1524	19.12
1.2419	30.15	1.1421	18.48
1.2374	29.41	1.1319	17.65+
1.2291	29.68	1.1284	16.91
1.2209	27.94	1.1241	16.17
1.2180	27.21+	1.1165	15.44
1.2152	26.47	1.1111	14.70
1.2033	25.74+	2.1040	13.27

From experiments made by Mr Davy, he has deduced the real quantities of nitric acid in ſolutions of different ſpecific gravities, and by his eſtimation the proportions will appear in the following table *.

Table of the quantities of True Nitric Acid in ſolutions of different Specific Gravities.

100 Parts Nitric Acid of ſpecific gravity.	True Acid (M).	Water.
1,5040	91,55	8,45
1,4475	80,39	19,61
1,4285	71,65	28,35
1,3906	62,96	37,04
1,3551	56,88	43,12
1,3186	52,03	47,97
1,3042	49,04	50,96
1,2831	46,03	53,97
1,2090	45,07	54,73

506 Action of light.

9. When colourleſs nitric acid is expoſed to the light, it undergoes a partial decompoſition. Some oxygen gas is ſeparated, the acid aſſumes an orange yellow colour, and part of it paſſes into the ſtate of nitrous acid.

10. It boils at the temperature of 248°, and is entirely diſſipated without alteration, if the heat be continued. When it is made to paſs through a red-hot porcelain tube, it is decompoſed, and converted into its conſtituent parts, oxygen and azotic gaſes †. When nitric

‡ *Iriſh Tranſ.* vol. iv. p. 34.

* *Davy's Reſearches*, p. 41.

† *Fourcroy Connaiſs. Chim.* tom. ii. p. 81.

(M) The quantities of oxygen and nitrogen in any ſolution, may be thus found: Let A = the true acid, X the oxygen, and Y the nitrogen,

$$\text{Then } X = \frac{238\,A}{239} \text{ and } Y = \frac{A}{239}.$$

nitric acid (N) is cooled down to the temperature of —55°, it begins to cryſtallize in a few minutes, aſſumes a deep red colour, and congeals into a thick maſs reſembling butter, by agitating the veſſel which contains it ‡.

‡ *Annal. de Chim.* tom. xxix. p. 282.

507 Of oxygen.

11. There is no action between nitric acid and oxygen or azotic gaſes; but when concentrated nitric acid is expoſed to the air, the vapour which it exhales combines with the moiſture of the atmoſphere, forms white fumes, and is condenſed into a liquid.

508 Hydrogen.

12. Hydrogen gas has no action on nitric acid at the ordinary temperature of the atmoſphere; but if they are made to paſs through a red-hot porcelain tube, there is a violent combuſtion with detonation. Water is formed by the combination of the hydrogen with the oxygen of the acid; and azotic gas, its other conſtituent part, is evolved.

509 Charcoal.

13. Nitric acid is alſo decompoſed by charcoal at a high temperature. Carbone combines with the oxygen and forms carbonic acid, while the azotic gas is ſet at liberty.

510 Phoſphorus and ſulphur.

14. It is alſo decompoſed in the ſame way by phoſphorus and ſulphur. When the acid is poured upon theſe combuſtibles at a high temperature, inflammation takes place, and they are converted into phoſphoric and ſulphuric acids.

511 Of ſulphuric acid.

15. When the nitric and ſulphuric acids are mixed together, heat is evolved. The ſulphuric acid attracts the water which exiſted in the nitric acid, and this water being more condenſed in combination with ſulphuric acid, the caloric with which it was combined along with the nitric acid, is given out. Thus, the nitric acid becomes more concentrated by the addition of the ſulphuric acid.

512 Of ſulphurous acid.

When the nitric and ſulphurous acids are mixed together, a very different action takes place. The nitric acid ſeparates it from water and its other combinations; parts with its oxygen, and thus converts it into ſulphuric acid, and paſſes itſelf into the ſtate of nitrous gas.

513 Compoſition.

16. According to Lavoiſier, the proportions of the components parts of nitric acid are, one part azote and four parts oxygen. This was the reſult of his experiments on the decompoſition of nitre by charcoal. According to Mr Cavendiſh, the proportions of the azote and oxygen combined by electricity are 1 part azote and 2.346 of oxygen. The reſult of Mr Davy's experiments ſhews that 100 parts of pure nitric acid are compoſed of

29.5	azote,
70.5	oxygen.
100.0	

514 Combination.

17. The combinations which are formed with the nitric acid, and the alkalies, earths, and oxides of metals, are denominated *nitrates*.

515 Affinities.

18. The order of the affinities of nitric acid is the following:

Barytes,
Potaſh,
Soda,
Strontites,
Lime,
Magneſia,
Ammonia,
Glucina,
Alumina,
Zirconia,
Oxide of Zinc,
Iron,
Manganeſe,
Cobalt,
Nickel,
Lead,
Tin,
Copper,
Biſmuth,
Antimony,
Arſenic,
Mercury,
Silver,
Gold,
Platina.

516 Uſes.

19. This is one of the moſt important of the acids, conſidered as an inſtrument of analyſis in the hands of the chemiſt. It is employed in many arts. It is alſo uſed in medicine, in diſeaſes of the ſkin; and it has lately been exhibited as a cure in venereal affections. In this caſe, perhaps, it may be regarded as a uſeful auxiliary to the ordinary remedies.

SECT. IV. *Of NITROUS ACID.*

517 Method of procuring.

1. According to the preſent nomenclature, the nitrous acid ſhould bear the ſame relation to nitric acid that the ſulphurous acid bears to the ſulphuric; that is, the conſtituent parts of the nitric acid ſhould be in different proportion from thoſe of the nitrous acid; but this does not appear to be the caſe. What is uſually denominated nitrous acid, may be formed by combining nitrous gas with the nitric acid: Or if the lower ſtratum in a veſſel of nitric acid be ſlowly decompoſed by a metallic ſubſtance, the oxygen of the acid combines with the metal; nitrous gas is evolved, which combines with the ſuperior ſtrata of the nitric acid, and converts it into nitrous acid †. It has then aſſumed a yellow colour, and its ſpecific gravity is diminiſhed. The ſame effect takes place when the nitric acid is expoſed to light. It is deprived of part of its oxygen, and nitrous gas is evolved, which mixes with the acid, changes it to a yellow colour, and converts it into nitrous acid.

† *Fourcroy Connaiſs. Chim.* tom. ii. p. 93.

518 Compoſition.

2. Thus it appears, that nitrous acid is nitric acid combined with nitrous gas. The acid of commerce, or what is commonly called *aqua fortis*, is nitrous acid.

519 Combines in different proportions with nitrous gas.

3. Nitric acid combines in different proportions with nitrous

---

(N) The acid employed in this experiment contained nitrous gas.

nitrous gas, which gives riſe to many varieties of nitrous acid; and, according to the quantity of nitrous gas abſorbed, the acid exhibits very different colours. The following table, drawn up by Mr Davy, ſhews in one view the proportions of nitric acid and nitrous gas, in different coloured nitrous acids.

Table containing Approximations to the quantities of Nitric Acid, Nitrous Gas, and Water in Nitrous Acids, of different colours and ſpecific gravities.

100 Parts.		Specifi gra.		Nitric Acid	Water	Nitrous Gas.
Sol. nitric acid	of	1.504	contain	91,55	8,45	——
Yellow nitrous ‡		1,502		90,5	8.3	1,2
Bright yellow		1,500		88,94	8,10	2,96
Dark orange		1,480		86,84	7,6	5,56
Light olive ‡		1,479		86,00	7.55	6,45
Dark olive ‡		1,478		85.4	7.5	7,1
Bright green ‡		1,476		84.8	7.44	7,76
Blue green *		1,475		84,6	7.4	8,00

520 Action of light and heat.

4. Light has no action on nitrous acid; but when heat is applied, the nitrous gas is driven off, and the nitric acid remains behind. In the ſtate of vapour, nitrous acid remains unchanged by the action of heat.

5. Neither oxygen gas, azotic gas, nor atmoſpheric air, produce any change on nitrous acid.

521 Combuſtibles.

6. On combuſtible bodies the action of nitrous acid is nearly ſimilar to that of the nitric acid; but many ſubſtances are more rapidly inflamed by nitrous acid. This ſeems not only to depend on the ſtate of the diviſion or rarefaction of the nitrous gas combined with the nitric acid, but alſo on the nitrous gas itſelf being more eaſily decompoſed, and giving up its oxygen, which is leſs ſtrongly attracted by the azote, on account of the great proportion of caloric united with it in the gaſeous ſtate. It decompoſes phoſphurated and ſulphurated hydrogen gas, and precipitates the phoſphorus and the ſulphur.

522 Sulphuric acid.

7. Sulphuric acid combines with the vapour of nitrous acid, and communicates the property of diſpoſing the ſulphuric acid to cryſtallize. It converts ſulphurous into ſulphuric acid, and, at the ſame time, parts with its nitrous gas.

523 Compounds.

8. Nitrous acid enters into combination with the alkalies and earths. The compounds are diſtinguiſhed by the name of *nitrites*. Theſe compounds are not made by direct combination, and therefore the affinities of this acid are little known.

Sect. V. *Of Muriatic Acid.*

524 Compoſition unknown.

1. The component parts of this acid are unknown. No attempt which has hitherto been made to diſcover its conſtituent parts, has yet ſucceeded. But, as it reſembles the other acids, the compoſition of which has been diſcovered, in many of its properties and combinations, it is uſually arranged among this claſs of bodies. The name of muriatic acid is derived from the Latin word *muria*, which ſignifies ſea-ſalt, or common ſalt, from which it is uſually extracted. It was formerly denominated *ſpirit of ſalt*, *acid of ſalt*, and *marine acid*.

525 Names.

526 Method of procuring.

2. Muriatic acid may be obtained by putting 100 parts of dry common ſalt, and 35 parts of ſulphuric acid, into a retort or matraſs with a bent tube. The beak of the retort at the end of the tube muſt communicate with a receiver in which there is water, that the muriatic acid may be condenſed as it paſſes into the receiver. In this way liquid muriatic acid may be obtained.

527 In the ſtate of gas.

3. But if the gas which comes over is received in a jar inverted in the mercurial apparatus, its properties may be examined in the ſtate of gas. When it firſt paſſes over, it is in the form of white ſmoke.

528 Properties.

4. Muriatic acid gas poſſeſſes the phyſical properties of common air. It is an inviſible elaſtic fluid. It has a ſtrong acid taſte, and a very pungent ſmell. The ſpecific gravity, according to Kirwan, is 0.002315.

5. It is unfit for reſpiration, and equally ſo for ſupporting combuſtion.

529 Action of water.

6. This gas has a ſtrong attraction for water. If a little water be introduced into a jar filled with this gas, ſtanding over mercury, the whole of the gas will be abſorbed, and the mercury will inſtantaneouſly riſe to the top. Or if a jar filled with muriatic acid gas be inverted into a veſſel of water, coloured with vegetable blue, the water ſuddenly ruſhes into the jar, which it completely fills, and the blue colour is changed to red, exhibiting the uſual effect of acids on vegetable colours.

530 Light and heat.

7. Light has no action whatever on this gas, nor does it undergo any change when it is made to paſs through a red hot porcelain tube. In the ſtate of gas, it has no action upon oxygen gas. When this gas comes in contact with atmoſpheric air, thick white fumes are produced, with the extrication of caloric. This is a combination of the gas with the water in the atmoſphere, by which they are mutually condenſed.

8. There is no action between muriatic acid gas and azote, hydrogen, charcoal, phoſphorus, or ſulphur.

531 Combines with water in great proportion.

9. The quantity of water which muriatic acid abſorbs is very conſiderable. Ten grs. of water combine with ten grs. of the gas. The liquid acid thus formed occupies the ſpace of 13.3 grs. and hence its ſpecific gravity is 1.500; and the ſpecific gravity of the pureſt muriatic acid in its condenſed ſtate is 3.300 (o).

The ſpecific gravity of the ſtrongeſt muriatic acid that can eaſily be procured and preſerved, is 1.196.

One

---

* "The blue green acid is not homogeneal in its compoſition. it is compoſed of the blue green ſpherules and the bright green acid. The blue green ſpherules are of greater ſpecific gravity than the dark green acid, probably becauſe they contain little or no water.

‡ "The compoſition of the acids thus marked, is given from calculations."

(o) "Let $D =$ the denſity of a mixture; m the weight of the denſer ingredient; d its denſity; l the weight

of

One hundred parts of this, Mr Kirwan calculates, will contain about 49 of acid, whoſe ſpecific gravity is 1.500, which he calls the ſtandard acid. By mixing this acid with different proportions of water, he obtained the reſults from which he conſtructed the following table.

Table of the quantity of Real Acid in 100 *parts of Muriatic Acid of different Specific Gravities, at the Temperature* 60°.

100 Parts Sp. Gravity.	Real Acid.	100 Parts Sp. Gravity.	Real Acid.
1.196	25.28	1.1282	16.51
1.191	24.76	1.1244	15.99
1.187	24.25	1.1206	15.48
1.183	23.73	1.1168	14.96
1.179	23.22	1.1120	14.44
1.175	22.70	1.1078	13.93
1.171	22.18	1.1036	13.41
1.167	21.67	1.0984	12.90
1.163	21.15	1.0942	12.38
1.159	20.64	1.0910	11.86
1.155	20.12	1.0868	11.35
1151	19.60	1.0826	10.83
1147	19.09	1.0784	10.32
1.1414	18.57	1.0742	9.80
1.1396	18.06	1.0630	8.25
1.1358	17.54	1.0345	5.16
1.1320	17.02	1.0169	2.58

532
Properties.

10. The liquid muriatic acid, in its ordinary ſtate, is of a pale yellow colour; but when it is pure, it is tranſparent and colourleſs.

533
Action of light and heat.

11. Light has no action whatever on muriatic acid. When heat is applied, it readily aſſumes the gaſeous form. Neither oxygen nor azotic gaſes are abſorbed by muriatic acid, nor has this acid any action on hydrogen, charcoal, phoſphorus, or ſulphur.

534
Of ſulphuric acid.

12. The ſulphuric acid ſeparates the muriatic acid from its compounds, and even from its combination with water; but the muriatic acid drives off the ſulphurous acid from this liquid.

535
Of nitric acid.

13. One of the moſt remarkable characters of the muriatic acid, is its combination with the nitric acid. When theſe two acids are mixed together, they act upon each other, are ſtrongly heated, and produce effervеſcence, with a change of colour to an orange red. A mixed acid is thus formed, which poſſeſſes properties which exiſted neither in the one acid nor the other when in a ſtate of ſeparation. It was formerly called *aqua regia*, from its property of diſſolving gold, which was diſtinguiſhed by the name of *king of the metals*. It is now denominated *nitro-muriatic acid*. This acid is not to be conſidered as a ſimple mixture of the two acids. A double attraction takes place in their mutual action; the muriatic acid attracts part of the oxygen of the nitric acid, and the nitric combines with the nitrous gas. The muriatic acid thus combined with a portion of oxygen, is diſengaged with effervеſcence in yellow fumes: the undecompoſed nitric acid ſeizes the nitrous gas which is formed, and when it is ſaturated with it, the action ceaſes. Hence ariſes the colour of the mixed acid. The peculiar effect of the nitro-muriatic acid on metallic ſubſtances, will be deſcribed in treating of the metals.

536
Nitro-muriatic acid.

537
Suppoſed formation of muriatic acid.

14. In analyſing a mineral water, Mr Lambe concluded, from ſome appearances which preſented themſelves during his experiments, that the muriatic acid was formed or generated; for when iron was acted upon by ſulphurated hydrogen gas, oxymuriate of iron was formed. He digeſted iron filings, previouſly purified, in a ſolution of ſulphurated hydrogen gas, in diſtilled water. A bottle was filled with the ſolution, and corked. The iron was preſently acted upon; air was extricated, probably hydrogen gas, which drove the cork out of the bottle. The liquor, gradually loſt its odour, and at the end of ſome days it had a ſmell reſembling that of ſtagnant rain water. As the bubbles ceaſed to be produced, it recovered its tranſparency: A ſmall quantity of this ſolution evaporated to dryneſs, left behind a bitter, deliqueſcent ſalt. Sulphuric acid dropt on this ſalt, and paper moiſtened with ammonia, held over the glaſs, produced vapours, ſo that ſome volatile acid was ſeparated. Eight ounce meaſures of the ſame liquor were evaporated, and a little ſulphuric acid was dropt on the reſiduum. A ſtrong effervеſcence was excited, and acid fumes aroſe, which, from their ſmell, were readily known to be muriatic acid. Paper moiſtened with water rendered the vapours viſible in the form of a gray ſmoke, which is the diſtinguiſhing characteriſtic of muriatic acid. The ſame appearances were exhibited with the ſame reſult, when manganeſe and mercury were diſſolved in ſulphurated hydrogen gas *.

The ſame experiments have been repeated; but no traces of muriatic acid, in any of the compounds that were formed, could be found. In an experiment by Berthollet, indeed, iron filings waſhed with water which gave no marks of containing muriatic acid, when they were expoſed ſome days to the air, and again waſhed, exhibited ſome traces of it; ſo that the acid itſelf, or its elements, muſt have come from the air or the iron.

15. The

* *Manch. Mem.* vol. x. p. 194.

---

of an equal bulk of water; and m', d', and l the ſame elements of the rarer: Then $D = \frac{m+m'}{l+l'}$. In the above caſe, $m+m' = 20$, and $l+l' = 13.3$. Then $D = \frac{20}{13.3} = 1.5$. Now to find the ſpecific gravity of the condenſed muriatic acid gas, we have from the above equation $l = \frac{m+m'-l'D}{D} = \frac{5}{1.5} = 3.3$; and $d = \frac{m}{l} = \frac{10}{3.3} = 3.03$. *Kirwan. Iriſh Tranſactions*, vol. iv. p. 5.

538 Action of electricity.
15. The bulk of muriatic acid gas is greatly diminiſhed by the action of electricity, and hydrogen gas is given out; but this action is limited. Mr Henry has ſhewn that it is not owing to the decompoſition of the acid, as might at firſt ſight be ſuppoſed, but to the decompoſition of water which it holds in ſolution; ſo that the action continues as long as there is any moiſture in the gas. The oxygen of the water combines with the acid, and forms oxymuriatic acid; while the hydrogen of the water is evolved.

539 Uſes in deſtroying noxious vapours.
16. Muriatic acid gas has been ſucceſsfully employed in deſtroying noxious, putrid exhalations. It was applied in this way in the year 1773 by Morveau, in purifying the cathedral of Dijon from theſe exhalations, on account of which it had been altogether deſerted. He put ſix pounds of common ſalt into a glaſs veſſel, placed in the middle of the church, poured two pounds of ſulphuric acid on the ſalt, placed the veſſel on ſome live coals, and immediately ſhut the doors. It was allowed to remain 12 hours; after which the doors were opened. A current of air was allowed to paſs through it; when the noxious vapours were found to be deſtroyed.

540 Compounds
17. The compounds which are formed by the muriatic aid, with alkalies, earths, and metallic oxides, are diſtinguiſhed by the name of *muriates*.

541 Affinities.
18. The following is the order of the affinities of this acid.

Barytes,
Potaſh,
Strontites,
Lime,
Ammonia.
Magneſia,
Glucina,
Alumina,
Metallic oxides.

Sect. VI. *Of Oxymuriatic Acid.*

542 Hiſtory.
1. The oxymuriatic acid was diſcovered by Scheele in the year 1774, and he gave it the name of *dephlogiſticated marine acid*. On account of its ſingular properties, and the important uſes to which it was ſoon applied, it has been much examined by chemical philoſophers.

543 Method of procuring.
2. This acid is obtained by the following proceſs: Take three parts of common ſalt, and one part of the black oxide of manganeſe reduced to powder. Introduce them into a tubulated retort; place the retort in a ſand bath, and immerſe its beak under the ſurface of the water in the pneumatic trough. Pour upon it two parts of ſulphuric acid a little diluted with water. An efferveſcence takes place, and a yellow coloured gas is evolved, which may be received in jars, or preſerved in large veſſels with ground ſtoppers.

The nature of this proceſs is ſufficiently obvious. Common ſalt is compoſed of the muriatic acid and ſoda; the affinity of the ſulphuric acid for ſoda is ſtronger than that of the muriatic acid; it therefore combines with the ſoda, and the muriatic acid is diſengaged in the ſtate of gas. The black oxide of manganeſe is compoſed of oxygen and the metallic ſubſtance. The ſulphuric acid combines with the manganeſe, and ſets the oxygen at liberty in the ſtate of gas. But there is alſo an affinity between the muriatic acid and oxygen, ſo that in the moment of evolution they unite, and paſs off in the ſtate of oxymuriatic acid gas.

544 Properties.
3. This gas is of a yellowiſh green colour, has a ſtrong penetrating odour, and excites violent coughing, when a mixture of it with atmoſpheric air is reſpired; but the pure gas is totally unfit for reſpiration. This gas ſupports combuſtion. It diminiſhes and reddens the flame of a taper; a great deal of ſmoke is evolved, and the taper conſumes very rapidly.

545 Unchanged by light and heat.
4. Neither light nor heat have any action on the gas. When paſſed through red-hot porcelain tubes, it remains unchanged.

546 Action of hydrogen gas.
5. It has no action whatever on oxygen or azotic gaſſes.

6. In the cold no effect is produced from a mixture of this gas with hydrogen gas; but when they are paſſed through a red-hot tube, there is a violent detonation.

547 Of charcoal.
7. In the cold there is no action between charcoal and this gas. When a mixture of equal bulks of this gas and carbonated hydrogen gas is ſet fire to, there is only a combuſtion of the hydrogen gas, with a depoſition of charcoal. If two meaſures of oxymuriatic acid gas, and one meaſure of carbonated hydrogen gas are mixed together in a cloſe phial, and allowed to remain for 24 hours, they decompoſe each other. Water, muriatic acid, carbonic acid, and gaſeous oxide of carbone, are the products. When water is admitted, the whole will be nearly abſorbed.

548 Of phoſphorus.
8. A bit of dried phoſphorus introduced into this gas, is inſtantly inflamed, and converted into phoſphoric acid. It alſo ſets fire to phoſphorated hydrogen gas, which has loſt the property of ſpontaneous inflammation in the air.

549 Of ſulphur.
9. Melted ſulphur, plunged into this gas, is immediately inflamed, and converted into ſulphuric acid. Sulphurated hygrogen gas is decompoſed, but without inflammation, and ſulphur is depoſited.

550 Sulphurous acid.
10. There is no action between this gas and ſulphuric acid; but, when ſulphurous acid gas is mixed with it a thick, white vapour is formed, which is the ſulphurous acid converted into ſulphuric acid, by depriving the oxymuriatic acid gas of its oxygen. It has no effect on nitric acid; but nitrous gas brought into contact with it, is reddened, and converted into nitrous acid.

551 In the liquid ſtate.
11. What is commonly known by the name of *oxymuriatic acid*, is water ſaturated with this gas. It has a pale green colour, and exhales the ſame odour as the gas. According to Berthollet, a cubic inch of water abſorbs $1\frac{6}{10}$ grs. French of the gas. The quantity abſorbed by the water is in proportion to the temperature and the preſſure. When veſſels containing water, and receiving this gas, are ſurrounded with ice, while the water is ſaturated, the gas cryſtallizes at the ſurface, and even at the bottom of the liquid, in the form of ſix-ſided plates, of a greeniſh white colour; but the ſlighteſt heat diſſolves them, and they riſe through the liquor in the form of gas.

Water ſaturated with this gas at the temperature of 43° has the ſpecific gravity of 1.003.

552 Deſtroys vegetable colours.
12. This acid does not redden vegetable blues, like the other acids. It has the ſingular property of deſtroying vegetable colours, on account of which it has been

been much employed in the art of bleaching. The effect which takes place in this proceſs, is the combination of the colouring matter with the oxygen of the acid; for the acid which has been employed is deprived of its oxygen, and converted into muriatic acid. But for the full account of this proceſs, ſee BLEACHING.

553 Action of light. 13. When this acid is expoſed to the light, it is decompoſed; it gives out its oxygen gas, becomes colourleſs, and paſſes into the ſtate of muriatic acid. But when heat is applied, the acid is diſengaged in the ſtate of gas, without any perceptible ſeparation of its oxygen. Expoſed to the air, the acid is gradually ſeparated, exhaling, at the ſame time, its pungent, diſagreeable odour.

554 Compoſition. 14. The conſtituent parts of oxymuriatic acid, according to Berthollet, are

89 muriatic acid,
11 oxygen.

100

But, according to the experiments of Mr Chenevix, it is compoſed of

84 muriatic acid,
16 oxygen.

100

SECT. VII. *Of* HYPER-OXYMURIATIC ACID.

555 Nature. 1. Oxygen combines in a different proportion with muriatic acid, and forms another acid, poſſeſſed of properties which are quite diſtinct from the properties of the laſt deſcribed. This acid has never been obtained in a ſeparate ſtate, but the peculiarity of its nature has been ſufficiently demonſtrated, in its combinations with other ſubſtances. As it contains a greater proportion of oxygen than the oxymuriatic acid, it has been denominated *hyper-oxymuriatic acid*.

556 How obtained. 2. It may be procured in combination with potaſh by the following proceſs. If a quantity of potaſh, with ſix times its weight of water, be put into one of the bottles of Woulfe's apparatus, and a ſtream of oxymuriatic acid gas be paſſed through it till the potaſh is ſaturated, cryſtals in the form of fine white ſcales fall to the bottom. Theſe are cryſtals of hyper-oxymuriate of potaſh, compoſed of potaſh and of hyper-oxymuriatic acid. The liquid in which theſe ſalts have been formed being evaporated to dryneſs, yields another ſalt which is compoſed of muriatic acid and potaſh. 557 Theory of the proceſs. This was the diſcovery of Berthollet; and the theory which he propoſed to account for the products that appeared in this proceſs was the following. He ſuppoſed that the oxymuriatic acid was decompoſed: part of it being deprived of its oxygen, combined in the ſtate of muriatic acid with part of the potaſh, forming the ſalt which was obtained by evaporation, namely, the muriate of potaſh; and part united with an additional portion of oxygen combined with another portion of the potaſh, and formed the ſalt which was depoſited in the liquid. This theory has been confirmed by the experiments of Mr Chenevix. According to theſe experiments the hyper-oxymuriatic acid is compoſed of

65 oxygen,
35 muriatic acid.

100

558 Compoſition. But its properties will be more fully detailed in conſidering its combination with potaſh, when we come to treat of that ſubſtance.

559 Affinities. 3. The order of the affinities of hyper-oxymuriatic acid, is the following, as they have been aſcertained by Mr Chenevix *.

Potaſh,
Soda,
Barytes
Strontites
Lime,
Ammonia,
Magneſia,
Alumina.

SECT. VIII. *Of* FLUORIC ACID.

560 Hiſtory. 1. The component parts of this acid are unknown. It was diſcovered by Scheele in 1771, and by him and Prieſtley its peculiar properties, which have been confirmed by the experiments of other chemiſts, were firſt detected. Margraaff, three years before, had aſcertained that the fluor ſpar, from which this acid is obtained, differed in its properties from other ſpars. When he diſtilled equal parts of ſulphuric acid and fluor ſpar, he obtained a white ſublimate, and found that the glaſs retort which he employed in the proceſs was greatly corroded, and pierced with holes. Scheele afterwards proved by his experiments, that the fluor ſpar is compoſed of lime and the peculiar acid to which the name fluoric has been given.

561 Method of obtaining it. 2. To procure fluoric acid, put one ounce of fluor ſpar (fluate of lime) reduced to powder into a retort of tin or lead, pour over it three ounces of concentrated ſulphuric acid, and adapt to the retort a tube and receiver of the ſame metal. When the acid comes in contact with the ſpar a gas is driven off, which is the fluoric acid. Toward the end of the proceſs, if a gentle heat be applied, a greater quantity of the acid may be obtained. If water has been previouſly introduced into the receiver, the gas is abſorbed by it, and the acid may then be exhibited in the liquid ſtate.

562 Properties of this gas. 3. The fluoric acid appears under two forms, that of gas and that of a liquid.

The fluoric acid gas has the common properties of air. It is inviſible and elaſtic. Its ſpecific gravity has not been accurately determined, but it is heavier than atmoſpheric air. Expoſed to the air it combines inſtantly with the moiſture of the atmoſphere, and appears in the form of vapour or white fumes. Like muriatic acid, it has a penetrating pungent ſmell. It reddens vegetable blues, and corrodes the ſkin. It is totally unfit for reſpiration. Animals who breathe it are inſtantly deſtroyed. It is alſo unfit for the ſupport of combuſtion. But before the flame of a candle introduced into this gas is extinguiſhed, it aſſumes a greeniſh colour. The moſt remarkable property of this gas is that of corroding glaſs, in conſequence of its ſtrong affinity for the ſilex one of the component parts

---

* *Phil. Tranſ.* 1802. p. 126.

parts of glaſs. This is the reaſon that it muſt be prepared in metallic veſſels. And even with this precaution, it is ſeldom entirely free from this earth, which it probably derives from the fluor ſpar, from which it is obtained.

4. Light and caloric have no effect on it. Its properties undergo no alteration, even when it has paſſed through a red-hot porcelain tube.

In contact with oxygenous gas or atmoſpheric air, no change takes place on fluoric acid gas; nor has it any action on azote, hydrogen, carbone, phoſphorus, or ſulphur. The other acids, it has been obſerved, are decompoſed by one or other of theſe combuſtibles; and in this way their conſtituent parts have been detected. We are not however to conclude from thence, that the fluoric acid is a ſimple ſubſtance. On the contrary, it would be more analogous to other facts, to draw the concluſion, that it is a compound, ſimilar to the other acids, whoſe baſes have been diſcovered, and that the baſe, whatever that may be, has ſo ſtrong an attraction for oxygen as to be unſuſceptible of decompoſition by the action of any ſubſtances yet known.

563 Combines with water. 5. When this gas comes in contact with water it is rapidly abſorbed, and in conſiderable proportion. In this ſtate it is called *fluoric* acid. The ſpecific gravity of this acid is greater than that of water. By heat the gas is almoſt entirely expelled from the water; and when it is cooled down to the temperature 23° it freezes.

564 Compounds. 6. The compounds with the alkalies, earths, and metallic oxides, are called *fluates*.

565 Affinities. 7. The order of its affinities is the following:

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Glucina.
Alumina,
Zirconia,
Silica.

Sect. IX. *Of Boracic Acid.*

566 Diſcovery. 1. The component parts of boracic acid are unknown. It was firſt diſcovered by Homberg in 1702, who gave it the name of *narcotic or ſedative ſalt*. The ſubſtance called borax of the ſhops is a compound of this acid and ſoda.

567 Preparation. 2. The proceſs for obtaining this acid is the following: Diſſolve a quantity of this ſubſtance in hot water, and filter the ſolution. Gradually pour on it ſulphuric acid, till the liquor acquires a ſlight degree of acidity. The ſulphuric acid combines with the ſoda; and the boracic acid, as the ſolution cools, is precipitated in ſmall, ſhining white ſcales. To purify the acid thus obtained, it is to be waſhed with cold water, which removes the more ſoluble ſalts with which it is mixed.

568 Properties. 3. The boracic acid is in the form of ſilvery white hexagonal ſcales, which have a greaſy feel, and ſome reſemblance to ſpermaceti. It has a ſouriſh taſte, which afterwards gives the ſenſation of coolneſs. It has no ſmell. It changes vegetable blues to red. In the ſcaly form, the ſpecific gravity is 1.479, but when it is fuſed, it is 1.803.

569 Action of heat. 4. When expoſed to heat, it froths up, which is owing to the ſeparation of the water of cryſtallization, and aſſumes the form of a viſcid paſte. In this ſtate it is known by the name of *calcined borax*. When it is expoſed to a red heat, it is converted into a hard, tranſparent glaſs, which, without attracting moiſture from the air, becomes opaque when expoſed to it, but it remains unchanged; for when it is re-diſſolved in warm water, it reſumes its former properties, by cooling and cryſtallization *.

570 Of water. 5. Boracic acid has very little attraction for water, boiling water only diſſolves about a 50th part of its weight, and cold water much leſs. When the ſolution in water is evaporated in cloſe veſſels, part of the acid riſes in the ſtate of vapour along with the water, and cryſtallizes in the receiver; but when the whole of the water is diſſipated, the proceſs ſtops; ſo that it is only by means of it that the acid is volatilized; otherwiſe it is perfectly fixed. The ſolution in water has little taſte, but it reddens the tincture of turnſole.

6. Neither oxygen, azotic, nor hydrogen gaſes, produce any effect upon it; and with charcoal, phoſphorus, and ſulphur, it alſo remains unchanged. When burnt with phoſphorus, indeed, there is left behind an earthy, yellow matter.

571 On acids. 7. At a red heat it drives off ſome of the acids from their combinations, even thoſe acids which have the ſtronger affinity for the ſame ſubſtances in the cold. Boracic acid has ſome peculiar action with the ſulphuric, the nitric, and oxymuriatic acids; for when it is heated with theſe acids, it deprives them of a portion of their oxygen; but the changes which take place by this action have not been diſtinctly aſcertained †.

8. Fabroni of Florence conſiders this acid as a modification of the muriatic, and he ſuppoſes that it may be entirely formed with this acid. The boracic acid, he farther ſuppoſes, is probably produced by this modification of the muriatic acid in the water of the lakes of Tuſcany; but the facts on which this opinion is founded, have not been publiſhed ‡.

572 Uſes. 9. The boracic acid is employed in chemiſtry not directly as an inſtrument of analyſis, becauſe its affinities and action have little energy compared with other acids, but to diſcover its peculiar combinations and compounds. It is alſo employed in the arts, as in ſoldering, to aſſiſt the fuſion of metallic ſubſtances. It is of great importance to the mineralogiſt, in promoting the fuſion of ſubſtances under the blow-pipe.

573 Compounds. 10. The compounds which boracic acid forms with the alkalies, earths, and metallic oxides, are diſtinguiſhed by the name of *borates*.

574 Affinities. 11. The affinities of boracic acid are the following:

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Glucina,
Alumina,
Zirconia,
Water,
Alcohol.

---

* *Fourcroy Connaiſſ.* tom. ii. p. 125.

† *Ibid.* p. 127.

‡ *Ibid.* p. 128.

Sect. X. *Of Phosphoric Acid.*

575 Formation. 1. When phoſphorus undergoes combuſtion in oxygen gas, a great quantity of white fumes are produced, which are depoſited in white flakes. Theſe are phoſphoric acid; ſo that it is a compound of phoſphorus and oxygen.

576 Hiſtory. 2. The phoſphoric acid was firſt ſhown to be diſtinct from all other acids, in the year 1743, by Margraaff. He found that it exiſted in the ſalts which were taken from human urine, and that phoſphorus could only be obtained from this acid; as well as that it could be converted into phoſphoric acid. This acid was found to exiſt in ſome vegetable ſubſtances, although it was formerly ſuppoſed to be peculiar to animal matters. It was diſcovered by Scheele and Gahn in bones, in the year 1772. Bergman, Prouſt, and Tenant, detected it in ſeveral foſſils, and Lavoiſier proved by a ſeries of accurate and ingenious experiments, that it was compoſed of phoſphorus and oxygen.

577 Preparation. 3. Phoſphoric acid may be obtained, not only by the method juſt mentioned, but alſo by tranſmitting a current of oxygen gas through phoſphorus melted under water. The acid as it is formed, combines with the water, from which it may be obtained in a ſtate of purity by evaporation. It may be procured alſo by dropping ſmall bits of phoſphorus into nitric acid moderately heated. An efferveſcence takes place, and nitrous gas is evolved. Phoſphorus combines with the oxygen, and forms phoſphoric acid. The precaution of adding but a little phoſphorus at a time, and of applying a moderate heat to the acid, ſhould be carefully obſerved. The liquid is then evaporated, and the phoſphoric acid remains behind in the ſolid ſtate. The water that may be combined with it is driven off, by expoſing it to a red heat.

578 Properties. 4. In this ſtate phoſphoric acid is a tranſparent, colourleſs, ſolid ſubſtance, reſembling glaſs, known under the name of *phoſphoric glaſs*.

The ſpecific gravity of this acid varies, according to the different ſtates in which it exiſts. In the liquid ſtate it is 1.417; in the dry ſtate it is 2.697; in the ſtate of glaſs 2.8516. It changes the colour of vegetable blues to red; has no ſmell, but a very acid taſte.

579 Attracts moiſture. 5. When it is expoſed to the air, it attracts moiſture, and is converted into a thick viſcid fluid, like oil. It is very ſoluble in water. When in the form of dry flakes, it diſſolves in a ſmall quantity of this liquid, producing a hiſſing noiſe like that of a red-hot iron plunged into water, with the extrication of a great quantity of heat. In the ſtate of glaſs it diſſolves more ſlowly, but the concentrated liquid phoſphoric acid unites with water with very little diſengagement of caloric.

580 Action of charcoal. 6. Phoſphoric acid being fully ſaturated with oxygen, has no action whatever on oxygen gas; nor is there any action between hydrogen or azotic gaſes, or ſulphur, with the phoſphoric acid. Charcoal has no effect on phoſphoric acid in the cold; but when they are expoſed together to a red heat, the phoſphoric acid is decompoſed; the oxygen combines with the carbone of the charcoal, forming carbonic acid, and the phoſphorus is ſet at liberty. This is the proceſs already deſcribed in treating of phoſphorus, which is generally employed for obtaining that ſubſtance.

581 Of acids. 7. The ſulphuric has no action on the phoſphoric acid; but when the two acids are mixed together in the liquid ſtate, the ſulphuric acid, on account of its ſtrong affinity for water, combines with the water in the phoſphoric acid; and if heat be applied, the ſulphuric acid is diſſipated, and the phoſphoric acid remains behind in the ſtate of a tranſparent viſcid matter, or in that of glaſs. The ſulphurous acid is ſeparated from its combinations by the phoſphoric acid. The nitric acid ſeparates the phoſphoric from its combinations. The muriatic acid has the ſame effect.

582 Compoſition. 8. The component parts of this acid have been accurately aſcertained by Lavoiſier, and it conſiſts of,

60 oxygen,
40 phoſphorus.
100

583 Importance. 9. The accuracy of our information with regard to the component parts and properties of phoſphoric acid, renders it of great importance in many chemical operations; and if it could be obtained with leſs difficulty and expence, its uſes might be extended to medicine and the arts.

584 Compounds. 10. It combines with the alkalies, earths, and metallic oxides, and forms ſalts which are denominated *phoſphates*.

585 Affinities. 11. The following is the order of its affinities.

Barytes,
Strontites,
Lime,
Potaſh,
Soda,
Ammonia,
Magneſia,
Glucina,
Alumina,
Zirconia,
Metallic oxides,
Silica.

Sect. XI. *Of Phosphorous Acid.*

586 Formation. 1. The phoſphorous acid bears the ſame relation to the phoſphoric as the ſulphurous acid does to the ſulphuric. It is combined with oxygen in the ſmaller proportion. This was demonſtrated by Lavoiſier in 1777, when he pointed out the difference between the product from the ſlow or rapid combuſtion of phoſphorus. It is obtained by the ſlow combuſtion of phoſphorus at the common temperature of the air. If phoſphorus, in ſmall pieces, be expoſed to the air in a glaſs funnel placed in a bottle, it attracts the oxygen and moiſture from the atmoſphere, and runs down into the bottle. This is the phoſphorous acid. By this proceſs, about three times the weight of the phoſphorus is obtained.

586 Properties. 2. It is then in the form of a white thick liquid, adhering to the ſides of the veſſel. It varies in conſiſtence according to the ſtate of the air. Its ſpecific gravity

gravity is not known. It has an acid, pungent taſte, not different from phoſphoric acid. It alſo reddens vegetable blue colours.

588 Action of heat. 2. The phoſphorous acid is not altered by light. When expoſed to heat in a retort, part of the water combined with it is firſt driven off, and when it is concentrated, bubbles of air ſuddenly riſe to the ſurface, and collect in the form of white ſmoke, and ſometimes inflame, if there be any air in the apparatus. If the experiment be made in an open veſſel, each bubble of air, when it comes to the ſurface, produces a vivid deflagration, and diffuſes the odour of phoſphorated hydrogen gas. This inflammable gas continues to be evolved for a long time, and when the action ceaſes, phoſphoric acid only remains behind. It ought to be obſerved, that the phoſphorated hydrogen gas is not diſengaged till the phoſphorous acid is concentrated and brought to a high temperature, which ſeems to prove that the phoſphorus which is not ſaturated with oxygen, ſtrongly adheres to it.

589 Oxygen. 4. There is little attraction between oxygen and phoſphorous acid, which ſeems to be owing to the great affinity between phoſphorus and phoſphoric acid. It abſorbs, however, very ſlowly, a ſmall quantity of oxygen; and even after long boiling, it is not completely converted into phoſphoric acid.

590 Hydrogen. 5. Hydrogen gas has no action on phoſphorous acid; but this acid is decompoſed at a red heat, by means of charcoal, which ſeparates from it a greater quantity of phoſphorus than from phoſphoric acid. There is no action between theſe bodies in the cold. Sulphur has no action on this acid at the ordinary temperature of the atmoſphere, and they cannot be combined by means of heat, becauſe the phoſphorus is diſſipated before it unites with the ſulphur.

591 Of acids. 6. There is no action between phoſphorous acid and ſulphuric acid in the cold; but when they are heated together to the boiling temperature, the phoſphorous acid deprives the ſulphuric of part of its oxygen, and is converted into phoſphoric acid, while part of the ſulphuric acid thus decompoſed, is diſengaged in the ſtate of ſulphurous acid gas. Phoſphorous acid produces a ſimilar effect on nitric acid. The phoſphorus is converted into phoſphoric acid, and part of the nitric acid is converted into nitrous gas.

592 Compoſition. 7. This acid is compoſed of the ſame conſtituent parts as the phoſphoric, and is conſidered by ſome as the phoſphoric acid holding in ſolution a ſmall quantity of phoſphorus *.

593 Compounds. 8. Phoſphorous acid forms compounds with alkalies, earths, and metallic oxides, which are known under the name of *phoſphites*.

594 Affinities. 9. The order of its affinities is the following.

Lime,
Barytes,
Strontites,
Potaſh,
Soda,
Ammonia,
Glucina,
Alumina,
Zirconia,
Metallic oxides.

SECT. XII. *Of Carbonic Acid.*

595 Formation. 1. When a piece of charcoal in a ſtate of ignition, is plunged into a jar of oxygen gas, it burns with great brilliancy; and after the combuſtion has ceaſed, the air in the veſſel is totally changed. If a little water is introduced into the jar, and agitated, the air combines with it; and this water, when examined, exhibits acid properties. This is the *carbonic acid*. It is formed by the combination of carbone and oxygen. This is one of the moſt important acids, both on account of its numerous combinations, and alſo on account of the diſcovery of it having occaſioned a total revolution in chemical ſcience.

596 Names. 2. It was regarded by the ancients, on account of the noxious effects which it produced as a peſtilential vapour, and they gave it the name of *ſpiritus lethalis*. Paracelſus and Van Helmont conſidered it as a peculiar matter, to which they gave the name, *ſpiritus ſylveſtris*, or *gas*. Hales, although he conſidered it merely as contaminated air, diſtinguiſhed it by the name of *fixed air*, becauſe it entered into the compoſition of many bodies. Dr Black demonſtrated, that it is a peculiar ſubſtance, different from the air; that lime, magneſia, and the alkalies, were deprived of their cauſticity, by being combined with this air, and therefore he gave it the name of *fixed air*. It was afterwards found by the experiments of Keir and Bergman, to be an acid, and hence Bergman gave it the name of *aerial acid*. The nature and properties of this acid were inveſtigated by many chemical philoſophers, and from them it received various names, as *mephitic acid*, *calcareous* or *cretaceous acid*, thus diſtinguiſhed from its effects, or from the ſubſtances from which it was obtained. In the preſent chemical nomenclature it has the name of *carbonic acid*, from its baſe *carbone*.

597 At firſt ſuppoſed ſimple. 3. For ſome time after the diſcovery of the difference between carbonic acid and common air, and its properties as an acid, it was conſidered by many as a ſimple elementary ſubſtance, and it was regarded as the acidifying principle. In the progreſs of inveſtigation it was found to be a compound ſubſtance, and that oxygen was one of its conſtituent parts, and it was generally believed that phlogiſton conſtituted the other. When hydrogen was ſubſtituted for phlogiſton, it was ſuppoſed that oxygen and hydrogen conſtituted carbonic acid. The diſcovery of Mr Cavendiſh, proved that water, not carbonic acid, was the product of the combination of oxygen and hydrogen. But the experiments of Lavoiſier have eſtabliſhed the fact, and placed it beyond diſpute. He demonſtrated that the weight of the carbonic acid which was obtained, was exactly equal to the quantity of the oxygen and charcoal which had diſappeared.

598 Method of obtaining. 4. Carbonic acid may be obtained by taking a quantity of chalk or limeſtone, or marble, and reducing them to a coarſe powder. Introduce it into a matraſs, pour over it a quantity of diluted ſulphuric or nitric acids; a violent efferveſcence takes place, carbonic acid gas is diſengaged, which paſſes over, and may be received in veſſels in the uſual way. The chemical action that takes place in this change muſt be obvious. The affinity of the ſulphuric acid for the lime is ſtrong-

er

---

* *Fourcroy Connaiſs. Chim.* tom. ii. p. 85. *Lagrange*, i. 183.

er than that of the carbonic acid, which is previouſly in combination with it; the ſulphuric acid, therefore, ſeizes the lime, and the carbonic acid is diſengaged in the ſtate of gas.

599 Properties. 5. Carbonic acid thus obtained in the ſtate of gas, is an inviſible, elaſtic fluid. Its ſpecific gravity is 0.0018. One hundred cubic inches of it weigh 46.5 grs. It is nearly double the weight of common air. It has no ſmell; it is totally unfit for reſpiration, and equally ſo for ſupporting combuſtion. It reddens the tincture of turnſole, which has its blue colour reſtored on being expoſed to the air, by the ſeparation of the acid.

600 Abſorbed by water. 6. Water abſorbs a conſiderable proportion of this acid, which is increaſed by agitation. At the temperature of 41° water abſorbs its own bulk. When artificial preſſure is employed, the quantity of gas abſorbed may be greatly increaſed. It is in this way that what are called the aerated alkaline waters are prepared, ſome of which, it is ſaid, contain no leſs than three times their bulk of the gas. Water impregnated with this gas, acquires an acidulous taſte, and when poured from one veſſel to another, has a ſparkling appearance. When water impregnated with this acid is expoſed to the air, it ſoon diſappears. The air of the atmoſphere attracts it from the water, having a ſtronger affinity for it than the water.

When water containing this gas is raiſed to the boiling temperature, the whole is driven off; and if water impregnated with it be expoſed to the temperature of 32°, the whole of the gas ſeparates during the freezing.

601 Not altered by light or heat. 7. Carbonic acid undergoes no change by the action of light. It is not changed by the action of heat in cloſe veſſels, or by paſſing it through a red-hot tube.

602 Attracted by the air. 8. There is no action between this gas and oxygen. Expoſed to the air of the atmoſphere, it is gradually diſſipated. The air of the atmoſphere generally contains from .01 to .02 parts of this gas.

603 Abſorbed by charcoal. 9. There is no action between this acid and azote. Charcoal has no chemical action on carbonic acid; but when it is heated, it has the property of abſorbing and condenſing within its pores the carbonic acid; but the acid is ſeparated by plunging the charcoal under water.

10. Phoſphorus has no action on carbonic acid; but by the aid of compound affinity, phoſphorus can decompoſe it.

11. Sulphur has ſtill leſs action on carbonic acid than phoſphorus. It is ſaid, indeed, that a ſmall quantity of ſulphur is diſſolved by this gas by means of heat, which gives it partly the fetid odour of ſulphurated hydrogen gas.

604 Diminiſhes combuſtibility. 12. Carbonic acid gas mixed with carbonated, phoſphorated, and ſulphurated hydrogen gaſes, diminiſhes the combuſtibility of theſe inflammable gaſes.

605 Compounds. 13. The carbonic acid combines with the alkalies ſome of the earths, and metallic oxides, forming compounds known by the name of *carbonates*.

606 Affinities. 14. The following is the order of the affinities of this acid.

Barytes,
Strontites,
Lime,
Potaſh,
Soda,
Magneſia,
Ammonia,
Glucina,
Zirconia,
Metallic oxides.

607 Very abundant. 15. Carbonic acid exiſts in great abundance in nature. It is produced during the proceſſes of combuſtion and reſpiration, and the fermentation of vegetable matters. Hence it is found in pits and caverns, where there is a ſtagnation of the air, and being ſpecifically heavier than common air, it remains at the bottom. This is the reaſon why ſmall quadrupeds, as dogs, are inſtantly ſuffocated, becauſe they reſpire only this gas, when they enter places where it is accumulated. This has been long obſerved in the celebrated Grotto dell Cani in Italy, where dogs are inſtantly ſuffocated; while men, whoſe heads are in the ſtratum of common air near the top of the cavern, receive no injury. 608 Fatal effects produced by it. Men have been ſuddenly killed by going down into large vats, in which the proceſs of fermentation had been carried on. In conſequence of the greater ſpecific gravity of the carbonic acid gas, and the great quantity generated during the proceſs, when the fermented liquor is drawn off, it ſinks to the bottom of the veſſel, and there remains till it is diſplaced by a denſer fluid, or ſlowly attracted by the air. Similar accidents have happened to perſons going down into pits or wells which have been long ſhut up, and where the air has been long ſtagnant. It is by reſpiring this gas that perſons are ſuffocated who have been expoſed to the fumes of burning charcoal in cloſe places. During the combuſtion of the charcoal, the carbone combines with the oxygen of the atmoſphere; carbonic acid is formed, which ſoon fills the apartment. 609 Mode of recovery. In theſe caſes, where life is not totally extinguiſhed, the beſt method of recovery is ſaid to be, to daſh cold water on the head and body; a practice which is commonly obſerved in accidents of this kind, in northern countries, where charcoal is burnt in cloſe apartments.

Sect. XIII. *Of Arsenic Acid.*

610 Five metallic acids. 1. This acid, and the four following, have metallic ſubſtances for their baſe. Moſt metallic ſubſtances combine with oxygen in different proportions, and the compounds formed with theſe ſubſtances and oxygen, are denominated *oxides*, becauſe they poſſeſs no acid properties; but ſome of the metals combine with oxygen in greater proportion, which gives them the characteriſtic properties of acid ſubſtances.

2. The metallic ſubſtance arſenic, combines with oxygen in two proportions; the firſt, which is uſually called the *white oxide of arſenic*, has been denominated by Fourcroy, the *arſenious acid*. Macquer diſcovered ſome of the combinations of arſenic acid, previous to the year 1746; for he ſhews that a mixture of white oxide of arſenic and nitre, ſubjected to the action of a ſtrong fire, yields a neutral ſalt, to which he gave the name of the neutral ſalt of arſenic. But it was by the inveſtigation of Scheele in 1775 that its properties were fully known.

611 Proceſs for obtaining it. 3. The proceſs for obtaining it which was pointed out

out by Scheele, is the following. Take three parts of the white oxide of arſenic, and diſſolve it in ſeven parts of muriatic acid. Add five parts of nitric acid to the ſolution, and diſtil it to dryneſs. The arſenic acid remains behind. It may alſo be procured by diſſolving the white oxide in liquid oxymuriatic acid, or by making a ſtream of oxymuriatic acid gas paſs through a ſolution of the white oxide of arſenic. The chemical action which takes place in theſe proceſſes, is the union of the arſenic with an additional portion of oxygen, which it derives from the nitric acid, the liquid oxymuriatic, or the oxymuriatic acid gas.

612 Properties. 4. By whatever proceſs it is obtained, the arſenic acid which is not cryſtallized has an acid, cauſtic, and metallic taſte. It reddens the ſyrup of violets, and its ſpecific gravity is 3.91. When it is expoſed to a ſtrong heat in a retort or crucible, it fuſes, attacks the glaſs of the retort, or the earth of the crucible; it remains tranſparent and pure at a high temperature, gives out a little oxygen, and is partly converted into white oxide.

5. Expoſed to the air, it attracts the moiſture from it, and abſorbs two thirds of its own weight of water from the atmoſphere, which is ſufficient to hold it in ſolution.

613 Action of water. 6. The arſenic acid is much more ſoluble in water than the white oxide. Three or four parts of water are ſufficient to diſſolve it. When it is evaporated, it aſſumes a thick conſiſtence like honey.

614 Of combuſtibles. 7. Combuſtible ſubſtances decompoſe arſenic acid, by depriving it of part of its oxygen, and converting it into the white oxide. Hydrogen gas mixed with a ſolution of this acid, has the property of precipitating it. Charcoal, phoſphorus, and ſulphur produce a ſimilar effect. Expoſed in a retort to heat with charcoal; the charcoal is inflamed, and the arſenic acid is reduced to the metallic ſtate. Sulphur heated with arſenic acid, is partly converted into ſulphurous acid gas, and partly ſublimed into the red ſulphuret of arſenic. When heated with phoſphorus, part of the phoſphorus is converted into phoſphoric acid, and the arſenic reduced to the metallic ſtate, unites with another part of the phoſphorus, with which it forms a phoſphuret of arſenic, which ſublimes.

615 Compoſition. 8. The arſenic acid is compoſed of the white oxide of arſenic and oxygen. The proportions of its conſtituent parts, according to the experiments of Prouſt, are

65 arſenic,
35 oxygen.
———
100

616 Compounds. 9. The compounds which arſenic acid forms with alkalies, earths, and ſome metallic oxides, are known by the name of *arſeniates*.

617 Affinities. 10. The order of its affinities is the following:

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Glucina,
Alumina,
Zirconia.

SECT. XIV. *Of the Tungstic Acid.*

618 Hiſtory. 1. In the year 1781, Scheele and Bergman, in inveſtigating the nature of a heavy ſtone (called tungſten by the Swedes), diſcovered that it is compoſed of lime combined with a peculiar acid. Their diſcovery was afterwards confirmed by ſeveral chemiſts, and particularly by the experiments of the D'Elhuyarts, who detected the ſame acid in the mineral called wolfram.

619 Method of obtaining. 2. This acid always exiſts in combination with lime and iron. It may be obtained by reducing the former to a fine powder, and treating it with nitric or muriatic acids, which unite with the lime, and then by alkalies, which diſſolve the acid. The alkaline ſolution is to be precipitated by the nitric or muriatic acid; the precipitate is to be carefully waſhed and dried, which is the tungſtic acid in the ſolid ſtate.

620 Properties. 3. The tungſtic acid thus prepared, is in the form of a white powder, which has an acid and metallic taſte, changes the colour of vegetable blues into red; and has a ſpecific gravity according to Bergman, equal to 3.600. 621 Action of heat. Heated under the blow-pipe, this tungſtic acid becomes firſt yellow, then brown, and at laſt black; it affords no ſmoke, and gives no ſign of fuſion. When it is calcined for ſome time in a crucible, it is deprived of the property of diſſolving in water.

622 Of water. 4. Expoſed to the air it ſuffers no change. It is ſoluble in 20 parts of boiling water, but it is partially ſeparated on cooling. This ſolution has an acid taſte, and reddens the tincture of turnſole. Heated with charcoal, it is reduced, but with difficulty, to the metallic ſtate. With ſulphur and phoſphorus it becomes of a gray colour, but without reduction.

623 Of acids. 5. The acids do not diſſolve the tungſtic acid in the form of white powder, but they change completely its properties. The ſulphuric acid changes it to a blue, and the nitric and muriatic acids convert it into a fine yellow colour. In this ſtate it has loſt its taſte and ſolubility, has become ſpecifically heavier, and has acquired the property of forming ſalts with the ſame baſes diſtinctly different from thoſe formed with what was called the white acid. The Spaniſh chemiſts D'Elhuyarts, conſider the latter as an acidulous triple ſalt, and yellow oxide as the real tungſtic acid.

624 Only an oxide. 6. Vauquelin and Hecht, who inſtituted a ſet of experiments on theſe oxides, as they propoſe to denominate them, obtained the ſame reſults. They conſider the tungſtic acid of Scheele as a triple ſalt, which has retained a portion of the acid by which it was precipitated in its compoſition, and when the oxide of tungſten is pure, it poſſeſſes none of the properties which are admitted and acknowledged as the characteriſtics of the acids, but that it has a ſtrong tendency to form triple combinations, in which only it exhibits acid properties. The compounds which it forms with the alkalies, earths, and metallic oxides, are a ſpecies of neutral ſalts; but the chemical combination is not fully completed to hide the alkaline properties of the former*. In forming theſe compounds, it is the only property in which it agrees with the acids. 625 Tungſtates. The compounds are denominated tungſtates.

626 Affinities. 7. The order of its affinities is the following:

Lime,
Barytes,

Strontites,

---

* *Jour. de Mines*, N° xix. p. 26.

Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Glucina,
Alumina,
Zirconia.

Sect. XV. *Of Molybdic Acid.*

627 History. 1. This acid was diſcovered by Scheele in the year 1778. It is a compound of the metallic ſubſtance molybdena and oxygen. Scheele ſuppoſed that it exiſted in the mineral from which he obtained it, and that this mineral was a compound of the acid, ſulphur and iron. The experiments of later chemiſts have ſhown that the acid is formed in the proceſs of preparing it, by the metal combining with oxygen.

628 Proceſſes for obtaining it. 2. There are various proceſſes for the preparation of this acid.

a. Scheele found that by treating a little of the ſulphuret of molybdena (ſulphur combined with the metal) on a ſilver plate, the white fumes which exhaled from it, adhered to the plate in form of a ſmall ſcale of a brilliant yellowiſh white colour, which was the true molybdic acid. But a very ſmall quantity can only be obtained in this way.

b. Another proceſs is by means of nitric acid. On one part of ſulphuret of molybdena in powder, pour five parts of nitric acid, and diſtil it to dryneſs. The ſame proceſs is repeated three or four times. The dry reſiduum is a white powder, which is the molybdic acid mixed with the ſulphuric acid, which is alſo formed during the proceſs with the nitric acid. The ſulphuric acid may be waſhed off with hot water, and the molybdic acid remains behind in a ſtate of purity.

c. It may be alſo prepared by projecting into a red-hot crucible three parts of nitrate of potaſh, and one part of ſulphuret of molybdena reduced to fine powder and well mixed together. A red maſs remains after the detonation compoſed of the oxide of iron, of the ſulphate of potaſh, and the molybdate of potaſh. By throwing the maſs into water, the two ſalts are diſſolved, and the oxide of iron is precipitated. Evaporate the ſolution to obtain the ſulphate of potaſh, and drop into the liquid which refuſes to cryſtallize, and which ſhould be diluted with water, ſulphuric acid, till there is no farther precipitation. The precipitate is molybdic acid, but not in a ſtate of perfect purity; for it is combined with a certain portion of potaſh.

629 Properties. 3. The molybdic acid prepared in this manner, and ſufficiently purified, is a white powder of a ſharp metallic taſte. According to Bergman, the ſpecific gravity is 3.4.

630 Action of heat. 4. When heated in a large glaſs retort, it yields a little ſulphurous acid. But when it is expoſed to a ſtrong heat in a cloſe veſſel, it fuſes, attaches itſelf to the ſides of the veſſel, and cryſtallizes on cooling in rays going out from a centre. But if at the moment the acid is in fuſion the veſſel be uncovered, it riſes into a white ſmoke by contact with air, and this vapour attaches itſelf to cold bodies in form of brilliant ſcales of a golden-yellow colour.

631 Of water. It is readily ſoluble in warm water. One part of the acid requires about 500 grs. the ſolution is of a yellow colour, has little ſmell, and reddens litmus paper.

632 Of charcoal and ſulphur. 5. Molybdic acid is decompoſed by charcoal, with the aſſiſtance of heat; it is alſo decompoſed by ſulphur, with the extrication of ſulphurous acid, and the formation of ſulphuret of molybdena.

633 Of acids. 6. The concentrated ſulphuric acid diſſolves a conſiderable quantity of molybdic acid, with the aid of heat. The ſolution on cooling becomes of a violet blue colour, which diſappears when it is heated. The muriatic acid diſſolves a conſiderable proportion by boiling. When this ſolution is diſtilled to dryneſs, one part of the acid is ſublimed, of a blue and white colour. The nitric acid has no effect whatever *.

634 Compounds. 7. Molybdic acid combines readily with the alkaline and earthy baſes, which have the name of *molybdates*.

8. This acid has not been applied to any uſe.

Sect. XVI. *Of Chromic Acid.*

635 Diſcovery. 1. This acid was diſcovered by Vauquelin in the year 1797. It has only been found in ſmall quantity, in combination with lead or iron.

636 Preparation. 2. Chromic acid may be obtained by boiling the red lead ore of Siberia in a ſolution of carbonate of potaſh, and precipitating it by means of another acid, which has a ſtronger attraction for the potaſh. A red or yellow orange powder falls to the bottom, which is chromic acid.

3. It has an acid and peculiar metallic taſte, more perceptible than any other metallic acid.

4. When expoſed to the action of light and caloric, in open veſſels, it aſſumes a green colour; but in cloſe veſſels, it gives out pure oxygen gas, and loſing its acid properties it returns to the ſtate of green oxide. This is the only metallic acid, which by the action of caloric, eaſily parts with its oxygen.

637 Action of charcoal. 5. Strongly heated with charcoal, chromic acid becomes black, and is eaſily reduced to the metallic ſtate without fuſion. It is probable alſo, that it may be decompoſed with equal facility by hydrogen, phoſphorus, and ſulphur.

638 Water. 6. Chromic acid is ſoluble in water, and cryſtallizes by cooling and evaporation, in priſms of a ruby red colour.

639 Muriatic acid. 7. The muriatic acid by diſtillation with a moderate heat with the chromic acid, paſſes to the ſtate of oxy-muriatic acid, and the mixture acquires the property of diſſolving gold. In this reſpect it reſembles the nitric acid, and it is the only metallic acid which is diſtinguiſhed by this property.

640 Compounds. 8. The chromic acid combines readily with the alkalies, and has the peculiar property of giving an orange colour to the cryſtals: from this it derived its name. The compounds are called *chromates*.

641 Uſes. 9. The chromic acid, from its peculiar colour, and the beautiful colours which it communicates to other bodies, promiſes to be uſeful in painting on porcelain and glaſs, or even in dying.

Sect. XVII. *Of Columbic Acid.*

642 Diſcovery. 1. The laſt of the metallic acids is the columbic, which was diſcovered by Mr Hatchet in 1801. In the

---

* *Phil. Tranſ.* 1789. p. 389.

the ore from which it was extracted, it is combined with oxide of iron, from which it was ſeparated, by 643 Preparation. expoſing it to a ſtrong red-heat, with five times its weight of carbonate of potaſh. The alkali combined with part of the acid, and from this it was ſeparated by water. By repeatedly fuſing the reſiduum with potaſh, he ſeparated the whole of the acid from the iron, which latter combined with muriatic acid that was added to it. By treating the alkaline ſolution with nitric acid, a precipitate of a white, flakey, inſoluble ſubſtance was obtained. This is the columbic acid.

644 Properties. 2. It is of a pure white colour, but not very heavy, and has ſcarcely any perceptible taſte; it is not ſoluble in boiling water. When ſome of the powder is placed upon litmus paper, moiſtened with diſtilled water, the paper in a few minutes becomes red. 645 Action of heat. When expoſed to the blow-pipe, it is not fuſible, but only becomes of a leſs brilliant white.

646 Of acids. 3. It is diſſolved in boiling ſulphuric acid, and forms a tranſparent colourleſs ſolution, which is only permanent while the acid is in a concentrated ſtate; for if it be diluted with water, it aſſumes a milky appearance; a white precipitate is depoſited, which, as it dries on the filter, changes when completely dry to a browniſh gray. It is then inſoluble in water, has no taſte, is ſemitranſparent, and breaks with a gloſſy, vitreous fracture. This compound appears to be formed of the ſulphuric and columbic acids. Nitric acid has no effect on the columbic acid *.

SECT. XVIII. *Of Acetic Acid.*

647 Hiſtory. 1. The acetic acid or vinegar was one of the earlieſt known. This indeed was to be expected, from the manner and the abundance in which it is produced, as it is the firſt change to which wine and ſimilar liquids are ſubject. The ſourneſs which exiſts in theſe liquids, is owing to the production of this acid. 648 Names. It has different names, according to the ſtate in which it is found. When it is firſt prepared, it is known under the name of *vinegar*; when purified by diſtillation, it is called *diſtilled* vinegar; and when it is ſtrongly concentrated, it is called *radical* vinegar, or *acetic acid.*

649 Preparation. 2. The proceſs by which vinegar is obtained is the fermenting proceſs of many vegetable matters, what is uſually denominated the acetous fermentation, or the ſecond ſtage of the fermentative proceſs of vegetable matters. The circumſtances in which this fermentation takes place are, a temperature between 70° and 80°, the addition of ſome fermenting ſubſtance, and expoſure to the air.

The proceſs which is recommended by Boerhaave, is generally followed. Two large hogſheads are prepared, by fixing about a foot from the bottom, a grating of rods, on which vine branches are to be placed. The wine to be fermented is poured into the veſſels; the one is to be filled to the top, and the other only one half. They are both left expoſed to the air. Fermentation begins in the veſſel which is half full; when it is completely begun, fill it up from the other veſſel, which interrupts the fermentation in the full hogſhead, and it commences in that which is half full. When this has continued for a little time, it is filled up from the other veſſel, in which the fermentation again commences, and is interrupted in the other. Thus, the proceſs is carried on by alternately emptying and filling the veſſels till vinegar is formed, which generally requires a period of from 12 to 15 days.

650 Properties. 3. Vinegar is generally of a yellowiſh colour, an acid taſte, and agreeable ſmell. It reddens vegetable blues, and when it is expoſed to heat, it is entirely diſſipated. The ſpecific gravity varies from 1.005 to 1.0251. It varies conſiderably in colour, ſpecific gravity, and other properties, according to the ſubſtances from which it has been obtained. Vinegar in this ſtate is extremely apt to be decompoſed. Scheele has pointed out a very ſimple proceſs, by which it may be preſerved for a long time. Put the vinegar into bottles, and place them over the fire in a veſſel filled with water. Let the water boil for a moment, and then take out the bottles, after which it may be kept for ſeveral years.

651 Purified by diſtillation. 4. To ſeparate the impurities with which vinegar is contaminated, it is diſtilled with a moderate heat; the temperature muſt not exceed that of boiling water, and the proceſs ſhould be carried on only till about $\frac{2}{3}$ of the quantity have paſſed over. This is diſtilled vinegar, or the acetous acid of the chemiſts. It is then perfectly tranſparent and colourleſs, has an agreeable odour, and a ſtrong acid taſte. The vinegar in this ſtate, when expoſed to a ſufficient degree of cold, is partly frozen. As the ice which is formed conſiſts almoſt entirely of water, when it is ſeparated the fluid which remains is the vinegar highly concentrated.

652 Of radical vinegar. 5. To prepare what has been denominated radical vinegar, a ſalt of which this acid forms a component, part muſt be decompoſed. The acetate of copper, or verdigris, is generally employed for this purpoſe. It is reduced to powder, and diſtilled in a retort with a ſtrong heat. The liquid which firſt comes over is inſipid and colourleſs, and muſt be kept ſeparate from the remaining part of the product, which is the acetic acid in a highly concentrated ſtate. It has generally a green colour, being contaminated with a little copper, but it may be purified by diſtillation with a moderate heat, by which it is rendered colourleſs.

653 Acetous and acetic acids ſuppoſed to be different. 6. The acid in this ſtate was at firſt conſidered by chemiſts as different from the acetous acid in its properties, affinities, and in the compounds it forms with other bodies. This was the opinion of the celebrated chemical philoſopher Berthollet, and this opinion was adopted by almoſt all chemiſts. It was ſuppoſed that it was the acetous acid in combination with another portion of oxygen, and hence it was denominated, according to the preſent nomenclature, *acetic acid.*

654 Found to be the ſame. 7. The nature and properties of theſe two ſuppoſed acids were at laſt inveſtigated fully by Adet and Darracq, who proved that there was no difference in the proportion of oxygen in the acetous and acetic acids. This concluſion was controverted by Chaptal and Dabit, who endeavoured to ſupport the opinion of Berthollet, that the two acids are diſtinguiſhed from each other by different properties and different combinations with other bodies. It is now generally admitted, that what have been called the acetous and acetic acids, are eſſentially the ſame, their apparent differences depending on the quantity of water, mucilage and other ſubſtances with which the acetous acid is combined.

655 Properties. 8. This acid when pure, is tranſparent and colourleſs,

---

* *Phil. Tranſ.* 1802. p. 44.

leſs. In the ſtate of acetous acid, it has an agreeable, aromatic odour. In the ſtate of acetic acid, or when it is highly concentrated, it acquires a ſharp, penetrating odour, different from that of the vinegar, and in this ſtate it is extremely acrid. Applied to the ſkin it reddens and deſtroys it. It is highly volatile; and when expoſed to the open air, it is ſoon diſſipated. When heated in contact with the air, it inflames.

656 Cryſtallizes. 9. This acid may be obtained in cryſtals, by forming diſtilled vinegar into a paſte with charcoal, and ſubjecting the mixture to a temperature which does not exceed 212°. 657 Action of heat. By this heat the watery part is diſſipated, and the acid remains behind; but when a ſtronger heat is applied, the acid itſelf is driven off. By repeating this proceſs the acid may be obtained cryſtallized.

10. Acetic acid undergoes no perceptible change by the action of oxygen, hydrogen, or azotic gaſes, and it is not altered by charcoal, phoſphorus, or ſulphur.

658 Of acids. 11. Acetic acid is decompoſed by the ſulphuric acid. It abſorbs carbonic acid, and diſſolves boracic acid. It is alſo decompoſed by nitric acid, and is converted into carbonic acid and water. 659 Analyſis. Dr Higgins analyzed the acetic acid by decompoſing it in combination with an alkali. He diſtilled in a glaſs retort 7680 grs. of acetate of potaſh, that is, potaſh combined with acetic acid, and he obtained the following products.

Potaſh,	3862.9940
Carbonic acid gas,	1473.5640
Carbonated hydrogen gas,	1047.6018
Charcoal,	0078.0000
Oil,	0180.0000
Water,	0340.0000
Deficiency,	0726.9402

Dr Higgins was at a loſs to account for this deficiency, till by repeated experiments he found that it is always owing to the water and oil, and chiefly to the water which is carried off by the elaſtic fluids. He ſtates the quantity of water carried off in vapour at 700 grs. and the quantity of oil carried off in the ſame way at 26.9402, which together make up the whole deficiency †. The potaſh remained behind unaltered; the acetic acid, therefore, has been decompoſed and has yielded the products which were obtained by diſtillation. 660 Compoſition. But the conſtituent principles of theſe products are oxygen, hydrogen, and carbone; and from the proportions of oxygen and carbone which enter into the compoſition of carbonic acid, the proportions of carbone and hydrogen in carbonated hydrogen gas, and of oxygen and hydrogen in the compoſition of water, 100 parts of acetic acid are compoſed of about

50 oxygen,
36 carbone,
14 hydrogen.
―――
100

661 Compounds. 12. The compounds which acetic acid forms with alkalies, earths, and metallic oxides, are denominated *acetates*.

662 Affinities. 13. The order of its affinities is the following.

Barytes,
Potaſh,
Soda,
Strontites,
Lime,
Ammonia,
Magneſia,
Metallic oxides,
Glucina,
Alumina,
Zirconia.

Sect. XIX. *Of Oxalic Acid.*

663 Found in plants. 1. This acid exiſts ready formed in the *oxalis acetoſella* or wood-ſorrel, and ſome other ſpecies belonging to the ſame genus of plants. From this it derives the name of *oxalic acid*. It was originally denominated the *ſaccharine acid*, or the acid of ſugar, becauſe it was obtained from that ſubſtance. Its properties were firſt particularly inveſtigated by Bergman and Scheele, and the method of preparing it is given by the former.

664 Method of obtaining. 2. An ounce of white ſugar in powder is put into a retort, with three ounces of ſtrong nitric aid. During the ſolution, a great quantity of fumes of the nitrous acid eſcapes. Apply heat till the liquor boils, and nitrous gas is then driven off. When the liquor in the retort acquires a reddiſh brown colour, add three ounces more of nitric acid; continue the boiling till the fumes ceaſe, and the colour of the liquor vaniſhes. Pour out the liquor into a wide ſhallow veſſel; and, when it cools, cryſtals will be formed in ſlender four-ſided priſms, which may be collected and dried on blotting paper. The cryſtals thus obtained may be again diſſolved in diſtilled water, and evaporated to obtain new cryſtals. The oxalic acid may be obtained by a ſimilar proceſs, from other vegetable, and from ſome animal ſubſtances, as gum arabic, alcohol and honey.

665 Properties. 3. Prepared in this way, oxalic acid is in the concrete ſtate, cryſtallized in four-ſided priſms, terminating in two-ſided ſummits. They are white and tranſparent, and have conſiderable luſtre. They have a ſtrong ſharp taſte, and change vegetable blues into a red colour, and produce the ſame effect on all vegetables except the indigo.

The acid properties of this ſubſtance are ſo ſtrong, that one part of concrete oxalic acid gives to 3600 parts of water, the property of reddening paper ſtained with turnſole.

666 Action of heat. 4. When the oxalic acid is expoſed to heat, it is volatilized, partly in a liquid, and alſo in a ſolid and cryſtalline form. It is not decompoſed, but at a high temperature; but when it is expoſed to a moderate heat, it dries, is covered with a white cruſt, and is ſoon reduced to powder. It loſes $\frac{3}{10}$ of its weight when put upon burning charcoal; it exhales a pungent, irritating ſmoke, and there remains behind a white alkaline reſidue.

667 Of water. 5. This acid is deliqueſcent in the air, when it is loaded with moiſture. Cold water diſſolves about $\frac{1}{2}$ its weight of the acid; boiling water diſſolves a quantity equal to its own weight.

668 Compoſition. 6. Oxalic acid is decompoſed by the ſulphuric acid with the aſſiſtance of heat, and charcoal is depoſited;

at

---

† *Experiments and Obſervations*, p. 27.

at the boiling temperature it is decompoſed by the nitric acid, and converted into water and carbonic acid. According to Fourcroy, the component parts of oxalic acid, as they have been aſcertained by him and Vauquelin, are

77 oxygen,
13 carbone,
10 hydrogen.

100 *

* *Connaiſs. Chim.* tom. vii. p. 225.

668 Compounds. 7. Oxalic acid combines with the alkalies, earths, and metallic oxides, and the ſalts thus formed are diſtinguiſhed by the name of *oxalates*.

669 Affinities. 8. The affinities of this acid are in the following order :

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Alumina.

SECT. XX. *Of Tartaric Acid.*

670 Hiſtory. 1. This acid was procured by Scheele in a ſeparate ſtate, in the year 1770, the proceſs for which he communicated to M. Retzius, who publiſhed the account of it in the Swediſh Memoirs for that year. It was the firſt diſcovery in the bright career of that diſtinguiſhed chemiſt.

671 Preparation. 2. The proceſs which he followed was by boiling a quantity of the ſubſtance called *tartar*, or *cream of tartar*, in water, and adding powdered chalk till effervescence ceaſes, and the liquid no longer reddens vegetable blues. It is then allowed to cool ; the liquor is filtered ; and a white inſoluble powder remains on the filter, which is carefully removed and well waſhed. This is put into a matraſs, and a quantity of ſulphuric acid, equal in weight to the chalk employed, diluted with water, is poured upon it. The mixture is allowed to digeſt for 12 hours on a ſand bath, ſtirring it occaſionally with a glaſs rod. The ſulphuric acid combines with the lime, and forms a ſulphate of lime, which falls to the bottom. The liquid contains the tartaric acid diſſolved in it. This is decanted off, and a little acetate of lead is dropt into it, as a teſt to detect the ſulphuric acid, ſhould any remain. With it it forms an inſoluble precipitate ; and if this be the caſe, it muſt be digeſted again with more *tartrate of lime*, to carry off what remains of the ſulphuric acid. It is then evaporated, and about $\frac{1}{3}$ of the weight of the tartar employed is obtained, of concrete tartaric acid. To purify this, the cryſtals may be diſſolved in diſtilled water, and again evaporated and cryſtallized. It ſeems probable, Fourcroy obſerves, that this acid exiſts in a ſtate of purity in ſome vegetables. Vauquelin has found a 64th part in the pulp of the tamarind.

672 Cryſtals. 3. Tartaric (or tartarous) acid thus obtained, is in the form of very fine needle-ſhaped cryſtals, but they have been differently deſcribed by different chemiſts. According to Bergman, they are in the form of ſmall plates attached by one extremity, and diverging at the other. They have been found by others grouped together in the ſhape of needles, pyramids, regular ſix-ſided priſms, and ſquare and ſmall rhomboidal plates. The ſpecific gravity is 1.5962.

673 Properties. 4. This acid has a very ſharp, pungent taſte ; diluted with water, it reſembles the taſte of lemon juice ; and it reddens ſtrongly blue vegetable colours.

674 Action of heat. 5. When it is expoſed to heat on burning coals, it melts, blackens, emits fumes, froths up, and exhales a ſharp, pungent vapour. It then burns with a blue flame, and leaves behind a ſpongy maſs of charcoal, in which ſome traces of lime have been detected. Four ounces of the concrete cryſtallized acid, carefully diſtilled, gave the following products * :

* *Fourcroy Connaiſs. Chim.* tom. vii. p. 255

Cub. In.
431 carbonic acid gas,
120 carbonated hydrogen gas.

675 Action of heat. 6. In the decompoſition of the tartaric acid by heat, one of the moſt remarkable products which particularly characterizes it, is an acid liquid of a reddiſh colour, which amounts to one-fourth part of the weight of the former. This was formerly known by the name of pyrotartarous acid. It has a ſlightly acid taſte, produces a diſagreeable ſenſation on the tongue, is ſtrongly empyreumatic, and reddens the tincture of turnſole. But it has been found by the experiments of Fourcroy and Vauquelin, to be the acetic acid impregnated with an oil † (q).

† *Ann. de Chim.* tom. xxxv. p. 161.

676 Water. 7. Tartaric acid is very ſoluble in water. The ſpecific gravity of a ſolution formed by Bergman, was found to be 1.230. This ſolution in water is not liable to ſpontaneous decompoſition, unleſs it is diluted. While it is concentrated, it loſes nothing of its acid nature or its other properties.

677 Converted into oxalic. 8. Bergman ſuppoſed that the tartarous acid could not be changed by the ſtrongeſt mineral acids, and eſpecially by the nitric ; but Hermſtadt has ſucceeded in converting it into oxalic acid by ſeveral ſucceſſive diſtillations, with ſix times its weight of nitric acid. Three hundred and ſixty parts of tartaric acid yielded 560 parts of oxalic acid, which ſhews that it had combined with a great additional proportion of oxygen ‡.

‡ *Fourcroy Connaiſs. Chim.* tom. vii. p. 256.

678 Compoſition. 9. According to the analyſis of Fourcroy and Vauquelin, 100 parts of this acid are compoſed of

70.5 oxygen,
19.0 carbone,
10.5 hydrogen,

100.0

(q) The pyromucous and the pyroligneous acids are to be regarded in the ſame light. The peculiar properties which were ſuppoſed to diſtinguiſh them from other acids, were found by the ſame philoſophers to be owing to a ſimilar impregnation.

679 Affinities. 10. The affinities of this acid are in the following order.

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Alumina.

Sect. XXI. *Of Citric Acid.*

680 Found in fruits. 1. The ſour or acid taſte of the juice of lemons and oranges is well known. This is the *citric acid*, but it is mixed with water and mucilage; and various proceſſes have been propoſed to obtain it in a ſtate of purity.

681 Preparation. 2. The firſt which ſucceeded was propoſed by M. Georgius, an account of which was publiſhed in the Swediſh memoirs for the year 1774. His proceſs was the following. It conſiſted in filling bottles with lemon juice, ſhutting them up cloſe, and placing them for ſome time in a cellar to ſeparate the mucilage. He afterwards expoſed it to a temperature of about 24°; the watery part froze, and carried with it a portion of mucilage. This was removed, and the liquid part which remained was again frozen, till the ſolid part had a perceptible acid taſte. The juice thus reduced to one-eighth part of its original bulk, is eight times ſtronger, and requires the ſame quantity of potaſh for ſaturation. In this ſtate of concentration it was preſerved.

682 Proceſs of Scheele. 3. But in this ſtate it is not pure. We are indebted to Scheele for the diſcovery of the proceſs by which it is obtained in a ſtate of purity, and for aſcertaining the characters by which it is diſtinguiſhed from tartaric acid, with which it was formerly confounded. Lemon juice which has been filtered, is ſaturated with powdered chalk. While the chalk is added, an efferveſcence takes place, which is owing to the combination of the citric acid with the lime, and the ſeparation of the carbonic acid from it in the ſtate of gas. When the efferveſcence ceaſes, a white powder falls to the bottom. This is the lime combined with the citric acid. Waſh this powder with warm water till it paſſes off colourleſs, then put the ſalt which has been waſhed into a matraſs with a little water. Take ſuch a quantity of concentrated ſulphuric acid diluted with ſix or ſeven parts of water as may be neceſſary to ſaturate the lime which has been employed; boil it for a few minutes, then let it cool, and filter the liquor. The ſulphate of lime formed by the decompoſition of the calcareous citrate, remains upon the filter. The filtered liquor contains the pure citric acid, which is to be evaporated to the conſiſtence of a ſyrup, and to be ſet by in a cool place to cryſtallize. The citric acid is thus obtained in ſmall cryſtals.

683 Exceſs of acid to be added. Scheele thinks that it is neceſſary to add a ſmall exceſs of ſulphuric acid, to take up the whole of the lime from the citric acid. But Dizè is of opinion that this exceſs of ſulphuric acid is only neceſſary, to deſtroy the remaining portion of mucilage which adheres to the citric acid, and thus to ſeparate from it every extraneous ſubſtance *.

684 Suppoſed to be unneceſſary. But it has been obſerved, that when an exceſs of ſulphuric acid is employed, it may act upon the citric acid itſelf, decompoſe it, and produce the black matter which was ſuppoſed to be owing to the mucilage which adhered to it. And it appears, from an inveſtigation by Prouſt on the preparation of this acid, that when too much ſulphuric acid is employed, it decompoſes the citric acid, and prevents it from cryſtallizing. To prevent this, a ſmall quantity of chalk is added. He found that four ounces of chalk were neceſſary for the ſaturation of 94 ounces of lemon juice, and that the product which he obtained amounted to 7½ ounces of citrate of lime; and to decompoſe this, he added 20 ounces of diluted ſulphuric acid †.

685 Properties. 4. When the citric acid is pure, it cryſtallizes in rhomboidal priſms, whoſe ſides are inclined to each other at angles of 60° and 120°, terminating at each end in four trapezoidal faces which include the ſolid angles. By ſlow cooling of large quantities of the ſolution of the pure acid, evaporated to the conſiſtence of ſyrup, Dizè obtained very fine cryſtals.

5. The citric acid has a very ſtrong acid taſte, and even ſeems to be cauſtic; but when it is diluted with water, the taſte is cooling and agreeable. It has a very ſlight odour of lemons, and it reddens blue vegetable colours.

686 Action of heat. 6. When expoſed to heat, it melts rapidly in its own water of cryſtallization. When the ſolid acid is put upon burning coals, it quickly fuſes, froths up, exhales a ſharp, penetrating vapour, and is reduced to the ſtate of charcoal. Diſtilled in a retort, it is partly diſengaged without decompoſition, ſeems to be converted partly into vinegar, and then yields carbonic acid gas, carbonated hydrogen gas, and there remains in the retort a maſs of light charcoal.

687 Water. 7. Expoſed to the air, it effloreſces in a dry, warm atmoſphere; but when the air is moiſt, it abſorbs water, and loſes its cryſtalline form. It is very ſoluble in water. Seventy-five parts of water diſſolve 100 of the acid.

688 Acids. 8. Sulphuric acid, when concentrated, converts it into acetic acid. It is alſo decompoſed by the nitric acid, which converts it partly into oxalic acid, but the greater proportion into acetic acid.

689 Compoſition. 9. From the experiments which have been made with this acid, by decompoſing it by means of other acids, and the products which it affords, and its converſion into acids whoſe component parts are known, it ſeems to be pretty certain that oxygen, hydrogen, and carbone enter into the compoſition of citric acid.

690 Compounds. 10. This acid enters into combination with alkalies, earths, and metallic oxides, and forms ſalts which are denominated *citrates*.

691 Affinities. 11. The affinities of the citric acid are the following.

Lime,
Barytes,
Strontites,
Magneſia,
Potaſh,
Soda,
Ammonia,
Alumina,
Zirconia.

---

* *Fourcroy Connaiſs. Chim.* tom. vii. p. 204.

† *Journ. de Phyſ.* 52. p. 369.

Sect. XXII. *Malic Acid.*

692 History. 1. The malic acid is found in great proportion in the juices of a great number of fruits. In them it exiſts ready formed, and particularly in the juice of apples, from which it has derived its name. In ſome fruits it exiſts in ſmall quantity, mixed with a great proportion of citric acid, as in two ſpecies of *vaccinium, oxycoccos* and *vitis idæa, prunus padus*, and *ſolanum dulcamara.* Theſe acids are found in nearly equal proportions in ſome other fruits, as in the gooſeberry, cherry, and ſtrawberry; but it exiſts in greateſt abundance, and in the greateſt purity, in the juice of apples.

693 Method of preparing it. 2. It is prepared by the following proceſs, which was diſcovered by Scheele. Bruiſe a quantity of four apples, expreſs the juice, and filter it through a linen cloth. Saturate this juice with potaſh, add to the ſolution acetate of lead, (ſugar of lead) diſſolved in water, and continue the addition till there is no more precipitation. The acetic acid combines with the potaſh, and remains in the liquid, while the malic acid unites with the lead, and being inſoluble, falls to the bottom. Waſh the precipitate with water, and pour upon it diluted ſulphuric acid. The ſulphuric acid combines with the lead, and forms an inſoluble ſalt, which falls to the bottom. The malic acid remains uncombined in the liquid. Care ſhould be taken to add a ſufficient quantity of the ſulphuric acid to ſeparate the whole of the malic acid from the lead, which may be known by the pure acid taſte unmixed with the ſweet taſte of the ſalt of lead.

694 Of ſeparating from the citric. 3. When this acid is mixed with the citric acid, as is the caſe in the juices of many fruits, Scheele contrived the following proceſs to ſeparate them. The juice is firſt evaporated to the conſiſtence of honey; alcohol is poured upon it, by which the two acids are diſſolved, and a great quantity of mucilage is ſeparated; the alcohol is then evaporated; the reſidue after evaporation is diluted with two parts of water, and ſaturated with chalk, which combines with both the acids. The citrate of lime, which is the leaſt ſoluble, is ſeparated by evaporation; the malate of lime, or the combination with the malic acid, may be alſo ſeparated, by adding another portion of alcohol, which does not diſſolve the ſalt, but a ſaccharine matter which had combined with the malate of lime. The malic acid may then be ſeparated as before, with the ſolution of the ſugar of lead.

695 Obtained from houſe-leek. 4. Vauquelin has extracted a very pure and nearly colourleſs malic acid from the juice of houſe-leek, (*ſempervivum tectorum*, Lin.) It exiſts in this juice combined with lime. He extracted it by evaporating the juice, pouring alcohol upon the reſidue to ſeparate a ſmall quantity of ſugar which it contained, and by adding to the remaining matter an equal weight of concentrated ſulphuric acid, previouſly diluted with ſeven or eight times the quantity of water. But as ſome traces of ſulphate of lime are always found in the malic acid prepared in this way, he prefers the following method.

Add to the juice, a ſolution of ſugar of lead; a precipitate is formed, which is to be decompoſed by means of diluted ſulphuric acid *.

696 Properties. 5. The malic acid thus obtained, is a reddiſh brown liquid, of a pungent acid taſte, leaving afterwards the ſenſation of ſweetneſs. It reddens blue vegetable colours. It never aſſumes a cryſtalline form, but becomes thick and viſcid like ſyrup; and when expoſed to dry air, it dries in thin ſtrata like a brilliant varniſh, for which purpoſe it might be employed on poliſhed ſurfaces †.

697 Action of heat. 6. The malic acid is very readily decompoſed by heat. It becomes of a dark colour, ſwells up, exhales a thick acrid vapour in the open air, and leaves behind a bulky maſs of coal. When diſtilled in a retort, it yields an acid water, a great deal of carbonic acid gas, a little carbonated hydrogen gas, and a light ſpongy coal.

698 Decompoſed ſpontaneouſly. 7. It is ſpontaneouſly decompoſed in the veſſels in which it is kept; undergoes a kind of vinous fermentation, and depoſits a mucous, flaky ſubſtance. This decompoſition is owing to the intimate re-action of its conſtituent parts.

699 by nitric acid. 8. All the ſtrong acids decompoſe it. The concentrated ſulphuric acid chars it; and it is converted into oxalic acid by nitric acid. Scheele diſcovered, that mucous matters treated with nitric acid, paſſed to the ſtate of malic acid, or were converted into this acid, and into oxalic acid.

700 Proportions of its conſtituents unknown; 9. The proportions of the conſtituent parts of this acid have not been aſcertained, but from its decompoſition, and the products which are thus obtained, it is obvious that it is compoſed of oxygen, hydrogen, and carbone, of which the latter is ſuppoſed to be in great proportion.

701 and alſo its affinities. 10. The affinities of this acid are not determined. The compounds which it forms with alkalies, earths, and metallic oxides, are denominated *malates.*

11. It is very ſoluble in water.

Sect. XXIII. *Of Gallic Acid.*

702 History. 1. This acid exiſts moſt abundantly in a well known ſubſtance, *nut galls*, and hence it has obtained the name of gallic acid. It is alſo found in the bark and wood of many other plants. It was firſt examined by the academicians of Dijon in 1772, and its acid properties clearly aſcertained; but it is to Scheele that we are indebted for the diſcovery of the proceſs by which it may be obtained pure and cryſtallized. The account of this proceſs was publiſhed in 1780, which is the following.

703 Preparation. 2. To one part of nut galls, reduced to a coarſe powder, add ſix parts of pure water. Let the infuſion macerate for 15 days at the temperature of between 70° and 80°; filter it, and put the liquid into a large glaſs or earthen veſſel, expoſe it to the air, and allow it to evaporate ſlowly. A thick glutinous pellicle forms on the top; a great quantity of mucous flakes are precipitated, and the ſolution has no longer an aſtringent, but a perceptibly acid taſte. At the end of two or three months, Scheele had obſerved on the ſides of the veſſels in which the ſolution was contained, a brown cruſt covered with ſhining cryſtals of a yellowiſh gray colour. He found alſo a great quantity of theſe cryſtals under the thick pellicle which covered the liquid. He then decanted it, and added alcohol to the precipitate, the pellicle and the cryſtal-

---

* *Annal. de Chim.* 34. p. 127.

† *Fourcroy Connaiſs. Chim.* tom. vii. p. 799.

line cruſt, and applied heat. The alcohol diſſolved the cryſtallized acid, without touching the mucilage. The ſolution was now evaporated, and the gallic acid was obtained pure, in ſmall, ſhining cryſtals of a yellowiſh gray colour.

704 Another proceſs. 3. Deyeux has pointed out another method by which, with proper precautions, the gallic acid may be more readily obtained. He introduces into a large glaſs retort, a quantity of nut galls reduced to powder, and applies heat ſlowly and cautiouſly, by which he obtains a large quantity of laminated, brilliant, ſilvery cryſtals, ſufficiently large, and which have all the properties of gallic acid. But in following this proceſs, it is neceſſary to obſerve, that the heat muſt be very moderate, and not continued till an oil is diſengaged, which inſtantly diſſolves all the cryſtals ſublimed before its appearance *.

705 Davy's. 4. Mr Davy prepares it by boiling together for ſome time carbonate of barytes, and a ſolution of gall nuts. This affords a bluiſh green liquor. When diluted ſulphuric acid is dropt into it, it becomes turbid; ſulphate of barytes is depoſited, and after filtration, if the ſaturation of the earth be complete, a colourleſs ſolution of gallic acid, apparently pure, is obtained †.

706 Properties. 5. The gallic acid is cryſtallized in tranſparent octahedrons, or brilliant plates; it has a ſharp, pungent, and auſtere taſte, but leſs ſtrong and aſtringent than that of the gall nut.

707 Action of water. 6. This acid is not ſenſibly affected by expoſure to the air. It requires 24 parts of cold water, and about two-thirds of its weight of boiling water, to diſſolve it, from which it can only be cryſtallized by a very ſlow evaporation.

708 Of heat. 7. With a moderate heat, it riſes into vapour, which on cooling is condenſed and cryſtallized. In the ſtate of vapour, it has a ſharp, aromatic odour, reſembling that of the benzoic acid. Every time that it is ſublimed, even with a moderate heat, it is partially decompoſed; water is formed, an acid liquid, carbonic acid gas, carbonated hydrogen gas, and ſome drops of a brown coloured oil; and there remains behind, a great quantity of coaly matter.

709 Of acids. 8. The concentrated ſulphuric acid decompoſes and chars the gallic acid. The nitric acid converts it into the malic and oxalic acids. The oxymuriatic acid produces peculiar changes on the gallic acid, but theſe have not been diſtinctly aſcertained ‡.

710 Of metallic oxides. 9. Although we have not yet treated of metallic ſubſtances, it may be neceſſary to anticipate a little, and mention the effects of gallic acid on metallic oxides. This indeed is its chief characteriſtic. On this account, it is much employed by chemiſts, to diſcover metallic ſubſtances, which are held in ſolution along with other bodies. Its effects on the metallic oxides are extremely various, and with different metals it affords different coloured precipitates. The more readily the metallic oxides give up their oxygen, the greater is the change produced by the gallic acid. On ſome metallic ſolutions it has no effect; ſuch are, ſolutions of platina, of zinc, of tin, of cobalt, and of mangneſe. The precipitates of the different metals produced by means of the gallic acid, exhibit the following colours.

Gold,	Brown.
Silver,	Brown.
Mercury,	Orange-yellow.
Copper,	Brown.
Biſmuth,	Citron-yellow.
Iron,	Black.
Lead,	White.
Nickel,	Grey.
Antimony,	White.
Tellurium,	Yellow.
Uranium,	Chocolate.
Titanium,	Reddiſh-brown.
Chromium,	Brown.
Columbium,	Orange.

711 Compoſition. 10. The component parts of gallic acid are the ſame as thoſe of the other vegetable acids, but having a greater proportion of carbone; but theſe proportions have not been aſcertained.

712 Compounds. 11. The compounds which the gallic acid forms with alkalies, earths, and metallic oxides, are denominated *gallates*.

713 Affinities. 12. The affinities of this acid have not been aſcertained.

Sect. XXIV. *Of Benzoic Acid.*

714 Hiſtory. 1. The benzoic acid is obtained from ſeveral plants, and particularly from the *ſtyrax benzoë*, a tree which grows in Sumatra; from the balſam of Peru and Tolu; from vanilla, and liquid amber. It alſo exiſts in the urine of children, and ſometimes in that of adults, but conſtantly in the urine of quadrupeds which live on graſs and hay, eſpecially in that of the horſe and cow. It is ſuſpected alſo that it exiſts in many of the graſſes, and that it is derived from them by means of the aliment to the urine of the animals in which it is found. Fourcroy and Vauquelin ſuſpect that it exiſts in the ſweet-ſcented graſs, (*anthoxanthum odoratum.* Lin.) which gives the fine flavour to hay *.

The firſt mention of the benzoic acid is made by Blaiſe de Vigenere, who wrote about the commencement of the 17th century (R). He ſays, that he obtained, by diſtilling benzoin, an acid ſalt which cryſtallized in needles of a penetrating odour. It was then called *flowers of benzoin*, but at preſent *benzoic acid.*

715 Preparation. 2. To obtain this acid by the moſt common proceſs, put into an earthern pot a quantity of benzoin groſsly powdered. Cover the veſſel with a cone of paper, and apply a very gentle heat. The benzoic acid is ſublimed, and attaches itſelf to the ſides of the cone, which may be renewed every two hours. Continue the proceſs till the acid ſublimed begins to be coloured by the oil which is diſengaged. By a proceſs propoſed by Geoffroy, the benzoin reduced to powder is digeſted in warm water, and this being filtered, yields on cooling needle-ſhaped cryſtals of the benzoic acid; but the quantity obtained in this way is very ſmall, which led Scheele to adopt the following proceſs. He took

* *Connaiſs. Chim.* viii. p. 181.

† *Jour. Roy. Inſtit.* vol. i. p. 274.

‡ *Fourcroy Connaiſs. Chim.* tom. vii. p. 183.

* *Fourcroy Connaiſs. Chim.* tom. vii. p. 187.

(R) *Traité du feu et du ſel*, which was printed at Paris in 1608.

took 1 part of quicklime, to which were added 3 parts of water, and afterwards about 30 parts more, which is then to be gradually mixed with 4 parts of powdered benzoin. Heat the whole on a moderate fire for half an hour, continually agitating the mixture; then remove it from the fire, and let it remain at reſt for ſeveral hours. Decant the clear ſupernatant liquor, and add 8 parts more water to the reſiduum. Boil it for half an hour, and mix it with the former. Reduce the liquor by evaporation to two parts; add drop by drop to a ſlight exceſs, muriatic acid, which cauſes the benzoic acid to precipitate, by ſeparating it from the lime. Waſh the precipitate well on a filter; and to obtain it in cryſtals, diſſolve it in 5 or 6 times its own weight of boiling water, which on cooling yields cryſtals in the form of long compreſſed priſms.

716 Properties. 3. Pure benzoic acid is either in the form of a light powder, perceptibly cryſtallized, or in the form of very ſmall needles, of which it is extremely difficult to determine the ſhape. It is white and brilliant, and has ſome degree of ductility and elaſticity. It has an acrid, pungent, acidulous, and very bitter taſte. In the cold the odour is ſlight, but is aromatic, and this is ſufficient to characterize it. It reddens the tincture of turnſole, but has no effect on the ſyrup of violets. The ſpecific gravity of benzoic acid is 0.667.

717 Action of heat. 4. Expoſed to a moderate heat, it melts, forms a ſoft brown and ſpongy body which cools into a ſolid cruſt, exhibiting on the ſurface ſome appearance of cryſtallization. With a ſtronger heat it is ſublimed, and exhales a white acrid vapour, which affects the eyes. It burns when brought into contact with flame, and the whole is conſumed without any reſiduum. When it is diſtilled in cloſe veſſels, great part ſublimes unchanged, but part is decompoſed and yields a viſcid liquid, a conſiderable quantity of oil, and a much greater quantity of carbonated hydrogen gas than any other body of this nature. A very ſmall portion of coaly matter remains in the retort.

718 Of water. 5. It is not ſenſibly changed by expoſure to the air. It is ſcarcely ſoluble in cold water. Four hundred parts of boiling water diſſolve 20 parts of the acid, 19 of which are ſeparated on cooling.

719 Of acids. 6. Concentrated ſulphuric acid readily diſſolves this acid, and one part of the ſulphuric acid paſſes into the ſtate of ſulphurous acid. Benzoic acid may be ſeparated from this ſolution without having undergone any change, by adding water. The nitric acid diſſolves it in the ſame way, and it is alſo ſeparated by means of water. Guyton found, by diſtilling nitric acid on the concrete benzoic acid, that nitrous gas was diſengaged, only towards the end of the proceſs, and that the acid itſelf then ſublimed without alteration.

720 Compoſition. 7. As this acid yields by diſtillation oil and carbonated hydrogen gas, it is obvious that it muſt be compoſed of carbone and hydrogen, and probably alſo oxygen, although this latter has not been diſcovered in any experiments that have been made on this ſubſtance.

721 Compounds 8. The benzoic acid unites very readily with alkalies, earths, and metallic oxides, and the compounds which are thus formed are denominated *benzoates*.

722 Affinities. 9. The order of the affinities of benzoic acid is the following.

White oxide of arſenic,
Potaſh,
Soda,
Ammonia,
Barytes,
Lime,
Magneſia,
Alumina.

Sect. XXV. *Of Succinic Acid.*

723 Hiſtory. 1. The ſuccinic acid, formerly called volatile ſalt of amber, was long regarded as an alkaline ſalt. It was not till towards the end of the 17th century, that its acid properties were diſcovered. As amber, the ſubſtance from which this acid is obtained, is found in conſiderable quantity under ſtrata of ſubſtances which contain pyrites, it was thought that this acid was formed by the ſulphuric acid. This was the opinion of Hoffman and Neuman. Amber is found on the ſea-coaſt of different countries, eſpecially in the Pruſſian territory on the ſhores of the Baltic. The name of the acid is derived from *ſuccinum*, the Latin name for this ſubſtance.

724 Preparation. 2. The ſuccinic acid may be obtained by the following proceſs. Introduce a quantity of amber in powder into a retort, and let it be covered with dry ſand. Adapt a receiver, and diſtill with a moderate heat in a ſand bath. There paſſes over firſt a liquid which is of a reddiſh colour, and afterwards a volatile acid ſalt, which cryſtallizes in ſmall, white, or yellowiſh needles in the neck of the retort; and if the diſtillation be continued, a white light oil ſucceeds, which becomes brown, thick, and viſcid. The acid which is obtained in this way is contaminated with the oil; and therefore to ſeparate this oil, it may be diſſolved in hot water, and paſſed through a filter on which has been placed a little cotton moiſtened with oil of amber, which retains the oil, and prevents it from paſſing through along with the acid. The acid may then be evaporated and cryſtallized. Guyton has obſerved, that the acid may be rendered quite pure, by diſtilling off it a ſufficient quantity of nitric acid, but with this precaution, that the heat employed is not ſtrong enough to ſublime the ſuccinic acid *.

725 Properties. 3. The acid thus obtained is in the form of white, ſhining, tranſparent cryſtals, which are foliated, triangular, and priſmatic. The taſte is acid, but not corroſive. It reddens the tincture of turnſole, but has no effect on the infuſion of violets.

726 Action of heat. 4. With the heat of a ſand bath, the cryſtals of ſuccinic acid firſt melt, and are then ſublimed and condenſed in the upper part of the veſſel. There is, however, a partial decompoſition, for there is a coaly matter left behind in the veſſel.

727 Of water. 5. At the temperature of 212°, two parts of water diſſolve 1 of this acid, which cryſtallizes on cooling. When the water is cold at the temperature of 50°, it requires 96 parts of water to diſſolve 1 of the acid.

728 Compoſition. 6. This acid like other vegetable acids, is compoſed of oxygen, hydrogen, and carbone; for when it is diſtilled in a retort with a ſtrong heat, carbonic acid gas, and carbonated hydrogen gas are evolved, and charcoal

---

* *Ann. de Chim.* tom. xxix. p. 162.

coal remains behind in the retort. The proportions of the component parts have not been aſcertained.

729 Compounds 7. This acid enters into combination with alkalies, earths, and metallic oxides, and forms with them compounds which are denominated *ſuccinates*.

730 Affinities. 8. The affinities of this acid are in the following order:

Barytes,
Lime,
Potaſh,
Soda,
Ammonia,
Magneſia,
Alumina,
Metallic oxides.

SECT. XXVI. *Of* SACLACTIC ACID.

731 Hiſtory. 1. To this acid Fourcroy has given the name of *Mucous acid*, becauſe it is obtained from gum arabic and other mucilaginous ſubſtances; and it was formerly called *acid of ſugar-of-milk*. This latter name it received from Scheele, who diſcovered it in the year 1780, while he was employed in making experiments on the ſugar of milk, in order to obtain from it oxalic acid, which he procured from ſugar.

732 Preparation. 2. This acid may be obtained by the following proceſs. To 1 part of gum arabic, or other mucilaginous ſubſtance, add 2 parts of nitric acid in a retort, and apply a gentle heat. There is at firſt diſengaged a little nitrous gas and carbonic acid gas, after which let the mixture cool. There is then precipitated a white powder which is ſlightly acid. This powder is the ſaclactic acid.

733 Properties. 3. Thus obtained, ſaclactic acid is in the form of a white powder, a little gritty, and with a weak acid taſte.

734 Action of heat. 4. It is readily decompoſed by heat, and yields an acid liquor which cryſtallizes by reſt in the ſhape of needles; a ſmall quantity of an acrid cauſtic oil, of a blood-red colour, carbonic acid gas, and carbonated hydrogen gas; and there is left behind a conſiderable quantity of coaly matter. It is partly ſublimed in needles or brown plates, with an odour ſimilar to that of benzoic acid *.

735 Of water. 5. Saclactic acid in the ſtate of powder is not very ſoluble in water. Cold water does not take up more than 200 or 300 parts of its weight; boiling water does not take up above one half more. On cooling, the acid is depoſited in brilliant ſcales, which become white in the air. The ſolution has an acid taſte. It reddens the tincture of turnſole. Its ſpecific gravity at the temperature of 59° is 1.0015†.

736 Compounds 6. This acid enters into combination with earths, alkalies, and metallic oxides; and the ſalts which it forms are known by the name of *ſaccolates*.

737 Affinities. 7. The order of its affinities, according to Bergmann, is the following.

Lime,
Barytes,
Magneſia,
Potaſh,
Soda,
Ammonia,
Alumina,
Metallic oxides.

SECT. XXVII. *Of* CAMPHORIC ACID.

738 Hiſtory. 1. This acid is obtained, as the name imports, from *camphor*, a concrete ſubſtance procured from a ſpecies of laurel (*Laurus camphora*, Lin.) which is a native of the Eaſt Indies.

739 Preparation. 2. Camphoric acid was firſt obtained by Koſegarten, by diſtilling nitric acid 8 times ſucceſſively off camphor. This experiment was repeated by Bouillon Lagrange with the ſame reſult. He introduced into a glaſs retort, 1 part of camphor, and he poured over it 4 parts of nitric acid. A receiver was adapted to the retort, and the joinings were well luted. The retort was placed on a ſand bath, and a gradual heat was applied. A great deal of nitrous gas and carbonic acid gas was diſengaged. One part of the camphor is ſublimed, and another part ſeizes on the oxygen of the nitric acid. The ſame proceſs muſt be repeated till the whole of the camphor is acidified, which is known by its cryſtallizing when the liquor cools which remains in the retort. Theſe cryſtals are camphoric acid. To purify it, it muſt be diſſolved in diſtilled warm water, and the liquor is then to be filtered and evaporated to nearly half its volume, or till a thin pellicle is formed on it. When it cools, cryſtals of pure camphoric acid will be obtained.

740 Properties. 3. The camphorc acid has a ſlightly acid, bitter taſte. It reddens the tincture of turnſole. The cryſtals reſemble, when in a maſs, thoſe of the muriate of ammonia. Expoſed to the air the maſs effloreſces.

741 Action of water. 4. Cold water diſſolves this acid with great difficulty. An ounce of water at the temperature of between 50° and 60°, cannot diſſolve more than 6 grs. while water at the boiling temperature will hold in ſolution eight times that quantity.

742 Of heat. 5. When this acid is put upon burning coals, it exhales a denſe, aromatic vapour; with a leſs degree of heat, it melts, and is ſublimed. When put into a heated porcelain tube, and if a ſtream of oxygen gas be paſſed through it, the acid remains unchanged, but it is ſublimed from the ſides of the tube. When diſtilled alone, it firſt melts and then ſublimes. This ſublimation produces ſome change in its properties. It no longer reddens the tincture of turnſole, and acquires a ſtrong aromatic odour, and a leſs pungent taſte; becomes inſoluble in water, and in the ſulphuric and muriatic acids. The nitric acid heated, makes it yellow, and diſſolves it *.

743 Compounds 6. The camphoric acid enters into combination with the alkalies, earths, and metallic oxides, and the compounds thus formed are denominated *camphorates*.

744 Affinities. 7. The affinities of this acid are the following †.

Lime,
Potaſh,
Soda,
Barytes,
Ammonia,
Alumina,
Magneſia.

SECT. XXVIII. *Of* SUBERIC ACID.

745 Hiſtory 1. This acid is obtained from cork, a well-known ſubſtance, which is the bark of a tree (the *quercus ſuber* Lin.

---

* *Fourcroy Connaiſs. Chim.* tom. vii. p. 147.

† *Encyc. Method.* i. p. 290.

* *Ann. de Chim.* tom. xxiii. p. 170.

† *Ibid.* xxvii. p. 40.

Lin. or cork-tree.) From the Latin name of this ſubſtance *ſuber*, the name of the acid is derived, and hence it is called *ſuberic acid*. The acid which is obtained from cork, by treating it with nitric acid, was ſuppoſed to be the oxalic acid, on account of poſſeſſing ſome common properties, and particularly that of forming with lime an inſoluble ſalt. But the experiments of Bouillon Lagrange have ſhewn, that this is a peculiar acid.

746 Preparation. 2. This acid is obtained by the following proceſs. Take a quantity of clean cork, grated down. Introduce it into a retort, and pour on it ſix times its weight of nitric acid; the acid ought not to be too concentrated. It is then to be diſtilled with a moderate heat. The cork ſwells up and becomes yellow, and there is diſengaged a quantity of red vapours; and as the diſtillation goes on, the cork is diſſolved, and ſwims on the ſurface like foam. If this ſcum is not formed, the cork has not been acted upon by the acid. In this caſe when the diſtillation begins to ſtop, return into the retort the acid which had paſſed over into the receiver, and diſtil as long as any red vapours appear, and then immediately remove the retort from the ſand bath, and pour out the contents while yet hot into a glaſs or porcelain veſſel; put it upon a ſand bath and apply a gentle heat, ſtirring it conſtantly with a glaſs rod. The matter gradually thickens, and as ſoon as white vapours are diſengaged, which excite a tickling in the throat, it is to be removed from the ſand bath, and conſtantly ſtirred till the maſs is nearly cold. In this way a ſubſtance is obtained of the conſiſtence of honey, of an orange-yellow colour, of a ſharp penetrating odour while it is warm, but which gives out a peculiar aromatic ſmell when it is cold.

To procure the acid which is contained in this ſubſtance, put it into a matraſs, and pour upon it double its weight of diſtilled water. Apply heat till the maſs becomes liquid, and ſeparate by filtration that part which is inſoluble in water. The liquor which is obtained is of a clear, amber colour, and of a peculiar odour. The filtered liquor on cooling becomes muddy, is covered with a thin pellicle, and depoſits a powdery ſediment. The precipitate is to be ſeparated from the liquid by filtration, and it is to be dried with a gentle heat. This precipitate is the ſuberic acid. The remaining liquor is then to be evaporated to dryneſs with a moderate heat, to obtain the whole of the acid which it holds in ſolution.

The acid which is prepared by this proceſs is a little coloured, and may be purified, either by ſaturating the ſuberic acid with potaſh, and precipitating with an acid, or by boiling it with charcoal powder.

747 Properties. 3. Suberic acid is in the ſolid form, but it is not cryſtallized. When it is obtained by precipitation, it is in the ſtate of a powder, and by evaporation it is in the form of thin irregular pellicles.

4. It has a ſlightly bitter and acid taſte. Diſſolved in a ſmall quantity of boiling water, it tickles the throat, and excites coughing. It reddens vegetable blues.

748 Action of light. 5. Expoſed to the light, it becomes brown after a certain time; but this effect is more ſpeedily produced when it is expoſed to the ſun's rays. 749 Of heat. Heated in a matraſs, the ſuberic acid is ſublimed, and the glaſs remains marked with zones of different colours. If the ſublimation be ſtopped in time the acid is obtained on the ſides of the veſſel, in ſmall points formed of concentric circles. When expoſed to the heat of the blow-pipe on a ſpoon of platina, it firſt melts, then falls down into powder, and at laſt is totally diſſipated by ſublimation.

750 Of acids. 6. It undergoes no change from the action of oxygen gas. The action of the acids on ſuberic acid is very weak. The ſolution is not complete, eſpecially when it is impure.

751 Of water. 7. Water at the temperature of 60° or 70° diſſolves the concrete acid only in the proportion of 10 grs. to the ounce. When the acid is very pure, the water will not diſſolve more than 4 grs. Boiling water diſſolves half its weight; but as the liquor cools, it becomes muddy, and the acid is depoſited *.

752 Compounds. 8. This acid combines with the alkalies, earths, and metallic oxides, and forms with them compounds which are known by the name of *ſuberates*.

753 Affinities. 9. The order of its affinities is the following †.

Barytes,
Potaſh,
Soda,
Lime,
Ammonia,
Magneſia,
Alumina,
Metallic oxides.

Sect. XXIX. *Of Mellitic Acid.*

754 Diſcovery. 1. This acid is procured from a mineral ſubſtance which was diſcovered about the year 1790. Werner gave it the name of *honigſtein*, (honeyſtone) from its colour. By other mineralogiſts it has been denominated mellite, from the Latin name of honey, and hence the acid which it affords has been called the *mellitic* acid. The mineral from which this acid is obtained ſeems to be of vegetable origin. It is found in ſmall cryſtals among the layers of wood coal at Arten in Thuringia. In the firſt analyſis to which this mineral was ſubjected no new acid was detected. But in the year 1799 the acute and accurate Klaproth examined its nature and component parts, and found that it is a compound of a peculiar acid and alumina. His experiments have been ſince repeated by Vauquelin, and the reſult of his analyſis has been fully confirmed.

755 Proceſs for obtaining. 2. It is procured from the mellite by the following proceſs. The mineral is to be reduced to powder, and boiled with about 72 times its weight of water. The alumina is precipitated in the form of flakes, and the acid combines with the water. By filtration and evaporation, cryſtals are depoſited, which are the cryſtals of the mellitic acid.

756 Properties. 3. This acid cryſtallizes in the form of fine needles, or in ſmall ſhort priſms with ſhining faces. They are conſiderably hard. It has a ſlightly acid taſte, accompanied with ſome degree of bitterneſs.

757 Action of water. 4. This acid has very little ſolubility in water, but it has not been aſcertained to what degree; or what proportion of water it requires for its ſolution.

758 Of heat. 5. A ſmall quantity of this acid expoſed to the flame of the blow-pipe, at firſt gave out ſparks like nitre; and then ſwelled up, and left a matter which penetrated

---

* *Ann. de Chim.* tom. xxiii. p. 42

† *Ibid.* p. 57.

penetrated the charcoal. Heated in a crucible of platina, it ſwells up at firſt, is then charred, without the production of any oily vapour, and leaves behind a light coaly alkaline matter *.

759 Of acids. 6. When the nitric acid is added to this acid, it produces no other change than giving it a yellowiſh colour. It has not yet converted it into any of the vegetable acids to which it is nearly allied in its properties and conſtituent parts.

760 Compoſition. 7. According to Klaproth's analyſis the mineral from which the acid is obtained conſiſts of

46	mellitic acid,
16	alumina,
38	water.
100	

When it was diſtilled in a retort the acid was completely decompoſed; and the products obtained by Klaproth in this way from 100 grains of mellite were the following:

54	cubic inches of carbonic acid gas,
13	hydrogen gas,
38	grs. of acidulous water,
1	aromatic oil,
9	charcoal,
16	alumina.

The conſtituent parts of mellitic acid are obviouſly carbone, hydrogen, and oxygen. But the proportions have not been aſcertained.

761 Compounds 8. The mellitic acid enters into combination with the earths, alkalies, and metallic oxides, and forms compounds with them which are called *mellates*.

SECT. XXX. *Of LACTIC ACID.*

762 Diſcovery. 1. In inveſtigating the changes which ſpontaneouſly take place in milk, the celebrated Scheele diſcovered that it contained a peculiar acid. To this has been given the name of the *lactic acid*. The formation of this acid depends on the change of the ſugar of milk, or of the ſaccharine mucous matter; for after the acid is once well formed, when the ſerous part of the milk being very ſour reddens vegetable blues, no more is obtained by evaporation and cryſtallization.

763 Preparation. 2. Scheele did not ſucceed in ſeparating the acid from the ſerous part of the milk by diſtillation. He therefore contrived the following proceſs. He evaporated a quantity of ſour whey to $\frac{1}{8}$th of its bulk, and then filtered it to ſeparate the whole of the coagulated cheeſy matter. He then added lime-water to precipitate the phoſphate of lime, and diluted the liquid with three times its weight of pure water. He then precipitated the exceſs of lime by means of the oxalic acid, adding no more of the latter than what is neceſſary. He evaporated the ſolution to the conſiſtence of honey, poured on a quantity of alcohol which ſeparates the portion of ſugar of milk and of other extraneous matter, and diſſolves the lactic acid; and diſtilled the clear filtered liquor till the whole of the alcohol employed be driven off: what remains in the retort is the lactic acid.

764 Properties. 3. This acid is never cryſtallized; but always appears in the form of a viſcid mucilaginous ſubſtance. It has a ſtrong ſharp taſte which is far from being agreeable. It reddens the tincture of turnſole, and gives a reddiſh violet ſhade to the ſyrup of violets.

765 Compoſition. 4. When it is diſtilled in a retort it yields an empyreumatic acid which is very ſtrong and analogous to the tartaric, very little oil, carbonic acid gas, and carbonated hydrogen gas, and a ſmall quantity of coaly matter which adheres to the glaſs. This ſhews what are the conſtituent parts of this acid, but the proportions of theſe have not been determined.

766 Compounds 5. The compounds with alkalies, earths, and metallic oxides which are formed with the lactic acid, are denominated *lactates*.

767 Affinities. 6. The affinities of this acid are in the following order.

Barytes,
Potaſh,
Soda,
Strontites,
Lime,
Ammonia,
Magneſia,
Metallic oxides,
Glucina,
Alumina,
Zirconia.

SECT. XXXI. *Of LACCIC ACID.*

768 Hiſtory 1. The ſubſtance from which this acid is obtained, is collected in the neighbourhood of Madras. It was firſt deſcribed by Dr Anderſon, who ſays that neſts of inſects reſembling ſmall cowry ſhells were brought to him from the woods by the natives, who eat them with avidity. Theſe ſuppoſed neſts, he ſhortly afterwards diſcovered to be the coverings of the females of an undeſcribed ſpecies of coccus; and having noticed in the Abbé Groſier's account of China, that the Chineſe collect a kind of wax, much eſteemed by them, under the name of *péla* from a coccus depoſited for the purpoſe of breeding on certain ſhrubs, and managed exactly in the ſame manner as the Mexicans manage the cochineal inſects, he followed the ſame proceſs with his new inſects, and found means to propagate them with great facility on trees and ſhrubs in the neighbourhood.

769 and nature of the ſubſtance from which it is obtained. This ſubſtance, which he called white lac, was found on examination to have a conſiderable reſemblance to bees wax. Dr Anderſon ſuppoſes, that the animal which ſecretes it provides itſelf, by ſome means or other, with a ſmall quantity of honey, reſembling that produced by our bees. The ſweetneſs of it tempted the children who were employed to collect it, to eat ſo much of it as very much to diminiſh his crop. A ſmall quantity of this matter was ſent to Europe in 1789. It was examined by Dr Pearſon, who publiſhed an account of his analyſis in the Philoſophical Tranſactions for 1794, from which we have extracted the information which we now lay before our readers.

A piece of white lac, which weighs from three to fifteen grains, is ſuppoſed to be produced by each inſect. Theſe pieces are about the ſize of a pea, of a gray colour, opaque and roundiſh, but with a flat ſide, by which they adhere to the bark. In its dry ſtate, white lac is ſoft and tough, and has a ſaltiſh and bitteriſh taſte.

---

* Ann. de Chim. xxxvi. 210.

taſte. A watery liquid, which has a ſlight ſalt taſte, oozes out on preſſing a piece of this ſubſtance. White lac has no ſmell, unleſs it be preſſed or rubbed, when it becomes ſoft, and then it emits a peculiar odour. When it is gathered from the tree, the pieces of lac are lighter than bees-wax, but after being melted and purified, it ſinks in water. It melts in alcohol and in water at the temperature of 145°, and very readily in boiling water.

770 Preparation.

2. Dr Pearſon expoſed 2000 grains of white lac to ſuch a degree of heat as was ſufficient to melt them. They became ſoft and fluid, and there oozed out 550 grains of a reddiſh watery liquid, which emitted the ſmell of newly baked bread. The liquid was filtered and purified from extraneous matter. This liquid is the *laccic acid*.

771 Properties.

3. It has a ſlightly ſaltiſh taſte, with ſome degree of bitterneſs. It ſmells when heated like newly baked hot bread. It reddens the tincture of turnſole. Its ſpecific gravity, at the temperature of 60° is 1.025. When this liquid remains for ſome time at reſt, it becomes turbid, and depoſits a ſediment. When it is evaporated, it becomes more turbid; and allowed to remain at reſt, it affords ſmall needle-like cryſtals in mucilaginous matter.

772 Action of heat.

4. Two hundred and fifty grains of this liquid were expoſed to heat in a ſmall retort. As the liquor grew warm, mucilage-like clouds appeared, but when it grew hot, they diſappeared. At the temperature of 200° it diſtilled over very faſt. On diſtillation to dryneſs, a ſmall quantity of extractive matter remained. The diſtilled liquid was tranſparent and yellowiſh, and while hot, had the ſmell of newly baked bread. Paper ſtained with turnſole which had been put into the receiver, was not reddened. One hundred grains of yellowiſh tranſparent liquid being evaporated till it became turbid, afforded in the courſe of a night, acicular cryſtals which had a bitteriſh taſte. Under a lens they appeared in a group, ſomewhat reſembling the umbel of parſley. One hundred grains of yellowiſh tranſparent liquid being evaporated in a low temperature to dryneſs, a blackiſh matter remained behind, which did not entirely diſappear when expoſed to pretty ſtrong heat; but on heating oxalic acid to a leſs degree, it evaporated, and left no trace behind.

From theſe properties, and from its peculiar action with the alkaline, earthy, and metallic ſalts, Dr Pearſon concludes, that this acid is different from any of the acids already known.

773 Compoſition.

5. The experiments which have been made on white lac, and on the acid obtained from it, ſhow that it is cloſely allied to the vegetable acids. Its component parts, therefore, probably are, carbone, hydrogen, and oxygen; but experiments are ſtill wanting fully to aſcertain its nature and properties *.

SECT. XXXII. *Of Pruſſic Acid.*

774 Hiſtory.

1. This is one of the moſt important acids, both to the chemiſt, and to the manufacturer. It has been alledged that the ancients were acquainted with Pruſſian blue, which they employed in painting; but Landriani has ſhown, in his diſſertation on this ſubſtance, from the evidence of Theophraſtus and Pliny, and from the analyſis of an Egyptian mummy, that the ancients employed ultramarine blue and the ſmalt or azure of cobalt; and that Pruſſian blue which is readily acted on by the ſubſtances to which it muſt have been expoſed in theſe countries, could not reſiſt their influence for ſo many ages, and retain the beautiful colours which are admired in the paintings of Herculaneum.

775 The diſcovery.

2. Stahl relates, in his 300 experiments, that the diſcovery of Pruſſian blue was owing to an accident. About the beginning of the 18th century, Dieſbach, a chemiſt of Berlin, wiſhing to precipitate a decoction of cochineal with an alkali, borrowed from Dippel ſome potaſh, on which he had diſtilled ſeveral times his animal oil, and as there was ſome ſulphate of iron in the decoction of cochineal, the liquor inſtantly exhibited a beautiful blue in place of a red precipitate. Reflecting on the circumſtances which had taken place, he found that it was eaſy to produce at pleaſure, the ſame ſubſtance, which afterwards became an object of commerce. It obtained the name of *Pruſſian blue*, from the place where it was diſcovered.

776 Firſt announced.

3. This diſcovery was announced in the Memoirs of the Academy of Berlin, for the year 1710; but the proceſs by which it was obtained was kept ſecret, that thoſe who were in poſſeſſion of it might derive the whole advantage from the manufacture. It was publiſhed for the firſt time by Woodward in the Philoſophical Tranſactions for the year 1724, who declared, that it had been ſent to him from Germany, by one of his friends. This is all that is known of the manner by which this proceſs was made public. It is not certain whether it came originally from the firſt inventors, or whether it be owing to the reſearches of ſome chemiſt.

777 Proceſs.

4. The method which is deſcribed by Woodward ſucceeds very well. It is by preparing an extemporaneous alkali, by detonating four ounces of nitre, and an equal quantity of tartar; then to add four ounces of bullock's blood, well dried, and to calcine the whole with a moderate heat, till the blood be reduced to a coal, or emit no ſmoke capable of blackening any white body that is expoſed to it. Towards the end of the proceſs the fire is to be increaſed, till the crucible which contains the materials ſhall be moderately red. Throw the red-hot matter into water, and boil it for half an hour; and having poured off the firſt water, add another quantity, and boil it again. Repeat this operation till the laſt water comes off inſipid, then add all the quantities of water together, and evaporate to the quantity of two pints. To this liquid the Germans have given the name of *blood ley*. By others it has been denominated *phlogiſticated alkaline ley*.

5. A ſolution of 2 ounces of ſulphate of iron, and 8 ounces of alum, in two pints of boiling water, is to be mixed with the former ſolution while both are hot. A great effervеſcence takes place; the liquor becomes muddy, aſſumes a greeniſh colour, inclining more or leſs to blue; and a precipitate is formed of the ſame colour. Separate this precipitate, and to heighten the colour, pour upon it carefully muriatic acid till it no longer increaſes the intenſity of the blue colour; then waſh it with water, and dry it ſlowly.

6. Such was the proceſs by which Pruſſian blue was obtained, before the theory was diſcovered, to account for the different changes and effects which it preſented.

---

* *Phil. Tranſ.* 1794, p. 383.

778 Nature of it inveſtigated by ſeveral chemiſts.

The ſame year in which Woodward publiſhed an account of the proceſs, Brown inſtituted a ſet of experiments, to diſcover the nature of this ſubſtance, and the circumſtances which attended its formation. He found that fleſh, as well as bullock's blood, poſſeſſed a ſimilar property. He thought that Pruſſian blue was the bituminous part of iron, developed by the alkaline ley, and fixed in the aluminous earth. Geoffroy adopted the ſame explanation. He found that, in the animal kingdom, oils, wool, hartſhorn, ſponge, had the ſame effect with the alkali as the blood, in precipitating iron of a blue colour; and that ſome vegetable charcoal treated with the alkali, in ſome meaſure communicated to it a ſimilar property. Neuman diſcovered that the animal empyreumatic oils might be employed for the ſame purpoſe. The abbé Menon was of opinion, that the colour of iron is blue; but that this colour, uſually diſguiſed by ſome ſaline matter, reappears, when it is ſeparated by the phlogiſticated alkaline ley, and thus Pruſſian blue was only iron precipitated in its natural ſtate. The aluminous earth, he ſaw, ſerved only to diminiſh the intenſity of the colour, and to give it a more agreeable ſhade.

779 By Macquer.

7. It is to the celebrated Macquer that we are indebted for the firſt correct views in developing the theory of this proceſs. He obſerved, 1. That pure alkalies precipitated iron from its ſolutions of a yellow colour. 2. That this precipitate is ſoluble in acids. 3. That the blue fecula obtained from the blue phlogiſticated ley after the addition of muriatic acid, was not acted on by acids. He therefore concluded, that the firſt green precipitate was not a homogeneous ſubſtance, but a mixture of two precipitates, the one yellow and the other blue; and that it was ſufficient to remove the firſt by any acid, to give to the ſecond its full intenſity of colour. Hence he ſuppoſed, that the acid of the alum employed in this proceſs was uſeful in ſaturating, in a great meaſure, the pure alkaline portion of the ley, and diminiſhing proportionally the yellow precipitate of iron. Having found that it was impoſſible to ſaturate the alkali with a colouring matter by means of a calcination; and, having diſcovered that the pure alkali deprived iron (which was converted into Pruſſian blue) of its characteriſtic properties; and finally, having aſcertained that the alkali which was employed in the proceſs became exactly ſimilar to that which was calcined with combuſtible matters, to prepare it for the precipitation of iron of a blue colour, and that its alkaline properties diſappeared as it was more or leſs ſaturated with the colouring matter, he attempted to ſaturate it fully. He therefore ſaturated an alkali ſo completely with the colouring matter, that it underwent no change by boiling, and exhibited none of its alkaline properties by chemical teſts. By this diſcovery we are now in poſſeſſion of this valuable ſubſtance which had been hitherto known under the name of the *ſaturated ley of the colouring matter of Pruſſian blue*.

In the courſe of his experiments Macquer found, that the ſaturated ley could not be decompoſed by ſulphuric acid, nor by the ſolution of alum; but, on the contrary, that every metallic ſubſtance diſſolved in an acid, ſeparated the phlogiſtic matter from all the fixed and volatile alkalies. Hence he concluded, that in the proceſs of the formation of the Pruſſian blue, it is neceſſary that the affinity of the iron ſhould combine with that of the acid with the alkali, to form a ſum of affinities capable of effecting the ſeparation. This luminous explanation of ſo ſtriking a proceſs, has not a little contributed to eſtabliſh the theory of compound affinities.

780 and others.

8. After the publication of Macquer's diſſertation, almoſt all chemiſts were occupied in reſearches into the nature of Pruſſian blue, either to diſcover the nature of its principles, or to improve the proceſs for preparing the colouring matter: but they were chiefly occupied in examining thoſe bodies which were capable of phlogiſticating the alkali, as it was called; and this property was found to exiſt in a great number of ſubſtances. Till the year 1775, no change or modification was propoſed on the theory of Macquer.

781 By Bergman.

9. About this time the celebrated Bergman, in his diſſertation on elective attractions, threw new light on this object of inveſtigation, by conſidering the colouring matter of Pruſſian blue as a diſtinct acid, and poſſeſſed of peculiar attractions. According to Sage, the alkali which precipitated Pruſſian blue was nothing but an alkali ſaturated with phoſphoric acid; but Lavoiſier juſtly remarked, that, according to this theory, the ſalt formed of phoſphoric acid and an alkali ought to precipitate a ſolution of ſulphate of iron of a blue colour, which was not the caſe.

Many chemiſts examined the nature of this ſubſtance by means of heat, and among others Delius and Scopoli, Deyeux and Parmentier, Bergman and Erxleben, ſubjected it to diſtillation, the product of which was a quantity of ammonia. By others an oil was obtained in this proceſs, and ſometimes a peculiar acid, which had the properties of the ſulphuric acid. The difference of theſe reſults probably aroſe from the different ſtates of purity of the Pruſſian blue which was employed in the experiment.

782 By Fontana.

Fontana diſcovered that the ſulphuric acid diſtilled on Pruſſian blue paſſed to the ſtate of ſulphurous acid, and that the colouring matter produced detonation with nitre. Landriani found that it yielded by diſtillation, beſides ammonia, a ſmall portion of liquid perceptibly acid, and ſome oil, and a great quantity of elaſtic fluids, which conſiſted of azotic and hydrogen gaſes, the latter burning with a blue flame, and detonating ſtrongly with oxygen gas.

783 By Scheele.

10. But the moſt important ſtep in the progreſs of the diſcovery of the nature and properties of this ſingular ſubſtance, was made by Scheele, an account of which he publiſhed in two diſſertations in the Stockholm tranſactions for 1782 and 1783. He began by examining the blood-ley, and he found by expoſing it for ſome time to the air, that it loſt the property of precipitating iron of a blue colour, and the precipitate which it then yields is ſoluble in acids. To diſcover what change had taken place on the air, he put ſome of the ley freſh prepared into a large glaſs globe cloſe ſhut up, and he found ſome time after, that neither the air nor the ley had undergone any change. He concluded, therefore, that the colouring matter was not pure phlogiſton. He ſuſpected that carbonic acid might have ſome effect in changing the nature of the alkali when expoſed to the open air. He filled a globe with carbonic acid gas, and having introduced a quantity of the Pruſſian alkali, he kept it cloſe ſhut up

784 He examines the ley.

785 Effect of carbonic acid.

up for 24 hours, after which, on examining the alkali, it gave a precipitate which was ſoluble in the acids; the change, then, muſt have been occaſioned by the carbonic acid gas. He repeated this experiment by adding to the colouring matter a ſmall quantity of ſulphate of iron. This matter was not changed by the action of the carbonic acid gas. The ſame reſult was obſerved when he boiled the colouring matter in an oxide of iron precipitated by an alkali. It ſuffered no change in the carbonic acid gas, but precipitated the iron as before. The iron then has the property of fixing the colouring principle, of defending it againſt the action of carbonic acid gas; and hence it happens that the neutral colouring ſalt formed with an alkali boiled on Pruſſian blue, does not ſo eaſily loſe its properties. But if the colouring ley be digeſted on an oxide of iron, as that which is obtained from the ſulphate of iron boiled in nitric acid, and afterwards precipitated by an alkali, no effect is produced. By this digeſtion the action of the gas is not prevented, and if the ſulphate of iron be added, even with an exceſs of acid there is no longer a production of Pruſſian blue.

786
Iron fixes the colouring principle.

To diſcover what happened to the colouring principle, when it was charged with the carbonic acid gas, Scheele introduced into a globe filled with this gas, ſome of the Pruſſian alkali, and ſuſpended in it a bit of paper, previouſly dipped in a ſolution of ſulphate of iron, and on which he had let fall two drops of alkaline liquor to precipitate the iron. The paper was removed at the end of two hours, and was covered with a fine blue colour, with the addition of a little muriatic acid. The ſame experiments repeated with alkali ſaturated with exceſs of ſulphuric acid, gave the ſame reſult; that is to ſay, the paper charged with oxide of iron and ſuſpended as above, became of a blue colour on adding muriatic acid. Hence it follows, that the colouring principle is diſengaged by acids, without decompoſition, for it ſtill has the property of being fixed with oxide of iron with which it comes in contact. Thus he found that the colouring matter might be ſeparated from the ſubſtances with which it was generally in combination, and without undergoing decompoſition.

787
It is diſengaged by acids.

788
To ſeparate the colouring matter.

11. To obtain it, therefore, in a ſeparate ſtate, he contrived the following proceſs. He put into a glaſs veſſel two parts of Pruſſian blue reduced to powder, one part of red oxide of mercury, and ſix parts of water. He boiled the mixture for ſome minutes, continually ſtirring it. It then aſſumes a yellowiſh green colour. He put the whole on a filter, and poured upon the reſiduum two parts more of boiling water, to waſh it completely. This liquid is a ſolution of mercury combined with the colouring matter, which has the metallic taſte, and is neither precipitated by acids nor alkalies. Pour this liquid into a glaſs veſſel upon one-half part of clean iron filings, and a ſmaller quantity of concentrated ſulphuric acid. Shake the mixture well for ſome minutes, when it becomes black by the reduction of the mercury. The liquid then loſes its metallic taſte, and gives out the odour which is peculiar to the colouring matter. Having allowed it to remain at reſt for ſome time, it is poured off, put into a retort to which a receiver is adapted, and diſtilled with a gentle heat. One-fourth part of the liquid only ſhould be allowed to paſs over, for the colouring matter is much more volatile than water, and conſequently riſes firſt. The liquid in the receiver is commonly mixed with a little ſulphuric acid, from which it may be ſeparated by diſtilling again off a little powdered chalk, which takes up the ſulphuric acid. The liquid then paſſes over in a ſtate of purity. This is *the pruſſic acid.*

789
Pruſſic acid obtained.

790
Nature of this proceſs.

12. In this proceſs the oxide of mercury which was mixed with the colouring matter, takes it from the iron with which it is combined in the ſtate of Pruſſian blue, and is then a cryſtallizable pruſſiate of mercury. The iron which is added in the metallic ſtate, reduces the oxide of mercury, and at the moment it combines with the ſulphuric acid, which has alſo been added, the heat applied ſublimes the pruſſic acid which has been diſengaged from the mercury, which is now reduced to the metallic ſtate. The pruſſic acid thus obtained, partly in the liquid, and partly in the gaſeous ſtate, combined with alkalies, produces the ſame effects as the blood ley, and the colourleſs Pruſſian blue.

791
Compoſition.

13. Having obtained the pruſſic acid in a ſeparate ſtate, it was his next object to diſcover its component parts. He had obſerved in the proceſs for procuring it, that the air in the receiver was inflammable, and in decompoſing the pruſſiates, he obtained ammonia and carbonic acid, and found that ſome metals were reduced by diſtillation with the metallic pruſſiates. He concluded from this, that the pruſſic acid was compoſed of ammonia and oil, and he endeavoured to prove this by the teſt of experiment; but he ſoon found that he could not ſucceed in forming the colouring compound, by combining ammonia and the different oils heated together. Seeing that water was an obſtacle to the formation of the pruſſic acid, he conducted his experiments in a different way, by combining the ammonia with the dry combuſtible principle, which he ſuppoſed exiſted in oils, and with the carbonic acid, equally in the dry ſtate. He ſaw that charcoal alone, ſtrongly heated with fixed alkalies, gave them the property of colouring iron blue. Having heated theſe two ſubſtances in crucibles, he added to the one muriate of ammonia, at the moment when the firſt mixture had acquired a white heat, and he continued the heat till no more vapour was diſengaged. This proceſs furniſhed him with a pure Pruſſian alkali, whilſt the combination of the alkali and the charcoal, without the addition of the muriate of ammonia, afforded none.

792
Berthollet's experiments.

14. Such was the ſtate of our knowledge with regard to the colouring matter of Pruſſian blue, when Berthollet, at the end of 1787, communicated to the Academy of Sciences, the reſult of his inveſtigations into the nature and properties of this ſubſtance. He repeated the experiments of Scheele, improved and extended his views, and confirmed his concluſions. The reſult of his reſearches on this ſubſtance was cloſely connected with the light which he had thrown on the nature and compoſition of ammonia ſome years before. He proved that the alkaline pruſſiate is a triple ſalt, which is compoſed of pruſſic acid, the alkali and iron; that when it is evaporated and re-diſſolved, it affords cryſtals in the form of octahedrons; and mixed with ſulphuric acid, and expoſed to the ſun, there is precipitated Pruſſian blue, which does not happen

in the dark. After theſe preliminary experiments, he proceeded to the examination of pruſſic acid, by the action of oxymuriatic acid. This acid, in proportion as it is diſſolved in the pruſſic acid, is deprived of its oxygen, and is converted into the ſtate of muriatic acid. The pruſſic acid becomes more odorous and volatile, and leſs ſuſceptible of combination with the alkalies, precipitating iron from its ſolutions, of a green colour. This green precipitate recovers its blue colour when expoſed to the light, by contact with ſulphurous acid, by iron.

793 Oxy-pruſſic acid.

It is the oxy-pruſſic acid. When the oxymuriatic acid is ſtill continued to be added in the ſtate of gas, and is expoſed to the light, the new acid ſeparates from the water, and is precipitated to the bottom in the form of an aromatic oil, which is converted by heat to an inſoluble vapour, which is no longer capable of combining with iron. Thus ſuperoxygenated, this acid can no longer return to its original ſtate. It is totally different in its properties.

When the oxypruſſiate of iron, which is prepared by treating Pruſſian blue with the oxymuriatic acid, and which is diſtinguiſhed by its green colour, is deprived of its acid, by being brought into contact with a cauſtic fixed alkali, it is inſtantly decompoſed, and is converted into carbonate of ammonia.

15. Scheele and Bergman were of opinion, that the pruſſic acid contained ammonia ready formed. Berthollet, however, concludes from his experiments, that it only contains the elements, namely, the azote and hydrogen, both in combination with carbone;

794 Pruſſic acid a triple compound.

and thus he conſiders pruſſic acid to be a triple compound of hydrogen, carbone and azote, but he has not been able to aſcertain the proportions. He thinks, however, that the hydrogen and azote come near to the proportions which exiſt in ammonia *.

16. In ſome experiments by M. Clouet, on the colouring matter of Pruſſian blue, he attempted to combine the elements of ammonia with charcoal, with the view of producing the pruſſic acid; but in whatever proportion he employed them, no colouring matter was obtained. He therefore concluded, that it was neceſſary to combine directly the ammonia with the charcoal, for the production of this ſubſtance. He took 2½ parts of quicklime in powder, and mixed them with one part of ſal ammoniac dried, and alſo in the ſtate of powder. He put the mixture into a porcelain retort, which he placed upon a ſand-bath. To the beak of the retort was adapted a porcelain tube filled with dry powdered charcoal. The porcelain tube paſſed acroſs a furnace, in which it might be ſtrongly heated.

795 Pruſſian blue formed of carbone and ammonia.

It was then made red hot, and heat was afterwards applied to the retort, and the ammonia was diſengaged in the ſtate of gas, which paſſed through the red-hot porcelain tube containing the charcoal. The product was received in proper veſſels, and when examined, was found to be the colouring matter of Pruſſian blue †.

796 Properties of pruſſic acid.

17. The pruſſic acid thus obtained, is a colourleſs, tranſparent liquid, having a ſtrong odour of peach flowers, or of bitter almonds. This odour impregnates for ſome time the ſaliva of thoſe who reſpire it. The taſte is at firſt ſweetiſh but ſoon becomes acrid and hot. It is apt to excite coughing, and has a ſtrong tendency to aſſume the gaſeous form, and is therefore ſoon diſſipated from the veſſels which contain it. It has no effect on vegetable blues.

797 Action of heat and light.

18. It is decompoſed at a high temperature; and when expoſed to light, is converted into carbonic acid, ammonia, and carbonated hydrogen gas. It combines with difficulty with alkalies and earths, and without deſtroying their alkaline properties.

798 Of carbonic acid.

19. The carbonic acid drives it off from theſe combinations. It deprives the oxymuriatic acid gas of its oxygen, and by this addition changes its properties. It has no action on the metals; but it combines with their oxides, changing the colour, and forming ſalts which are in general inſoluble.

799 Triple compounds

20. This acid has the greateſt tendency to form triple ſalts with the alkaline and metallic baſes. Theſe complex combinations are more permanent and fixed than the ſimple alkaline pruſſiates.

800 not eaſily decompoſed

They are not decompoſed by carbonic acid, light, air, or the other acids.

801 Affinities.

21. The affinities of pruſſic acid are the following.

Barytes,
Strontites,
Potaſh,
Soda,
Lime,
Magneſia,
Ammonia.

Sect. XXXIII. *Of Sebacic Acid.*

802 Hiſtory.

1. The penetrating fumes which are exhaled from melted tallow, and which affect the eyes, the noſtrils, and even the lungs, had been long ago obſerved, and Olaus Borrichius has thrown out ſome hints, warning againſt the danger of being expoſed to theſe fumes. But little attention was paid to their nature and properties. Grutzmacher was the firſt who demonſtrated the exiſtence of this acid, in a diſſertation *de oſſium medulla*, printed at Leipſic in the year 1748. Rhodes publiſhed a ſmall work in 1753 at Gottingen, in which he makes particular mention of this acid. The following year appeared a diſſertation by M. Segner, *on the acid of animal fat*, which contained a number of well-conducted experiments. Crell endeavoured to improve the proceſs for the ſeparation and purification of this acid, and to aſcertain the properties of its combinations. Theſe were publiſhed in the Philoſophical Tranſactions for the years 1780 and 1782.

But it appears, as Thenard, who made experiments on this acid, obſerves, that the acid obtained by thoſe who firſt treated of the ſubject, was either the acetic acid, or ſome acid different from the ſebacic, the properties of which are quite diſtinct from thoſe which had been formerly deſcribed.

803 Preparation.

2. The proceſs by which this chemiſt obtained the ſebacic acid is the following. He diſtilled a quantity of hogs lard, and waſhed the product ſeveral times with hot water. He then dropt into it acetate of lead: there was formed a flakey precipitate, which was collected and dried, put into a retort with ſulphuric acid, and heated. The liquor in the receiver had no acid character; but there appeared in the retort a melted matter analogous to fat. This is carefully ſeparated; and after being waſhed, is boiled with water. By the action of heat the whole is diſſolved by the water, and when it cools, cryſtals in the ſhape of needles are depoſited.

Theſe

---

* Fourcroy Connaiſs. Chim. tom. ix. p. 89.

† Annal. de Chim. tom. xi. p. 30.

Theſe are the ſebacic acid. To be certain that theſe were not produced by means of the ſulphuric acid, he waſhed the fat which had been diſtilled with water, which was filtered and evaporated, and needles were formed, exhibiting exactly the ſame properties. Or, after having waſhed with water the diſtilled fat, he ſaturated the filtered liquor with potaſh, evaporated it, and dropt into it a ſolution of lead. There was inſtantly formed a ſalt compoſed of the ſebacic acid and lead. This is to be decompoſed as before with ſulphuric acid. This acid has the following properties.

804 Properties. 3. It has no ſmell, a ſlight acid taſte, and reddens ſtrongly the tincture of turnſole. When heated it melts like tallow.

4. It is much more ſoluble in warm than in cold water. Boiling water ſaturated with this acid forms a ſolid maſs on cooling. It cryſtallizes in ſmall needles, but with certain precautions may be obtained in the form of long, large, and very brilliant plates *.

Sect. XXXIV. *Of Uric Acid.*

805 History and names. 1. This acid was diſcovered by Scheele in the year 1776. It was at firſt called *lithic acid.* It conſtitutes one of the component parts of urinary calculi, and is alſo found in human urine. There is one ſpecies of calculus which is almoſt entirely compoſed of this ſubſtance. It is that ſpecies which reſembles wood in appearance and colour.

806 Properties. 2. This acid, as its properties have been deſcribed by Scheele, is thus characterized. It is inſipid, inodorous, almoſt inſoluble in cold water, and ſoluble only in about 360 parts of boiling water. 807 Action of water. It ſeparates from this when it cools, into ſmall yellowiſh cryſtals. The ſolution in water reddens the tincture of turnſole.

808 Of acids. 3. There is ſcarcely any action between the uric acid and the ſulphuric and muriatic acids. It is ſoluble in the concentrated nitric acid, to which it communicates a red colour. It would appear that in this change of colour the nature of the acid is alſo changed, for part of it is converted into oxalic acid. Oxymuriatic acid very readily acts upon uric acid, either by ſuſpending a calculus in the liquid acid, or, which is eaſier, by paſſing a ſtream of oxymuriatic acid gas through water at the bottom of which is placed the uric acid in powder. Its colour becomes pale, the ſurface ſwells up, it ſoftens, and is at laſt converted into a jelly. This part diſappears, and is ſoon diſſolved, giving a milky colour to the liquid. There is extricated by ſlow efferveſcence ſmall bubbles of carbonic acid gas. The liquid by evaporation gives muriate of ammonia, acidulous oxalate of ammonia, both cryſtallized; muriatic acid, and malic acid. Thus the oxymuriatic acid decompoſes the uric acid, and converts it into ammonia, carbonic, oxalic, and malic acids.

809 Of heat. 4. When uric acid is diſtilled, there is a little of it ſublimed without decompoſition. It yields alſo a very ſmall quantity of oil and water, cryſtallized carbonate of ammonia, carbonic acid gas; and there remains behind a very black coal without any alkali, and without any lime.

810 Compoſition. 5. All theſe facts ſhew that uric acid is a compound of a very peculiar kind, formed of azote, of carbone, of hydrogen and oxygen, and ſuſceptible of a great number of different changes by chemical agents.

Sect. XXXV. *Of Rosacic Acid.*

811 Origin. 1. During certain diſeaſes, the urine, when it cools, depoſits a peculiar ſubſtance which has been denominated from its colour, which reſembles bricks, *lateritious ſediment.* During fevers, this appearance of the urine takes place; and in gouty perſons, at the termination of the paroxyſms, it is very abundant. And when this ſuddenly diſappears, and the urine at the ſame time continues to depoſit this ſubſtance, a relapſe may be dreaded. It appears in the form of red flakes, and adheres ſtrongly to the ſides of the veſſel. If the urine be heated, this ſediment is again diſſolved.

812 Preparation. 2. This ſubſtance was formerly conſidered by chemiſts as the uric acid. If into freſh urine a little nitric acid is dropt, it becomes muddy, and a precipitate is formed. The nitric acid, and the ſubſtance to which the name of *roſacic acid* has been given, combine together, and are depoſited. 818 Properties. The uric acid being much leſs ſoluble than the roſacic acid, it is very eaſy to ſeparate them. All that is neceſſary is to pour boiling water on the ſediments, and to waſh them on the ſame filter, in which caſe the uric acid remains behind.

Prouſt, who made experiments on this ſubſtance, conſiders it as another characteriſtic of roſacic acid that it produces with a ſolution of gold, a cloudy precipitate of a violet colour *.

Sect. XXXVI. *Of Amniotic Acid.*

814 Properties. 1. A peculiar acid has been detected in the liquor of the amnios of the cow. This was diſcovered by Buniva and Vauquelin. This acid is concrete, white, and brilliant, has a very ſlight acid taſte, and reddens the tincture of turnſole. It is little ſoluble in cold water, but diſſolves more readily in boiling water, from whence it is depoſited by cooling, in long needle-ſhaped cryſtals. When this acid is expoſed to heat, it ſwells up, and exhales an odour of ammonia ſenſibly mixed with pruſſic acid. It leaves behind a voluminous coal.

815 And diſtinctive characters. 2. It ſeems at firſt to have ſome analogy with the ſaclactic and uric acids, but this is not really the caſe. The ſaclactic acid does not furniſh ammonia by diſtillation; the uric acid yields ammonia and pruſſic acid by heat, but it is not equally ſoluble in warm water, and does not cryſtallize, in long, white, brilliant needles, nor is it ſoluble in boiling alcohol, as the amniotic acid is †.

Chap. XI. Of INFLAMMABLE SUBSTANCES.

816 Introduction. The claſs of bodies which we are to examine in this chapter, under the title of inflammable ſubſtances, are *alcohol*, *ether*, and *oils*. Theſe ſubſtances are cloſely allied to many of the bodies which were treated of in the laſt chapter. Their conſtituent parts are the ſame with many of the vegetable acids, arranged, however, in different proportions, and totally different in their properties and effects. The elements of theſe inflammable ſubſtances are carbone and hydrogen chiefly, but

---

* *Ann. de Chim.* tom. xxxix. p. 193.

* *Ann. de Chim.* tom. xxxvi. p. 265.

† *Ann. de Chim.* tom. xxxiii. p. 279.

but in ſome there is a triple compound of carbone, of hydrogen and oxygen; the latter does not exiſt in that quantity as to exhibit acid properties, or theſe properties are concealed by the proportions of the other conſtituent parts. It was therefore thought neceſſary to treat of theſe ſubſtances in this place, that we might be early acquainted with their properties, ſome of which are of great importance in chemical reſearches, particularly their effects on many ſaline bodies. They may be regarded, therefore, as valuable inſtruments of chemical analyſis. We ſhall conſider the inflammable ſubſtances in the four following ſections, namely; 1. Alcohol, 2. Ether, 3. Fixed oils, and 4. Volatile oils.

Sect. I. *Of Alcohol.*

817 Preparation. 1. When vegetable matters have been ſubjected to the vinous fermentation, the fluid is totally changed. It is converted into a ſubſtance called *wine* or *beer*, according to the nature of the materials from which it has been prepared. When this product, the wine or beer, is ſubjected to another proceſs, a very different product is obtained. By diſtillation a fluid is obtained of very different properties from the beer or wine from which it is extracted. This liquid, when it is perfectly pure, is known in chemiſtry by the name of *alcohol*, or *ſpirit of wine*, becauſe it is produced from wine. It is ſometimes denominated alſo *ardent ſpirit*, from its effects. Ardent ſpirit, as it is firſt obtained by diſtillation, is to be conſidered as a mixture of alcohol and water, becauſe the alcohol in the proceſs of diſtillation is condenſed by water. In this ſtate, ardent ſpirit is different in flavour, in colour and in ſtrength, according to the nature of the materials from which it is obtained, 818 Different names. and hence in common language it is diſtinguiſhed by different names. When it is obtained from the fermented juice of the grape, it is known by the name of *brandy;* from that of the ſugarcane, by that of *rum;* and from that of farinaceous ſubſtances by that of *whiſky*. All theſe ſubſtances, therefore, are to be conſidered as compoſed of alcohol, or pure ſpirit of wine, water, and a peculiar oil, to which the flavour is owing.

819 Hiſtory. Ardent ſpirit, it is ſuppoſed, was known in the dark ages. It does not appear, from any of the writings of the Greeks or Romans, that they were acquainted with ſuch a liquor. The preparation of it from wine, and even the diſcovery of alcohol, or pure ſpirit itſelf, is aſcribed to Arnold de Villa Nova, who lived in the 13th century.

820 Purification. 2. Ardent ſpirit thus obtained, it has been obſerved, is a mixture of alcohol or pure ſpirit, water and oil, with ſome colouring matter. To purify it from theſe ſubſtances, it is again diſtilled; and to have it perfectly pure, this proceſs muſt be repeated ſeveral times. When ardent ſpirit is diſtilled for the firſt time, after it is extracted from the fermented liquors, it is diſtinguiſhed by the name of rectified ſpirits. The proceſs which is recommended by ſome is the following. Diſtil it in a water bath, till one fourth of the quantity has paſſed over; then diſtil it again for ſeveral times, taking only the firſt half of the product. Mix all theſe products together, and diſtil them with a very gentle heat; the firſt half of the liquor which paſſes over, is the pureſt alcohol that can be obtained; the remainder may be reſerved for ordinary purpoſes†. Even in this ſtate, the alcohol thus obtained, contains a certain proportion of water, to ſeparate which, Boerhaave has given a very good proceſs, by means of an alkali. Take a quantity of carbonate of potaſh which has been expoſed to a red heat, to ſeparate the moiſture; reduce it to powder, and put it into the ſpirit. This ſalt, on account of its ſtrong attraction for water, combines with the water of the alcohol; and this ſolution of the alkali having the greater ſpecific gravity, falls to the bottom. The alcohol which remains at the top, may be eaſily ſeparated. To purify this alcohol, from a ſmall quantity of potaſh which it holds in ſolution, it may be rediſtilled in a water bath. It ought to be obſerved, however, that the diſtillation ſhould not be carried on till the whole of the alcohol is driven off, becauſe towards the end of the proceſs, it carries part of the potaſh along with it.

821 Properties. 3. Alcohol thus prepared and purified, is a light, tranſparent, and colourleſs liquor, of a ſharp, penetrating, agreeable ſmell, and of a warm, ſtimulating, acrid taſte. It has the property, in a much greater degree than wine, of producing intoxication. The ſpecific gravity of alcohol when perfectly pure, is 0.800, but the ſtrongeſt ſpirit which is afforded by mere diſtillation, according to Mr Nicholſon, is 0.820 at the temperature of 71°. The alcohol or rectified ſpirit of commerce, has rarely a ſpecific gravity below 0.8371.

822 Volatile. 4. When alcohol is expoſed to the air at a temperature between 50° and 60°, it evaporates, and when it is pure, without leaving any reſiduum. By this rapid evaporation it produces great cold, which is very ſenſibly felt by dipping the fingers in alcohol, and expoſ- 823 Action of heat. ing them to the air. It boils at the temperature of 176°, and is then converted into an elaſtic fluid. In the vacuum of an air-pump it boils at 56°. It has never yet been frozen by the greateſt degree of cold to which it has been expoſed. It remains fluid when the thermometer ſtands at —69°. When it is paſſed through a red-hot porcelain tube, it is decompoſed, and converted into carbonic acid gas, carbonated hydrogen gas, and water.

824 Phoſphorus. 5. With the aid of heat, alcohol diſſolves a ſmall quantity of phoſphorus. When this ſolution, which has a fœtid odour, is precipitated, by dropping a little of it into water, it becomes luminous in the dark. There ariſe jets of flame from the ſurface of the water; and there is formed an oxide of phoſphorus in the ſtate of white powder. Alcohol ſeems alſo capable of diſſolving phoſphorated hydrogen gas.

825 Sulphur. 6. There is no action between alcohol and ſulphur, neither at the ordinary temperature, nor even when they are boiled together; but when the two bodies are brought in contact with each other in the ſtate of vapour, they combine readily, and there is formed a fœtid ſulphurated alcohol, which depoſits a ſmall quantity of white ſulphur, and becomes muddy in cooling. The ſulphur is precipitated by water, and gives about $\frac{1}{60}$th part. Alcohol combines ſtill more readily with ſulphurated hydrogen gas, which communicates to the alcohol a little colour, and in this combination is decompoſed with more facility by oxygen gas, and all other oxygenated bodies, than when it is in the ſtate

---

† Fourcroy Connaiſs. Chim. tom. viii. p. 142.

ſtate of gas. Alcohol combines with ſulphurated hydrogen gas, which is contained in mineral waters, and deprives them of this gas by diſtillation.

826 Of acids. 7. The ſtrong acids have a very powerful effect on alcohol. It is decompoſed by the ſulphuric, the nitric, the oxymuriatic, and the acetic acids; and the product of this decompoſition varies according to the nature of the acid, its ſtrength, and the proportions in which it is employed. Some of the acids are ſoluble in alcohol. With the aid of heat, it diſſolves the boracic acid, which communicates to it the property of burning with a green flame. It alſo holds in ſolution carbonic acid gas in greater proportion than its own bulk. It precipitates from water, on the contrary, the phoſphoric acid, almoſt in the concrete ſtate, and alſo the metallic acids which are ſoluble in this liquid.

827 Of water. 8 Alcohol combines with water in all proportions. The affinity between the two fluids is ſo ſtrong that water is capable of ſeparating from alcohol many bodies with which it is combined, while the alcohol decompoſes many ſaline ſolutions, and precipitates the ſalt. When water and alcohol are combined together, there is an increaſe of temperature, which ſhews that there is a condenſation of the two liquids. Accordingly it is found, that the denſity or ſpecific gravity of the mixture is greater than the mean of the uncombined liquids. This denſity varies according to the different proportions of the alcohol and water which are employed. In conſequence of this variation, it becomes an object of conſiderable importance to be able to aſcertain the ſtrength of ſpirits; that is, the proportions of alcohol and water of different degrees of denſity or ſpecific gravity. This object is important, both in a political and commercial view. For the purpoſes of commerce, various inſtruments have been contrived, and tables conſtructed, for the conveniency of thoſe who are concerned in the purchaſe and ſale of ſpirituous liquors. For the purpoſes of revenue, a moſt elaborate and minute ſet of experiments was inſtituted by Sir Charles Blagden, who was expreſsly employed by the Britiſh government to aſcertain the relative value or ſtrength of ardent ſpirit at different temperatures and different ſpecific gravities. An account of theſe experiments was publiſhed in the Philoſophical Tranſactions for the year 1790. Tables which ſhew the reſult of the experiments, were publiſhed by Mr Gilpin in 1794; but as theſe are not immediately connected with the elements of chemiſtry, we refer our readers to the original papers, and to the article *Spirituous Liquors*, in this work.

828 Alkalies and ſalts. 9. Alcohol diſſolves the fixed alkalies in the pure ſtate, and forms with them an acrid ſolution of a reddiſh colour. The ſolution of potaſh in alcohol was formerly denominated *the acrid tincture of tartar.* It is in this way that the fixed alkalies are obtained in their pureſt ſtate. Alcohol, therefore, becomes a valuable inſtrument of analyſis for ſeparating the fixed alkalies from a great number of extraneous ſubſtances. Ammonia alſo combines with alcohol by the aſſiſtance of heat. The ammonia with a higher temperature is driven off, and carries with it part of the alcohol. Many of the ſaline bodies may be diſſolved in alcohol, and on this account alſo it is valuable to the chemiſt in his reſearches. Tables have been conſtructed, ſhewing the quantity of different ſalts which may be diſſolved at different temperatures. The following tables were drawn up from the experiments of M. Guyton †.

I. *Table of Salts which are readily Diſſolved.*

	Temperature.	Grains.	
240 grains of alcohol diſſolve at	54.5°	240	Nitrate of cobalt.
	54.5	240	copper.
	54.5	240	Muriate of zinc.
	54.5	240	alumina.
	54.5	240	Nitrate of alumina.
	113.	240	Acetate of lead.
	180.5	694	Nitrate of magneſia.
	180.5	1313	Muriate
	180.5	240	of iron.
	180.5	240	of copper.
			Nitrate of zinc decompoſed.
			Nitrate of iron partly decompoſed.
			Nitrate of biſmuth.

II. *Table of Salts that are little Soluble.*

	Grains.	
240 grains of alcohol at the boiling temperature diſſolve	240	Muriate of lime.
	214	Nitrate of ammonia.
	212	Oxymuriate of mercury.
	112	Acetate of ſoda.
	100	Nitrate of ſilver.
	23	Nitrate of ſoda.
	18	Acetate of copper.
	17	Muriate of ammonia.
	9	Arſeniate of potaſh.
	7	Superoxalate of potaſh.
	5	Nitrate of potaſh.
	5	Muriate of potaſh.
	4	Arſeniate of ſoda.
	1	Tartrate of potaſh.

III. *Salts that are Inſoluble.*

- Borax,
- Tartar,
- Alum,
- Sulphate of ammonia,
  - iron,
  - copper,
  - zinc,
  - ſoda,
  - potaſh,
  - lime,
  - ſilver,
  - mercury,
- Tartrate of ſoda,
- Nitrate of lead,
  - mercury,
- Muriate of lead,
- Carbonate of potaſh,
  - ſoda.

---

* *Jour. de Phyſique*, 1785, p. 65.

The following table drawn up by Mr Kirwan, ſhews the quantity of ſalts that are ſoluble in 100 parts of alcohol of different denſities. The temperature in which the ſolutions were made was from 50° to 80°†.

Salts.	*Alcohol of*				
	0.900	0.872	0.848	0.834	0.817
Sulphate of ſoda.	0.	0.	0.	0.	0.
Sulphate of magneſia.	1.	1.	0.	0.	0.
Nitrate of potaſh.	2.76	1.		0.	0.
Nitrate of ſoda.	10.5	6.		0.38	0.
Muriate of potaſh.	4.62	1.66	0.	0.38	0.
Muriate of ſoda.	5.8	3.67	0.	0.5	0.
Muriate of ammonia.	6.5	4.75	0.	1.5	0.
Muriate of magneſia dried at 120°	21.25	0.	23.75	36.25	50.
Muriate of barytes. Do. cryſtallized.	1. 1.56	0. 0.	0.29 0.43	0.185 0.32	0.09 0.06
Acetate of lime.	2.4	0.	4.12	.4.75	4.88

829 Compoſition. 10. A great variety of different opinions have been propoſed with regard to the compoſition of alcohol. It had been obſerved, in burning this combuſtible ſubſtance, in cloſe veſſels, that water was formed. Some philoſophers had even obſerved that the quantity of water obtained by the combuſtion of alcohol, was greater than the whole weight of the alcohol which was conſumed. From obſerving this circumſtance, it was ſuppoſed to conſiſt of water, combined with an acid, an oil, or phlogiſton, according to the views and theories of different philoſophers.

830 According to Lavoiſier. It is to the experiments of Lavoiſier that we are indebted for aſcertaining the real conſtituent parts of this ſubſtance. He burnt in a proper apparatus, with a known quantity of oxygen gas, 76.7083 grs. troy of alcohol, and after the combuſtion, carbonic acid gas and water were found to be the only products; and by eſtimating the oxygen gas conſumed, the quantity of carbonic acid and of water which were formed, it appeared that the quantity of alcohol conſumed was compoſed of

22.840	carbone,
6.030	hydrogen,
47.830	water.
76.700	

831 To Fourcroy. But it has been ſince proved, by the experiments of Fourcroy and Vauquelin, that oxygen is a component part of alcohol; for when they mixed together equal parts of alcohol and concentrated ſulphuric acid, and while ether is formed from it, there was alſo at the ſame time a production of water; the alcohol in this caſe was decompoſed, but the ſulphuric acid ſuffered no change. The oxygen, therefore, which combined with the hydrogen in the formation of water, muſt have come from the alcohol *.

Sect. II. *Of Ether.*

832 Formation. By the action of different acids with alcohol, the latter is decompoſed, and different products are obtained, according to the proportions of the acid employed, and the heat which is applied. When the acid and the alkali are in a certain proportion, and are expoſed to a moderate temperature, the product is a peculiar ſubſtance which has received the name of *ether*. Ether has been obtained by the action of different acids or alcohol, and hence it has received different names, as *ſulphuric ether*, *nitric ether*, *muriatic ether*. The firſt, namely the ſulphuric ether, which ſeems to have been longeſt known, and is moſt eaſily obtained, has excited the greateſt attention among chemiſts. We ſhall therefore conſider it firſt. 833 Names.

I. Of Sulphuric Ether.

834 Hiſtory. 1. It appears from different paſſages in the writings of the earlier chemiſts, that the knowledge of ſulphuric ether was among their ſecrets. It was then called *oleum vitrioli dulce*. The method of preparing it is deſcribed in a book publiſhed at Nuremberg about the year 1540. But the nature of this ſubſtance was not much attended to till the year 1730, when a certain quantity was preſented to the Royal Society by Dr Frobenius, with a paper which was publiſhed in their tranſactions for that year, containing an account of a number of experiments which were made upon it.

---

† *Min. Wat.* p. 274.

* *Nichol. Jour.* i. p. 191.

it. It was long known under the name of *naphtha* among the German chemiſts.

834 Preparation. 2. The following is the proceſs by which ſulphuric ether may be obtained. Equal parts of concentrated ſulphuric acid and alcohol are put into a retort, to which a receiver is to be adapted and luted. Or perhaps it is better to add the acid by ſmall portions at a time, that the action may not be too violent, and the heat produced too great. The receiver ſhould be immerſed in cold water, or ſurrounded with ice, or it may be kept cool by the application of wet cloths, over which a ſmall ſtream of water is directed. Heat is then applied, and the firſt product which comes over is a fragrant ſpirit of wine; but as ſoon as the mixture begins to boil, the ether comes over, is condenſed by the cold, and runs in ſtreams down the ſides of the receiver. When the quantity obtained amounts to about one half of the alcohol employed, the proceſs ſhould be ſtopped, and the receiver unluted and removed; but if it be continued, white fumes begin to come off, which are known to be the fumes of ſulphurous acid. After this there riſes a light yellowiſh coloured oil, which has been called *the ſweet oil of wine*. The heat ſhould now be moderated after the ether has paſſed over, becauſe the matter contained in the retort becomes black, thick, and ſwells conſiderably. When the whole of the ſweet oil has come over, there is ſtill an evolution of ſulphurous acid, which becomes thicker and thicker, till at laſt there is nothing but a dark coloured ſulphuric acid.

835 Purification. 3. The ether which is obtained by this proceſs is impure. It is generally contaminated with ſulphurous acid. To purify it, it has been uſual to mix a quantity of potaſh with the fluid, and to diſtil it over again. The acid in this caſe combines with the potaſh, and the ether being ſeparated, paſſes over into the receiver. Dizè, however, conſidering this proceſs as tedious and uncertain, has propoſed other ſubſtances in the room of potaſh, and he has tried ſeveral metallic oxides, ſuch as the red oxide of lead, the yellow oxide of iron, the red oxide of mercury, and the oxide of mangaueſe. But after a variety of experiments, he is of opinion, that the black oxide of manganeſe is the moſt convenient for the purification of ether. It is mixed with ether, allowed to remain ſome time, and is to be frequently agitated. The oxygen of the manganeſe combines with the ſulphurous acid, and converts it into ſulphuric acid, which is a more fixed body than the ſulphurous acid *.

To ſeparate the liquid from the ſulphurous acid, Prouſt recommends the following method, which he ſays is employed in the large way, as by far the moſt preferable. Introduce into a bottle which is $\frac{3}{4}$ths filled with impure ether, ſome water, and a portion of ſlacked lime. Agitate the bottle ſtrongly, and do not open it to examine its odour, till after it has remained for ſome minutes in cold water, and when the vapour within the bottle has ceaſed to exert its elaſtic force againſt the cork; if the ſulphurous ſmell is not entirely removed, the proceſs is to be repeated till it is completely deſtroyed. This method, which was employed by Woulfe, Prouſt prefers on account of its economy, particularly as it affords at the ſame time a ſulphite of lime, which is formed by the combination of the ſulphurous acid with the lime. When the liquids have ſeparated, the ether which ſwims on the top, may be drawn off by means of a ſyphon, and it may be introduced into a retort to be rectified by diſtillation *.

836 Properties. 4. The ether which is thus obtained, is a tranſparent colourleſs fluid, of a very fragrant ſmell, and a hot pungent taſte. The ſpecific gravity is only 0.7581, ſo that it is conſiderably lighter than alcohol. It is extremely volatile, ſo that when it is agitated, or poured from one veſſel to another, it is inſtantly diſſipated. It produces ſo great a degree of cold, that water may be frozen by means of it. It riſes in the ſtate of gas which burns with great rapidity, and the air which holds ether in ſolution may be paſſed through water without being deprived of its combuſtibility or fragrance.

837 Action of heat. 5. It boils in the open air at the temperature of 98°, and in the vacuum of an air-pump at —20°, ſo that it would conſtantly remain in the ſtate of gas if the preſſure of the air were removed.

When ether is kindled in the open air, it burns very readily. The electric ſpark alſo inflames it. It burns with a copious white flame, and leaves behind it a black trace on the ſurface of bodies expoſed to the flame. Lavoiſier has obſerved that there is always formed an acid during the combuſtion of this liquid; and Scheele ſays that the reſiduum of ether burnt over a little water, contains ſulphuric acid. When the ether is expoſed to a cold of —46°, it freezes and cryſtallizes. It is decompoſed when the vapour is paſſed through a red-hot porcelain tube, and the product is carbonated hydrogen gas.

838 Increaſes the volume of gaſes. 6. Dr Prieſtley diſcovered that ether agitated with any kind of gas, greatly increaſed its volume, and in moſt caſes doubled it. Mr Cruickſhank made a ſimilar experiment, by agitating ſome oxygen gas with a little ether. The bulk was exactly doubled. In this ſtate the gas did not explode, but when one part of this mixture was added to three parts of oxygen, an ignited body or the electric ſpark produced a dreadful exploſion. The products were water, with $2\frac{1}{3}$d carbonic acid gas. Hence it would appear, Mr Cruickſhank obſerves, that one part of this vapour requires about ſeven of oxygen to ſaturate it; and according to this experiment, the proportion of carbone to hydrogen in the vapour of ether or ether itſelf, ſhould be as five to one †.

839 Action of phoſphorus. 7. Phoſphorus is diſſolved in ſmall quantity in ether, and produces a tranſparent ſolution, but when alcohol is added to the ſolution, it becomes milky.

840 Of acids. 8. Sulphuric acid has a peculiar action on ether, by converting it into a kind of oil, which is called *the ſweet oil of wine*. This is one of the products in the preparation of ſulphuric ether. When a ſmall quantity of ether is introduced into a bottle filled with oxymuriatic acid gas, it explodes, and inflames; or if paper moiſtened with ether be introduced, the ſame effect follows. Carbonic acid gas is produced, and charcoal is depoſited on the ſides of the bottle.

841 Compoſition. 9. Various theories have been propoſed, to account for the production of ether. From the manner of its production by means of ſulphuric acid, it was natural to ſuppoſe that this acid formed one of its component parts. This accordingly became a general opinion, till it was found that the ſulphuric acid ſuffered no change in the proceſs, but merely aſſiſted or diſpoſed the alcohol to that

---

* *Jour. de Phyſ.* xlvi. p. 298.

* *Ann. de Chim.* xlii. p. 257.

† *Nichol. Jour.* v. p. 205.

that change which it undergoes when it is converted into ether. According to Macquer, the alcohol has not been changed, but merely deprived of the whole of its water. Scheele ſuppoſed, that ether was alcohol deprived of its phlogiſton; and when the new theories were introduced, ether was conſidered as a combination of alcohol and oxygen.

10. The experiments and reſearches of Fourcroy and Vauquelin have thrown new light on this ſubject, and have led to different views of the nature and compoſition of ether. According to the reſult of theſe experiments, ether contains a ſmaller proportion of carbone, but a greater proportion of hydrogen and oxygen. From their experiments, and from thoſe of others, it appears that the changes induced by the action of ſulphuric acid on alcohol, depend on the quantity and ſtrength of the acid, and the temperature.

A. Equal parts of concentrated ſulphuric acid and alcohol mixed together raiſe the temperature to 189°. Bubbles of gas are emitted; the liquid becomes turbid, and at the end of ſome hours aſſumes a deep red colour.

B. A mixture of two parts ſulphuric acid, and one part alcohol, produces a temperature of 200°. The mixture becomes inſtantly of a deep red colour, paſſes to black a few days after, and diffuſes an odour which is perceptibly that of ether.

C. When equal parts of ſulphuric acid and alcohol are expoſed to the action of heat, in a proper apparatus, ſuch as is employed for the preparation of ether, the following phenomena are obſerved.

a. When the temperature is raiſed to 207°, the liquid boils; there is produced a fluid which is condenſed by cold, into a light, colourleſs and fragrant liquor, which from its properties has received the name of ether. If the proceſs be properly conducted, no permanent gas is evolved, till about $\frac{1}{2}$ of the alcohol is converted into ether.

b. If as ſoon as the ſulphurous acid appears, the receiver be changed, there is no longer any production of ether, but the ſweet oil of wine, water, and acetic acid are formed, without a ſingle particle of carbonic acid. When the ſulphuric acid makes about $\frac{4}{5}$ths of the maſs which remains in the retort, there is evolved an inflammable gas, which has the odour of ether, and which burns with a white oily flame. This is the gas which the Dutch chemiſts have called *carbonated hydrogen gas*, or *olefiant gas*, becauſe when it is mixed with oxymuriatic acid it forms oil. At this period, the temperature of the matter contained in the retort is elevated to 230° or 234°.

c. When the ſweet oil of wine ceaſes to flow, if the receiver be again changed, there is only ſulphurous acid emitted, water which was previouſly formed, carbonic acid gas; and there remains only in the retort, a maſs which conſiſts chiefly of ſulphuric acid thickened with charcoal.

842 Inferences. From theſe phenomena, which were uniform and conſtant, the following concluſions were drawn.

a. A ſmall quantity of ether is formed ſpontaneouſly without the aid of heat, by the combination of two parts of ſulphuric acid and one part of alcohol.

b. As ſoon as the ether is formed, and there is at the ſame time a production of water, the ſulphuric acid undergoes no change in its intimate nature, while the firſt of theſe compoſitions takes place.

c. When the ſulphurous acid appears, there is no longer any production of ether; but then there paſs over the ſweet oil of wine, water, and acetic acid.

d. The ſweet oil of wine having ceaſed to paſs over, nothing is obtained but ſulphurous acid, carbonic acid, and at laſt ſulphur, if the diſtillation be continued.

The operation of ether, then, may be divided into three periods, the firſt, in which a ſmall quantity of ether and water is formed, without the aſſiſtance of heat; the ſecond period, in which the greateſt quantity of ether which can be obtained without the evolution of ſulphurous acid at a temperature of 207°; and the third, in which the ſweet oil of wine, olefiant gas, acetic acid, ſulphurous and carbonic acid are produced, while the temperature of the mixture is raiſed to 230° and 234°. In all theſe three periods there is only one common circumſtance, and this is, the continual formation of water from the beginning to the end of the operation.

843 Theory. On theſe obſervations, Fourcroy and Vauquelin have eſtabliſhed their theory of the formation of ether. In the caſe in which ether is formed by the ſimple mixture of alcohol and ſulphuric acid, without the aid of heat, the formation which appears by heat as well as by the black precipitate, the charcoal which is ſeparated without the production of ſulphurous acid, prove that the ſulphuric acid acts in a different manner on alcohol from what was ſuppoſed. This acid is not decompoſed by charcoal at that temperature. There is no action between theſe two bodies in the cold, nor is there any action between this acid and alcohol; for in that caſe, ſulphurous acid would be formed, of which not the ſmalleſt trace can be perceived at the beginning of the operation. Recourſe then muſt be had to a different action, namely the ſtrong affinity which exiſts between ſulphuric acid and water. It is this which determines the union of the conſtituent principles of water exiſting in the alcohol, and with which this acid comes in contact; but this action muſt be very limited. There is ſoon eſtabliſhed a balance of affinities, and no farther change takes place.

If then it be proved that ether is formed by the mixture of certain quantities of ſulphuric acid and alcohol, it muſt obviouſly follow, that a maſs of alcohol may be completely converted into ether, water, and acetic acid, by increaſing the quantity of ſulphuric acid; and it is equally obvious, that this acid would undergoes no change but that of being diluted with water.

It is not neceſſary to ſuppoſe, according to this theory, that ether is alcohol deprived of a certain portion of oxygen and hydrogen, for there is ſeparated at the ſame time a quantity of charcoal proportionally greater than that of the hydrogen; and it may be conceived, that the oxygen which is combined in this caſe with the hydrogen, to form water, would not only ſaturate this hydrogen in the alcohol, but that it would ſaturate at the ſame time the carbone which has been precipitated. Thus, then, in place of conſidering ether as alcohol with a ſmaller proportion of hydrogen and oxygen, if we take into account the carbone which is precipitated, and the ſmall quantity of hydrogen contained in the

the water that is formed, it muſt be conſidered as alcohol with a greater proportion of hydrogen and oxygen. Such ſeems to be the nature of the ſpontaneous action between ſulphuric acid and alcohol without the aid of heat.

But when the mixture is ſubjected to heat, the production of ether is more complicated, and the products more numerous.

It ought to be obſerved, that the mixture of ſulphuric acid and alcohol in equal proportions, boils only at the temperature of 207°, whilſt alcohol alone boils at 176°; whence we muſt conclude, that the alcohol is retained by the affinity of the ſulphuric acid, which fixes it. Now, if we compare what happens in this caſe to the change produced on all other vegetable matter expoſed to the action of heat, in which the principles are volatilized, according to the order of their affinity for caloric, carrying with them a ſmall quantity of the more fixed elements, in proportion as the ſulphuric acid attracts the alcohol and the water, of which it favours the formation, the ether which is evolved attracts caloric, and is ſublimed; and when the greateſt part of the alcohol has been changed into ether, the mixture becomes denſer, the heat more conſiderable, and the affinity of the ſulphuric acid for the undecompoſed alcohol being increaſed, the acid is decompoſed, ſo that on one hand its oxygen combines with the hydrogen of the alcohol, and forms water, which riſes gradually into vapour, whilſt, on the other, the ether retaining a greater quantity of carbone, with which it riſes in vapours at this temperature, affords the ſweet oil of wine, which ought to be conſidered as an ether with a greater proportion of carbone. This ſeems to be proved by its greater ſpecific gravity, leſs volatility, and its citron colour.

11. From this theory the ingenious authors of it have deduced the following practical concluſions.

a. The formation of ether is not owing, as was ſuppoſed, to the immediate action of the principles of the ſulphuric acid on thoſe of alcohol, but to the reaction of the principles of the latter on each other, and particularly of its oxygen and hydrogen, occaſioned by the ſulphuric acid.

b. A portion of alcohol may be converted into ether without the aid of heat, by increaſing ſufficiently the proportion of ſulphuric acid.

c. With regard to the change which takes place on alcohol in the production of ether, the proceſs may be divided into two periods. In the one, ether and water only are produced; in the other, ſweet oil of wine, water, and ſulphuric acid.

d. During the formation of ether, the ſulphuric acid is not decompoſed, and there is no production of the ſweet oil of wine. When the latter makes its appearance, there is given out no more, or at leaſt very little, ether; and at the ſame time the ſulphuric acid is decompoſed by hydrogen ſolely, whence ſulphurous acid is formed.

e. The formation of the ſweet oil of wine may be avoided, by keeping the temperature of the mixture between 200° and 207°. This is managed by introducing a few drops of water into the retort.

f. And laſtly, alcohol differs from ether, in containing more carbone, leſs hydrogen and oxygen, and the ſweet oil of wine is to ether very near what alcohol is to the latter *.

II. Of Nitric Ether.

1. Nitric acid, or rather nitrous acid, acts with much greater violence on alcohol than ſulphuric acid. In this caſe the action muſt be moderated, either by diluting the two liquids, or by cooling the mixture. The firſt eaſy proceſs which was propoſed for the preparation of nitric ether, was given by Navier, a phyſician of Chalons.

844 Preparation by Navier.

2. The proceſs of Navier is the following. He put into a ſtrong bottle 12 parts of pure alcohol, and plunged it into cold water, or rather ſurrounded it with ice. To this he added, in different portions, eight parts of concentrated nitric acid, agitating the mixture, after every addition. The bottle is then ſtopped with a cork, which is ſecured with leather, and the mixture is ſet in a convenient place, to avoid the danger of accidents on the burſting of the bottle, which ſometimes happens. At the end of ſome hours, bubbles riſe from the bottom of the veſſel, and drops are collected on the ſurface of the liquid, which gradually form a ſtratum of ether. This action continues for the ſpace of ſix days. When it ceaſes, the cork is to be pierced with a needle, to permit the eſcape of a quantity of nitrous gas, which, without this precaution, would ruſh out rapidly on uncorking the bottle, and would carry along with it the ether, which would be loſt. When the gas is diſſipated, the cork is to be drawn out, and the whole liquid in the bottle is to be poured into a funnel. The ether ſwims on the top, and the remaining liquor being heavier, is allowed to paſs off, and the ether is retained.

845 Beaumè.

3. This proceſs was improved by Beaumè. He found that the greateſt produce of ether was from two parts of acid to three of alcohol. He directed both ingredients to be uſed in the coldeſt ſtate, by keeping each in melting ice, and the bottle in which the mixture is made, to be kept equally cold. In this proportion of ingredients, the danger of exploſion is avoided, and the low temperature greatly moderates the violent action. The mixture in the bottle is always to be well agitated before any new addition of acid is made, and by this means the accumulation in any particular ſpot is prevented. The ether begins to form, as in the former proceſs, in the courſe of a few hours, and if the bottle is allowed to remain undiſturbed for eight or ten days, a quantity of ether equal to one half the weight of the alcohol is obtained, after which no more is produced.

846 Black's proceſs.

4. Dr Black's proceſs is deſcribed by himſelf in the following words. "Into a ſtrong phial, having a ground ſtopper, I firſt pour four ounces of ſtrong pale nitric acid. I then add three ounces of water, pouring it in ſo gently, that it ſwims on the ſurface of the acid. I then pour in after the ſame manner ſix ounces of alcohol. I put in the ſtopper ſlightly, and I ſet the phial in a tub of water and ice. The acid mixes ſlowly with the water, and in a diluted ſtate comes in contact with the alcohol on which it immediately acts, and ether is produced ſlowly and quietly. The liquor gets a dim appearance, becauſe imperceptible bubbles are formed, which get to the top, and having collect-

---

* Fourcroy Connaiſs. Chim. tom. viii. p. 161,—166.

ed to a certain degree, they lift the ſtopper, and eſcape (s). After eight or ten days I find upwards of three ounces of nitric ether, though I am certain by the ſmell, that much eſcapes with the vapour. This is however, a certain, eaſy, and ſafe proceſs, though it is ſlow and imperfect*."

847 Laplanche's. 5. Many other proceſſes have been propoſed for the preparation of nitric ether. Laplanche, a Pariſian apothecary, has employed nitre, which he introduced into a tubulated ſtone-ware retort, and firſt pouring the concentrated ſulphuric acid, and then the alcohol upon it, there is an immediate production of ether; but by this proceſs it is ſuſpected that the nitric ether may be mixed with ſulphuric ether. He has therefore propoſed another proceſs, which is more complicated†.

848 Chaptal's. 6. The proceſs which has been propoſed by Chaptal, is, according to Prouſt, the beſt that can be adopted. This proceſs, with ſome additions and alterations, which he has found it neceſſary to make from his own experience, is the following. The proportions which he employs are, 32 ounces of alcohol, and 24 of nitric acid. Theſe are introduced into a large retort, which is to be luted to a globular glaſs veſſel, furniſhed with a tube of ſafety. A tube paſſes from this globe to a ſecond, which is alſo furniſhed with a tube of ſafety. One or two ounces of water ſhould be introduced into the ſecond globe to ſhut up its tube of ſafety. Three bottles of Woulfe's apparatus, containing from 64 to 80 ounces of liquid, are then to be connected with the ſecond globe. Theſe bottles are half filled with alcohol. The alcohol and the acid are poured into the retort, and are mixed by agitation. The retort is luted to the glaſs globe, and heat is applied, with this precaution, that it muſt be removed as ſoon as there is any efferveſcence. The proceſs now goes on, and requires no farther attention than occaſionally cooling the globes and the bottles with cloths moiſtened with ſnow-water. The greateſt part of the ether which is formed, condenſes in the firſt bottle, and gives the alcohol a yellow colour. It then paſſes to the ſecond, in which the colour is lighter, and at laſt to the third, where there is little perceptible change. To ſeparate the ether of the firſt bottle, the mixture is to be ſaturated with an alkali, and diſtilled‡.

849 Purification. 7. But by whatever proceſs nitric ether is obtained, it requires to be purified, to ſeparate the acid and alcohol, which are generally mixed with it. This is done by diſtilling it from potaſh, which reduces its quantity, for the diſtillation muſt not be continued longer than when two-thirds or one-half of the firſt ether has come over. To purify this ſtill more, it is directed to be mixed with one-fifth of nitrous acid, and diſtilled again, taking two-thirds of the product ſet apart, and rectify it from an alkali. The remainder which comes over is a leſs pure ether, which has been known under the name of *Hoffman's mineral anodyne liquor*. What remains in the retort has been called *dulcified ſpirit of nitre*.

850 Properties. 8. Nitric ether thus obtained, is a yellowiſh coloured liquid, equally volatile as ſulphuric ether. Its odour, though ſtronger and leſs ſweet, is analogous to the ſulphuric ether. The taſte is hot and more diſagreeable. It is often of a deeper yellow colour, and always contains a ſmall exceſs of acid and nitrous gas. The ſtopper is frequently driven out of the bottle in which it is kept, for there is a conſtant evolution of a conſiderable quantity of gas.

851 Burns with a brilliant flame. 9. When it is ſet fire to, it gives out a more brilliant flame, and a denſer ſmoke, than ſulphuric ether; and it depoſits a greater quantity of charcoal. When it is long kept in a cloſe veſſel, there is formed ſome water, holding a ſmall quantity of oxalic acid in ſolution, which falls to the bottom of the veſſel.

852 Analogous to ſulphuric ether. 10. Nitric ether is not only analogous to ſulphuric ether in its properties, but alſo in the nature of the proceſs by which it is obtained, and in the other products which accompany this proceſs. But in the production of nitric ether, there is no depoſition of charcoal, and the acid itſelf is decompoſed. This appears from the great quantity of nitrous gas which is evolved during the proceſs; and the reaſon aſſigned for the diſappearance of the charcoal is, that the oxygen of the acid combines with it, and forms carbonic acid, which eſcapes in the form of gas. The products which are generally obtained in the proceſſes for the preparation of nitric ether are nitrous gas, ether, oil, acetic acid, oxalic acid, and carbonic acid gas.

If equal parts of nitric acid and alcohol are mixed together, a violent efferveſcence immediately takes place, which is owing to the evolution of a great quantity of gas, which being a compound of ether and nitrous gas, has been denominated *etheriſed nitrous gas*. The ſame gas is obtained by employing a diluted acid; but then the mixture requires the aſſiſtance of heat. This gas may be collected in veſſels over water. It has a diſagreeable ethereal odour, quite different from the odour of nitric ether, and exactly ſimilar to that kind of ether which is furniſhed by the oily, carbonated hydrogen gas, treated with oxymuriatic acid gas. If a candle be applied to this gas, it burns ſlowly with a yellow flame. This gas is ſoluble in water, and is wholly abſorbed; but the abſorption is ſlow. The water acquires the odour of the gas. Alcohol alſo diſſolves it completely, and more rapidly. Oxygen gas mixed with this gas, provided it be pure, produces no change; but when the mixture is ſet fire to, there is a violent detonation. When this gas was expoſed to ſulphuric, nitric, and muriatic acids, the ether was abſorbed by the acids, and the nitrous gas remained behind. The ſulphurous acid in the ſtate of gas, combined with an equal bulk of the inflammable gas, alſo decompoſed it; but this effect did not take place till after ſeveral days*.

If the alcohol and nitric acid be mixed together in the proportion of one of the former to three of the latter, and a gentle heat be applied, there is a copious evolution of gas, which is compoſed of the etheriſed nitrous gas and nitrous gas. If towards the end of the proceſs, when a ſmall part of the liquid remains in the retort,

* *Black's Lect.* ii. 324.

† *Fourcroy Connaiſs. Chim.* tom. viii. p. 170.

‡ *Ann. de Chim.* tom. xlii. p. 261.

* *Jour. de Phyſ.* 45. p. 245.

(s) Dr Black, we believe, contrived a ſpring for the ſtopper which kept down the cork till it was puſhed up by the elaſtic vapours; and when they had eſcaped, it returned to its place by the force of the ſpring.

retort, it be allowed to cool, cryſtals are formed; and theſe cryſtals are found to be oxalic acid. They were formerly called *cryſtals of Hierne*, from the name of a Swediſh chemiſt, who firſt diſcovered them *.

If one part of nitric acid be added to its own weight of alcohol, and one part of ſulphuric acid be added ſoon after, the mixture is ſuddenly inflamed, and burns with great violence. In this caſe, when the products are collected, they are found to be ether and oil.

From this ſtatement of facts, therefore, it appears, that the production of nitric and ſulphuric ethers is nearly the ſame; that the differences which take place, are owing to the different nature of the acids; the violent action which follows in the formation of nitric ether, depending on the nitric acid itſelf being decompoſed, and by the operation of new affinities, new actions having taken place.

III. Of Muriatic Ether.

853 Proceſſes for obtaining it. 1. Muriatic acid has no ſenſible action on alcohol, either by ſimple mixture, or by diſtilling them together, as in the former caſe. Beaumè obtained a ſmall quantity of muriatic ether, by combining together muriatic acid and alcohol in the ſtate of vapour. But other means were thought of for this purpoſe, and particularly the oxymuriate of antimony, and the oxide of zinc diſſolved in muriatic acid, and to diſtil this ſalt, concentrated by evaporation, in cloſe veſſels with alcohol. By this proceſs muriatic ether has been obtained. But the moſt ſucceſsful method of procuring this ether, was propoſed by Courtanvaux. His proceſs is the following.

854 From ſalts of tin. 2. One part of alcohol is mixed with three parts of oxymuriate of tin, or the fuming liquor of Libavius, in a glaſs retort. A ſtrong heat is produced, with the production of a white ſuffocating vapour, which diſappears when the mixture is agitated. There is then emitted an agreeable odour, and the liquor aſſumes a lemon colour. The retort is then to be placed on a ſand bath; two receivers are to be attached, one of which is to be immerſed in cold water. There paſſes over at firſt ſome pure alcohol, and ſoon after the ether, which is known by its fragrant odour, and the ſtreams which run down the ſides of the retort. When the odour changes, and becomes ſharp and ſuffocating, the receiver muſt be changed; and if the diſtillation be continued, a clear acid liquor is procured, on the ſurface of which are obſerved ſome drops of ſweet oil, which is ſucceeded by a yellow matter of the conſiſtence of butter, which is a true muriate of tin, and at laſt a brown heavy liquid, which exhales very copious white vapours; and there remains in the retort a gray matter in the ſtate of powder.

855 Purification. 3. To purify this ether, it is put into a retort over carbonate of potaſh. A briſk efferveſcence takes place, and a very copious precipitate is produced. This is owing to the oxide of tin which the acid had carried off during the diſtillation. A little water is to be added, and diſtilled with a gentle heat. About the one-half of the product of the ether is thus obtained. All the fluids which come over after the muriatic ether, are loaded with oxide of tin; they attract moiſture from the air, and combine with the water without any precipitation.

856 Prepared from common ſalt. 4. Another method has been propoſed for the preparation of muriated ether by Laplanche. He pours into a tubulated retort ſulphuric acid and alcohol on common ſalt which has been ſtrongly dried. The muriatic acid gas, diſengaged by the ſulphuric acid, meeting the vapours of the alcohol in the retort, combines with them. In this way an ether is obtained, which may be purified in the uſual way. But in this proceſs, Fourcroy thinks, that the production of ether is owing to a ſmall portion of oxymuriatic acid which is formed during the proceſs.

857 and mangeneſe, 5. Pelletier has ſucceeded in obtaining muriatic ether, by diſtilling in a large tubulated retort, a mixture of oxide of mangeneſe, common ſalt, concentrated ſulphuric acid, and alcohol. The quantity of ether obtained by this proceſs, is equal to one half the weight of the alcohol employed.

858 and oxymuriatic acid gas. 6. Another proceſs has been propoſed by Berthollet, by diſtilling with a gentle heat, alcohol which has been ſaturated with oxymuriatic acid gas, and by diſtilling the oxide of mangeneſe, a mixture of alcohol, and ſtrongly concentrated muriatic acid.

859 Properties. 7. Muriatic ether thus obtained, is tranſparent and very volatile. It has nearly the ſame odour as ſulphuric ether. It burns like it, and gives out a ſimilar ſmoke; but it differs in two of its properties; the one is, that it exhales, while burning, an odour as pungent and acrid as ſulphurous acid; and the other is, that the taſte is aſtringent like that of alum. This difference in odour and taſte is owing, it is ſuppoſed, to ſome extraneous ſubſtances with which it is contaminated; for in the whole proceſs of its formation it appears to be exactly the ſame; a conſtant product of the decompoſition of alcohol, by whatever re-agent this is effected.

IV. Acetic Ether.

860 Preparation. 1. An ether has alſo been obtained by diſtilling a mixture of acetic acid and alcohol. This was the firſt proceſs which was employed in the production of this ether. It was diſcovered by the count de Lauraguais in 1759. It has been improved by Pelletier, who diſtilled equal quantities of acetic acid, obtained from acetate of copper, and alcohol. It was then poured back into the retort, and diſtilled a ſecond time. When this proceſs is finiſhed, it is diſtilled a third time, and the product of the third diſtillation is a mixture of acetic acid and ether. To ſeparate the acid from the ether, it is ſaturated with potaſh, and diſtilled with a gentle heat. The acetic ether paſſes over in a ſtate of purity.

2. Another proceſs has been propoſed to obtain the ſame ether. Take 16 parts of acetate of lead, ſix parts of concentrated ſulphuric acid, and nine parts of alcohol. Let it be diſtilled till ten parts come over. Let this liquid be agitated with one-third of its bulk of lime water; the ether ſeparates and ſwims on the top. The quantity generally amounts to about ſix parts.

3. This ether is ſimilar to the other ethers in its properties, excepting that it has a ſlight odour of acetic acid.

4. Ether has alſo been formed by ſeveral other acids, and it appears, that theſe acids poſſeſs one common property in their action on alcohol, for all the ethers

---

* *Jour. de Phyſique*, p. 346.

ethers produced by the different acids are nearly the ſame, and indeed it is ſuppoſed would be exactly the ſame, were it not that they are contaminated with extraneous matters derived from the acids, the alcohol, or other ſubſtances, which are employed in their formation.

Sect. III. *Of Fixed Oils.*

861 Oils of two kinds.

1. Oils, which are copious productions of nature, have been long known; and their extenſive utility in domeſtic economy and the arts, have always rendered them objects of great importance. The general characters of oils are combuſtibility, inſolubility in water, and fluidity. From the peculiar properties of different oils, they are naturally divided into two kinds; fixed or fat oils, and volatile or eſſential oils. The fixed or fat oils, require a high temperature to raiſe them to the ſtate of vapour, a temperature above that of boiling water; but the volatile or eſſential oils are volatilized at the temperature of boiling water, and even at a lower one. Both the volatile and fixed oils are obtained from plants, and ſometimes from the ſame plant, but always from different parts of it. While the ſeeds yield fixed oil, the volatile oil is extracted from the bark or wood.

862 Found only in the ſeed of vegetables.

2. One of the moſt diſtinguiſhing characteriſtics of the fixed oils is, that they exiſt only in one part of the vegetable. They are only found in the ſeeds. No trace of fixed oil can be detected in the roots, the ſtem, leaves or flowers of thoſe plants, whoſe ſeeds afford it in great abundance. The olive may ſeem an exception to this. The oil which it yields is extracted, not from the ſeed, but from its covering. Among plants too, fixed oils are only found exiſting in thoſe whoſe ſeeds have a peculiar ſtructure. The ſeeds of plants have ſometimes one lobe, in which caſe they are called *monocotyledonous* plants; and ſometimes they have two, when they are denominated *dicotyledonous*. The formation of fixed oil in plants is excluſively limited to the latter claſs. There is no inſtance of fixed oils being found in the ſeeds of plants which have only one lobe *. Thoſe ſeeds which yield the fixed oils, contain alſo a conſiderable portion of mucilage, ſo that when ſuch ſeeds are bruiſed and mixed with water, they form what is called an *emulſion*, which is a white fluid containing a quantity of the oil of the ſeed mixed with the mucilage. One of the moſt common emulſions, that of almonds, is an inſtance of this.

Fixed oils are extracted from the ſeeds of a great number of plants. Thoſe which yield it in greateſt abundance are, the olive, thence called *olive oil;* the ſeeds of lint, and the kernels of almonds, called *linſeed*, or *almond oil.* Fixed oils are alſo obtained from animals, ſuch as *train oil*, as it is called, which is extracted from the fat or blubber of the whale. Fixed oil is obtained alſo in great abundance from the liver of animals, and is found to exiſt in the eggs of fowls.

863 Have different properties.

3. Theſe different kinds of fixed oils, although they poſſeſs many common properties, yet in others they are very different. Many of the vegetable oils have no ſmell, and ſcarcely any perceptible taſte. The animal oils, on the contrary, are generally extremely nauſeous and offenſive. Theſe differences are ſuppoſed to be owing to the mixture of extraneous bodies, or to certain chemical changes which ariſe from the action of theſe bodies upon each other, or on the oil itſelf.

864 Preparation.

4. As the fixed oils exiſt ready formed in the ſeeds of plants, they are generally obtained by *expreſſion*, and hence they have been called *expreſſed oils*. This is done by reducing the ſeeds to a kind of pulp, or paſte, which is incloſed in bags, and ſubjected by means of machinery, when it is obtained in the large way, to ſtrong preſſure, ſo that the oil flows out, and is eaſily collected. The oil which is obtained by this proceſs, which has been called *cold-drawn oil*, becauſe it is procured without the application of heat, and merely by preſſure, is the pureſt; but the quantity which ſeeds in general yield is comparatively ſmall, and ſome ſeeds which contain a conſiderable portion of oil, ſcarcely afford any when treated in this way. It therefore becomes neceſſary for extracting the oil from ſeeds of the latter deſcription, and to have it in greater abundance from all ſeeds, to employ heat, to facilitate the ſeparation of the oil from the mucilage or other matters with which it is combined. For this purpoſe heat is applied, either to the apparatus which is employed in preſſing out the oil, or the bruiſed ſeeds are expoſed to the vapour of water, and ſometimes they are boiled in the water itſelf, by which means thoſe ſubſtances which are ſoluble in water, are ſeparated, and thus the oily part which adhered to theſe ſubſtances, is diſengaged.

865 Purification.

5. The oils which are obtained in this way are very impure. They are mixed with mucilage, and other parts of the ſubſtances from which they have been extracted. Many of theſe matters ſeparate from the oils when they are left at reſt. They are ſometimes mechanically purified by filtration through coarſe cloths, by which means the groſſer parts are ſeparated. Different oils too, it is ſaid, undergo different kinds of purification by different manufacturers, but theſe proceſſes are kept ſecret. After they have remained at reſt for ſome time, they are filtered and agitated with water, by which the parts that are ſoluble in this fluid are ſeparated from the oil. Sometimes they are gently heated, for a ſhorter or longer time, according to the nature of the ſubſtances with which the oil is contaminated. Acids diluted with water are employed to ſeparate the mucilage; lime and the alkalies are alſo uſed to combine with an acid which holds this mucilage in ſolution, and thus to favour its precipitation. Alum, chalk, clay, and aſhes, are alſo employed in the purification of oils.

866 Properties.

6. Fixed oils are generally liquid, but of a thick, viſcid conſiſtence. They are mild or inſipid to the taſte; ſometimes, however, they have a peculiar taſte, which is analogous to that of the plant from which they have been extracted. When pure, they have no ſmell, but are ſometimes impregnated with the odour of the ſeed which produces them. The fixed oils are rarely quite colourleſs, but are generally green or yellowiſh. If they are green when freſh prepared, this colour changes to a yellow, and in time to an orange or red. Fixed oils in general are lighter than water. The ſpecific gravity varies from 0.9153, which is that of olive oil, to 0.9403, that of linſeed oil. The boiling point of the fixed oils is not under the temperature of

---

* Fourcroy Connaiſs. vii. 319.

of 600°. When expoſed to cold, they congeal, and even cryſtallize. There is, however, a conſiderable variety in this reſpect, among fixed oils: ſome become ſolid at the temperature of a few degrees above the freezing point of water; while others on the contrary require a degree of cold =5°; and ſome remain fluid when expoſed to the greateſt cold. Thoſe oils, it has been obſerved, which moſt readily become ſolid, ſuch as olive oil, are leaſt ſubject to change; while thoſe which congeal with difficulty have a greater tendency to ſpoil and become rancid.

867 Action of heat.

7. When fixed oil is expoſed to heat, it does not evaporate, till it is raiſed to the temperature of boiling, or 600°; but when it is thus raiſed in vapour its properties are changed. It is decompoſed by the ſeparation of ſome of its principles. The part that is volatilized has a greater proportion of hydrogen; charcoal is depoſited, and water and ſebacic acid are formed, while carbonated hydrogen gas is diſengaged. By this diſtillation an oil was produced, denominated by the older chemiſts, *philoſophical oil*.

When oil is expoſed to the open air, and a burning body is brought in contact with it, it readily takes fire, and burns rapidly, with a yellowiſh white flame. It is on this converſion of oil into vapour, and the inflammation of this vapour, that the application of oil in lamps and candles, depends. The oil is gradually and in ſmall quantities brought in contact with the burning part of the wick; it is converted into vapour, which is immediately inflamed, and continues to burn till new portions are ſupplied to undergo the ſame change, and thus keep up a conſtant and uniform light and heat.

868 Compoſition.

8. According to the analyſis of olive oil by Lavoiſier, it is compoſed of hydrogen and carbone. In the experiment which he inſtituted to aſcertain its component parts, he burnt

oil 15.79 grs. troy,
oxygen gas 50.86

66.65

The products of this combuſtion were water and carbonic acid. The weight of the water could not be aſcertained with much preciſion, but the quantity of carbonic acid which was formed, amounted to 44.50 grs. This quantity ſubtracted from the whole weight of the ſubſtances conſumed, namely the oil and oxygen gas, left 22.15 grs. for the weight of the water. The proportion of oxygen in this quantity of water is 18.82 grs. which leaves 3.33 grs. of hydrogen, the other component part. The proportion of oxygen in 44.50 grs. carbonic acid gas is 32.04 grs. which leaves 12.46 of carbone. The oxygen of the water and of the carbonic acid, namely 18.82 grs. of the one, with 32.04 grs. of the other, make up the whole quantity of oxygen, namely 50.86 grs. that was conſumed. From this analyſis, therefore, 15.79 of olive oil are compoſed of

12.46 carbone,
3.33 hydrogen.

15.79

The component parts, therefore, of 100 grains of olive oil are

78.92 carbone,
21.08 hydrogen.

100.00

869 Inſoluble in water.

9. The fixed oils are inſoluble in water. When it is neceſſary to combine them with this liquid, it is by means of mucilaginous ſubſtances, in which caſe the mixture is known under the name of *emulſion*, or with alkaline ſubſtances, when it is diſtinguiſhed by the name of ſoap.

870 Action of air.

10. When fixed oils are expoſed to the air, they undergo peculiar changes; and theſe changes are different, according to the nature of the oil.

11. Some of theſe oils become thick, opaque, white, granulated, and are analogous in appearance to tallow. Oils ſubject to this change are called *fat oils*, ſuch, for inſtance, is olive oil, almond oil, and rapeſeed oil. This change is more or leſs rapid in different circumſtances. If a thin layer of oil be ſpread on the ſurface of water, and expoſed to the air, it takes place in a few days, and this effect is owing to the abſorption of oxygen, which combines with the oils. It was ſuppoſed by Berthollet, that it depended on the action of light, but his experiments were repeated by Senebier, who found that olive oil when kept in the dark, became rancid, while the ſame kind of oil expoſed to the light, but excluded from the air, remained unchanged *.

871 Drying oils.

12. But other oils, when they are expoſed to the air, dry altogether, yet have the property of retaining their tranſparency. Oils which have this peculiar property are called *drying oils*. The oil of poppies, hempſeed oil, and particularly linſeed oil, are poſſeſſed of this property. The nature of the change which takes place in theſe drying oils, is ſuppoſed to depend on the abſorption of oxygen; and this oxygen combining with the hydrogen of the oil forms water. This opinion is ſupported by the practice which is followed to increaſe the drying property of linſeed oil. It is uſually boiled with litharge, before it is employed by painters. The litharge in this caſe is partly reduced to the metallic ſtate, by being deprived of its oxygen, which is ſuppoſed to combine with the oil.

872 Rancidity.

13. But many of the fixed oils, when expoſed to the air for a ſufficient length of time, undergo a farther change, and acquire very different properties. They are then ſaid to become *rancid*. During this change, they aſſume a brown colour, have the property of changing vegetable blues to red, and acquire a peculiar ſmell and taſte. In this change, the ſebacic acid is formed, which depends on a new combination of the hydrogen and carbone of the oil in certain proportions with the oxygen abſorbed from the atmoſphere. To this acid therefore, the rancidity of oils ſeems to be owing. Part of the hydrogen of the oil too, it would appear, combines with the oxygen and forms water †.

873 Action of charcoal.

14. Carbone in the ſtate of charcoal, has no action upon oils; but they are purified and rendered colourleſs by being paſſed through charcoal powder.

874 Of phoſphorus.

15. Phoſphorus combines with oils, with the aſſiſtance of heat. A ſmall portion of the phoſphorus is diſſolved,

---

* *Seneb. Ann. de Chim.* xi. 91.

† *Fourcroy Connaiſs. Chim.* vii. 328.

ſolved, which communicates a luminous property to the oils, ſo that when they are ſpread upon any ſurface, they ſhine in the dark. When the oil is completely ſaturated with the phoſphorus with the aſſiſtance of heat, and is allowed to cool, part of the phoſphorus is depoſited, and cryſtallized in tranſparent octahedrons. When this phoſphorated oil is diſtilled, phoſphorated hydrogen gas is diſengaged.

875 Of ſulphur. 16. Sulphur eaſily combines with fixed oil, with the aſſiſtance of heat. The ſolution which was formerly called *ruby of ſulphur*, is of a reddiſh colour. When it cools, the ſulphur cryſtallizes, by which proceſs Pelletier obtained ſulphur in the form of octahedrons. When the cooling is too rapid, the ſulphur is precipitated of a yellow colour, in the ſhape of needles. If this ſulphurated oil, which has a peculiarly fœtid odour, be diſtilled, it affords a great quantity of ſulphurated hydrogen gas *.

876 Of acids. 17. The acids have a powerful effect on the fixed oils. The ſulphuric acid, when concentrated, decompoſes them. They become brown, thick, and at laſt of a black colour. Water is formed, charcoal is precipitated, and even an acid is formed. Nitric acid in the cold thickens fixed oils, by communicating part of its oxygen. In the ſtate of nitrous acid it produces a more violent action. There is conſiderable efferveſcence, with the evolution of a great quantity of nitrous gas. If a mixture of nitrous acid and concentrated ſulphuric acid be thrown upon fixed oils, they inſtantly inflame, and leave behind a ſpongy maſs of charcoal. Muriatic acid has little effect on fixed oils, but the oxymuriatic acid thickens and bleaches them, in the ſame way as tallow or wax.

877 Uſes. 18. The various purpoſes to which fixed oils are applied, are too well known to require particular enumeration. They are employed in domeſtic economy, either as articles of food, and for this purpoſe are uſed alone, or in combination with other ſubſtances; or they are employed for giving light, by being burnt in lamps. They are uſed in medicine, either on account of the properties which peculiar oils poſſeſs, or on account of the properties they communicate to other ſubſtances with which they are combined. In this ſtate the uſe of oils is well known in the form of unguents, plaſters, and liniments. In the arts, fixed oils are of the moſt extenſive utility. They are employed in the fabrication of ſoaps, for mixing colours in painting, for ſome kinds of varniſh, and for defending ſubſtances from the action of air and moiſture †.

878 Affinities. 19. The order of the affinities of fixed oils is the following:

Lime,
Barytes,
Fixed alkalies,
Magneſia,
Ammonia,
Oxide of mercury,
Other metallic oxides,
Alumina.

Sect. IV. *Of Volatile Oils.*

879 Characters. 1. Volatile oils are diſtinguiſhed from the fixed oils by their volatility, fragrance, and acrid taſte. They are alſo known under the name of *aromatic oils*, from their odour; or *eſſential oils*, or ſimply *eſſences*, from being ſuppoſed to conſtitute the *eſſence* or the *exiſtence* of the vegetable matters which furniſh them.

880 Names. 881 Found in all parts of plants but the lobes of the ſeeds. 2. Volatile oils are not limited to particular parts of plants, but are found to exiſt in every part of the plant, excepting in the ſeed, which furniſhes the fixed oils. A great number of roots which are generally diſtinguiſhed by an aromatic odour, and have more or leſs of an acrid taſte, afford volatile oils. They are furniſhed alſo by many woods, ſuch as thoſe of the pine and fir tribe, and by many of thoſe which are natives of warm climates. The leaves of a great number of plants belonging to the didynamia claſs alſo afford volatile oil, as well as many of the umbelliferous plants. It is obtained alſo from many flowers of vegetables, and alſo from the covering of many fruits, as the ſkin of oranges and lemons. It is alſo obtained from a great number of ſeeds; but it is never found in the cotyledons or lobes themſelves, but only in the external covering. The quantity of volatile oil which is obtained from vegetables, varies according to the age, the ſoil in which they grow, and the ſtate of the plant. Some plants while green furniſh it in greateſt abundance, while others yield moſt when they are dry.

882 Preparation. 3. There are two proceſſes by which volatile oil may be obtained. When it exiſts in plants in great abundance, and in veſicles in a fluid ſtate, it may be ſeparated by mechanical means. Thus, by ſimple expreſſion, the volatile oils are extracted from many plants, as, for inſtance, from the fruit of the orange and the lemon. From the outer rind of theſe fruits, when they are freſh, the volatile oil is obtained in the liquid form; but in general, the volatile oils of plants are neither ſo abundant, nor do they exiſt in that ſtate of fluidity, by which they can be procured by ſo ſimple a proceſs. In moſt caſes they are ſubjected to the proceſs of diſtillation; and for this purpoſe they are macerated for ſome hours in water. They are then introduced into a ſtill along with the water; a moderate heat is applied and continued till the fluid boil, when a great quantity of vapour of water, mixed with the volatile oil, paſſes over, and is received in proper veſſels. The oil collects on the ſurface of the water, from which it may be eaſily ſeparated. The water itſelf is of a milky colour, on account of a ſmall quantity of oil ſuſpended in it; and even after the water becomes tranſparent by the particles of the oil ſeparating from it, and riſing to the top, it is ſtill loaded with the peculiar odour of the plant. This was ſuppoſed to be a ſeparate principle of vegetables, to which Boerhaave gave the name of *ſpiritus rector*, and which is ſtill known by the name of *aroma*. This fragrance of the water is owing to the ſolution of a certain portion of oil in it. In the diſtillation of the volatile oils, different practices are followed, according to the nature of the plant, and the proportion of the oil exiſting in it. The roots, wood, bark, fruits, dried plants, after being cut in pieces, raſped down or bruiſed, are macerated for ſome hours, or for ſome days, according to the ſolidity or particular ſtate of the vegetable matter. Freſh plants are diſtilled with the ſmalleſt quantity of water, have no need of previous maceration, and do not require ſo high a temperature.

883 Fragrance. 4. The volatile oils are particularly diſtinguiſhed by their fragrance, which varies in the oils extracted from different

---

* *Fourcroy Connaiſs. Chim.* vii. 329.

† *Fourcroy Connaiſs Chim.* vii. p. 330.

different plants. The conſiſtence of the volatile oils alſo varies conſiderably. Sometimes they are as fluid as water, which is the caſe with thoſe oils obtained by expreſſion. 884 Fluidity. Some are thick and viſcid, as thoſe generally are which are extracted from woods, roots, barks, and fruits of the warmer regions. Some congeal, or aſſume a granulated ſolid conſiſtence at different temperatures. Of theſe laſt, ſome are always found to be in the concrete ſtate. 885 Cryſtals. Several of the volatile oils are ſuſceptible of cryſtallization, depoſiting in the remaining portion of the oil which continues liquid, tranſparent polyhedrons, more or leſs of a yellow colour, which are found to be pure oil. This laſt change, Vauquelin thinks, is owing to an incipient oxidation; for it never takes place, unleſs oils have been kept for ſome time.

886 Colour. 5. There is great variety of colour among volatile oils. Some indeed are nearly colourleſs, as the oil of turpentine; but in general they are of different ſhades of colour. Some are yellow, as the oil of lavender; ſome are of a reddiſh yellow or brown, as the oil of cinnamon or of rhodium; ſome are blue, as the oil of chamomile; and ſome are green, as that of parſley. But the moſt prevailing colour among volatile oils is yellow or reddiſh.

887 Taſte. 6. Volatile oils have almoſt always an acrid, hot, and even burning taſte. It is obſerved that the moſt acrid vegetable matters do not yield an oil poſſeſſed of this quality. The ſpecific gravity of volatile oils is generally leſs than that of water. Some volatile oils, however, as thoſe of ſaſſafras and canella, have a greater ſpecific gravity. The ſpecific gravity of oils varies from 0.8697 to 0.9910, in thoſe which are lighter than water; but thoſe which are heavier are from 1.0363 to 1.4049.

888 Action of light. 7. When volatile oils are expoſed to the light, the colour becomes conſiderably deeper; they become thicker, and increaſe in ſpecific gravity. In ſpeaking of a ſimilar change which takes place in the fixed oils, this change was aſcribed to the abſorption of oxygen; but, according to the experiments and obſervations of M. Tingry, this change is effected merely by the action of light; for in his experiments oxygen gas was entirely excluded.*

889 Of heat. 8. When volatile oils are expoſed to heat, they evaporate very readily. They are much more combuſtible than the fixed oils; and in burning give out a great quantity of ſmoke, a very bright white flame, and a good deal of heat. They require a greater proportion of oxygen than the fixed oils, and yield a greater quantity of water. This ariſes from a greater proportion of hydrogen, and a ſmaller quantity of carbone, which they contain.

890 Of air. 9. When volatile oils are expoſed to the open air, they undergo another change. They aſſume a deeper colour, and become viſcid, exhaling at the ſame time a very ſtrong odour. The air around is deprived of its oxygen; it combines with the hydrogen of the oil, and forms water, which is obſerved in drops on the ſurface. Many of the volatile oils when thus expoſed paſs into the reſinous ſtate, and are almoſt entirely deprived of their odour. This depends on the loſs of part of their hydrogen, and conſequently the increaſe of the proportion of carbone.

891 Of water. 10. The volatile oils are in ſome degree ſoluble in water. When they are agitated with this liquid, they combine with it, and communicate a very ſtrong odour, and a ſlightly acrid taſte.

892 Phoſphorus and ſulphur. 11. Phoſphorus and ſulphur are ſoluble in volatile oils. With phoſphorus the ſolution is luminous in the dark, is extremely fetid, and gives out, by the force of heat, phoſphorated hydrogen gas. The combination with ſulphur is known under the name of *balſam of ſulphur*. This gives out ſulphurated hydrogen gas on the application of heat.

893 Of acids. 12. The concentrated ſulphuric acid produces a brown colour, and increaſes the viſcidity of the volatile oils, and diſengages part of their hydrogen with efferveſcence and heat. Part of the oil is decompoſed; charcoal is depoſited, and it contains an acid. Nitrous acid, when brought into contact with the volatile oils, produces inſtantaneous deflagration; converts them into water in a great meaſure, and carbonic; and there remains behind a voluminous maſs of charcoal. Muriatic acid has ſcarcely any action; but the oxymuriatic acid renders them colourleſs, concrete in part, or viſcid, and brings them more nearly to the ſtate of reſins.

894 Uſes. 13. Some of theſe oils are employed in medicine. They are uſed alſo for the ſolution of thoſe ſubſtances which are to be employed as varniſhes; and many of them are uſed in perfumery.

895 Teſts of purity. 14. As many of the volatile oils are produced but in ſmall quantity, they are conſequently high priced. There is therefore ſome temptation to adulterate them with fixed oils, with cheaper volatile oils, or with other ſubſtances, to increaſe the quantity. It is therefore of ſome importance, to be able to detect ſuch frauds. When a volatile oil is adulterated with a fixed oil, there is a very eaſy teſt to diſcover it. Let a ſingle drop of the oil that is ſuſpected fall on clean paper, and expoſe it to a gentle heat. If the oil is pure, the whole will be evaporated, and no trace remain on the paper; but if it has been mixed with a fixed oil, a greaſy ſpot remains behind. Volatile oils are frequently adulterated with oil of turpentine; but this can only be detected by its peculiar odour, which continues for a longer time than moſt of the other volatile oils. When they are adulterated with alcohol, it is eaſily detected by mixing a little of the oil with water, which immediately produces a milkineſs, by the abſtraction of the alcohol from the oil, and its combination with the water.

896 Empyreumatic oils. 15. There is another claſs of oils known under the name of *empyreumatic oils*, which have different properties from thoſe which have been deſcribed. Theſe oils are acrid and ſtimulating, with a ſtrongly fetid and diſagreeable odour. It would appear, that theſe properties are owing to a partial decompoſition of other oils. Theſe oils are produced, as the name imports, by the action of fire. They are obtained when oils are forced to riſe in vapour, and paſs over in common diſtillation, with a greater degree of heat than that of boiling water, or by the application of a ſtrong heat to ſubſtances from which no oil was previouſly extracted. Theſe empyreumatic oils agree in ſome of their properties with the volatile oils. They combine in ſmall proportion with water, and they are ſoluble in alcohol; and probably any difference that exiſts between them, is owing to a partial decompoſition; for when they are

---

* *Jour. de Phyſique*, xlvii. p. 169.

diſtilled, the oil is reſtored to a ſtate of purity, and the carbonaceous matter which had been ſeparated, remains behind.

Chap. XII. Of ALKALIES.

897 Origin of the name. The word *alkali* is derived from the Arabian name of a plant, which affords the ſubſtance now diſtinguiſhed by that term. The name of the plant is kali, to which the Arabic particle *al* was added, expreſſive of the valuable qualities of the plant. When other ſubſtances were diſcovered, poſſeſſed of ſimilar properties, the meaning of the term was extended, and applied to ſuch matters as had ſeveral common properties. Three ſubſtances are generally ranked under the head of alkalies. Theſe are potaſh, ſoda, and ammonia. They are characterized by the following properties.

898 Characters. 1. They have a peculiar taſte, which is diſagreeably cauſtic, even when they are diluted with water.

2. They change vegetable blue colours to a green.

3. They have a ſtrong attraction for water, and combine with it in all proportions.

4. They have a ſtrong affinity for acids.

5. They melt in a moderate heat, but with a ſtronger heat they are volatilized.

899 Natural diviſion. The alkalies have been divided into two kinds, namely, the *fixed* and *volatile*. The two firſt, potaſh and ſoda, are denominated *fixed alkalies*, becauſe they require a great degree of heat to diſſipate or volatilize them. Ammonia has been called the *volatile alkali*, becauſe a very moderate degree of heat is ſufficient to volatilize it.

Fourcroy has claſſed two of the earths, namely, barytes and ſtrontites, under the head of alkalies. In ſome of their properties, theſe earths, no doubt, are analogous to the alkalies; but in other properties they are more cloſely allied to the earths. There ſeems, therefore, to be no inconvenience or ambiguity in claſſing them, as uſual, among earthy ſubſtances.

It may perhaps be conſidered as one of the general characters of the alkalies which we have now enumerated, that they have no action on oxygen, azotic, or hydrogen gaſes, nor is there any action between the alkalies and carbone.

Sect. I. *Of Potash and its Combinations.*

900 Names. 1. This ſubſtance has been long known in commerce, under many different names, derived from the ſubſtances from which it is extracted, or from the proceſſes by which it is prepared. The name of *aſh* or *aſhes* has been given to this ſubſtance, becauſe it is procured from the burnt aſhes of vegetables; and it has received the epithet of pot-aſhes, becauſe it is prepared in iron pots. It got the name of vegetable alkali, becauſe it was ſuppoſed that it only exiſted in vegetables. Being prepared from nitre and tartar, it was called the *alkali of nitre* or *tartar*, and the *ſalt of tartar*, a name which it ſtill retains in the ſhops. It has been propoſed alſo to diſtinguiſh it by the name of *kali*, the name of the plant from which it was originally procured.

901 Preparation. 2. Potaſh is generally prepared by burning wood or other vegetable matters, and thus reducing them to aſhes. The aſhes are then to be waſhed repeatedly with water, till the liquid comes off perfectly taſteleſs. If the liquid thus obtained be purified by filtration, and evaporated to dryneſs, a ſalt is obtained, which is the potaſh. In this ſtate it is contaminated with much extraneous matter; but if it be expoſed to a red heat, many of the foreign ſubſtances with which it is mixed, are diſſipated; it becomes whiter, and from its colour is then ſold under the name of *pearl-aſh*. This ſalt is prepared in great abundance in thoſe countries where wood abounds, as in North America and the north of Europe; and hence it is known in commerce under the name of *Ruſſian* or *American pearl-aſh*.

902 In this ſtate is impure. 3. Potaſh, in this ſtate, is conſidered as ſufficiently pure for the ordinary purpoſes of life to which it is applied; but it is ſtill mixed with much foreign matter, which renders it unfit for the purpoſes of the chemiſt. It has therefore always been conſidered as an object of great importance, to obtain it in a ſtate of purity.

But even when it is ſeemingly pure, by being deprived of all extraneous ſubſtances, it is found to poſſeſs very different properties, after being ſubjected to certain proceſſes. In one ſtate it is comparatively mild and inactive; in another, extremely acrid and corroſive. Various opinions were entertained of the cauſe of this remarkable difference, which it is unneceſſary to enumerate. 903 Black's diſcovery. The true cauſe was diſcovered and demonſtrated by Dr Black in the year 1756. This ingenious philoſopher, by a few ſimple and ſatisfactory experiments, clearly proved, that the different effects of the alkalies, lime, and magneſia, are owing to their combination with a peculiar ſubſtance, to which he gave the name of *fixed air*, becauſe it is fixed in theſe bodies. This fixed air, it has been already obſerved, is now known by the name of *carbonic acid*. When the alkalies are in combination with carbonic acid, they are in the mild ſtate; but when they are deprived of this acid, their effects being more powerful and corroſive, they are ſaid to be in the cauſtic ſtate.

When ſulphuric acid is poured upon a quantity of potaſh in its ordinary ſtate, a violent efferveſcence takes place. This, Dr Black proved, is owing to the eſcape of the carbonic acid in the ſtate of gas; for when the alkali is in its pure or cauſtic ſtate, no efferveſcence whatever takes place. He alſo proved, that the alkalies and lime in their mild ſtate, that is, when combined with carbonic acid, are heavier than in the cauſtic ſtate, and that this difference of weight is exactly equal to the quantity of carbonic acid which eſcapes. Since, then, theſe ſubſtances exhibit ſuch different properties in theſe two ſtates, it is neceſſary to procure them in a ſtate of purity, to examine their properties and effects. This is not without difficulty, on account of the ſtrong affinity which exiſts between the alkalies and carbonic acid; for although they are perfectly pure, as ſoon as they are expoſed to the air, they begin to attract the carbonic acid and return to their former mild ſtate.

904 Purification. 4. As this, therefore, is an object of importance, various proceſſes have been propoſed, to procure them as pure as poſſible. Some of theſe proceſſes we ſhall now detail.

905 Berthollet's proceſs. *a*. The following proceſs for the purification of potaſh is recommended by Berthollet. It is to be mixed with

with double its weight of quicklime, with eight or ten times the weight of the whole mixture, of pure or rain water. Boil it for two or three hours in an iron veſſel; then let it remain in a cloſe veſſel for 48 hours, taking care to agitate it occaſionally. Let it afterwards be filtered, and boiled in a ſilver veſſel with a ſtrong heat, till it aſſume the conſiſtence of honey. Pour a quantity of alcohol upon it, equal in weight to $\frac{1}{7}$ of the alkali which has been employed; then put it on the fire, and let it boil for ſome minutes. Pour it afterwards into a bottle, and allow it to cool. The matter in the bottle ſeparates into three different ſtrata: at the bottom are depoſited ſolid bodies; in the middle there is an aqueous ſolution, or carbonate of potaſh; and on the top a liquor of a reddiſh brown colour, mixed with alcohol. Let this be carefully decanted off by means of a ſyphon. This is a ſolution of pure potaſh in alcohol. Put it into a baſon of ſilver, or of tinned copper; evaporate it rapidly, till a dry, black, and charry cruſt forms on the ſurface, and the liquor below, which has an oily appearance, becomes ſolid by cooling. Let the cruſt be removed, and pour the ſolution into porcelain veſſels. When it cools, it becomes ſolid. It is then to be broken in pieces, and put into cloſe veſſels. This is the potaſh in a ſtate of purity, not only freed from foreign matters, but alſo deprived of the carbonic acid.

Lime has a ſtronger affinity for carbonic acid than the potaſh. When, therefore, the lime deprived of its carbonic acid, as it is in the ſtate of quicklime, is brought into contact in ſufficient quantity with the potaſh, it deprives it of the carbonic acid. It is with this view that the lime is employed in this proceſs. The alcohol has the property of diſſolving potaſh, but has no action on the other ſubſtances with which it is combined. This is the reaſon why the alcohol, holding in ſolution the pure potaſh by its leſs ſpecific gravity, forms the upper ſtratum in the bottle. By the evaporation, the laſt ſtep of the proceſs, the alcohol and water are driven off, and the pure potaſh remains behind in the ſolid ſtate.

906 By Lowitz. *b.* A more economical proceſs has been propoſed by Profeſſor Lowitz of Peterſburgh. He boils together the potaſh and quicklime, as in the former proceſs; filters the liquor, and evaporates, till a thick pellicle is formed on the ſurface. It is then ſet by to cool, till cryſtals are formed in it, which are cryſtals of extraneous ſalts, and are to be removed. He then continues the evaporation, and removes the pellicle as it forms on the ſurface during the proceſs. When the fluid ceaſes to boil and no more pellicle is formed, he removes it from the fire, and keeps conſtantly ſtirring it while it cools. He then diſſolves it in double the quantity of cold water, filters the ſolution, and evaporates in a glaſs retort, till regular cryſtals begin to be depoſited. If the maſs ſhould conſolidate ever ſo little by cooling, a ſmall quantity of water is to be added, and it muſt be heated again, to render it fluid. When a ſufficient quantity of regular cryſtals has been formed, he decants the liquid, which has a brown colour, and re-diſſolves the ſalt after it is ſuffered to drain, in the ſame quantity of water. The decanted liquor is preſerved in a well-cloſed bottle for ſeveral days, till it ſubſide and become clear. He then decants it, evaporates, and cryſtallizes a ſecond time, and repeats this proceſs as long as the cryſtals afford, with the leaſt poſſible quantity of water, ſolutions that are perfectly limpid. Theſe ſolutions are to be preſerved in well-cloſed bottles, to defend them from the acceſs of air *.

907 By Klaproth. *c.* The method of preparing pure potaſh by the indefatigable and accurate Klaproth, is ſomewhat different from this. We ſhall detail it in his own words. "As many perſons think that the preparation of a perfectly pure cauſtic ley is ſubject to more difficulties than it really is, I will here briefly ſtate my method of preparing it. I boil equal parts of purified ſalt of tartar, (carbonate of potaſh, or vegetable alkali prepared from tartar) and Carrara marble, burnt to lime, with a ſufficient quantity of water, in a poliſhed iron kettle; I ſtrain the ley through clean linen, and, though yet turbid, reduce it by boiling, till it contain about one half of its weight of cauſtic alkali; after which I paſs it once more through a linen-cloth, and ſet it by in a glaſs bottle. After ſome days, when the ley has become clear of itſelf, by ſtanding, I carefully pour it off from the ſediment into another bottle. To convince myſelf of its purity, I ſaturate part of it with muriatic or nitric acid, evaporate it to dryneſs, and re-diſſolve it in water. If it be pure, no turbidneſs will take place in the ſolution. The quantity of cauſtic alkali which this ley contains, I aſcertain by evaporating a certain weighed portion of the ley to dryneſs, in an evaporating diſh of a known weight. I alſo take care, in the preparation of this cauſtic ley, that the alkali be not entirely deprived of carbonic acid; becauſe, in that caſe, I can with greater certainty, depend on the total abſence of diſſolved calcareous earth. By employing burnt marble, or, in its ſtead, burnt oyſter-ſhells, I avoid the uſual contamination of the cauſtic ley by aluminous earth; becauſe lime, prepared from the common ſpecies of lime-ſtone, is ſeldom entirely free from argil" *.

908 Properties. 5. Potaſh thus obtained, is a white ſolid ſubſtance, which is ſuſceptible of cryſtallization in long, compreſſed, quadrangular priſms, terminating in ſharp-pointed pyramids. Theſe cryſtals, which are only obtained from very concentrated ſolutions, are ſoft and deliqueſcent (T). The taſte is extremely acrid; and it is ſo corroſive, that it deſtroys the texture of the ſkin, the moment it touches it. It is from this property that it has derived the name of cauſtic; and in ſurgical language it has obtained the name of *potential cautery*, becauſe it is employed for the purpoſe of opening abſceſſes, or for deſtroying excreſcences. According to Haſſenfratz, the ſpecific gravity of potaſh is 1.7085. It converts vegetable blues into a green colour.

909 Action of heat. 6. Light has no action on potaſh. When it is heated in cloſe veſſels, it becomes ſoft and liquid, and is afterwards converted into a white, opaque, and granulated maſs, when it cools. If the heat be increaſed to

* *Nicholſon's Journal*, 4to, vol. i. p. 164.

* *Analyt. Eſſays, Pref.* p. 8. *Tranſl.*

(T) By deliqueſcence is meant the melting of ſubſtances in the water which they attract from the air. Such ſalts are ſaid to be *deliqueſcent*.

to redneſs, it ſwells up, and riſes in vapour. If the veſſel be opened, there ariſes a white ſmoke, which is extremely acrid, and condenſes on cold bodies with which it comes in contact. But though it is thus ſublimed, it undergoes no other change than aſſuming a ſlight green colour.

7. There is no action between potaſh and oxygen or azotic gaſes, nor is there any direct action between potaſh and carbone. Phoſphorus and ſulphur enter into combination with potaſh, and form peculiar compounds, the nature of which we ſhall conſider, after having detailed the general properties of potaſh.

910 Of water.

8. Potaſh has a very ſtrong affinity for water. Water at the ordinary temperature diſſolves double its weight of potaſh. The ſolution, when the potaſh is pure, is colourleſs and tranſparent, and is nearly of the conſiſtence of oil.

911 Acids.

9. Potaſh combines readily with the acids, and forms compounds with them, having different properties, according to the nature of the acid which is employed.

912 Affinities.

Its affinities for the acids are in the following order:

Sulphuric,
Nitric,
Muriatic,
Phoſphoric,
Phoſphorous,
Fluoric,
Oxalic,
Tartaric,
Arſenic,
Succinic,
Citric,
Lactic,
Benzoic,
Sulphurous,
Acetic,
Saclactic,
Boracic,
Carbonic,
Pruſſic.

913 Uſes.

10. Potaſh is employed for a great variety of purpoſes; it enters into combination with many ſubſtances, and forms with them valuable and important compounds. It is employed in medicine as a uſeful and powerful remedy; in many arts and manufactures, as in bleaching, dyeing, and glaſs-making.

914 A ſimple ſubſtance.

11. Potaſh is to be conſidered as a ſimple ſubſtance. No attempts yet made have ſucceeded in decompoſing it. But although not the ſlighteſt proof has been adduced of its formation or decompoſition, it is conſidered by ſome as a compound ſubſtance. This opinion is founded on the analogy of its properties with ammonia; the compoſition of which has been fully demonſtrated. According to ſome, it is compoſed of lime and azote; and, according to others, of hydrogen and lime; but all theſe are mere conjectures, which have probably had their origin in that eagerneſs of the human mind, which leads it to fancy what it wiſhes to be true.

12. But we ſhall now conſider more particularly the action of the different ſubſtances which have been already treated of, on potaſh, and the different combinations which it forms with them.

I. Action of Phoſphorus on Potaſh.

915 Phoſphorated hydrogen gas.

1. There is no direct combination betwen potaſh and phoſphorus; but although theſe two bodies have little tendency to unite, they have a very powerful effect upon each other when they are heated together with water. It was in this way that Gengembre firſt obtained the ſingular gas, which has been already deſcribed, when treating of phoſphorus, under the name of *phoſphorated hydrogen gas*.

916 Proceſs for obtaining it.

2. If one part of phoſphorus and ten parts of a concentrated ſolution of pure potaſh be introduced into a ſmall retort, and expoſed to heat till it boils, phoſphorated hydrogen gas will paſs over, which may be received in jars over water: or if the beak of the retort be kept under the ſurface of water, the bubbles of the gas, as they riſe to the ſurface, explode, and form the beautiful coronet of white ſmoke, formerly mentioned. In making this experiment, the retort ſhould not be larger than to hold the ſolution, or, it ſhould be filled with hydrogen or azotic gaſes, in which the phoſphorated hydrogen gas will not inflame and explode, with the riſk of breaking the veſſel; for the inflammation can only take place when it comes in contact with the oxygen of the atmoſphere.

917 Nature of the proceſs.

3. In this proceſs, the water which holds the potaſh in ſolution, is decompoſed. The oxygen combines with part of the phoſphorus, and forms phoſphoric acid, while another part of the phoſphorus unites with the hydrogen, and paſſes over in the form of phoſphorated hydrogen gas. Thus, without any perceptible action between the phoſphorus and the potaſh, the decompoſition of the water is aided by means of the potaſh, in conſequence of its attraction for the phoſphorus, combined with the oxygen in the ſtate of phoſphoric acid. For it is found, that a quantity of phoſphate of potaſh is formed, correſponding to that of the phoſphorated hydrogen gas which is obtained. This decompoſition is alſo aſſiſted by the affinity of the phoſphorus for the oxygen and hydrogen of the water. The whole of the phoſphorated hydrogen gas which is formed, being diſengaged, ſhews that no combination takes place between it and the potaſh *.

II. Action of Sulphur on Potaſh.

1. Sulphur and potaſh very readily combine together. If one part of potaſh and three of ſulphur be triturated together in a glaſs or porcelain mortar, the mixture becomes hot, the ſulphur loſes its yellow colour, and acquires a greeniſh tinge. There is diſengaged a fetid ſmell of garlic; the mixture attracts moiſture from the air, becomes ſoft, and is almoſt entirely ſoluble in water.

918 Sulphuret of potaſh.

If two parts of potaſh and one of ſulphur be well mixed together, and heated in a crucible, the mixture fuſes; and by this proceſs is obtained *ſulphuret of potaſh* in the dry ſtate. This was formerly called *hepar ſulphuris*, or *liver of ſulphur*, from its reſemblance to the liver of animals. The ſame ſubſtance may be obtained by treating ſulphur with the potaſh of commerce, with this precaution, not to apply too ſtrong a heat, to occaſion a ſublimation of the ſulphur, and the too rapid evolution of the carbonic acid from the potaſh. When the fuſion is completed, it is poured out

---

* *Fourcroy Connaiſs. Chim.* tom. ii. p. 202.

out on a marble ſlab; it is covered up from the air, allowed to cool, and broken into ſmall pieces, to be inſtantly put up in well-cloſed glaſs veſſels.

919 Properties. 2. The ſolid ſulphuret of potaſh thus prepared, is of a ſhining brown colour like that of the liver of animals, from which it derived its former name. Expoſed to the air it becomes green, then paſſes to gray, and even to white. It is denſe, ſmooth, and has a vitreous fracture. It has no other ſmell than that of heated or ſublimed ſulphur; is acrid, cauſtic, and bitter to the taſte, and leaves a brown ſpot on the ſkin. With a ſtrong heat, in a porcelain retort, the ſulphur is ſublimed, and the potaſh remains in a ſtate of purity at the bottom of the veſſel. The ſulphuret of potaſh converts vegetable blue colours to green, and afterwards deſtroys them.

920 Hydro-ſulphuret. 3. But the ſulphuret of potaſh poſſeſſes theſe properties, only while it is recently prepared, and very pure. When expoſed to the air, it is readily decompoſed, and more ſo, as the air is loaded with moiſture. It abſorbs water with avidity, acquires a green colour, and exhales the fetid odour of ſulphurated hydrogen gas. This change is owing to the decompoſition of the water which has been abſorbed. Part of the ſulphur combines with the hydrogen, and forms ſulphurated hydrogen gas, which combines with the ſulphuret, and forms hydrogenated ſulphuret of potaſh.

921 Obtained by another proceſs. 4. This may alſo be formed by paſſing the ſulphurated hydrogen gas into a ſolution of potaſh. The gas is abſorbed and condenſed, till the potaſh is fully ſaturated. To this ſubſtance Berthollet, who particularly inveſtigated the nature of theſe compounds, gave the name of *hydro-ſulphuret of potaſh*.

922 Properties. This compound cryſtallizes, and is more permanent than the ſulphuret. The cryſtals are tranſparent and colourleſs, while thoſe of the ſulphuret are brown and opaque. The cryſtals are large and in the form of four-ſided priſms, terminating in four-ſided pyramids. It is decompoſed by heat, and by the action of the acids. Sulphurated hydrogen gas is diſengaged, but there is no depoſition of ſulphur. The oxymuriatic acid decompoſes the ſulphurated hydrogen, and then ſulphur is precipitated. The pure hydro-ſulphuret has no ſmell, when it has no addition of ſulphur beyond the ſaturation of the hydrogen. The alkali ſeems to have a ſtronger affinity for the ſulphurated hydrogen than for the ſulphur, ſo that when it is ſaturated with the firſt, that is, in the ſtate of hydro-ſulphuret of potaſh, which is in the form of cryſtals, and without ſmell or inodorous, it combines with no more ſulphur; but when ſulphurated hydrogen gas is made to paſs into a ſolution of the ſulphuret of potaſh already hydrogenated by its ſolution in water to a certain degree of ſaturation, the ſulphurated hydrogen acts in the manner of acids, precipitates the ſulphur like them, renders the liquid colourleſs, and leaves behind nothing but the hydro-ſulphuret of potaſh *.

* *Fourcroy Connaiſs. Chim.* tom. ii. p. 206.

923 Hydrogenated ſulphuret. 5. Sulphur combines with the latter compound, and forms a new compound, which may be obtained by pouring a liquid hydroſulphuret upon ſulphur. The ſulphur is diſſolved without the aſſiſtance of heat; the liquid aſſumes a darker colour, and then it is converted into the *hydrogenated ſulphuret*. Hydrogenated ſulphuret of potaſh is prepared by boiling together a mixture of pure potaſh and ſulphur in water. This ſolution is of a deep greeniſh yellow colour, has a very acrid bitter taſte, and a powerful action on many ſubſtances. It readily abſorbs oxygen when expoſed to the air. When it is kept in cloſe veſſels, ſulphur is depoſited; the liquid becomes tranſparent, and the ſmell is diſſipated. Thus, there are three different compounds of ſulphur with potaſh; namely, ſulphuret of potaſh, hydroſulphuret of potaſh, and hydrogenated ſulphuret, which are all diſtinguiſhed by peculiar properties.

III. Compounds of Potaſh with Acids, or Neutral Salts.

1. Sulphate of Potaſh (u).

924 Names. 1. This ſalt, which was one of the moſt early known, is a compound of ſulphuric acid and potaſh. It has been diſtinguiſhed by a great variety of names, as *ſal de duobus*, *ſal polychreſtus*, or ſalt of many virtues, *arcanum duplicatum*, and more lately *vitriolated tartar*, till in the new nomenclature it received the name of *ſulphate of potaſh*.

925 Preparation. 2. It is prepared by different proceſſes, either by directly combining the ſulphuric acid with the potaſh, and evaporating and cryſtallizing it; or by decompoſing other ſalts which have potaſh for their baſe, by means of the ſulphuric acid, which having a ſtronger affinity for the potaſh, combines with it and forms the new compound.

926 Properties. 3. The ſulphate of potaſh cryſtallizes in hexaëdral priſms, terminated by ſix-ſided pyramids; but this form is ſuſceptible of ſeveral varieties. It has a diſagreeable bitter taſte, it is not very hard, and may be eaſily reduced to powder. The ſpecific gravity is 2.4073. At the temperature of 60°, it is ſoluble in 16 times its weight of water; boiling water diſſolves about one-fifth part; on cooling it cryſtallizes in a confuſed maſs; and it is only by ſlow ſpontaneous evaporation that regular cryſtals can be obtained.

927 Action of heat. 4. It ſuffers no change by the action of the air. When placed upon burning coals, it decrepitates, and loſes its water of cryſtallization. At a greater heat it melts, and is converted into a kind of enamel as it cools.

5. When this ſalt is expoſed to a red heat, along with hydrogen gas or carbone, it is decompoſed, and converted into a hydrogenated or carbonated ſulphuret of potaſh.

6. The ſulphuric acid, with the aſſiſtance of heat, combines with the ſalt, and forms another with exceſs of acid. It undergoes a partial decompoſition by the action

---

(u) The compounds of acids with any baſe are known by this name in the preſent chemical nomenclature; and when the acid has its greateſt proportion of oxygen, as in this caſe the ſulphuric acid, the name of the compound terminates in the ſyllable *ate*, as ſulphate of potaſh, nitrate of potaſh; but when the acid has its ſmaller proportion of oxygen, the name of the compound terminates in *ite*; as ſulphite of potaſh, nitrite of potaſh.

tion of nitric acid. The nitric acid combines with nearly $\frac{1}{3}$ of the potaſh, which is owing to the action of double affinity. The nitric acid combines with one part of the potaſh, while the ſulphuric acid unites with the ſulphate of potaſh, and forms a ſalt with exceſs of acid. A ſimilar decompoſition takes place by means of the muriatic acid.

928 Compoſition. 7. The component parts of ſulphate of potaſh are, according to

	Bergman,	Kirwan,
Acid	40	45.2
Potaſh	52	54.8
Water	8	00.0
	100	100

929 Names. *Acidulous ſulphate of potaſh*, or *ſuper-ſulphate of potaſh*.—1. This ſalt was formerly called *vitriolated tartar with exceſs of acid.* It is prepared by heating together, in a retort, three parts of the ſulphate of potaſh, with one part of its weight of concentrated ſulphuric acid.

930 Properties. 2. It cryſtallizes in long, flexible, ſhining cryſtals, and ſometimes it exhibits the form of ſix-ſided priſms. It has a ſharp, acrid, and hot taſte. It reddens vegetable blues. Expoſed to the air it becomes a little more opaque, but without any other change. 931 Action of water. It is more ſoluble in water than the ſulphate of potaſh, requiring only 2 parts of water at 60°, and diſſolves in leſs than its own weight of boiling water. 932 Of heat. It melts very readily, and has the appearance of a thick oil. When it cools, it becomes a white, opaque maſs, exhibiting on its ſurface ſhining ſilky cryſtals. When expoſed to a great heat, the exceſs of acid is driven off, and it is converted into the ſulphate of potaſh.

933 Hydrogen. 3. It is readily decompoſed by the action of hydrogen and of red-hot charcoal, which deprive it of a great portion of the ſulphur; and by ſulphur itſelf, which carries off the exceſs of ſulphuric acid in the form of ſulphurous acid.

4. The firſt of theſe ſalts, the ſulphate of potaſh, is employed in medicine as a purgative; the laſt has been applied to no uſe whatever.

2. Sulphite of Potaſh.

934 Names and preparation. 1. This ſalt was long known under the name of the *ſulphurous ſalt of Stahl.* It is a compound of the ſulphurous acid and potaſh. Its nature and properties have been particularly inveſtigated by Berthollet, Fourcroy, and Vauquelin. It may be formed by paſſing a current of ſulphurous acid gas into a ſolution of carbonate of potaſh in three times its weight of diſtilled water, till the effervеſcence ceaſes. The liquor becomes tranſparent and hot, and as it cools, the ſulphite of potaſh is depoſited in cryſtals.

935 Properties. 2. This ſalt is in the form of long, ſmall needles, diverging from a center, or in rhomboidal plates, or in decahedrons formed by two tetrahedral pyramids, united and truncated very near the baſe. The cryſtals are white and tranſparent, but ſometimes of a ſlight yellow colour. The taſte is acrid and ſulphureous. The ſpecific gravity is 1.586. 936 Action of the air. The ſulphite of potaſh, expoſed to the air, very readily effloreſces (u); becomes white and opaque, and is converted into ſulphate of potaſh. This is owing to the ſulphurous acid abſtracting oxygen from the air, and becoming ſulphuric acid. It is very ſoluble in water, at the temperature of the atmoſphere, and much more ſo in boiling water. When this ſolution is expoſed to the air, it is ſoon covered with a thick pellicle, which falls to the bottom, and is afterwards replaced by another. This is the ſulphate of potaſh, which is formed in contact with the air. The oxymuriatic acid gas combined with this ſolution, forms almoſt immediately ſhining cryſtals of the ſulphate of potaſh.

937 Of charcoal. 3. Charcoal heated with this ſalt in a retort, yields ſulphurated hydrogen gas, and carbonic acid; and there remains in the retort, a hydrogenated ſulphuret of potaſh.

3. Nitrate of Potaſh.

938 Conſtituent parts and names. 1. This ſalt is compoſed of nitric acid and potaſh, and is well known under the names of *ſaltpetre* and *nitre.* It has alſo been denominated *ſalt of nitre*, *nitre of potaſh*, or *nitrated potaſh.* It is one of the moſt important of the ſalts, not only on account of the attention which it has excited, in tracing its formation, and ſtudying its nature and compoſition, but alſo on account of its numerous and valuable applications in domeſtic economy and in the arts.

939 Found in many plants. 2. The nitrate of potaſh exiſts ready formed in many plants, as in tobacco, borage, bugloſs, pellitory. It has been obſerved cryſtallized in needles in their dried ſtalks. According to ſome, it has been abſorbed by the vegetable from the ſoil in which it grows, while others ſuppoſe that it is formed within the plant, from the elementary principles.

Nitre exiſts in great abundance on the ſurface of the earth in different parts of the world, eſpecially in the warmer regions, as in India, Egypt, and South America. But the production of nitre is not limited to theſe countries. 940 Prepared artificially. It is produced artificially in Germany and France, by means of what are called *nitre beds.* Theſe are formed by collecting together the refuſe of animal and vegetable matters, in which the putrefactive proceſs is going on. They are mixed with earthy ſubſtances, but chiefly with calcareous earth, ſuch as the rubbiſh from buildings, or collections of the ſoil in which lime abounds. All that is neceſſary to favour the formation of the nitre, is to moiſten occaſionally with water the mixture of the animal, vegetable, and earthy matters; to expoſe it to a moderate temperature, and to defend it from rains, which would carry off the ſalt as it is formed. This artificial production of nitre was greatly improved and extended by the French during the late war, when they were precluded

---

(u) A ſalt is ſaid to effloreſce, when deprived of its water of cryſtallization in the ordinary temperature of the atmoſphere. A powdery cruſt is firſt formed on the ſurface; and as the proceſs goes on, the whole falls down into powder. The term *effloreſcence* is oppoſed to *deliqueſcence*, by which the deliqueſcent ſubſtance attracts moiſture from the air.

ed from the uſual ſupply of this ſalt from India. It is now produced, it is ſaid, in great abundance in France.

The nature of the proceſs, and the change which takes place in this artificial production of nitre, will be underſtood by conſidering its component parts. The conſtituent parts of the nitric acid are azote and oxygen. The oxygen is furniſhed by the air; and unleſs there is a ſupply of air, no change takes place. A great quantity of azotic gas is given out by animal matters during the putrefactive proceſs. But although theſe ſubſtances, when brought into contact with each other, do not combine to form nitric acid, it has been found by experiment, that azote, in its naſcent ſtate, or in the moment of evolution, enters into union with oxygen, and forms nitric acid, while the nitric acid thus formed combines with the potaſh which is furniſhed by the ſoil, or the vegetable matters.

941 Purification.

3. After the nitre is formed, it is mixed with water, which is evaporated, and a ſalt is obtained of a brown colour, which is called *crude nitre.* This is a mixture of ſeveral ſalts, and from theſe the pure nitre is ſeparated by other proceſſes. When it is ſufficiently purified, it is obtained in cryſtals of ſix-ſided priſms, terminating in ſix-ſided pyramids. The primitive form of its cryſtals is a rectangular octahedron, in which two faces of a pyramid are inclined to the other pyramid at an angle of 120°, and the two others at an angle of 111°. The form of the integrant molecule is the tetrahedron; but there are conſiderable varieties in the cryſtals of this ſalt, according as it is ſlowly or more rapidly evaporated.

942 Properties.

4. This ſalt is diſtinguiſhed by a cool, ſharp, and bitteriſh taſte. It is very brittle. When nitre in large cryſtals is reduced to powder, it is found to be a little humid; but that which is in the form of a white, opaque, irregular maſs, yields a dry powder, on which account it is generally preferred for many purpoſes, particularly in the manufacture of gunpowder. The ſpecific gravity of nitre is 1.9369. It is not altered by expoſure to the air. At the temperature of 60° it diſſolves in ſeven times its weight of water, and during the ſolution, a great degree of cold is produced. Boiling water diſſolves twice its weight of this ſalt.

943 Action of heat.

5. When the nitrate of potaſh is expoſed to heat, it fuſes before it becomes red, and is converted into a liquid of an oily conſiſtence. It loſes but very little of its water of cryſtallization, and if it be allowed to cool, it congeals into an opaque maſs with a vitreous fracture, which is known by the name of *mineral cryſtal.* While it is melted, it undergoes no change; but when the temperature neceſſary for ſimple fuſion is increaſed, it gives out oxygen gas to the amount of about $\frac{1}{7}$ of its weight. Towards the end of the proceſs, azotic gas is evolved, and the potaſh remains behind pure, ſo that the ſalt has been completely decompoſed. But to effect this decompoſition, a very ſtrong heat is neceſſary. When only part of the gas is extracted, the nitrate of potaſh is converted into the *nitrite.*

944 Of charcoal.

6. When nitre is mixed with charcoal in the proportion of three parts of the former to one of the latter, a violent inflammation takes place, either by expoſing the mixture to a red heat, or by bringing it into contact with a burning body. Or the mixture may be projected into a red-hot crucible, when a deflagration or detonation takes place, and when the reſiduum in the crucible is examined, it is found to be potaſh partly united with carbonic acid, or the carbonate of potaſh. This was formerly called *nitre fixed by charcoal,* or an *extemporaneous alkali of nitre.* The deflagration in this caſe is owing to the combuſtible matter, the charcoal, coming in contact with the oxygen which is evolved by the nitre, expoſed to a high temperature. In another proceſs, this experiment was performed in cloſe veſſels, to collect the elaſtic fluids which are diſengaged; and beſides the carbonic acid gas which is formed by the union of the carbone and oxygen, and the azotic gas diſengaged by the decompoſition of the nitre, a ſmall quantity of water was found in the veſſels. To this product the alchemiſts gave the name of *clyſſus,* and aſcribed to it very wonderful properties in the preparation of the philoſopher's ſtone.

945 Of phoſphorus.

7. A violent deflagration alſo takes place when phoſphorus and nitre are treated in the ſame way. But this experiment ſhould be performed with very ſmall quantities, and with great caution. A mixture of nitre and phoſphorus ſtruck ſmartly with a hammer, produces a very violent detonation.

946 Of ſulphur.

8. When ſulphur is combined with three times its weight of nitre, it burns with great rapidity. This preparation was formerly made by detonating the two ſubſtances in a red-hot crucible. The product is ſulphate of potaſh, known by the name of *ſal polychreſt of Glaſer.* The ſulphur combines with the oxygen of the nitric acid, and forms ſulphuric acid, which enters into combination with the potaſh.

947 Gunpowder.

9. But one of the moſt important combinations of nitre is with charcoal and ſulphur, in the formation of gunpowder. This ſubſtance was firſt known in Europe in the 14th century. It is ſaid that it was known to the Chineſe much earlier. The proportions of the materials which enter into the compoſition of gunpowder are,

Nitre	76
Charcoal	15
Sulphur	9
	100

948 Preparation.

The materials are firſt reduced to a fine powder ſeparately. They are then carefully mixed together, and formed into a paſte with a little water. When the paſte has dried a little, it is forced through a ſieve, by which means it is reduced to grains of ſuch a ſize as may be wanted. The powder is then dried in the air, or in the ſun; and, after being dried, it is put into barrels which turn round by means of machinery, and thus by the friction of the grains of powder againſt the ſides of the barrel and againſt each other, it is poliſhed. This is called *glazing* the powder.

949 Nature of its action.

10. The theory of the combuſtion, and terrible effects of gunpowder is thus explained. The ſulphur and the charcoal burn with great rapidity by the addition of the nitre with which they are intimately mixed. During the combuſtion carbonic acid gas, azotic gas, ſulphurous acid gas, and according to ſome, ſulphurated hydrogen gas, are formed. Water and ammonia alſo are ſaid to be produced[*]. But according to Mr Cruickſhank, the quantity of water formed is not perceptible. The ſubſtances which remain after the deflagration are, carbonate of potaſh, ſulphate and ſulphuret

[*] *Fourcroy Connaiſs. Chim.* iii. 122.

ſulphuret of potaſh, and ſome charcoal. It is obvious, that the irreſiſtible effects of gunpowder are owing to the ſudden evolution and expanſive force of the elaſtic fluids which are formed and diſengaged.

950 Fulminating powder.

11. Another combination of nitre produces effects ſtill more terrible. When three parts of nitre, two parts of potaſh, and one of ſulphur, are previouſly well dried and mixed together by trituration, they form a compound which is known by the name of *fulminating powder*. A few grains of this mixture expoſed to heat in an iron ladle firſt melt, aſſuming a darker colour; and when the whole is in fuſion, there is a violent exploſion. The heat ſhould be applied ſlowly and gradually, till it is completely fluid, and then by bringing it nearer the heat, the full effect of the exploſion is obtained. This combuſtion and exploſion are alſo owing to the inſtantaneous evolution of elaſtic fluids. The potaſh unites with the ſulphur, and forms a ſulphuret, which, with the aſſiſtance of the nitre, is converted into ſulphurated hydrogen. At a certain temperature the ſulphurated hydrogen gas is diſengaged, along with the oxygen gas of the nitre, and ſuddenly taking fire, ſtrikes the air by the exploſion which accompanies the evolution of the gaſes. When the mixture is made with equal parts of nitre and ſolid ſulphuret of potaſh, the detonation is more rapid, but the exploſion is leſs violent.

951 Powder of fuſion.

With three parts of nitre, one of ſulphur, and one of ſawduſt, well mixed together, what is called *powder of fuſion* is formed. If a little of this powder is put into a walnut ſhell, with a thin plate of copper rolled up, and the mixture ſet fire to, it detonates rapidly, and reduces the metal to a ſulphuret, without any injury to the ſhell.

952 Fluxes.

12. A mixture of equal parts of nitre and tartar detonated in a crucible, gives a product which is much employed in metallurgy. This compound, called *white flux*, is a mixture of pure potaſh with the carbonate. When one part of nitre and two of tartar are treated in the ſame manner, the product obtained is a mixture of potaſh and charcoal. From its black colour, it is known under the name of *black flux*. This alſo is employed for a ſimilar purpoſe.

953 Compoſition.

13. Nitrate of potaſh, according to Bergman, is compoſed of

31 acid,
61 potaſh,
8 water.
———
100

According to Kirwan, it is compoſed of

44 acid,
51.8 potaſh,
4.2 water.
———
100.0

954 Uſes.

14. Nitre is not only employed for the purpoſes already mentioned, but it is uſed in medicine as a cooling remedy in feveriſh diſorders, and as a diuretic in urinary affections. It is employed alſo in many arts, as in dyeing, and in domeſtic economy, for the preſervation of animal matters, which are to be uſed as food. To theſe ſubſtances it imparts a red colour. From nitre, nitric acid is obtained, by decompoſing it by means of ſulphuric acid. Nitre is alſo employed to burn along with ſulphur in the formation of ſulphuric acid.

4. Nitrite of Potaſh.

1. This ſalt cannot be formed by direct combination of the nitrous acid with potaſh; but if a quantity of nitre be expoſed for ſome time in a crucible or retort, to a ſtrong heat, it becomes deliqueſcent and acrid. It changes the blue colours of vegetables into green, attracts moiſture from the air, detonates feebly with combuſtible ſubſtances, and gives red thick vapours by the action of ſulphuric, nitric, muriatic, phoſphoric, and fluoric acids. This is the nitrite of potaſh, which is decompoſed by theſe acids, and gives out the red fumes of nitrous acid. Little more is known of the nature of this ſalt, with regard to its form, ſolubility, affinities, or proportion of its conſtituent parts.

5. Muriate of Potaſh.

955 Names.

1. This ſalt was formerly known by the name *febrifuge ſalt of Sylvius*. It was afterwards called *digeſtive ſalt*, *regenerated ſea ſalt*, and by Bergman, *ſalited vegetable alkali*.

2. It is prepared by the direct combination of muriatic acid and potaſh. The ſolution is evaporated till a pellicle appears, when it is ſet by to cryſtallize.

956 Properties.

3. The cryſtals are in the form of regular cubes, or rectangular parallelopipeds. It has a diſagreeable bitter taſte, and by this is eaſily diſtinguiſhed from muriate of ſoda or common ſalt. The ſpecific gravity of this ſalt is 1.836. When the air is moiſt, it deliqueſces; but when the air is dry, it parts with its moiſture. Three parts of cold water are ſufficient for its ſolution. Boiling water diſſolves a little more, but regular cryſtals cannot be obtained by cooling. The ſolution muſt be left to ſlow, ſpontaneous evaporation.

957 Action of heat.

4. When the muriate of potaſh is expoſed to heat, it decrepitates, loſes its cryſtalline form, and falls into powder by the ſeparation of .08 parts of its weight of water. When it acquires a red heat, it melts; if the temperature be elevated, it is ſublimed in the form of white vapour, unchanged. After complete fuſion, if it is allowed to cool ſuddenly, it becomes ſolid, and divides on the ſurface, into many ſmall plates of a ſquare form.

5. This ſalt is decompoſed by means of the ſulphuric and nitric acids. The firſt diſengages the muriatic acid with effervеſcence in the gaſeous form. By the action of the nitric acid the muriatic acid is converted into the oxymuriatic by combining with the oxygen of the nitric acid. With one part of nitric acid and two parts of muriate of potaſh, a compound of the two acids is formed, which was formerly employed in the ſolution of gold. This is a *nitro-muriatic acid*, or *aqua regia*.

958 Uſes.

6. This ſalt is no longer employed in medicine. It is recommended to be uſed for the decompoſition of nitrate of lime in the mother waters of nitre, to obtain the nitrate of potaſh, and alſo for procuring the cryſtallization of alum.

6. Hyperoxymuriate of Potaſh.

959 Diſcovery and hiſtory.

1. This ſingular ſalt was the firſt known of all the combinations with the acid in this ſtate. Fourcroy mentions,

mentions, that Dr Higgins prepared this ſalt, which he calls *nitre*, by paſſing the oxymuriatic acid gas into a ſolution of potaſh; but he ſeems to have paid no farther attention to it, except obſerving, that it detonated on red-hot coals (x). It was firſt formed, and its nature and properties were firſt inveſtigated, by Berthollet. And ſince its diſcovery, it has been particularly examined by Lavoiſier, Dolfuz, Vanmons, Fourcroy, and Vauquelin, on the continent, and in England by Hoyle and Chenevix. The method of preparing this ſalt has been already deſcribed (at N° 556, p. 520.) in treating of hyperoxymuriatic acid. After the ſalt has been removed from the ſolution in which it cryſtallized, it may be purified by diſſolving it in boiling water. The ſolution may be filtered, and allowed to cool, when the cryſtals are depoſited.

960 Properties. 2. The cryſtals of this ſalt are moſt commonly in the form of ſquare plates or of parallelopipeds, of a ſhining ſilvery white colour. The primitive form of the cryſtals is an obtuſe, rhomboidal priſm; they are very tranſparent and brittle; the taſte is cool, pungent, and diſagreeable, very different from that of nitrate of potaſh. When it is rubbed ſmartly, it phoſphoreſces, and gives out a great quantity of ſparks or luminous traces.

3. It becomes yellow after long expoſure to the air, but is otherwiſe not changed. It is ſoluble in about 20 parts of water at the ordinary temperature of the atmoſphere; but boiling water diſſolves about one-third of its weight, ſo that the whole is nearly cryſtallized by cooling.

961 Action of heat. 4. When this ſalt is expoſed to heat, although it contains a conſiderable proportion of water of cryſtallization, it fuſes quietly; and when the heat is increaſed, it gives out a quantity of oxygen gas nearly equal to one-third of its weight. This is the pureſt oxygen gas that can be obtained.

5. But the moſt extraordinary effects of this ſalt are thoſe produced by its action on combuſtible ſubſtances.

962 Of charcoal. *a.* If a ſmall quantity of charcoal reduced to powder and this ſalt be rubbed together in a mortar, there is a ſlight exploſion, and the charcoal is inflamed.

963 Of ſulphur. *b.* Three parts of the ſalt with one of ſulphur, rubbed together in a mortar, produce a violent detonation. Or, if the ſame mixture is ſtruck with a hammer on an anvil, there is an exploſion like the report of a piſtol (y).

964 Of phoſphorus. *c.* The ſame effect is produced by employing phoſphorus, and treating it in the ſame way with this ſalt. One or 1½ grains of the ſalt ſhould firſt be reduced to powder, and brought together to one place in the bottom of the mortar, and then introducing the phoſphorus, and rubbing it ſtrongly on the ſalt, a violent exploſion will inſtantly take place. A ſimilar detonation may be produced with the ſame ſubſtances, by percuſſion.

d. Three parts of the ſalt, one-half part of ſulphur, and one-half of charcoal, give more rapid and ſtronger detonations, with the evolution of a very bright flame. Detonations are alſo produced, by treating this ſalt with ſugar, gums, oils, and ſome metallic ſubſtances.

965 Of acids. 6. When concentrated ſulphuric acid is poured upon this ſalt, there is a conſiderable detonation; it is thrown about to a great diſtance, ſometimes with a red flame; and there is exhaled a brown vapour, accompanied with a ſtrong odour of oxymuriatic acid. Even when a lighted taper is brought into contact with the gas which is diſengaged, it explodes more violently than when the acid firſt came in contact with the ſalt. In ſome caſes, the exploſion was ſo ſudden and ſo violent, that it broke the veſſels in which the mixture was made. This happened to Mr Hoyle of Mancheſter, and afterwards to Mr Chenevix; ſo that experiments with ſulphuric acid and this ſalt, ſhould be conducted with ſmall quantities, and with great caution. If concentrated ſulphuric acid be poured on any of the mixtures of this ſalt with ſulphur, charcoal, the metals, or with ſugar, there is an inſtantaneous inflammation, the moſt brilliant that can be conceived. There is no detonation, but the combuſtion is extremely rapid, and the odour of oxymuriatic acid is perceptible. Concentrated nitric acid poured upon this ſalt, cauſes it to crackle and effervеſce, but without exploſion, and without flame; oxymuriatic acid gas is diſengaged. With the muriatic acid this ſalt produces effervеſcence, with the evolution of a conſiderable quantity of gas, ſimilar in colour and ſmell to oxymuriatic acid gas; but in ſome of its properties conſiderably different. This gas is more rapidly abſorbed by water. If a ſmall jar or bottle be filled with this gas, and a ſlip of paper moiſtened with ether be introduced into it, and the mouth of the jar be ſlightly covered to prevent the contact of air, an exploſion takes place, with a depoſition of charcoal. A ſimilar experiment may be made, by moiſtening a feather with oil of turpentine, and introducing it into the jar filled with this gas. It inſtantly takes fire with a red flame, and a great quantity of black ſmoke.

966 Compoſition. 7. According to the analyſis of this ſalt, as given by Fourcroy, it conſiſts of

Muriate of potaſh,	67
Oxygen,	33
	100 *.

But according to the experiments of Mr Chenevix, its conſtituent parts are,

---

* Fourcroy Connaiſs. Chim. iii. p. 226.

(x) "The acid elaſtic fluid (ſays Dr Higgins), which iſſues when two pounds of manganeſe are mixed and diſtilled with two or three of ordinary ſpirit of ſea ſalt (muriatic acid), may all, except a ſmall portion of phlogiſtic air, be condenſed in a ſolution of fixed vegetable alkali; and the ſolution, thus impregnated, yields a conſiderable quantity of nitre, which cryſtallizes in the ordinary form, and detonates on red-hot coals. The ſolution at the ſame time yields regenerated ſea-ſalt (muriate of potaſh)." *Higgins, Exper.* p. 181.

(y) In experiments with this ſalt, the quantity employed ſhould never exceed one or two grains, at leaſt by thoſe who have not been previouſly acquainted with its terrible effects.

Acid,	58.3
Potaſh,	39.2
Water,	2.5
	100.0 †.

967 Uſes. 8. This ſalt has been employed in bleaching ; but other ſubſtances, particularly lime, have been ſubſtituted for the potaſh ; ſo that at preſent it is more rarely uſed. It was propoſed by M. Berthollet, when he firſt obſerved its effects, to employ it as a ſubſtitute for nitre in the manufacture of gunpowder ; and when it was tried in the way of experiment, it ſeemed to be more powerful than the uſual component parts of powder ; but when it was attempted to be made in the large way, at Eſſone in the year 1788, a dreadful accident, which happened by the ſpontaneous exploſion of the mixture, in the death of M. le Tors, and Mademoiſelle Chevraud, prevented its effects from being fairly proved. The danger which attends the trituration of the proper materials with this ſalt, has precluded any future attempt.

7. Fluate of Potaſh.

968 Little known. This ſalt has only been examined by Scheele and Bergman. It is the combination of fluoric acid with potaſh. When the acid is ſaturated, there is formed a gelatinous maſs, which does not cryſtallize, and which has a ſlightly acrid ſaline taſte. When it is evaporated to dryneſs, and expoſed to the air, it attracts moiſture. If it be ſtrongly heated in a crucible, it fuſes without efferveſcence. It then becomes cauſtic, is very ſoluble in water, and is decompoſed by the ſulphuric and nitric acids.

8. Borate of Potaſh.

This is a compound of the boracic acid and potaſh ; but very little is known of its nature and properties. It is prepared by decompoſing nitre by means of the boracic acid with the aſſiſtance of heat. The heat drives off the nitric acid, and there remains behind a white, half-fuſed porous maſs, which is ſoluble in water and yields by evaporation and cooling, ſmall cryſtals. The ſame ſalt may be formed by direct combination of the boracic acid and potaſh. This ſalt ſeems to be analogous in many of its properties to borax.

9. Phoſphate of Potaſh.

This combination of phoſphoric acid with potaſh was announced and deſcribed by Lavoiſier in the year 1774. Its properties have been more carefully inveſtigated by Vauquelin ; but from the inveſtigation of other chemiſts it appears, that there are two ſalts formed from the ſame acid and baſe ; the one in which they are neutralized, and the other in which there is an exceſs of acid.

a. Superphoſphate of Potaſh, is formed by the direct combination of phoſphoric acid and potaſh. This ſalt does not cryſtallize, but exiſts in a gelatinous form, 969 Properties. and has a ſweetiſh ſaline taſte. Its ſpecific gravity, when dry, is 2.8516. It is very ſoluble in water ; it attracts the moiſture from the air, and becomes thick and viſcid.

970 Action of heat. 2. When heated, it undergoes the watery fuſion, then froths up, and becomes dry. When the temperature is raiſed, it melts into a tranſparent glaſs. The ſulphuric, nitric, and muriatic acids decompoſe this ſalt. It has been applied to no uſe.

b. Phoſphate of Potaſh.—This ſalt may be formed by expoſing pure potaſh and the former variety to a ſtrong heat. The alkali combines with the exceſs of acid, and neutralizes the whole. By the action of heat, a white-coloured ſubſtance is obtained, which is the phoſphate of potaſh. It is ſcarcely ſoluble in cold water, but ſoluble in hot water ; and as the ſolution cools, there is depoſited a ſhining gritty powder. This ſalt is very fuſible. Before the blow-pipe it melts into a tranſparent bead, which becomes opaque on cooling. 971 Action of heat.

972 Of acids. 2. This ſalt is ſoluble in nitric, muriatic, and phoſphoric acids, and forms with them thick glutinous ſolutions. It has not yet been applied to any uſe.

10. Phoſphite of Potaſh.

This ſalt is prepared by diſſolving carbonate of potaſh in phoſphorous acid. The ſolution is evaporated, and it depoſits cryſtals of the *phoſphite of potaſh*. It has a ſharp ſaline taſte. It is cryſtallized in four-ſided rectangular priſms with dihedral ſummits. It is very ſoluble in water, requiring only three parts of it for ſolution. It is not altered by expoſure to the air.

11. Carbonate of Potaſh.

1. This ſalt, which is a compound of carbonic acid and potaſh, has been known under a great variety of names, in ſome meaſure deſcriptive of its properties, before its compoſition was diſcovered by Dr Black.

973 Preparation. 2. This ſalt is obtained from vegetable matters by burning, and waſhing out the ſalt and evaporating it ; but the potaſh obtained in this way is not fully ſaturated with carbonic acid. After it has been purified from foreign ingredients, the ſaturated carbonate of potaſh may be prepared by expoſing a pure ſolution of potaſh to carbonic acid gas, as it is diſengaged from fermenting liquors. The carbonate of potaſh as it is formed, cryſtallizes in the ſolution. The cryſtals may be taken out and dried upon unſized paper, and put up in well-cloſed bottles. Or it may be prepared by paſſing a current of carbonic acid gas diſengaged from the carbonate of lime by an acid, into a ſolution of potaſh, in tall narrow bottles. The carbonate cryſtallizes at the ſurface of the liquid. It may alſo be obtained by the proceſs of Berthollet, which is to diſtil with an unſaturated ſolution of potaſh, ſolid carbonate of ammonia, from which the potaſh carries off the carbonic acid, while the ammonia is diſengaged in the ſtate of gas.

974 Properties. 3. The carbonate of potaſh cryſtallizes in quadrangular priſms, terminated by quadrangular pyramids. It has a ſweet alkaline taſte, and changes vegetable blues to a green colour. The carbonate of potaſh requires very near four times its weight of water to diſſolve it. At the boiling temperature it diſſolves five-ſixths of its weight. It does not cryſtallize by cooling, but only by ſlow evaporation. Pelletier has obſerved, that carbonate of potaſh diſſolved in boiling water, gives out bubbles of carbonic acid gas, which ſhews that this ſalt loſes a portion of its acid at this temperature. Its ſpecific gravity is 2.012. When it is expoſed to the air, it ſoon effloreſces. When it is

deliqueſcent,

---

† Phil. Tranſ. 1802.

deliqueſcent, it is owing to part of the potaſh being unſaturated with carbonic acid.

975 Action of heat.

4. When it is expoſed to a ſlight degree of heat, it loſes its water of cryſtallization. Part of its carbonic acid alſo ſeparates from it, but the whole cannot be driven off by this proceſs. The laſt portions adhere with a very ſtrong affinity.

976 Decompoſed by ſulphur.

5. When the carbonate of potaſh is heated with ſulphur at a high temperature, the acid eſcapes in the ſtate of gas; and there is formed a ſulphuret, at the moment of the efferveſcence produced by the extrication of the acid.

977 By all acids.

6. All the acids hitherto diſcovered, have the property of ſeparating the carbonic acid from potaſh, and of forming with its baſe particular ſalts. This ſalt loſes more than a third of its weight, by being deprived of its carbonic acid. The component parts of carbonate of potaſh are, according to,

	Bergman,	Pelletier,	Kirwan,
Carbonic acid,	20	43	43
Potaſh,	48	40	41
Water,	32	17	16
	100	100	100

978 Potaſh of commerce.

7. Potaſh of commerce is never ſaturated with carbonic acid. It is in this ſtate that the carbonate of potaſh is generally employed. It has a ſtronger alkaline taſte, and is more acrid and corroſive. It ſoon deliqueſces when expoſed to the air. It does not combine with a greater proportion of carbonic acid, merely by expoſure to the atmoſphere. For the purpoſes of the manufacturer it is of great importance to be able to aſcertain, by a ſimple teſt, the quantity of pure potaſh in the different kinds which are brought to market.

979 Teſts of its purity.

Mr Kirwan has propoſed to diſcover the proportion of the ſalt, by determining the quantity of the earth of alum which is precipitated by the potaſh. A different method has been propoſed by Vauquelin with the ſame view. His method is to ſaturate a given weight of the ſalt with nitric acid of known denſity. He has alſo made a number of experiments to diſcover the quantity of foreign ingredients in different kinds of potaſh. The following table ſhews the kinds of matter and the proportions in ſix ſpecies of potaſh *.

	Potaſh.	Sulphate of Potaſh.	Muriate of Potaſh.	Inſoluble Reſidue.	Carbonic Acid and Water.	Total.
Potaſh of Ruſſia,	772	65	5	56	254	1152
Potaſh of America,	857	154	20	2	119	1152
American pearl-aſh,	754	80	4	6	308	1152
Potaſh of Treves,	720	165	44	24	199	1152
Potaſh of Dantzic,	603	152	14	79	304	1552
Potaſh of Voſges.	444	148	510	34	304	1440

12. Arſeniate of Potaſh.

980 Preparation.

1. The compound of arſenic acid and potaſh forms a ſalt which does not cryſtallize. When evaporated to dryneſs, this ſalt deliqueſces in the air, gives a green colour to ſyrup of violets without changing the tincture of turnſole.

981 Properties.

2. When ſtrongly heated it fuſes into a white glaſs; and by the contact of ſilica and alumina in the crucible it paſſes to the acidulous ſtate, having been deprived of part of the potaſh. Expoſed to a red heat in cloſe veſſels with charcoal, the arſenic is ſublimed. It is decompoſed by the ſulphuric acid. It decompoſes ſalts which have baſes of lime and magneſia; forming in the ſolution arſeniates of lime and magneſia *.

982 With more acid cryſtallizes.

Superarſeniate of potaſh.—If the arſenic acid be added to the arſeniate of potaſh till it no longer change the colour of violets, but reddens that of turnſole, it yields regular tranſparent cryſtals in quadrangular priſms, terminated by tetrahedral pyramids. This ſalt is the *arſenical neutral ſalt* of Macquer. He obtained it by decompoſing the nitrate of potaſh, by means of the white oxide of arſenic, employing equal parts of each. It is different from the former, becauſe it cryſtallizes, reddens vegetable blues, and does not decompoſe ſalts with a baſe of lime or magneſia.

13. Tungſtate of Potaſh.

983 Preparation.

1. This compound of tungſtic acid and potaſh, is formed by diſſolving the oxide of the metal in a ſolution of pure potaſh, or its carbonate. The alkali is not fully neutralized. The ſalt precipitates from the ſolution by evaporation, in the ſtate of a white powder.

984 Properties.

2. It is diſtinguiſhed by a cauſtic metallic taſte, deliqueſces in the air, and is ſoluble in water. This ſolution in water is decompoſed by all the acids which produce a white precipitate. This precipitate is a triple ſalt, differing according to the nature of the acid which is employed †.

14. Molybdate of Potaſh.

985 Preparation.

1. The compound of molybdic acid and potaſh is formed by detonating three parts of nitre and one of

---

* Ann. de Chim. xl. 284.

* Fourcroy Connaiſs. v. 85.

† Journ. de Mines. N° 19. p. 21.

ſulphuret of molybdena in a crucible; or by combining directly the molybdic acid with potaſh. This ſalt affords ſmall irregular cryſtals, from its ſaturated ſolution in boiling water. According to Klaproth, the cryſtals are in the form of ſmall rhomboidal plates, of a ſhining appearance, and heaped together.

986 Properties. 2. The taſte is metallic. When expoſed to the blow-pipe on charcoal, they fuſe rapidly, without ſwelling up, and are converted into ſmall globules, which are abſorbed by the charcoal. In a ſilver ſpoon they are melted by the blow-pipe into ſmall gray particles, which ſhrink on cooling, and depoſit, during the proceſs, a whitiſh powder. This ſalt is completely ſoluble in diſtilled water with the aſſiſtance of heat. It has an exceſs of acid, and is therefore an acidulous molybdate of potaſh, or ſupermolybdate of potaſh. It is decompoſed by the nitric acid, which unites with the alkali, and precipitates the molybdic acid in the form of ſmall cryſtals *.

15. Chromate of Potaſh.

Nothing farther is known of the nature of this ſalt, than that it is eaſily formed by the combination of the chromic acid with potaſh, and that the cryſtals are of an orange colour, which ſufficiently diſtinguiſhes them from the cryſtals of all other ſalts.

16. Columbate of Potaſh.

Columbic acid digeſted for an hour with a ſolution of potaſh, affords this ſalt by evaporation and cooling, in the form of white glittering ſcales, reſembling the concrete boracic acid. It is not changed by expoſure to the air, has a diſagreeable acrid taſte, and is not very ſoluble in cold water; but after it is diſſolved, the ſolution is perfect and permanent. It is decompoſed by nitric acid, and precipitates in the form of white powder †.

17. Acetate of Potaſh.

1. This ſalt, which is a compound of acetic acid and potaſh, has been long known under a variety of names, which were derived from the ſubſtances from which it was obtained; or, from its properties and effects. 987 Names. It was called *regenerated tartar*, *ſecret foliated earth of tartar*, *eſſential ſalt of wine*, *digeſtive ſalt of Sylvius*, *diuretic ſalt*. 988 Preparation. It may be formed by ſaturating carbonate of potaſh with diſtilled vinegar, and by evaporating the ſolution ſlowly to dryneſs. When the heat is too great, the acid is decompoſed, and the ſalt aſſumes a brown colour.

989 Properties. 2. This ſalt has a pungent, and ſomewhat alkaline taſte. Expoſed to the air, it becomes moiſt. It is very ſoluble in water, and if the ſolution be diluted, it is ſpontaneouſly decompoſed in cloſe veſſels. Thick, mucous flakes are depoſited.

990 Action of heat. 3. When it is heated, it melts and froths up, and is then decompoſed and charred. When diſtilled in a retort, it yields an acid liquid, an empyreumatic oil, and a great deal of carbonic acid gas, and carbonated hydrogen gas. In this proceſs the acid is completely decompoſed; what remains in the retort is potaſh mixed with charcoal. According to Prouſt, this acid liquid contains ammonia and the pruſſic acid, and the carbonate and pruſſiate of potaſh are found in the retort ‡.

4. This ſalt is decompoſed by the ſtrong acids. Diſtilled with the ſulphuric acid, it yields an acetic acid which is very acrid. 991 Compoſition. The component parts of the acetate of potaſh are, according to Dr Higgins,

38.5 Acid and water,
61.5 Potaſh.
———
100.0

18. Oxalate of Potaſh.

The compound of oxalic acid and potaſh may be formed by direct combination of the acid and the alkali. The oxalic acid combines in two proportions with potaſh, either in a ſmall quantity, or in ſufficient quantity to ſaturate the potaſh. When the acid is in exceſs, it is called the *acidulous oxalate*, or *ſuperoxalate of potaſh*.

992 Preparation. 1. The oxalate of potaſh is formed by completely ſaturating the oxalic acid with potaſh; and by adding an exceſs of the alkali, cryſtals are obtained.

2. Without this exceſs of acid, the ſalt does not cryſtallize, but aſſumes a gelatinous form.

993 Properties. 3. When this ſalt cryſtallizes, it is in the form of ſix-ſided priſms, with two-ſided ſummits. It is decompoſed by heat, and alſo by the ſtrong acids, which deprive it of a portion of the potaſh, and convert it into the acidulous oxalate. With an addition of oxalic acid the acidulous oxalate is alſo formed.

994 Exiſts in plants. *Superoxalate of Potaſh.*—1. This ſalt exiſts ready formed in the *rumex acetoſa*, and the *oxalis acetoſella*; hence it has been diſtinguiſhed by the name of *ſalt of ſorrel*, becauſe it is extracted from this plant.

995 Preparation. 2. This ſalt may be formed by gradually combining potaſh with a ſaturated ſolution of oxalic acid. When a ſufficient quantity of the alkali has been added, the ſalt is precipitated in cryſtals. Scheele diſcovered that the ſalt which is extracted from theſe plants, is in this ſtate of combination. He proved the exiſtence of the acid, and he ſhewed that the natural ſalt might be imitated by this proceſs.

996 Properties. 3. The cryſtals of this ſalt are in the form of ſmall opaque parallelopipeds. The taſte is acid, pungent and bitter. It is not very ſoluble in cold water, but ſoluble in about ten times its weight of boiling water. Expoſed to the air, it undergoes no change. It is decompoſed by heat.

19. Tartrate of Potaſh.

997 Preparation. 1. This is a compound of tartaric acid and potaſh. It has been long known under the name of *ſoluble tartar*, and *vegetable ſalt*. It is formed by adding tartar or cream of tartar to a hot ſolution of carbonate of potaſh. The additions of the tartar are to be continued as long as there is any efferveſcence. The ſolution is then boiled for half an hour, filtered and evaporated, till a pellicle appears on the ſurface, and when it is allowed to cool ſlowly, it depoſits cryſtals.

998 Properties. 2. The cryſtals of this ſalt are in the form of long, rectangular priſms terminated by two-ſided ſummits. This ſalt has a bitter taſte. The ſpecific gravity is 1.5567. Expoſed to the air it is deliqueſcent. Four parts of cold water diſſolve one of the ſalt; hot water diſſolves a greater quantity. When heated, it ſwells up and blackens. By diſtillation it yields an acid liquid, ſome oil, and a great quantity of gas. It leaves behind

---

* Ann. de Chim. viii. p. 106.

† Phil. Tranſ. 1802. p. 58.

‡ Annal. de Chim. xlii. p. 132.

behind a conſiderable portion of alkali, mixed with charcoal. It is decompoſed by the ſtronger acids, which deprive it of a portion of its potaſh, and reduce it to the acidulous tartrate, which is precipitated in the ſolution. By the addition of the tartaric acid to the ſolution of this ſalt, it is alſo converted into the acidulous tartrate.

999 Tartar.

1000 Purification.

Supertartrate of Potaſh.—1. This is a compound of tartaric acid with potaſh, but with an exceſs of acid. The ſubſtance which is well known under the name of *tartar*, and which is found encruſted on the bottom and ſides of veſſels in which wine has been kept, is the ſupertartrate or the acidulous tartrate of potaſh; but in this ſtate it is very impure. It is purified by ſolution in boiling water, and by filtration while it is hot. When it cools, there is a copious depoſition of the pure ſalt in cryſtals. Theſe are the cryſtals or cream of tartar.

1001 Contains an alkali.

2. It had been long known to chemiſts, that potaſh could be obtained from tartar, by expoſing it to a ſtrong heat, which produced a controverſy whether the alkali exiſted ready formed in the tartar, or whether it was not, in ſome way or other, produced by the action of heat during the proceſs. This point was not fully ſettled till Scheele diſcovered the method of extracting the acid, the other component part of tartar.

1002 Properties.

3. The cryſtals of tartar are in the form of ſmall irregular cryſtals, but chiefly of ſix-ſided priſms. This ſalt has an unpleaſant acid taſte, is very brittle, and its ſpecific gravity is 1.953. It requires for its ſolution 30 parts of boiling water, and 60 of cold water. It undergoes no change when expoſed to the air, but in the ſolution in water the ſalt is decompoſed, depoſiting a mucous matter, and leaving behind an impure carbonate of the alkali.

1003 Action of heat.

4. Expoſed to heat, it melts, ſwells up, blackens, and the acid is totally decompoſed. When it is diſtilled, an oily matter, and an acid liquid, which is an impure acetic acid, with a great quantity of carbonic acid, are obtained. This acid was formerly called the *pyrotartarous acid* (z).

1004 Compoſition.

5. The component parts of tartar, according to Bergman, are

Acid	77
Potaſh	23
	100

Or of the ſaturated ſalt,

Tartrate of potaſh	56
Acid	44
	100

By the analyſis of Thenard, it is compoſed of

Acid	57
Potaſh	33
Water	7
	97 *

* *Ann. de Chim.* xxxviii. p. 39.

20. Citrate of Potaſh.

1005 Properties and compoſition.

This compound of citric acid with potaſh may be formed by combining together 36 parts of the acid with 61 parts of the carbonate of the alkali. This ſalt is very ſoluble in water, but little diſpoſed to cryſtallize. It is very deliqueſcent. According to the analyſis of Vauquelin, it conſiſts of

Acid,	55.55
Potaſh,	44.45
	100.00

21. Malate of Potaſh.

This ſalt, which is a compound of malic acid and potaſh, is deliqueſcent, and very ſoluble in water, but its properties are little known.

22. Gallate of Potaſh.

The compound of gallic acid and potaſh has little ſolubility in water, but its other properties are unknown.

23. Benzoate of Potaſh.

This ſalt, compoſed of benzoic acid and potaſh, cryſtallizes on cooling, into ſmall needles. A drop of the ſolution ſpread on the ſide of the veſſel, as it evaporates, exhibits an arboreſcent cryſtallization. It has a ſharp ſaline taſte, is deliqueſcent in the air, and very ſoluble in water.

24. Succinate of Potaſh.

This compound of ſuccinic acid and potaſh, forms cryſtals in three-ſided priſms; the taſte is bitter and ſaline; it deliqueſces in the air, and is very ſoluble in water.

25. Saccolate of Potaſh.

This is the compound of ſaclactic acid and potaſh. It forms ſmall cryſtals, which are ſoluble in eight times their weight of boiling water.

26. Camphorate of Potaſh.

1006 Preparation.

1. This ſalt, which is a combination of camphoric acid and potaſh, may be formed by ſaturating a ſolution of carbonate of potaſh with camphoric acid. When the efferveſcence has ceaſed, the ſolution is to be evaporated with a gentle heat, when it affords cryſtals by cooling.

1007 Properties.

2. The camphorate of potaſh is in the form of regular hexagonal cryſtals, which are white and tranſparent; the taſte is bitteriſh and ſlightly aromatic. Expoſed to the air, when it is moiſt, the ſalt loſes its tranſparency; but if the air is dry, there is no change. It is ſoluble in four parts of boiling water; but in water at the temperature of 60°, it requires 100 parts.

1008 Action of heat.

3. Expoſed to heat before the blow-pipe, it burns with

(z) The pyrotartarous acid, the pyromucous, and the pyroligneous acids were diſcovered by Fourcroy and Vauquelin to be nothing elſe than the acetic acid impregnated with extraneous ſubſtances, particularly with what is called an empyreumatic oil. See *Annales de Chimie*, xxxv. p. 161.

with a blue flame, and the potaſh remains behind pure. When the heat is ſtronger, it froths up, the acid is ſublimed, and it gives out a thick ſmoke, which is ſlightly aromatic.

1009 Of acids. 4. It is decompoſed by the mineral acids. If the ſolution be much diluted with water, the decompoſition is not perceptible; but if brought to the conſiſtence of a thick ſyrup, the camphoric acid cryſtallizes in cooling. A new ſalt alſo is partially cryſtallized. By ſolution in cold water the acid may be ſeparated.

1010 Of alcohol. 5. The camphorate of potaſh is ſoluble in alcohol, and it burns with a deep blue flame.

1011 Decompoſition. 6. It is decompoſed by, 1. Nitrate of barytes and of ſilver; 2. By all the ſalts whoſe baſe is lime; 3. Sulphate of iron; 4. Muriate of tin and of lead *.

27. Suberate of Potaſh.

1012 Preparation. 1. This ſalt, which is a compound of ſuberic acid with potaſh, is formed by ſaturating the acid with the cryſtallized carbonate of the alkali.

1013 Properties. 2. It cryſtallizes in four-ſided priſms, which have unequal ſides. The taſte is bitter and ſaline. It reddens vegetable blues, and is very ſoluble in water.

1014 Action of heat. 3. Expoſed to heat, it ſwells up and melts; the acid is diſſipated, and the potaſh remains behind. It is decompoſed by the mineral acids, which combining with the potaſh, precipitate the ſuberic acid. It is decompoſed alſo by barytes, by all the metallic ſalts, by ſulphate and phoſphate of alumina; by the nitrates and muriates of lime and of alumina †.

28. Mellate of potaſh.

The mellitic acid combines with potaſh, and forms this ſalt, which is fully ſaturated with the acid, and in this ſtate it cryſtallizes in long priſms; but with an additional portion of acid, an acidulous mellate, or ſupermellate is formed. This ſalt, as Vauquelin obſerves, alſo cryſtallizes; but the properties of theſe ſalts have not been much examined ‡.

29. Lactate of Potaſh.

This ſalt is only known as being deliqueſcent, and ſoluble in alcohol.

30. Pruſſiate of Potaſh.

The compound of pruſſic acid and potaſh, is formed by diſſolving the alkali in the acid. The ſalt is very ſoluble in water, produces a green colour on vegetable blues, and, with the application of a moderate heat, it is decompoſed.

31. Sebate of Potaſh.

This ſalt has been little examined. According to the experiments of Thenard, it has little taſte, is not affected by expoſure to the air, and is decompoſed by the ſulphuric, nitric, and muriatic acids; the ſolution, if it be concentrated, becoming ſolid on the addition of the acid from the cryſtallization of the ſebacic acid ||.

32. Urate of Potaſh.

This compound of the uric acid with potaſh, is formed by triturating the acid with the alkali. The mixture aſſumes the form of a ſaponaceous paſte, which is very ſoluble in water, when there is an exceſs of the alkali, but leſs ſo when the acid is ſaturated. This ſalt has little taſte; when neutralized is not very ſoluble in water, and ſeems little diſpoſed to cryſtallize. It is decompoſed by the muriatic acid *.

IV. Compounds of Potaſh with Inflammable Subſtances.

1015 Alcohol. 1. Potaſh is very ſoluble in alcohol. The ſolution aſſumes a red colour, and becomes acrid. It is by a ſolution of potaſh in alcohol, that the former is obtained in a ſtate of purity; for the alcohol diſſolves the potaſh, while other ſubſtances are depoſited. By the application of heat to this ſolution, there is a partial decompoſition of the alcohol.

2. Ether has no perceptible action on potaſh.

1016 Fixed oils. 3. Potaſh readily enters into combination with the fixed oils, but particularly with that claſs of them denominated *fat oils*; and forms with them very important compounds, namely, ſoaps. The compound with potaſh and the fat oils is a *ſoft* ſoap.

1017 Volatile. 4. Potaſh alſo enters into combination with the volatile oils, but in very ſmall proportion, which likewiſe forms a ſpecies of ſoap.

SECT. II. *Of* SODA *and its Combinations.*

1018 Names. 1. Soda, the other fixed alkali, has been diſtinguiſhed by a great number of different names. It was called *foſſil* or *mineral alkali*, becauſe it was ſuppoſed that it only exiſted in the mineral kingdom. It is the ſubſtance which is mentioned in ſcripture as a detergent, under the name of *nitre*.

1019 Found in the ſoil. This alkali exiſts in great abundance in different parts of the earth, and particularly on the ſurface of the ſoil in Egypt, where it is diſtinguiſhed by the name of *natron*. It is alſo found on the walls of caves and places under ground, and old edifices.

1020 Obtained from plants. But the ſoda of commerce is generally obtained from different ſpecies of plants which grow on the ſea-ſhore; and as it is prepared from them, it has received different names in different countries. The *ſalſola ſoda*, yields this alkali in greateſt abundance. This plant is called *barilla* in the Spaniſh language, and from this the ſoda which is prepared on the ſhores of that country, has been called *barilla aſhes*. For the purpoſes of commerce alſo, ſoda is prepared in great quantities from the aſhes of another tribe of marine plants, namely the *algæ*, and particularly from the *fuci*, all of which yield it in greater or leſs proportion. As it is prepared from theſe plants, it is known in France by the name of *varec*, and in Britain by the name of *kelp*. Soda exiſts in great abundance in the waters of the ocean. There it is in combination with the muriatic acid, forming the well-known compound of *common ſalt*.

1021 Firſt diſtinguiſhed from potaſh. 3. In many of their properties ſoda and potaſh approach very near to each other. They were accordingly conſidered as the ſame alkali; till, towards the middle of the 18th century, by the experiments of Duhamel, Pott, and Margraff, they were diſtinctly characteriſed, and the properties of each fully aſcertained.

1022 Purification. 4. The ſoda of commerce is in very different degrees of purity, according to the care and attention with which it is prepared, and the purpoſes for which it is intended. To have it perfectly pure, it muſt be ſubjected

---

* Ann. de Chim. xxvii. p. 24.

† Ann. de Chim. xxiii. p. 52.

‡ Ibid. xxxvi. p. 208.

|| Ibid. xxxix. p. 193.

* Fourcroy Connaiſs. Chim. x. p. 221.

jected to a ſimilar proceſs with thoſe which have been already detailed for the purification of potaſh; and by means of theſe proceſſes it may be procured in a ſolid and cryſtalline form.

1023 Properties. 5. When ſoda is in a ſtate of purity, it is uſually in the form of ſolid plates, of a grayiſh white colour, and the taſte exactly ſimilar to that of potaſh. It is alſo extremely cauſtic and corroſive. By ſlow evaporation from a ſolution in alcohol, it aſſumes the form of priſmatic cryſtals; but theſe when expoſed to the air, very ſoon effloreſce, and fall to powder. Soda changes the blue colour of vegetables to green. Its ſpecific gravity is 1.336. 1024 Action of heat. When it is expoſed to heat, it ſoftens, and readily melts. It liquefies by the action of heat like an oily matter, and when it becomes red-hot, boils, and is reduced to vapour, which is the ſoda unchanged, extremely acrid, and corroding the ſkin when it comes in contact with it.

1025 Of air and water. 6. When expoſed to the air, it firſt becomes moiſt and ſoft, by abſorbing water and carbonic acid; but when the air becomes dry, it effloreſces and falls into a powder; and in this reſpect is ſufficiently diſtinguiſhed from potaſh. Soda has a very great affinity for water. When the dry alkali is moiſtened with water, it is abſorbed, and becomes ſolid, with the extrication of caloric. When more water is added, it diſſolves, and alſo gives out heat, and a peculiar odour, which is no doubt owing to a portion of the alkali raiſed in the ſtate of vapour along with the water.

1026 A ſimple ſubſtance. 7. Soda, as well as potaſh, is to be conſidered as a ſimple ſubſtance; for no attempt which has yet been made to decompoſe it, has ſucceeded. Supported by certain analogies, Fourcroy is of opinion that ſoda is a compound of magneſia and azote; and he thinks this conjecture derives ſome degree of probability from the conſtancy with which magneſia accompanies ſoda in the waters, and different compounds, of which this alkali makes a part; eſpecially in animal matters and marine productions. 1027 Conjectures about its compoſition. Vauquelin, he obſerves, has detected magneſia in conſiderable abundance in the aſhes of the *ſalſola ſoda*; and the ſame earth is always obtained in great quantity during the proceſs for the extraction and purification of ſoda.

8. The affinities of ſoda are the ſame with thoſe of potaſh.

9. Soda is employed for many ſimilar purpoſes as potaſh. On account of ſome of its qualities, it is preferred to potaſh in many manufactures, becauſe it is leſs acrid and corroſive, and is therefore leſs apt to deſtroy the texture of animal and vegetable matters to which it is applied.

I. Action of Phoſphorus on Soda.

1028 Phoſphorus. Soda ſcarcely enters into combination with phoſphorus. There is no phoſphuret formed either by the dry or humid way; but when phoſphorus is boiled with a pure ſolution of ſoda, phoſphorated hydrogen gas is evolved in the ſame way as when it is treated with potaſh.

II. Action of Sulphur on Soda.

1029 Sulphur. Soda readily combines with ſulphur by ſimple trituration, by fuſion, and by the humid way. In the two firſt caſes, there is formed a ſulphuret of ſoda, which may be decompoſed by heat, and by the acids, and which decompoſes water in the ſame way as the ſulphuret of potaſh. By the humid way there is formed a hydrogenated ſulphuret of ſoda, which has an extremely fetid odour, and emits, by the action of the acids which decompoſe it, ſulphurated hydrogen gas.

Hydroſulphuret of Soda.

This may be prepared in the ſame way as the hydroſulphuret of potaſh. It forms a cryſtallized ſalt in the ſhape of four-ſided priſms, terminated by quadrangular pyramids. The cryſtals are colourleſs, inodorous, and very ſoluble in water. When this ſalt is expoſed to the air, it deliqueſces, and becomes of a green colour. It is decompoſed by the action of acids. Soda, it would appear, has leſs affinity for ſulphur and ſulphurated hydrogen, than potaſh.

III. Compounds of Soda with the Acids.

1. Sulphate of Soda.

1. This ſalt, which is a compound of ſulphuric acid and ſoda, is well known under the name of *Glauber's ſalt*, from the name of Glauber, a German chemiſt, who diſcovered it, in examining the reſiduum of the decompoſition of common ſalt by means of ſulphuric acid. It has alſo been called the *admirable ſalt of Glauber*, *vitriolated mineral alkali*, and *vitriol of ſoda*. 1030 Names.

1031 Preparation. 2. This ſalt may be obtained by the direct combination of ſulphuric acid and ſoda. But it is more commonly prepared by the decompoſition of muriate of ſoda or ſea ſalt, by means of ſulphuric acid. The ſolution is then to be filtered, purified and cryſtallized in the uſual way.

1032 Properties. 3. It cryſtallizes by ſlow evaporation, in tranſparent, ſix ſided priſms, terminated by two-ſided ſummits, but the cryſtals are ſeldom regular, and the ſides of the priſms are furrowed. The taſte is cool, bitter, and nauſeous. The ſpecific gravity is 1.4457 *.

1033 Action of air. 4. When it is expoſed to the air, eſpecially when the air is dry, it effloreſces, which is owing to the eſcape of the water of cryſtallization. It loſes about 0.3 of its weight. It is very ſoluble in cold water, and it requires only ⅘ths of its weight of boiling water.

1034 Of heat. 5. When it is expoſed to heat, it melts, on account of the great quantity of water of cryſtallization which it contains, and this is called the *aqueous fuſion*. Afterwards it dries, when the water is evaporated. It loſes about .58 of its weight. To melt it afterwards, it muſt be expoſed to a red-heat long continued, which is called the *igneous fuſion*. After it is cooled, it is found to have ſuffered no change. When water is added, it returns to its former ſtate.

6. It is decompoſed by means of charcoal which at a red-heat converts it into ſulphuret of ſoda, by depriving the acid of its oxygen. 1035 Compoſition. The component parts of this ſalt, according to Bergman, are

Acid	27
Soda	15
Water	58
	100

But

---

* *Ann. de Chim.* xxviii. p. 12.

But according to Mr Kirwan, it is compoſed of

	Cryſtallized.	Dried at 700°.
Acid	23.52	56
Soda	18.48	44
Water	58	0
	100.00	100 [*]

It is decompoſed by barytes; and by potaſh, but leſs powerfully. Lime and ſtrontites are alſo capable of producing a partial decompoſition in the humid way, and in contact with the air.

7. This ſalt is a good deal employed in medicine, as a purgative; in chemiſtry, for the purpoſe of decompoſing other ſubſtances; and in the arts, for the extraction of ſoda.

2. Sulphite of Soda.

1036 Diſcovery. 1. This ſalt, which is a compound of ſulphurous acid and ſoda, was firſt taken notice of by Berthollet. It is prepared by paſſing ſulphurous acid gas into a ſaturated ſolution of carbonate of ſoda. The ſulphite of ſoda is precipitated at firſt, in a confuſed maſs of very ſmall cryſtals, which are re-diſſolved in warm water, and cryſtallize again on cooling.

1037 Properties. 2. The cryſtals of ſulphite of ſoda are in four-ſided priſms, two broad, and two narrow, terminated by two-ſided ſummits. They are perfectly tranſparent. The taſte is cool and ſulphureous. The ſpecific gravity is 2.9566.

1038 Action of the air. 3. Expoſed to the air, it effloreſces, and the powder formed on the ſurface is converted into a ſulphate. It is extremely ſoluble in water. Boiling water takes up more than its own weight. 1039 Of water. It cryſtallizes again on cooling, but ſometimes the ſolution is formed into a ſingle maſs when it is expoſed to the air; and if quickly cooled with agitation, it affords nothing but needle-formed cryſtals. This ſolution expoſed to the air is converted into the ſulphate.

1040 Of heat. 4. This ſalt readily undergoes the aqueous fuſion; if the heat be increaſed, a portion of ſulphur is driven off, and it is converted into a ſulphate.

5. It is decompoſed by means of the acids, which diſengage the ſulphurous acid in the ſtate of gas. The oxymuriatic acid gas brought into contact with a ſolution of this ſalt in water, inſtantly converts it into ſulphate. It is decompoſed by barytes, lime and potaſh; by the ſulphates of lime, of ammonia, and of magneſia.

1041 Compoſition. 6. The component parts of this ſalt have been found by analyſis to be,

Sulphurous acid	31
Soda	18
Water	51
	100

It has not been applied to any uſe.

3. Nitrate of Soda.

1042 Names. 1. This compound of nitric acid and ſoda was formerly known by the name of *cubic nitre*, and *rhomboidal nitre*. It is prepared by the direct combination of the acid with the alkali; or by decompoſing the muriate or carbonate of ſoda by nitric acid.

1043 Properties. 2. It cryſtallizes in the form of rhomboids and priſms. The taſte is cooling, but more bitter than that of the nitrate of potaſh.

3. The ſpecific gravity is 2.0964. Expoſed to the air, it attracts moiſture in a ſlight degree. It is ſoluble in three parts of cold water, and in leſs than its own weight of boiling water.

1044 Heat. 4. When it is thrown on red-hot coals, it decrepitates ſlightly; it is not ſo fuſible as nitre, but it is alſo decompoſed, and gives out oxygen gas mixed with azotic gas.

5. In its decompoſitions it is ſimilar to the nitrate of potaſh. It detonates, however, leſs powerfully with combuſtible bodies, and burns them with leſs facility. It is decompoſed by barytes and potaſh.

1045 Compoſition. 6. The proportions of its conſtituent parts are, according to Bergman,

Acid	43
Soda	32
Water	25
	100

According to Mr Kirwan,

	Dried in a heat of 400°.	After being ignited.
Acid	53.21	57.55
Soda	40.58	42.34
Water	6.21	00.00
	100.00	99.89 [†].

4. Nitrite of Soda.

Chemiſts are not acquainted with the properties of this ſalt, although it is known to be formed after the partial decompoſition of nitrate of ſoda by means of heat.

5. Muriate of Soda.

1046 Common ſalt. 1. The muriate of ſoda, which is a compound of muriatic acid and ſoda, of all the other ſalts, from its great abundance in nature, and its valuable uſes, was the earlieſt known under the name of *ſalt*. 1047 Names. It has been diſtinguiſhed by the names of *common ſalt*, *kitchen ſalt*, *ſea-ſalt*, and ſometimes *ſal gem*, or *rock ſalt*.

1048 Abundant in nature. 2. This ſalt, which is found in ſuch abundance in nature, is never formed by art. In ſome parts of the world it exiſts in the bowels of the earth in large maſſes, from whence it is dug out, and ſimply reduced to powder, to be applied to uſe. But to obtain it from the waters of the ocean, in which it exiſts in different proportion, according to the temperature, the climate, and other circumſtances, it muſt be extracted by evaporation, which is effected by different proceſſes, according to the ſtrength of the ſolution, and the art of the manufacturer. In ſome parts of the world, all that is done is to collect the ſalt as it forms on the ſhores of the ſea, or on the rocks, by the evaporation of the water; but, in general, ſome art is neceſſary, even when the ſalt is obtained by ſpontaneous evaporation. On the coaſts of France, Spain, Portugal, and the ſhores of the Mediterranean, the ſea water is admitted into ponds during the flowing of the tide, and its return is prevented by ſluices, which are ſhut. It is then evaporated by the heat of the ſun; and, as this evaporation is gradual and ſlow, the ſalt cryſtallizes in large cubes, and it is known in commerce by the name of

---

[*] *Nichol. Jour.* iii. p. 215.

[*] *Nichol. Jour.* iii. p. 215.

bay ſalt, from the circumſtance of its having been formed in creeks and bays of the ſea.

1049 By art.

3. But as this proceſs can only be followed in thoſe climates where there is a ſufficient degree of temperature to promote the evaporation ſpeedily; artificial heat is generally employed in the manufacture of ſalt. Sometimes the water is received in large ponds or flat veſſels, where it is allowed to evaporate for ſome time in the open air. It is afterwards boiled in flat iron pans; and, during the boiling, the impurities which riſe to the ſurface are removed. When the water is ſufficiently concentrated by the evaporation, a pellicle forms on the ſurface, which is the cryſtallization of the ſalt. This falls to the bottom, and another pellicle forms, till the whole of the ſalt is cryſtallized. The purity of the ſalt and the ſize of the cryſtals depend on the ſlow evaporation; and hence it is, that the pureſt ſalt, as it is manufactured it Britain, is that which is called *Sunday ſalt*. This is obtained from the laſt quantity of water, which is boiled on the Saturday night; and, as it has time to cool ſlowly, the evaporation is more gradual, and the cryſtals are purer and larger.

1050 Purification.

4. But in this ſtate the muriate of ſoda is far from being pure. A very ingenious method has been propoſed for the purification of ſea ſalt by Lord Dundonald. The ſalts with which common ſalt is impregnated, are more ſoluble in water than the ſalt itſelf, and they diſſolve in much greater proportion in hot than in cold water. But common ſalt is nearly equally ſoluble in both. On this principle, therefore, the proceſs proceeds: A quantity of ſalt to be purified is put into a conical veſſel or baſket, which is ſlightly ſtopped at the apex, ſo that the water may paſs through. A ſaturated ſolution of common ſalt is then prepared. This ſolution of ſalt is poured boiling hot over the ſalt in the baſket. It can diſſolve none of the common ſalt in the baſket, becauſe it is already ſaturated; but, as it paſſes through, it diſſolves the other ſalts, and carries them along with it. It was found by experiment, that a ſaturated ſolution of 1lb. of common ſalt poured upon 10lbs. removes about ⅘ of all the foreign ſalts with which it is impregnated.

1051 By other proceſſes.

5. But, even after this proceſs, the ſalt is not perfectly pure for the purpoſes of chemiſtry. For this purpoſe it may be diſſolved in four parts of cold water. Filter the ſolution, to ſeparate any ſubſtances with which it is mixed. Pour into it ſome drops of a ſolution of ſoda, till no farther precipitate is obſerved. The fluid is then to be evaporated, and the ſalt, as it forms on the ſurface in ſmall cubical cryſtals, may be extracted; or it may be obtained in larger cryſtals by ſlow evaporation.

It may alſo be purified, by dropping into a ſolution of common ſalt, a ſolution of muriate of barytes, and then of carbonate of ſoda, as long as any precipitate is formed. The liquid may then be filtered and evaporated, till the ſolution cryſtallizes.

1052 Properties.

6. The muriate of ſoda cryſtallizes in perfect cubes; but from theſe there are ſeveral deviations in the form of its cryſtals. Sometimes the angles of the cubes are truncated; ſometimes they are in the form of octahedrons; which is the caſe when common ſalt is diſſolved in human urine, and allowed to evaporate ſpontaneouſly. But the primitive form of the cryſtal, as well as of the integrant particle, according to Hauy, is the cube. The taſte is ſweetiſh and agreeable, and is that which is properly called *ſalt*, with which all ſimilar taſtes are compared. The ſpecific gravity is 2.120.

1053 Action of air,

7. It undergoes no change by expoſure to the air. Common ſalt attracts moiſture from the atmoſphere; but this is owing to an impregnation of other ſalts which are deliqueſcent. Theſe ſalts are muriate of magneſia, ſulphate of magneſia, and ſulphate of lime. It is from theſe that it is to be purified by the proceſſes, which have been deſcribed above. It is ſoluble in little more than 2½ times its weight of water; and it is almoſt equally ſoluble in hot and cold water.

1054 and water.

8. When it is expoſed to a ſtrong heat, it decrepitates and gives out its water of cryſtallization. It melts in a red heat, and riſes in the air in the ſtate of white vapour; but it is unchanged; for if this vapour be collected by condenſing it in the cold, it is found to poſſeſs all the properties of common ſalt.

1055 Decompoſition.

9. The muriate of ſoda is decompoſed readily by ſulphuric acid, as well as by ſeveral other acids which have a ſtronger attraction for its baſe than the muriatic acid; or by the aid of double affinity, when an acid is in combination with a baſe, which at the ſame time acts on the muriatic acid. It is by means of the ſulphuric acid that the chemiſt procures muriatic acid from the muriate of ſoda. Sometimes the ſalt is decompoſed by the ſame acid to obtain the ſoda. The ſulphuric acid combines with the ſoda, and forms ſulphate of ſoda, while the muriatic acid is diſengaged, and that it may not be loſt, it is conveyed into a leaden chamber, which contains a ſolution of ammoniac, where it forms ſal ammoniac. The ſulphate of ſoda is expoſed to ſtrong heat in a furnace, to drain off any portion of ſulphuric acid that it may contain. It is then mixed with its own weight of chalk, and half its weight of charcoal in powder. The mixture is ſtrongly heated in a reverberatory furnace, and occaſionally ſtirred to permit the eſcape of gas and ſulphur which fly off. When the maſs cools, it becomes ſolid and black. The charcoal in decompoſing the ſulphuric acid of the ſulphate of ſoda, ſets the ſulphur free, which combines with the lime of the carbonate of lime, and is partly ſublimed; while a part of the carbonic acid combines with the ſoda; ſo that the product is a mixture of carbonate of ſoda, of lime and charcoal, analogous to the ſoda of commerce. In this way 0.58 of crude ſoda may be extracted. Other acids, as well as the ſulphuric, ſuch as the acetic, the phoſphoric, and boracic, have been propoſed to be employed with the ſame view; or indeed, any acid which has a ſtronger affinity for the ſoda than the muriatic acid, and is not decompoſed with much difficulty.

1056 By ſulphuric acid.

10. But theſe proceſſes are not ſufficiently economical to anſwer the purpoſes of the manufacturer: Other proceſſes have, therefore, been propoſed and tried with the ſame view; but ſcarcely any has ſucceeded. This ſalt is very readily decompoſed by barytes and potaſh, which combines with the muriatic acid, and ſets the ſoda free; but the expence of preparing theſe ſubſtances far exceeds the price of the ſoda in the market, ſo that they cannot be employed to advantage.

1057 By lime.

It has been propoſed to decompoſe ſea ſalt by means of lime, for obtaining the ſoda. Soda is ſeparated from

from the acid by mixing the common ſalt with lime, in the form of paſte, and by expoſing it to moiſture. In a ſhort time the ſoda appears on the ſurface in the ſtate of effloreſcence. Scheele, it is obſerved by Berthollet, was the firſt who noticed the decompoſition of the muriate of ſoda by means of lime. He explains this decompoſition by ſhowing, that lime acts on ſalts with fixed alkaline baſes. It decompoſes a ſmall part of the muriate of ſoda, with which it is in contact, and the ſoda eliminated by this means, combines with the carbonic acid of the atmoſphere. The carbonate of ſoda effloreſces, ſo that it oppoſes all reſiſtance to the action of the lime, and the decompoſition of the muriate of ſoda continues until it is impeded by the quantity of muriate of lime formed. It is in this way that the ſame philoſopher accounts for the formation of ſoda in the ſoil of Egypt. The circumſtances neceſſary for this are, 1ſt, A ſand containing a great quantity of carbonate of lime; 2d, moiſture; and 3d, muriate of ſoda: and theſe circumſtances are found to exiſt in thoſe places where there is an abundant production of ſoda *. A manufactory for the purpoſe of extracting ſoda from ſea ſalt, by means of lime, was eſtabliſhed in France by Guyton.

1058 By lead. 11. Common ſalt is decompoſed for the purpoſe of obtaining the ſoda, by means of litharge. In a mixture of four parts of litharge, and one of ſea ſalt, with a little water, in the courſe of a few hours, a decompoſition of the ſalt is effected. The muriatic acid of the ſalt combines with the lead, and is precipitated; while the ſoda remains in the ſolution, from which it may be ſeparated by filtration and evaporation.

1059 By iron. It has been found too, that ſea ſalt may be decompoſed by other metallic ſubſtances. Scheele obſerved, that iron produced this effect. By dipping a plate of iron in a ſolution of ſalt, and expoſing it in a moiſt place, it was incruſted with ſoda. From other experiments it appears, that this decompoſition may be effected by means of copper and zinc.

1060 Compoſition. 12. Muriate of ſoda, according to Bergman, is compoſed of

Acid	52
Soda	42
Water	6
	100

According to Kirwan, when dried in the temperature of 80°, it is compoſed of

Acid	38.88
Soda	53.00
Water	8.12
	100.00

1061 Uſes. 13. Common ſalt may be regarded almoſt as a neceſſary of life. It is the moſt uſeful of all ſubſtances for the preſervation of animal matters which are intended for food. It is probable that it is highly uſeful, not merely as a ſeaſoning for food, of which it is one of the moſt agreeable, but alſo to promote its digeſtion. It is alſo employed in many arts, as in metallurgy, in dyeing, and in the enamelling of ſtoneware.

6. Hyperoxymuriate of Soda.

1062 Preparation. 1. This ſalt is prepared in the ſame manner as the combination of this acid with potaſh. It is, however, difficult to obtain it pure, as it has nearly the ſame degree of ſolubility in water as the muriate of ſoda. It is ſoluble in three parts of cold and leſs of warm water. It is alſo ſoluble in alcohol, and it ſeems to communicate a greater degree of ſolubility to the muriate of ſoda.

1063 Properties. 2. The cryſtals of this ſalt are in the form of cubes, or in rhomboids. It produces the ſenſation of cold in the mouth, and its taſte is eaſily diſtinguiſhed from muriate of ſoda. It is decompoſed by heat, by combuſtible bodies, and by acids, in the ſame manner as the hyperoxymuriate of potaſh.

1064 Compoſition. 3. This ſalt is compoſed of

Hyperoxymuriatic acid	66.2
Soda	29.6
Water	4.2
	100.0 *

7. Fluate of Soda.

1065 Preparation. 1. This ſalt, which is a compound of fluoric acid and ſoda, is formed by ſaturating the acid with the alkali. If the ſolution be evaporated till a pellicle appears, cryſtals of fluate of ſoda are obtained.

1066 Properties. 2. Theſe cryſtals are in the form of ſmall cubes, have a bitter and aſtringent taſte, are not deliqueſcent, and not very ſoluble in water. They decrepitate on hot charcoal, and melt before the blow-pipe into a ſemitranſparent globule.

3. The concentrated acids diſengage the fluoric acid with efferveſcence. This ſalt is alſo decompoſed by limewater, barytes, and magneſia.

8. Borate of Soda.

1. This ſalt, a compound of the boracic acid and ſoda, is formed by ſaturating the acid with the alkali; but nothing is known of its nature and properties. The ſpecific gravity is 1.1351. But the combination of ſoda with this acid, which is a natural production, has been particularly examined.

Sub-borate of Soda, or Borax.

1067 Hiſtory. 1. This ſubſtance has been long known. Indeed it is ſuppoſed, that the ancients were acquainted with it, and that they employed it for ſeveral purpoſes, under the name of *chryſocolla* which is mentioned by Pliny. It received this name from them, it is ſuppoſed, from knowing its property of ſoldering gold and the other metals. The name borax is derived from ſome of the oriental languages. Although borax was the ſubject of reſearch among the alchemiſts and earlier chemiſts, yet nothing was known of its nature and compoſition, till the beginning of the 18th century. It was then decompoſed by Homberg, by expoſing it to heat with ſulphate of iron. The acid was ſeparated by ſublimation, and long after known by the name of the *ſedative ſalt of Homberg*. In 1732 its real compoſition was diſcovered by Geoffroy. He obtained the acid cryſtallized in the humid way. In 1748 Baron decompoſed

---

* *Reſearches*, p. 59, and 112.

* *Phil. Tranſ.* 1802, p. 144.

poſed borax by means of the vegetable acids, and he completed the knowledge of its compoſition, by forming it with the acid and the alkali. Bergman afterwards ſhewed, that borax is a ſalt with exceſs of ſoda; and to be neutralized, it requires one half of its weight of boracic acid.

2. Borax is a natural production of the earth in many parts of the world. It is formed at the bottom of ſome lakes in Perſia, the Mogul territory, in Thibet, in China and Japan. It has been alſo found in ſome lakes in Tuſcany. In the Eaſt Indies it is known under the name of *tincal*, and in commerce under that of *crude borax*. In this ſtate the borax is in the form of ſmall, ſemitranſparent, greeniſh cryſtals, intermixed with a greaſy matter, of a dirty grey colour, and of a ſweetiſh alkaline taſte.

1068 Purification. 3. The purification of borax was originally in the hands of the Venetians; but it has ſince been practiſed, and now almoſt excluſively, by the Dutch. Their proceſs is not exactly known. Valmont-Bomare, who viſited one of theſe places in Holland, ſays, that 80 parts of purified borax are obtained from 100 of the crude materials; that to extract the ſalt completely, from eight to twelve ſolutions and cryſtallizations are neceſſary; that all the veſſels employed in the purification of this ſalt, are either of lead, or covered with lead: but he adds, that one part of the proceſs was concealed from him, and he ſuſpects that lime water may have been employed in this part of the proceſs.

1069 Properties. 4. Borax, after being thus purified, is in the form of compreſſed ſix-ſided priſms with three-ſided ſummits. The taſte is ſweetiſh, and perceptibly alkaline. It changes the vegetable blues to a green colour. The ſpecific gravity is 1.742. It effloreſces ſlightly in the air, and is ſoluble in water. Twelve parts of water at the temperature of 60° diſſolve one of borax. Six parts are only neceſſary at the boiling temperature.

1070 Action of heat. 5. When borax is expoſed to heat, it readily melts. As the water of cryſtallization flies off, it ſwells up and acquires a greater bulk, and aſſumes the form of a porous maſs. By this proceſs it loſes more than one-third of its weight, and in this ſtate it is called *calcined borax*. When it is expoſed to a red-heat, it is converted into a tranſparent glaſs, which is ſoluble in water.

1071 Of acids. 6. Borax is decompoſed by all the acids which have a ſtronger affinity for the ſoda. It is by means of the ſulphuric and the nitric acids, that boracic acid is obtained from borax.

1072 Compoſition. 7. The component parts of borax, according to Kirwan, are

Boracic acid	36
Soda	17
Water	47
	100

It is ſuppoſed that only five parts of the ſoda are ſaturated with the acid, and that the other twelve parts form the exceſs of alkali which is contained in the ſalt.

1073 Uſes. 8. Borax is much employed in the arts, as a flux for metals, and to promote the ſoldering of the more precious metals. It is alſo employed by the mineralogiſt as a flux for treating minerals by the blow-pipe. Calcined borax is employed in medicine as an abſorbent *.

9. Phoſphate of Soda.

1074 Hiſtory. 1. This compound of phoſphoric acid and ſoda, was the firſt diſcovered of the combinations of phoſphoric acid. Margraaff was the firſt who extracted it from human urine, then in combination with ammonia, forming a triple ſalt, which was known by the name of *fuſible* or *microcoſmic ſalt*. Haupt afterwards obtained it ſeparate, and diſtinguiſhed it by the name of *ſal mirabile perlatum*, or wonderful perlated ſalt, on account of its pearl-like colour. At laſt the younger Rouelle diſcovered that ſoda was one of its conſtituent parts. By ſome it was ſuppoſed, that the acid was different from the phoſphoric, becauſe no phoſphorus could be obtained from it. To this acid Bergman gave the name of perlated acid; but by the analyſis of Klaproth, it was proved that this ſalt conſiſts of phoſphoric acid and ſoda, with an exceſs of acid.

1075 Preparation. 2. This ſalt is prepared by ſaturating the liquid acid phoſphate, which is obtained from burnt bones by means of the ſulphuric acid, with carbonate of ſoda, which muſt be added in exceſs. The carbonate and a little phoſphate of lime are precipitated in the ſolution, which muſt be filtered and evaporated till a thin pellicle appears on the ſurface. The phoſphate of ſoda is cryſtallized by cooling. Or it may be obtained by the direct combination of phoſphoric acid and ſoda, which muſt alſo be added in exceſs.

1076 Properties. 3. The phoſphate of ſoda cryſtallizes in lengthened rhomboids whoſe angles are often truncated, and ſometimes it affords rhomboidal priſms, and ſeveral other varieties. The exceſs of ſoda is neceſſary, to make it aſſume a regular form, and thus it changes vegetable blues to green. The ſpecific gravity is 1.33. It has a ſweetiſh, ſaline taſte, ſimilar to that of common ſalt.

1077 Action of water. 4. It effloreſces in the air, and is very ſoluble in water. Four parts of water at the temperature of 60°, and one half its weight of boiling water, are ſufficient to diſſolve it.

1078 Of heat. 5. The phoſphate of ſoda expoſed to heat, undergoes the watery fuſion. In a red heat it melts, and is converted on cooling, into a milky white glaſs. By the action of the blow-pipe on charcoal, it melts into a globule which is tranſparent while it is hot, but becomes opaque on cooling, and aſſumes the polyhedral form when it becomes ſolid.

1079 Of acids. 6. The ſulphuric, nitric, and muriatic acids decompoſe it partially, and convert it into the acidulous phoſphate of ſoda.

1080 Uſes. 7. Since the properties of this ſalt were diſcovered, it has become an object of conſiderable importance, on account of the various uſes to which it has been applied. It was introduced into medicine by Dr Pearſon, and is found to be a mild laxative, particularly agreeable on account of its taſte, as it may be taken in broth, as a ſubſtitute for common ſalt. It is employed by mineralogiſts as a teſt for the fuſion of mineral ſubſtances by the blow-pipe, and in ſoldering, as a cheap ſubſtitute for borax.

10. Phoſphite of Soda.

1081 Preparation. 1. This compound of phoſphorous acid and ſoda, may be formed by the direct union of the acid and

---

* *Fourcroy Connaiſs. Chim.* iii. p. 325.

alkali in ſolution ; and by evaporation cryſtals may be obtained.

1082 Properties. 2. This ſalt cryſtallizes ſometimes in four-ſided priſms with unequal faces ; ſometimes in long rhomboids, or in the form of feathers. The taſte is cool and ſweetiſh. It effloreſces in the air, and is ſoluble in two parts of cold water, and little more ſoluble in warm water ; ſo that it cryſtallizes by evaporation rather than in cooling.

1083 Action of heat. 3. It melts readily under the blow-pipe, gives out fine phoſphoric light, and is converted into a glaſs which continues tranſparent while it is hot, but becomes opaque when it cools.

1084 Compoſition. 4. The component parts of this ſalt are,

Phoſphorous acid	16.3
Soda	23.7
Water	60.0
	100.0

5. This ſalt is eaſily decompoſed by lime, barytes, and magneſia. It decompoſes the ſulphates, nitrates, and muriates of lime, of barytes, ſtrontites, and magneſia. It has not yet been applied to any uſe.

11. Carbonate of Soda.

1085 Hiſtory. 1. This ſalt, which is a compound of carbonic acid and ſoda, was long applied to various uſes, before its nature and compoſition were known ; nor was it perfectly underſtood till the diſcovery of Dr Black, which ſhewed the two ſtates in which the alkali exiſts ; in the cauſtic or pure ſtate, and in the mild ſtate, when it is combined with fixed air, or carbonic acid. The different names under which it is known, have been already mentioned in treating of ſoda. It is found in great abundance in Egypt, where it effloreſces on the ſoil, and is diſtinguiſhed by the name of *natron*. In a ſimilar ſtate of effloreſcence, the carbonate of ſoda is found in ſubterraneous places, and the walls of buildings ; but it is chiefly extracted, as has been already obſerved, from ſea plants, eſpecially from thoſe which belong to the genus of *fuci*.

1086 Preparation. 2. Carbonate of ſoda may be obtained by diſſolving a quantity of the ſoda of commerce with three or four times its weight of pure cold water, and then by filtering the liquor, and evaporating till a ſlight pellicle is formed. This pellicle, which conſiſts of ſmall cubes of common ſalt, is to be removed. The heat is to be continued as long as any pellicle is formed, after which the liquid is ſet by to cool, and the carbonate of ſoda cryſtallizes.

1087 Properties. 3. The form of the cryſtals of carbonate of ſoda are irregular or rhomboidal octahedrons, formed by two quadrangular pyramids, truncated near the baſe, which exhibits dicahedral ſolids, with two acute and two obtuſe angles. The taſte is ſlightly acrid ; it converts vegetable blues to a green colour, and its ſpecific gravity is 1.3591.

1088 Action of water. 4. The carbonate of ſoda effloreſces very rapidly in the air. It is ſoluble in two parts of cold, and little more than its weight of boiling water. It cryſtallizes on cooling ; but to obtain regular cryſtals, the evaporation muſt be ſlow and ſpontaneous.

1089 Of heat. 5. When expoſed to heat, it undergoes the watery fuſion, and if the heat be continued, it paſſes into the igneous fuſion. It is ſomewhat more fuſible than the carbonate of potaſh, which renders it preferable in the manufacture of glaſs.

6. In its decompoſition by other ſubſtances, it is exactly ſimilar to the carbonate of potaſh.

1090 Compoſition. 7. The component parts of carbonate of ſoda are according to

	Bergman.	Kirwan.	
		In cryſtals.	Dry.
Carbonic acid	16	14.42	40.05
Soda	20	21.58	59.86
Water	64	64.00	00.00
	100	100.00	99.91

12. Arſeniate of Soda.

1. This is the compound of the arſenic acid with ſoda ; and when the acid is ſaturated with the alkali, the ſalt cryſtallizes.

2. According to Scheele the form of the cryſtals of this ſalt is like thoſe of the acidulous arſeniate of potaſh. Pelletier obſerves that the arſeniate of ſoda cryſtallizes in ſix-ſided priſms, terminated by planes perpendicular to their axis. In other reſpects it is ſimilar to the arſeniate of potaſh, being decompoſed by charcoal, by the acids and the earths. With an exceſs of acid, it does not cryſtallize, but becomes deliqueſcent.

13. Tungſtate of Soda.

1091 Preparation. 1. This ſalt, which is the compound of tungſtic acid and ſoda, may be formed by diſſolving the oxide of tungſten in a ſolution of pure ſoda, or carbonate of ſoda. By evaporating the ſolution, cryſtals of tungſtate of ſoda are obtained.

1092 Properties. 2. The cryſtals of this ſalt are in the form of elongated, ſix-ſided plates. The taſte is acrid and metallic. It is ſoluble in four times its weight of cold water ; and boiling water diſſolves one half of its weight. It reſtores the colour of turnſole which has been reddened by an acid.

1093 Action of acids. 3. This ſalt is decompoſed by the ſulphuric, nitric, muriatic, acetic, and oxalic acids. They form a white triple ſalt, which is alſo produced by lime water. The phoſphoric acid produces no change, and if the ſulphuric acid be afterwards added, it no longer cauſes a precipitate. The tungſtate of ſoda is not decompoſed by the ſulphate of potaſh or of magneſia. The muriates of lime and barytes occaſion a white precipitate. The ſolution of tin, and all other metallic ſolutions, alſo decompoſe it *.

14. Molybdate of Soda ?

15. Chromate of Soda.

The chromic acid combines with ſoda, and forms a ſalt, the cryſtals of which are of an orange colour, but its other properties are unknown.

16. Columbate of Soda.

Columbic acid enters into combination with ſoda, but little is known of its properties.

17. Acetate of Soda.

1094 Preparation. 1. The combination of the acetic acid with ſoda was formerly

---

* *Jour. de Mines*, No 19. p. 21.

formerly known by the name of *cryſtallized foliated earth*. This ſalt is prepared by ſaturating the acetic acid with carbonate of ſoda. The ſolution is then filtered, and evaporated till a ſlight pellicle appear on the ſurface; and when it is ſet by to cool, cryſtals are depoſited.

1095 Properties.

2. The cryſtals of acetate of ſoda are in the form of ſtriated priſms, like thoſe of ſulphate of ſoda. It has a bitter, pungent taſte, is not deliqueſcent in the air, and is ſoluble in about three parts of cold water. The ſpecific gravity is 2.1. When expoſed to heat it is decompoſed, being firſt deprived of its water of cryſtallization. After diſtillation, the reſiduum has the property of phoſphorus. It is decompoſed by barytes and potaſh *.

18. Oxalate of Soda.

The oxalic acid is capable of forming an acidulous ſalt with ſoda; but when it is fully ſaturated, the oxalate of ſoda thus formed, is difficult of cryſtallization. If two parts of cryſtallized carbonate of ſoda are diſſolved in one part of oxalic acid, part of the oxalate of ſoda is precipitated, and what remains in the ſolution, being evaporated, affords cryſtals in the form of ſmall grains. This ſalt is more ſoluble in warm than in cold water, and gives a green colour to the ſyrup of violets. It is decompoſed by potaſh. In other reſpects it reſembles the oxalate of potaſh.

19. Tartrate of Soda.

This compound of tartaric acid and ſoda, is formed by ſaturating the acid with the alkali. The form of the cryſtals of this ſalt is that of fine needles. The ſpecific gravity is 1.7437. This ſalt combines with another portion of acid, and forms an acidulous tartrate or ſupertartrate of ſoda, which is not more ſoluble in water than the acidulous tartrate of potaſh.

20. Citrate of Soda.

1. This ſalt, which is a compound of citric acid and ſoda, is formed by directly combining the acid and alkali.

2. It cryſtallizes in ſix-ſided priſms which are not terminated by a pyramid. It has a ſaline taſte, effloreſces in the air, and is ſoluble in two parts of water. When heated it boils up, ſwells, and is charred. It is decompoſed by barytes and lime water. It is compoſed of

Acid	60.7
Soda	39.3
	100.0

21. Malate of Soda.

This ſalt, formed of malic acid and ſoda, is deliqueſcent in the air, and very ſoluble in water. Its other properties are unknown.

22. Gallate of Soda.

The nature of the compound of gallic acid with ſoda has not yet been aſcertained. A green colour is produced, when the alkali is dropt into the acid.

23. Benzoate of Soda.

The compound of benzoic acid with ſoda, forms a ſalt which readily cryſtallizes. It is deliqueſcent in the air, and very ſoluble in water. The taſte is ſharp and ſaline. This ſalt exiſts ready formed in the urine of graminivorous animals.

24. Succinate of Soda.

The combination of ſuccinic acid with ſoda, forms beautiful tranſparent cryſtals by ſpontaneous evaporation. The cryſtals are in the form of four-ſided priſms with two-ſided ſummits. The taſte of this ſalt is bitter. It is not deliqueſcent in the air, and it requires about three times its weight of water to diſſolve it. It is decompoſed when it is expoſed to heat in cloſe veſſels.

25. Saccolate of Soda.

All that is known of this ſalt is, that it cryſtallizes in ſmall cryſtals, and is ſoluble in five times its weight of boiling water.

26. Camphorate of Soda.

1. This compound of camphoric acid with ſoda is formed by ſaturating a ſolution of carbonate of ſoda in water with the acid; and by evaporation with a gentle heat, the cryſtals are obtained, when the ſolution cools.

2. The cryſtals of camphorate of ſoda are irregular. They are white and tranſparent. The taſte is bitter. Expoſed to the air, this ſalt effloreſces. It is ſoluble in eight parts of boiling water.

3. Expoſed to heat, it melts and ſwells, and the acid is diſſipated in thick vapours of an aromatic odour. With the blow-pipe it burns with a blue flame, and is decompoſed. The acid is ſublimed, and the alkali remains behind. It is decompoſed by potaſh, and by the ſtrong acids *.

27. Suberate of Soda.

The compound of ſuberic acid with ſoda, forms a ſalt which does not cryſtallize. It has a ſlightly bitter taſte, and reddens the tincture of turnſole. It deliqueſces in the air, and is very ſoluble in water. Expoſed to heat, it ſwells and melts; the acid is ſublimed, and the alkali remains behind. The mineral acids decompoſe it, and it is alſo decompoſed by the calcareous, aluminous and magneſian ſalts †.

28. Mellate of Soda.

The compound of mellitic acid with ſoda, when it is ſaturated, forms cryſtals in cubes or three-ſided tables. Sometimes they are formed in groups, and ſometimes they are inſulated.

29. Lactate of Soda.

All that is known of this ſalt is, that it does not cryſtallize, but is ſoluble in alcohol.

30. Pruſſiate of Soda.

This ſalt, which is a compound of pruſſic acid and ſoda, is very ſoluble in water, converts vegetable blues to green, and when it is expoſed to a very moderate heat, it is partially decompoſed.

---

* *Fourcroy Connaiſs. Chim.* viii. p. 198.

* *Ann. de Chim.* xxvii. p. 28.

† *Ibid.* xxiii. p. 53.

31. Sebate of Soda.

Nothing farther is known of the compound of ſebacic acid with ſoda, than that it is ſoluble in water.

IV. Compounds of Soda with Inflammable Subſtances.

1. Soda enters into combination with alcohol, and forms a reddiſh coloured acrid ſolution; but when heat is applied to this ſolution, it appears that the alcohol is partially decompoſed.

2. There is no action between ether and ſoda.

3. Soda readily combines with the fixed oils, and eſpecially that claſs of them called *fat oils*, and forms with them compounds called ſoaps.

4. Soda combines in very ſmall quantity with the volatile oils, and the compounds thus formed have ſome of the properties of ſoap.

Sect. III. *Of Ammonia and its Combinations.*

1096 Hiſtory. 1. This ſubſtance has been long known under the names of *volatile alkali*, *volatile ſpirit of ſal ammoniac*, *cauſtic volatile alkali*, *hartſhorn*, *ſpirit of hartſhorn* and *of urine*, becauſe it was obtained from theſe ſubſtances. It has received the name *ammonia*, from *ſal ammoniac*, a ſalt which was extracted from the urine and dung of camels, collected near the temple of Jupiter Ammon in Africa. This ſalt was unknown to the ancients. It is firſt mentioned by Baſil Valentine, who lived in the 15th century, as being prepared from certain ſubſtances, with an account of ſome of its properties. But the difference between the pure ſalt and its compound with the carbonic acid was not known till the diſcovery of Dr Black. It was ſuppoſed to be in the ſtate of greateſt purity in the ſolid and cryſtalline form; and in its pure, cauſtic, and liquid ſtate, it was ſuppoſed to be changed, and contaminated with the lime or the different matters which had been employed in extracting it from ſal ammoniac. It was afterwards examined by Dr Prieſtley in the ſtate of gas, and he decompoſed it by electricity, but without diſcovering its conſtituent parts. This was at laſt effected by the reſearches and experiments of Scheele and Bergman, and finally confirmed by thoſe of Berthollet.

1097 Preparation. 2. Ammonia may be obtained by the following proceſs. Three parts of quicklime, and one part of ſal-ammoniac reduced to powder, are to be put into a retort, and the beak of the retort immerſed under mercury in the mercurial apparatus. A jar filled with mercury is inverted above it. Heat is applied to the retort, and a gas comes over in great abundance. This gas is *ammonia*, or *ammoniacal gas*. Sal-ammoniac conſiſts of the muriatic acid and ammonia. The affinity of lime for muriatic acid is ſtronger than that of ammonia, and therefore the ammonia is diſengaged in the ſtate of gas, while the lime combines with the acid. The gas muſt be received over mercury, becauſe it is readily abſorbed by water.

1098 Properties. 3. Ammonia in the ſtate of gas reſembles common air. It is tranſparent and colourleſs, and may be indefinitely compreſſed and dilated. The ſmell is extremely pungent and acrid, particularly irritating the eyes and noſtrils. It has an acrid and cauſtic taſte, but is much leſs corroſive than the other alkalies. It changes vegetable blues to a green colour. It is lighter than common air. Its ſpecific gravity is 0.000732; ſo that it is nearly one half lighter. According to Mr Kirwan, a cubic inch of this gas weighs only .27 of a grain.

It is totally unfit for reſpiration. No animal can breathe it without inſtant death. It is alſo unfit for the ſupport of combuſtion; but although it extinguiſhes burning bodies, the flame of a candle let down into this gas, is conſiderably enlarged in volume by the addition of another flame, which is of a pale yellow colour.

1099 Action of heat. 4. This gas is unaltered by the action of light. When it is expoſed to a ſtrong heat, as when it is paſſed through a red-hot porcelain tube, it is decompoſed and converted into azotic and hydrogen gaſes. It is alſo decompoſed by the electric ſpark. When it is expoſed to the temperature of —45°, it is condenſed, and aſſumes a liquid form; but it returns to the gaſeous ſtate by an elevation of temperature.

1100 Of oxygen. 5. There is no action between oxygen gas and this gas in the cold; but if the two gaſes mixt together are made to paſs through a red-hot porcelain tube, the ammonia is decompoſed; a detonation takes place, the hydrogen combines with the oxygen and forms water. The azote paſſes off in the ſtate of gas.

1101 Common air. 6. There is no action between this gas and azotic gas, nor is there any action between common air and ammoniacal gas in the cold; but if the mixture be made to paſs through a red-hot porcelain tube, water is formed, and the gas which eſcapes is a combination of the azotic gas of the atmoſphere, and of that which entered into the compoſition of ammonia. But if the ſame experiment be made with a greater proportion of oxygen gas, the product is nitric acid, which is formed by the combination of part of the oxygen and the azote *.

1102 Compoſition. 7. It has been already mentioned, that the conſtituent parts of ammonia were diſcovered by Scheele and Bergman, and Prieſtley and Berthollet. Acccording to the experiments of the latter, ammonia is compoſed of 121 parts of azote, and 29 of hydrogen. This reſult was obtained by decompoſing the ammonia by means of electricity. One hundred parts of ammonia, therefore, are compoſed of

Azote	80
Hydrogen	20
	100

1103 Of water. 8. Ammoniacal gas combines very rapidly with water. If a bit of ice be brought into contact with this gas, it abſorbs and condenſes it, and inſtantly becomes liquid. There is at the ſame time a production of cold; but water in the liquid ſtate, as it abſorbs this gas, becomes warm, becauſe the gas is deprived of that quantity of caloric which is neceſſary to retain it in the gaſeous form. The water, as it abſorbs the gas, becomes ſpecifically lighter. When water is ſaturated with this gas, it is known under the name of liquid ammonia. The ſpecific gravity of a ſaturated ſolution is 0.9054. When this ſolution is expoſed to the temperature of 130° the ammonia is driven off, and aſſumes the gaſeous form; and when it is ſlowly and gradually cooled to the temperature of from —35 to

—42°,

---

* Fourcroy Connaiſs. Chim. ii. p. 236.

—42°, it cryſtallizes; but when the temperature is rapidly diminiſhed to —58° it aſſumes the form of jelly. At that temperature it has no ſmell †,

By Mr Davy's experiments, a ſaturated ſolution of ammonia contains, in 100 parts,

Water	64.63
Ammonia	25.37
	100.00

He has alſo aſcertained the different proportions of water and ammonia which are contained in 100 parts of liquid ammonia of different ſpecific gravities ‡. Theſe are exhibited in the following table.

Table of the quantities of Ammonia, ſuch as exiſts in the aëriform ſtate, ſaturated with water at 52°, in Aqueous ammoniacal Solutions of different ſpecific gravities.

100 Specific gra.		Ammoniac.	Water.
9054	contain	25,37	74,63
9166		22.07	77,93
9255		19.54	80,46
9326		17.52	82,48
9385		5.88	84,12
9435		14.53	85,47
9476		13,46	86,54
9513		12,40	87,60
9545		11,56	88,44
9573		10,82	89,18
9597		10,17	89,83
9619		9,60	90,40
9684		9,50	90,5
9639		9,09	90,91
9713		7,17	92,83

1104 Affinities. 9. The order of affinities of ammonia is the ſame as the fixed alkalies.

I. Action of Phoſphorus on Ammonia.

1105 With heat. 1. There is no action between ammonia and phoſphorus in the cold; but when the two gaſes are paſſed through a red-hot porcelain tube, the ammonia is decompoſed, and its conſtituent parts enter into combination with the phoſphorus. There is formed phoſphorated hydrogen gas and phoſphorated azotic gas. In this caſe, there is a double action of the phoſphorus, one part combining with the hydrogen, and another with the azote.

2. Ammonia is alſo decompoſed by red-hot charcoal, when it paſſes over in the ſtate of gas at this temperature. Part of the carbone of the charcoal combines with the ammonia, and forms pruſſic acid.

II. Action of Sulphur on Ammonia.

1. Ammonia combines with ſulphur in the ſtate of vapour. This combination conſtitutes a ſulphuret of ammonia, which has the property of decompoſing water, and is then converted into a hydrogenated ſulphuret of ammonia. This may be prepared by diſtilling in a retort, a mixture of muriate of ammonia, lime, and ſulphur. By this proceſs a liquid of a deep orange colour, which exhales extremely fetid vapours, on account of the exceſs of ammonia which it contains, is produced. This was known under the name of the *fuming liquor of Boyle*. This ſulphuret is decompoſed by heat, by the acids and ſulphurated hydrogen gas.

2. When ammonia abſorbs ſulphurated hydrogen gas, either by agitating the gas in a veſſel with liquid ammonia, or by paſſing a current of the gas through it, there is an evolution of caloric and the formation of vapour, and the liquid is converted into an orange colour. This is the hydroſulphuret of ammonia. It has no longer the fetid odour of the hydrogenated ſulphuret, and it may be cryſtallized. It is decompoſed by the action of heat, by the acids, and by the metallic oxides.

III. Compounds of Ammonia with the Acids.

1. Sulphate of Ammonia.

1. The compound of ſulphuric acid with ammonia was formerly called *ſecret ſal ammoniac of Glauber*, becauſe it was diſcovered by that chemiſt. It was alſo called *vitriolated ammonia*, and *vitriolated volatile alkali*. It was diſcovered by Glauber in examining the reſiduum of the decompoſition of ammonia by means of ſulphuric acid. 1106 Hiſtory.

2. This ſalt may be formed by ſaturating the acid with the alkali, and afterwards cryſtallizing it. 1107 Preparation.

3. The cryſtals of ſulphate of ammonia are ſix-ſided priſms with unequal ſides, terminated by ſix-ſided pyramids. The ſulphate of ammonia undergoes little change in the air. It ſlowly attracts moiſture in a humid atmoſphere. It is ſoluble in two parts of cold water, and in a ſmaller quantity of boiling water. 1108 Properties.

4. When expoſed to heat, it melts; and if the heat be continued, it loſes a part of its baſe, and is converted into the acidulous ſulphate of ammonia. This differs from the ſulphate by its ſharp taſte, and its property of reddening vegetable blues, greater ſolubility, and a different action on ſeveral compounds. 1109 Action of heat.

5. This ſalt is not decompoſed like the other ſulphates, on account of its greater volatility. The component parts of this ſalt, according to Mr Kirwan, are,

Acid	54.66
Ammonia	14.24
Water	31.10
	100.00

2. Sulphite of Ammonia.

1. The compound of ſulphurous acid with ammonia is prepared by paſſing a ſtream of ſulphurous acid gas into a veſſel with liquid ammonia. The gaſeous acid is readily abſorbed, much heat is produced, and the ſulphite of ammonia cryſtallizes on the cooling of the ſaturated ſolution. 1110 Preparation.

2. This ſalt is in the form of ſix-ſided priſms terminating in ſix-ſided pyramids, or in that of four-ſided rhomboidal priſms, with three-ſided ſummits. The taſte is at firſt cool and pungent, and afterwards ſulphurous. It is deliqueſcent in the air, from which it abſorbs oxygen, and is converted into the ſulphate. It is ſoluble in its own weight of cold water. The ſolution produces 1111 Properties.

---

† Ann. de Chim. xxix. p. 289.

‡ Davy's Reſearches, p. 68.

produces a great degree of cold. Boiling water diſſolves ſtill more. Water ſaturated with ſulphite of ammonia, and agitated in the open air, preſents this ſalt in a few hours converted into the ſulphate, without any cruſt on the ſurface, or muddineſs in the liquid, becauſe it is very ſoluble in water.

3. It decrepitates ſlightly on red-hot coals: when it is gradually heated in a cloſe veſſel, it gives out at firſt, water and ammonia, and then ſublimes totally in the ſtate of acidulous ſulphite.

1112 Compoſition. 4. The conſtituent parts of this ſalt are,

Sulphurous acid	60
Ammonia	29
Water	11
	100

3. Nitrate of Ammonia.

1113 Hiſtory. 1. This compound of nitric acid and ammonia, was formerly called *nitrous ſal ammoniac*, *inflammable nitre*. This ſalt has been particularly examined by Berthollet, and more lately by Mr Davy.

1114 Preparation. 2. Nitrate of ammonia is prepared by directly combining the acid and the alkali, and it may be obtained in cryſtals by careful evaporation and ſlow cooling.

1115 Properties. 3. This ſalt cryſtallizes in ſix-ſided priſms, terminating in long ſix-ſided pyramids; but the appearance of the cryſtals varies with the temperature in which the evaporation goes on. Sometimes they are in long ſilky threads, ſoft and elaſtic; the taſte is very acrid, bitter, and penetrating; and the ſpecific gravity is 1.5785.

1116 Action of water. 4. When the nitrate of ammonia is expoſed to the air, it attracts moiſture, and deliqueſces. It is ſoluble in two parts of cold water. Boiling water diſſolves double of its own weight.

1117 Of heat. 5. Nitrate of ammonia very readily undergoes the watery fuſion. If the heat be continued, it is entirely deprived of its water of cryſtallization; and when the temperature is increaſed, it explodes ſpontaneouſly, giving out at the ſame time a brilliant white flame, with conſiderable noiſe; it is then entirely diſſipated into vapour. This detonation inſtantaneouſly takes place, when the nitrate of ammonia is thrown on a red-hot iron. It was from this property that the ſalt derived its name of *inflammable nitre*. The nature of this rapid combuſtion will be underſtood by conſidering the component parts of the ſalt. The hydrogen of the ammonia enters into combination with the oxygen of the acid; water is formed, and azotic gas is diſengaged from each of the component parts of the ſalt. In the different ſtates of cryſtallization, this ſalt requires different temperatures for its fuſion and decompoſition. The following are the concluſions from Mr Davy's experiments.

"*a.* Compact or dry nitrate of ammonia undergoes little or no change at temperatures below 260°.

"*b.* At temperatures between 275° and 300°, it ſlowly ſublimes without decompoſition, or without becoming fluid.

"*c.* At 320° it becomes fluid, decompoſes, and ſtill ſlowly ſublimes; it neither aſſuming, nor continuing in, the fluid ſtate, without decompoſition.

"*d.* At temperatures between 340° and 480°, it decompoſes rapidly.

"*e.* The priſmatic and fibrous nitrates of ammonia become fluid at temperatures below 300°, and undergo ebullition at temperatures between 360° and 400°, without decompoſition.

"*f.* They are capable of being heated to 430° without decompoſition or ſublimation, till a certain quantity of their water is evaporated.

"*g.* At temperatures above 450°, they undergo decompoſition without previouſly loſing their water of cryſtallization *."

1118 Compoſition. 6. The component parts of nitrate of ammonia are, according to

	Kirwan,	Fourcroy,
Acid,	57	46
Ammonia,	23	40
Water,	20	14
	100	100

Mr Davy has aſcertained the proportions of the component parts of this ſalt in its three different ſtates †.

	Fibrous.	Priſmatic.	Compact.
Acid,	72.5	69.5	74.5
Ammonia,	19.3	18.4	19.8
Water,	8.2	12.1	5.7
	100.0	100.0	100.0

1119 Uſes. 9. This ſalt has been applied to no uſe, but for the purpoſes of chemical experiment, and eſpecially for the preparation of the nitrous oxide or gaſeous oxide of azote, which has been already deſcribed in treating of the compounds of azote.

4. Nitrite of Ammonia.

If this ſalt be formed by depriving the nitrate of ammonia of part of its acid, it muſt be extremely difficult, Fourcroy obſerves, to obtain it in this way, before the ſalt is totally decompoſed ‡.

5. Muriate of Ammonia.

1120 Hiſtory. 1. The compound of muriatic acid and ammonia has been known, from time immemorial, by the name of *ſal ammoniac*. It derives this name from Ammonia, a country of Libya, which name is deſcriptive of the ſandy ſoil of that region (A). Hence too is the origin of the epithet given to Jupiter, to whom a temple was erected in that country. This ſalt was originally collected in great quantities near this temple, where it was formed in the ſand from the excrementitious matters of different animals, particularly camels. It was well known to the Greeks and Romans, and was employed by them in ſeveral arts. Before the nature

* *Reſearches*, p. 85.

† *Ibid.* p. 72.

‡ *Connaiſs. Chim.* iii p. 160.

(A) From the Greek word αμμος, which ſignifies *ſand*.

ture of this ſalt was known, it was chiefly brought from Egypt; but it is now found to exiſt, ready formed, in different countries, particularly in the vicinity of volcanoes, where it ſeems to be ſublimed. It is found alſo in the mountains of Tartary and Thibet, in grottos in the neighbourhood of Puzzuoli, and diſſolved in the waters of ſome lakes in Tuſcany. The nature of the muriate of ammonia was firſt diſcovered by Geoffroy; it was afterwards more accurately examined by Duhamel; and, at laſt, its properties were fully developed by Black, Bergman, and Scheele, Berthollet and Fourcroy.

1121 Purification. 2. The muriate of ammonia, which is found ready prepared in nature, is extremely impure. It muſt therefore be ſubjected to ſeveral proceſſes, to ſeparate the foreign matters with which it is impregnated. The ſalt which is found ſublimed in the crater of volcanoes, is generally mixed with arſenic and ſulphur. In Egypt it is prepared by collecting together the excrements of animals which feed on ſaline plants. Theſe ſubſtances are dried and burnt in furnaces which are conſtructed on purpoſe, or uſed as the common materials of fuel. The ſoot which is thus formed, is collected, and put into large glaſs bottles, and expoſed to a ſtrong heat, which is gradually increaſed for 72 hours. Towards the ſecond day the ſalt is ſublimed, and attaches itſelf to the upper part of the bottles. When the apparatus has cooled, the bottles are broken, and the ſalt in form of a cake is taken out, which amounts to little leſs than one-third of the ſoot which was employed. This manufacture is carried on at Grand Cairo; and the French conſul then reſident there, communicated an account of it to the Academy of Sciences, in the year 1719. But it was not till 40 years after this period that it was manufactured in Europe. The firſt manufactory was eſtabliſhed in Germany in 1759; others afterwards commenced in France, and in different parts of Britain.

In the European manufactories it is prepared by different proceſſes. Sometimes the calcareous muriate is precipitated by a carbonate of ammonia extracted from animal matters. After the lime is depoſited, the liquor is evaporated, and the muriate of ammonia is ſublimed. Sometimes too it is prepared by forming a ſulphate of ammonia, and by mixing ths ſalt with a muriate of ſoda, and expoſing the mixture to heat, a double decompoſition is effected, and the muriate of ammonia is ſublimed. It is alſo prepared by the direct combination of muriatic acid and ammonia.

1122 Properties. 3. Prepared in this way by ſublimation, it is in the form of a ſolid maſs, which has ſome degree of elaſticity. It yields to the preſſure of the finger, may be compreſſed into a ſmaller bulk, and is with difficulty reduced to powder. The ſpecific gravity is 1.42. The taſte is pungent, acrid, and cooling. By ſolution in water and ſlow evaporation, it cryſtallizes in the form of long four-ſided pyramids. The primitive form of the cryſtal is the regular octahedron; and that of the integrant particle, the regular tetrahedron. Sometimes it cryſtallizes in cubes, and ſometimes the priſms are very ſmall, and grouped together, exhibiting a feathery appearance.

1123 Action of water. 4. The muriate of ammonia is not altered by expoſure to the air. It is ſoluble in three or four times its weight of cold water. Great cold is produced during the ſolution; and on this account it is employed with ſnow and ice in the production of artificial cold. Boiling water diſſolves nearly its own weight of this ſalt.

1124 Of heat. 5. The muriate of ammonia is fuſible and volatile. When it is thrown on red-hot coals, it is entirely diſſipated in white vapour. Expoſed to a high temperature, it is decompoſed.

1125 Of acids. 6. This ſalt is readily decompoſed by the ſulphuric acid, which diſengages the muriatic acid with violent effervеſcence. It is alſo decompoſed by the nitric acid, which oxygenates the muriatic acid. In this way a nitro-muriatic acid is prepared, which is employed for the ſolution of gold. Barytes, potaſh, ſoda, and lime, decompoſe the muriate of ammonia, and diſengage the ammonia in the ſtate of gas, merely by trituration; but if heat be applied, the decompoſition is more rapid and complete.

1126 Compoſition. 7. According to the analyſis of Mr Kirwan, the component parts of the muriate of ammonia are,

Acid,	42.75
Ammonia,	25.00
Water,	32.25
	100.00 *.

1127 Uſes. 8. No ſalt is more generally employed than muriate of ammonia. In chemiſtry it is uſed for the extraction of ammonia, the carbonate of ammonia; for the production of cold, and as an inſtrument of analyſis. It is alſo employed in medicine; in the art of dyeing, for the preparation of colours; in metallurgy, for the indication and ſeparation of ſome metallic ſubſtances. It is uſed alſo for covering the ſurface of copper and other veſſels, to prevent oxydation in the proceſs of tinning; and for the ſame purpoſe in ſoldering.

6. Hyperoxymuriate of Ammonia.

1128 Preparation. The compound of hyperoxymuriatic acid and ammonia is formed by pouring carbonate of ammonia into a ſolution of any of the earthy hyperoxymuriates. A double decompoſition takes place, and a hyperoxymuriate of ammonia is formed. It is very ſoluble in water and in alcohol.

1129 Properties. It is decompoſed at a low temperature, and gives out a quantity of gas together with a ſmell of hyperoxymuriatic acid. Such a ſmell, Mr Chenevix obſerves, is doubtleſs owing to the great quantity of oxygen contained in the acid, which is more than what is neceſſary to combine with the hydrogen contained in the alkali. Some part, therefore, is diſengaged without decompoſition. Mr Chenevix, who formed this ſalt, could not ſucceed in aſcertaining the proportion of its conſtituent parts *.

7. Fluate of Ammonia.

1130 Preparation and properties. 1. This compound of fluoric acid and ammonia is prepared by ſaturating the acid with the alkali. By evaporation it cryſtallizes in ſmall needles or priſms, which have a pungent taſte analogous to that of ſulphate of ammonia.

2. When it is heated, this ſalt gives out ammonia, and is ſublimed in the ſtate of an acidulous fluate. This ſalt decompoſes the nitrate and muriate of lime, and the ſulphate of magneſia.

---

* *Nicholſon's Journal*, iii. 216.

* *Phil. Tranſ.* 1802, p. 148.

8. Borate of Ammonia.

The compound of boracic and ammonia is little known. It is formed by the direct union of the acid with the alkali. It has ſo little permanency, that the ſolution being evaporated, the whole of the ammonia is volatilized, while the boracic acid cryſtallizes. The baſe of every other ſalt decompoſes it †.

9. Phoſphate of Ammonia.

1131 Names and hiſtory. 1. This ſalt, the compound of phoſphoric acid and ammonia, was long confounded with the phoſphate of ſoda, as it exiſts with it in urine, under the names of *fuſible ſalt, native ſalt of urine, microcoſmic ſalt.* It was firſt accurately diſtinguiſhed by Schloſſer, De Chaulnes, and Rouelle, about the year 1770; ſoon after by Lavoiſier, and more lately by Vauquelin.

1132 Preparation. 2. At firſt it was extracted from the ſalt of urine; and many proceſſes were adopted to obtain it pure, and ſeparate from the muriate and phoſphate of ſoda, with which it is always accompanied. It is now prepared artificially by directly combining phoſphoric acid with ammonia; and by ſlow evaporation of the ſolution to a certain conſiſtence cryſtals are obtained on cooling.

1133 Properties. 3. The phoſphate of ammonia cryſtallizes in regular four-ſided priſms, terminated by four equal-ſided pyramids, and ſometimes in the form of ſmall needles cloſely interwoven with each other. It has a cooling, ſaline, pungent taſte, and changes the ſyrup of violets to a green colour. Its ſpecific gravity is 1.8051.

1134 Action of water. 4. In a moiſt air, it is ſlightly deliqueſcent, but otherwiſe it is unchanged. It is ſoluble in four parts of cold water, and ſtill more ſo in boiling water.

1135 Of heat. 5. Expoſed to heat, it undergoes the watery fuſion, ſwells up, and melts into a tranſparent glaſs, which is acid, part of the baſe being driven off. Hence it derived the name of *fuſible ſalt*.

1136 Acids. 6. It is readily decompoſed by charcoal, by the ſulphuric, nitric, and muriatic acids, and by the two fixed alkalies.

1137 Uſes. 7. The phoſphate of ammonia is employed as a flux in eſſaying mineral ſubſtances with the blow-pipe. It is greatly uſed alſo in the fabrication of coloured glaſſes and artificial precious ſtones.

10. Phoſphite of Ammonia.

1138 Preparation. 1. This is a compound of phoſphorous acid and ammonia. It is prepared by the direct combination of the acid with ammonia or the carbonate of ammonia, and by ſlow evaporation it may be obtained in cryſtals.

1139 Properties. 2. It ſometimes cryſtallizes in long tranſparent needles, and ſometimes in four-ſided priſms, terminated by four-ſided pyramids. It has a ſtrong pungent taſte.

1140 Action of water. 3. This ſalt is ſlightly deliqueſcent in the air, is ſoluble in twice its weight of cold water, and being more ſoluble in boiling water, it cryſtallizes on cooling.

1141 Of heat. 4. When it is heated on charcoal with the blow-pipe, it boils up, and loſes its water of cryſtallization. When this has eſcaped, it is ſurrounded with a fine phoſphoric light; and as the ſalt begins to vitrify, there are evolved bubbles of gas, which burn as they come in contact with the air, with a vivid flame, and form with the atmoſphere a ring of white vapour of phoſphoric acid. What remains is phoſphoric acid in the vitreous ſtate. The ſame effect may be produced by heating ſix or ſeven grains of the ſalt in a ſmall glaſs globe to which a tube is adapted, and immerſed under jars over mercury. The ſalt melts, ſwells, and gives out bubbles of phoſphorated hydrogen gas, which ſpontaneouſly inflame as they come in contact with the air, and exhibit the white coronet of vapour which is the characteriſtic property of the combuſtion of this gas. During this decompoſition, the baſe of the ſalt, the ammonia, is alſo volatilized, and pure phoſphoric acid remains behind. This ſalt is decompoſed by charcoal, the acids, and by potaſh and ſoda.

1142 Compoſition. 5. The conſtituent parts of this ſalt are the following.

Phoſphorous acid,	26
Ammonia,	51
Water,	23
	100

6. It has not hitherto been applied to any uſe.

11. Carbonate of Ammonia.

1143 Names. 1. The compound of carbonic acid with ammonia has been diſtinguiſhed by different names, as *concrete volatile alkali*, *aerated volatile alkali*, and *cretaceous ſal ammoniac.* Its peculiar nature and properties were not clearly underſtood, till, by the diſcovery of Dr Black, it was demonſtrated to be a compound ſalt. This ſalt is obtained by a great many different proceſſes. Formerly it was procured by diſtilling animal matters, and particularly horns, as the horns of the hart, whence it derived the name of volatile ſalt of hartſhorn.

1144 Preparation. 2. Carbonate of ammonia may be prepared by directly combining carbonic acid and ammonia in the ſtate of gas over mercury; or it may be obtained by mixing together two parts of chalk, and one part of muriate of ammonia, well dried and reduced to powder, and expoſing them to heat in a porcelain retort. The gas, as it comes over, is collected in a receiver, which is to be cooled with cloths moiſtened with water. This is the carbonate of ammonia, which is ſublimed and attaches itſelf to the ſides of the receiver. In this proceſs there is a double decompoſition. The carbonic acid of the lime combines with the ammonia, and forms carbonate of ammonia, which is driven off by heat; and the muriatic acid of the muriate of ammonia combines with the lime, and forms muriate of lime, which remains in the retort.

1145 Properties. 3. The carbonate of ammonia is cryſtallized; but the cryſtals are ſo irregular, that their form has not been accurately aſcertained. Bergman deſcribes them as octahedrons, whoſe four angles are truncated; while, according to Romè de Liſle, they are compreſſed four-ſided priſms, terminated by a two-ſided ſummit. The taſte of this ſalt is ſlightly acrid, and the ſmell is perceptibly that of ammonia, though more feeble. It converts vegetable blues to green. Its ſpecific gravity is 0.966.

1146 Action of water. 4. When this ſalt is pure, it is not ſenſibly changed by expoſure to the air. It is very ſoluble in water, and, during its ſolution, produces cold. Two parts of cold water diſſolve more than one of the ſalt. Water, at the temperature of about 120°, diſſolves more than its

---

† Fourcroy Connaiſs. Chim. iii. p. 336.

its own weight, &c. When it is rapidly cooled, the ſalt cryſtallizes in the moſt regular form which it aſſumes. Boiling water cannot be employed for its ſolution, becauſe at this temperature the ſalt is driven off in the ſtate of vapour.

1147 Of heat. When this ſalt is thrown upon hot iron, it melts, boils, and is converted into vapour.

1148 Of acids. 5. It is decompoſed by all the acids with effervescence; and the effervescence with this ſalt is more violent than with the carbonates of the two fixed alkalies, becauſe the proportion of carbonic acid is greater.

1149 Compoſition. 6. The conſtituent parts of this ſalt, according to Bergman, are,

Carbonic acid	45
Ammonia	43
Water -	12
	100

But Mr Davy has found, that the proportion of acid and water in this ſalt depends on the temperature at which it is formed. It is greater when the temperature is low, and diminiſhes as the temperature is increaſed.

1150 Uſes. 7. This ſalt is employed in medicine, and alſo in the manufacture of muriate of ammonia, for which purpoſe it is produced by diſtillation from animal matters. The uſe of it, when it is mixed with volatile oils, as a perfume, or as a ſtimulant in ſmelling bottles, is well known.

12. Arſeniate of Ammonia.

1151 Preparation. 1. This ſalt, the compound of arſenic acid and ammonia, is formed by combining the acid with the alkali. When the ſolution is evaporated, it affords cryſtals of arſeniate of ammonia.

1152 Properties. 2. It cryſtallizes in the form of rhomboidal priſms; or, with an exceſs of acid, in the form of needles. The cryſtals of the firſt convert the ſyrup of violets into green, and thoſe of the ſecond are deliqueſcent in the air.

1153 Action of heat. 3. When this ſalt is gently heated, the ammonia is diſengaged, and the arſenic acid remains behind; but when the heat is violent and ſudden, part of the alkali and of the acid are decompoſed, water is formed, azotic gas is diſengaged, and the arſenic is ſublimed in the metallic ſtate.

13. Arſenite of Ammonia.

This is a compound of the white oxide of arſenic, or arſenious acid, with ammonia; but nothing is known of its properties.

14. Tungſtate of Ammonia.

1154 Preparation. 1. This compound of tungſtic acid and ammonia is formed by diſſolving the oxide of tungſten in the ſolution of ammonia or carbonate of ammonia; and by evaporating the ſolution, the ſalt is obtained in the form of cryſtals.

1155 Properties. 2. It cryſtallizes in ſmall ſcales, which have ſome reſemblance to boracic acid; or in ſmall needles, which are four-ſided. This ſalt has a metallic taſte. It is not deliqueſcent in the air, but is ſoluble in water. When it is expoſed to heat, it is decompoſed.

3. The component parts of this ſalt are,

Tungſtic acid	18
Ammonia and water	22
	100

15. Molybdate of Ammonia.

16. Chromate of Ammonia,

17. Acetate of Ammonia.

1156 Preparation. 1. This compound of acetic acid and ammonia has been long known by the name of *ſpiritus mindereri*. In this ſtate it is combined with an exceſs of acid. It may be obtained, but with ſome difficulty, on account of its volatility, by ſlow evaporation. It then cryſtallizes in the form of needles. Cryſtals are alſo obtained by very ſlow ſublimation of this ſalt.

1157 Properties. 2. The cryſtals of acetate of ammonia are long, ſlender, flat, and pointed, of a pearly white colour *. The taſte is cooling, with a mixture of ſweet. Expoſed to air, it is deliqueſcent, and is very ſoluble in water. When it is heated to the temperature of 170°, it melts; and when the temperature is raiſed to 250°, it is ſublimed. By diſtillation of the ſalt in ſolution, with a ſtrong heat, it is partly decompoſed. The ammonia is firſt driven off, then the acid, and, towards the end of the proceſs, part of the neutral ſalt.

18. Oxalate of Ammonia.

1158 Preparation. 1. The compound of oxalic acid and ammonia may be prepared by directly combining the acid with the alkali. By evaporating the ſolution, the ſalt cryſtallizes.

2. When the acid is ſaturated with the alkali, the cryſtals are in the form of four-ſided priſms, terminated by two-ſided ſummits; one of which is larger, and includes three ſides of the priſm. Theſe ſalts are ſoluble in water.

1159 Action of heat. 3. When this ſalt is expoſed to heat, carbonate of ammonia is driven off, and nothing remains behind but a little charcoal. From this it appears, that the acid is decompoſed, the carbone and oxygen combining together to form carbonic acid, which enters into combination with ammonia. It is decompoſed by the mineral acids. The oxalic acid combines with it, and forms an acidulous oxalate of ammonia. The oxalates of potaſh and ſoda form compounds with this ſalt, which are known by the name of *triple ſalts*.

1160 Uſes. 4. This is one of the moſt uſeful ſalts to be employed as a reagent in detecting lime in liquid ſolutions, and for aſcertaining the nature and proportions of calcareous ſalts.

19. Tartrate of Ammonia.

The compound of tartaric acid and ammonia forms a ſalt which very readily cryſtallizes. This ſalt has a cooling bitter taſte, is very ſoluble in water, and eaſily decompoſed by heat. It is ſubject alſo to ſpontaneous decompoſition. By the action of the ſtronger acids part of the baſe is ſeparated, and it is converted into an acidulous tartrate of ammonia.

20. Citrate of Ammonia.

1. This ſalt, which is a compound of citric acid and ammonia, is formed by the direct combination of the

---

* *Higgins' Experiments*, p. 188.

acid and alkali, and it cryſtallizes when the ſolution is evaporated to the conſiſtence of a thick ſyrup.

2. The cryſtals are in the form of an elongated priſm. They are very ſoluble in water, and have a ſaline cooling taſte. This ſalt is decompoſed by heat, the ammonia being driven off.

3. It is compoſed of

Acid	62
Ammonia	38
	100

21. Malate of Ammonia.

This ſalt, which is a compound of malic acid and ammonia, is a very ſoluble and deliqueſcent ſalt. Its other properties are unknown.

22. Benzoate of Ammonia.

The compound of benzoic acid and ammonia forms a very ſoluble ſalt, which readily cryſtallizes, and the cryſtals arrange themſelves in an arboreſcent or plumoſe form. This ſalt is volatile, and is decompoſed by all other acids *.

23. Succinate of Ammonia.

The compound of ſuccinic acid and ammonia forms a ſalt, which affords needle-ſhaped cryſtals that are deliqueſcent, and are ſublimed by heat, without being decompoſed.

24. Saccolate of Ammonia.

Nothing farther is known of this ſalt, than that it has an acid taſte, and is readily decompoſed by heat.

25. Camphorate of Ammonia.

1161 Preparation. 1. This ſalt, which is a compound of camphoric acid and ammonia, is prepared by adding the acid to a ſolution of carbonate of ammonia, and hot water, till efferveſcence ceaſes. The evaporation muſt be conducted with a very gentle heat, on account of the volatility of the ammonia.

1162 Properties. 2. It is difficult to obtain this ſalt cryſtallized. When the ſolution is too much evaporated, it affords a cryſtalline maſs, in which appear ſmall needles; but if it be evaporated to dryneſs there remains a ſolid opaque maſs, which has a ſlightly bitter and pungent taſte.

3. This ſalt is ſlightly deliqueſcent in the air; it is not very ſoluble in cold water, but may be diſſolved in three parts of boiling water. In theſe ſalts, it would appear that the acid reſiſts the action of the water; for when there is an exceſs of baſe, they become more ſoluble.

1163 Action of heat. 4. Expoſed to heat on red-hot coals, it ſwells and melts, and then riſes in vapour. With the blow-pipe, it gives a blue and red flame, and is entirely diſſipated.

1164 Of acids. 5. This ſalt is decompoſed by the ſulphuric, nitric, and muriatic acids, and if the ſolution be ſufficiently concentrated, the camphoric acid is depoſited. It is alſo decompoſed by potaſh and ſoda, and more rapidly with the aſſiſtance of heat. This ſalt is completely ſoluble in alcohol †.

26. Suberate of Ammonia.

This compound of ſuberic acid with ammonia affords cryſtals in the form of parallelopipeds. It has a ſlight ſaltiſh taſte, leaving an impreſſion of bitterneſs. It reddens vegetable blues, and is deliqueſcent in the air. It is very ſoluble in water. When it is thrown on burning coals, it ſwells up, and is deprived of its water of cryſtallization. It is entirely diſſipated by the action of the blow-pipe. It is decompoſed by the ſulphuric, nitric, muriatic, and oxalic acids, by the fixed alkalies, and the aluminous and magneſian ſalts ‡.

27. Mellate of Ammonia.

This ſalt, which is a compound of mellitic acid and ammonia, is formed by ſaturating the acid with the alkali. By evaporation it affords tranſparent, ſix-ſided cryſtals. This ſalt when expoſed to the air, becomes opaque, and of a ſilvery white colour.

28. Lactate of Ammonia.

This compound of lactic acid and ammonia forms a ſalt which cryſtallizes. It is deliqueſcent in the air, and is decompoſed by heat, great part of the ammonia being driven off.

29. Pruſſiate of Ammonia.

The compound of pruſſic acid and ammonia affords a ſalt which has the odour of ammonia. When this ſalt is expoſed to heat, it is entirely diſſipated.

30. Sebate of Ammonia.

31. Urate of Ammonia.

The compound of uric acid and ammonia, forms a ſalt which is not very ſoluble in water, and in many of its properties reſembles the acid itſelf.

IV. Compounds of Ammonia with Inflammable Subſtances.

1. Ammonia enters into combination with alcohol, with the aſſiſtance of a moderate heat; but the ammonia is ſeparated when the mixture is expoſed to a temperature below the boiling point of alcohol.

2. Ammonia readily mixes with ether; but the nature of the compound, or whether it be a chemical combination, is not known.

3. Ammonia forms a compound with the fixed oils, which is well known under the name of *ſoap* or *liniment*.

4. With the volatile oils it forms compounds, which have ſomewhat ſimilar properties.

CHAP. XIII. OF EARTHS.

1. THE word *earth* is taken in different ſignifications. Sometimes it ſignifies the globe, and ſometimes it is uſed to denote the ſoil on the ſurface of the globe. In chemiſtry it is employed to ſignify certain elementary ſubſtances, of which a great proportion of the ſolid parts of the globe is compoſed; and theſe ſubſtances are found to poſſeſs many peculiar, and ſome common properties.

1165 Properties. 2. The general properties of the earths are the following.

a. They have neither taſte nor ſmell.

b. They

---

* *Fourcroy Connaiſs. Chim.* vii. 193.

† *Ann. de Chim.* xxvi. p. 31.

‡ *Annal. de Chim.* xxiii. 55.

b. They are incombuſtible.

c. They are nearly inſoluble in water.

d. They have a ſpecific gravity which is under 5.

1166 Enumeration. The number of the earths which are at preſent known, is nine, and we ſhall treat of them in the following order.

1. Lime,
2. Barytes,
3. Strontites,
4. Magneſia,
5. Alumina,
6. Silica,
7. Yttria,
8. Glucina,
9. Zirconia.

Sect. I. *Of Lime.*

1167 Early known. 1. Lime has been known from the remoteſt antiquity. The great abundance in which it is found in nature, and the important uſes to which it may be applied, led men to employ it for many purpoſes from the earlieſt ages of the world. It was well known to the ancients as mortar, and as a manure, and they were not unacquainted with ſome of its medical virtues. But it was long before the nature and properties of lime were fully known; and particularly thoſe changes which quicklime undergoes when it is expoſed to the air, or limeſtone to the action of heat. It was not till Dr Black made his brilliant diſcoveries, that the nature of theſe changes was fully developed, and the fanciful theories which had been propoſed to account for them, were entirely rejected.

1168 Preparation of pure lime. 2. Lime is ſeldom found perfectly pure in nature, but it is univerſally diffuſed, and exiſts in ſome places in the greateſt abundance, in combination with other ſubſtances, and particularly with carbonic acid. To obtain it pure, a quantity of chalk, or marble, or limeſtone, is expoſed to a ſtrong heat, by which means the carbonic acid with which it is in combination is driven off. When the limeſtone, or marble, or chalk, which has been employed, is ſufficiently burnt or calcined, and removed from the fire, and water poured upon it, it ſwells up, and at laſt falls down into a powder. This powder is called *quicklime*. In this proceſs of ſlaking lime, as it is called, a great quantity of water is quickly abſorbed, and the water being fixed in the lime in the ſolid ſtate, gives out that caloric which is neceſſary to retain it in the ſtate of liquidity, 1169 Slaking. ſo that a great quantity of heat is evolved. Part of the water, alſo, riſes in vapour, in conſequence of the great heat, before it is conſolidated with the lime. The heat produced is ſo great, that water may be boiled, and combuſtible bodies may be inflamed. Accidents have happened to carriages and veſſels loaded with lime, to which water had been admitted. So much heat was produced, that they have been ſet fire to, and burnt. Light is alſo emitted when lime is ſlaked. This, it is ſaid, is ſeen when the proceſs is conducted in a dark place, and the quantity of lime conſiderable.

3. The purity of lime thus obtained, is in proportion to the purity of the ſubſtance which was calcined. The lime which is obtained by burning pure white marble, or what is called *calcareous ſpar*, is tolerably pure. But there are other proceſſes by which thoſe ſubſtances with which it may happen to be mixed may be ſeparated. If a quantity of chalk be waſhed in pure water, diſſolved in diſtilled acetic acid, and afterwards precipitated by carbonate of ammonia, the precipitate being waſhed and calcined, pure lime is the product. The lime which is obtained from oyſter-ſhells, may be rendered pure by the following proceſs. Firſt waſh the ſhells in different quantities of water, and boil them, to ſeparate any mucilaginous ſubſtance. Introduce them into a furnace, and calcine them to whiteneſs. After the firſt calcination, put them into a porcelain retort, and expoſe it to a red heat. By this proceſs pure lime is obtained. To preſerve it in this ſtate of purity, it muſt be kept in cloſe veſſels.

1170 Properties. 4. Pure lime is of a white colour, has a hot, ſharp, cauſtic taſte, and deſtroys the texture of animal ſubſtances, to which it is for ſome time applied. It converts the ſyrup of violets and other vegetable blues to a green colour. The ſpecific gravity of lime is 2.3.

1171 Action of water. 5. After the lime has been thus prepared and ſlaked; if more water be added to dilute it, and reduce it to the conſiſtence of thick cream, this is what was formerly called *milk* or *cream of lime*. But if a greater quantity of water be added, and the ſolution be filtered, a tranſparent liquid is thus obtained, which is known by the name of lime water. Four hundred and fifty parts of water are required, it is ſaid, to diſſolve one of lime. This water is clear and limpid, has a ſharp, acrid taſte, and renders the ſyrup of violets green. When this water is evaporated, and the whole driven off, the lime remains pure. If the ſolution of lime-water be expoſed to the air, the ſurface is ſoon covered with a pellicle, which gradually acquires ſolidity and thickneſs. This pellicle is owing to the attraction of the lime for the carbonic acid of the atmoſphere, forming a carbonate of lime, which being inſoluble in water, is precipitated.

1172 Cryſtallizes. 6. Lime, according to Trommſdorf, cryſtallizes. This was firſt diſcovered by Scheele. The method by which Mr Trommſdorf obtained the cryſtals of lime is the following. Boil any quantity at pleaſure of muriate of lime, with one-fourth or leſs of cauſtic lime, and evaporate the ſolution till a drop of it let fall on a cold ſtone aſſume the conſiſtence of ſyrup. It is then to be filtered, and put into a cloſe veſſel, that the ſolution may cool as ſlowly as poſſible. Cryſtals of lime are thus obtained, which muſt be waſhed in alcohol, to ſeparate any part of the muriate of lime which may adhere. For the complete ſucceſs of this experiment, ſome pounds of the muriate of lime muſt be employed *.

1173 Action of heat. 7. Lime undergoes no change by the action of light, and it remains unaltered when it is expoſed to the greateſt heat.

8. Lime is one of the moſt important of the earthy bodies. It is applied to a great many valuable purpoſes, and fortunately it can be obtained in the greateſt abundance. It is employed in medicine, both as an internal remedy, and an external application. As a manure, it is of the moſt extenſive utility; nor is it of leſs importance, as it is employed for a cement in building. When quicklime is mixed with ſand and water, and reduced to the form of a thick paſte, it is in the ſtate

---

* *Phil. Mag.* xii. 53.

ſtate of mortar. It is an object of the utmoſt importance that the mortar which is employed as a cement in building, ſhould be durable. To attain this object, a good deal of attention has been paid by different philoſophers, in aſcertaining the proportions which ſeem to anſwer beſt, or the additions which may be made to the uſual materials in the formation of good and durable mortar.

1174 Mortar. The proportions which have been propoſed by Dr Higgins are,

Coarſe ſand,	4 parts,
Fine ſand,	3
Quicklime,	1

The lime ſhould be recently ſlaked, and the quantity of water ſhould be juſt ſufficient to bring it to a proper conſiſtency.

Dr Higgins found that burnt bones, if they did not exceed one-fourth of the lime, added to the mortar, improved its tenacity, and prevented it from cracking in drying.

It has been propoſed to add a certain proportion of unſlaked lime to the mortar, with the view of giving it greater ſolidity. Mortar acquires its hardneſs from the lime abſorbing carbonic acid, and returning to the ſtate of limeſtone, and alſo from the combination of part of the water with the lime. According to Guyton's experiments the following proportions compoſe a good, durable mortar.

Fine ſand	3 parts,
Cement of well-baked bricks	3
Slaked lime	2
Unſlaked	2

It is ſometimes neceſſary to uſe mortar as a cement under water, but common mortar is unfit for this purpoſe. It has been found by experiment, that manganeſe added to mortar, gives it the property of conſolidating under water. To prepare a mortar for this purpoſe, Guyton recommends the following proceſs. Mix together 90 parts of limeſtone, ſix parts of black oxide of manganeſe, and 4 parts of blue clay in the ſtate of powder. Let the mixture be calcined, to drive off the carbonic acid; then add 60 parts of ſand and mix it together with a ſufficient quantity of water, to bring it to the conſiſtency of mortar.

1175 Affinities. 9. The order of the affinities of lime is the following:

Oxalic acid,
Sulphuric,
Tartaric,
Succinic
Phoſphoric,
Saclactic,
Nitric,
Muriatic,
Suberic,
Fluoric,
Arſenic,
Lactic,
Citric,
Benzoic,
Sulphurous,
Acetic,
Boracic,
Carbonic,
Pruſſic.

I. Phoſphuret of Lime.

1176 Preparation. 1. Lime combines with phoſphorus, and forms a compound which is called *phoſphuret of lime*. To prepare this compound, introduce into the bottom of a glaſs tube, cloſed at one end, one part of phoſphorus, and afterwards place a little above it four or five times its weight of quicklime in powder. Expoſe to a heat that part of the tube which contains the lime, ſo that it may become red-hot. In this ſtate raiſe the tube and draw it along the coals, till that part of it containing the phoſphorus be alſo expoſed to the heat. The phoſphorus is raiſed in the ſtate of vapour through the lime, and combines with it, ſo that the whole maſs forms a compound of a brown colour. This is the phoſphuret of lime.

1177 Properties. 2. It has a deep brown colour, no ſmell, and when it is expoſed to the air it falls to pieces. It is inſoluble in water, but it decompoſes that liquid at the moment it comes in contact with it. An efferveſcence takes place, and phoſphorated hydrogen gas is emitted, which is ſpontaneouſly inflamed when it comes to the ſurface of the water. It is owing to this gas that phoſphuret of lime, when it is moiſtened, gives out the fetid ſmell of garlic; and as this gas is formed by the decompoſition of the water, part of it combines with the phoſphuret of lime and forms a hydrogenated phoſphuret, ſo that the phoſphuret when it is taken from the water and dried, gives out flame, when concentrated muriatic acid, which diſengages the phoſphorated hydrogen gas, is poured upon it.

II. Sulphuret of Lime.

1178 Preparation. 1. This compound of ſulphur and lime may be formed by expoſing to heat in a crucible, ſulphur and lime reduced to powder. They fuſe ſlightly, or rather combine into an acrid, reddiſh maſs, which is the ſulphuret of lime, formerly called *calcareous liver of ſulphur*.

1179 Hydrogenated ſulphuret. 2. When it attracts moiſture from the air, or if a little water be thrown upon it, it changes colour, and paſſes to a greeniſh yellow, emitting at the ſame time an extremely fetid odour, and forming ſulphurated hydrogen gas, becomes a hydrogenated ſulphuret.

3. When ſulphur and lime are combined together by means of water, the reſult is not a ſimple ſulphuret, but always a hydrogenated ſulphuret, on account of the water which is decompoſed. This may be prepared, either by throwing water on quicklime, covered with ſulphur in powder; the heat which is emitted by the ſlaking of the lime effecting the combination: or it may be prepared by heating in a matraſs, ſulphur and lime in powder with 10 times their weight of water, or by heating lime water on ſulphur. By the two firſt proceſſes, a liquid is obtained of a red, orange, or yellow colour, of an extremely fetid odour, and a pungent, acrid taſte. This hydrogenated ſulphuret of lime expoſed to the air, is deprived of its colour, gradually decompoſed, and the ſulphur combining with the oxygen of the air, is firſt converted into ſulphurous, and afterwards into ſulphuric acid. It is decompoſed by

by the acids, ſulphur is precipitated, and ſulphurated hydrogen gas is diſengaged.

1180 Hydro-ſulphuret. 4. Lime combines readily with ſulphurated hydrogen. When ſulphurated hydrogen gas is paſſed into a bottle of lime-water, the gas is abſorbed and fixed by combining with the lime, it renders it more ſoluble, and forms the hydroſulphuret lime. This hydroſulphuret, as Berthollet obſerves, performs the part of an acid, by ſaturating the lime, and gives it the property of cryſtallizing. This hydroſulphuret has no colour, and expoſed to the air, emits a ſtrong fetid odour. It is extremely ſoluble in water, and is decompoſed by the acids with efferveſcence, while ſulphurated hydrogen gas is given out. Thus, lime enters into three different combinations with ſulphur, namely into the ſulphuret of lime, the hydroſulphuret, and the hydrogenated ſulphuret.

III. Compounds of Lime with Acids.

1. Sulphate of Lime.

1181 Names. 1. The compound of ſulphuric acid and lime has been known under a great variety of names, as *ſelenite, gypſum, plaſter of Paris, alabaſter, vitriol of lime*. 1182 Found native. The ſulphate of lime is found in great abundance in nature; and it is found ſufficiently pure, ſo that artificial preparation is not required.

1183 Properties. 2. When ſulphate of lime is pure, it is frequently found cryſtallized. The primitive form of its cryſtals is a quadrangular priſm, whoſe baſes are rhomboidal, and the angles 113° and 67°. The integrant particle has the ſame form. The ſpecific gravity is from 2.1679 to 2.3114. It is not changed by expoſure to the air. It is little ſoluble in water. Five hundred parts of cold water, and 450 of boiling water, are required to diſſolve it. 1184 Action of heat. When it is expoſed to heat, it loſes its water of cryſtallization, decrepitates, becomes very friable, and falls down into a very white opaque powder. When this powder is reduced to a paſte with water, it abſorbs it very rapidly, and becomes in a very ſhort time ſolid. From this peculiar property, it is employed for forming *caſts*, under the name of plaſter of Paris. When it is ſtrongly heated for a long time, it becomes phoſphoreſcent, and then melts; and before the blowpipe it gives an opaque, vitreous globule.

1185 Of acids. 3. This ſalt becomes more ſoluble by the action of ſulphuric acid, without being converted into an acidulous ſulphate of lime. The nitric and muriatic acids increaſe its ſolubility without decompoſing it. It is partly decompoſed by the phoſphoric acid in the cold.

1186 Compoſition. 4. The component parts of ſulphate of lime, according to Bergman, are,

Acid	46
Lime	32
Water	22
	100

After being dried in different temperatures, according to Mr Kirwan, the component parts are,

	Dried in 270°.	In a red-heat.	In a white heat.
Acid	50.39	55.84	59
Lime	35.23	38.81	41
Water	14.38	5.35	00
	100.00	100.00	100

Anhydrous Sulphate of Lime.

This is a variety of the ſulphate of lime found native in different places, which, as the name imports, contains no water of cryſtallization. It is found cryſtallized. The primitive form of the cryſtal is a rectangular priſm, having two of its baſes broader than the other two. The ſpecific gravity is 2.950. It has a pearly luſtre, conſiderable hardneſs, phoſphoreſces when it is heated, is tranſparent, and inſoluble in water. The component parts are, according to the analyſis of Mr Chenevix,

Acid	44.88
Lime	55.12
	100.00

2. Sulphite of Lime.

1187 Preparation. 1. This ſalt may be prepared by paſſing a current of ſulphurous acid gas into a bottle of diſtilled water, in which is ſuſpended pure carbonate of lime in powder. A briſk efferveſcence takes place; the ſulphite as it forms, falls to the bottom in the ſtate of powder; and if the gas be continued to be added after the efferveſcence has ceaſed, the ſulphite of lime in the ſtate of powder is completely re-diſſolved; the liquid becomes warm; and as it cools, it affords cryſtals.

1188 Properties. 2. This ſalt is either in the ſtate of white powder, or in the form of ſix-ſided priſms, terminated by long, ſix-ſided pyramids. At firſt it has no taſte, but when it is kept in the mouth for ſome time, it becomes ſulphureous. It effloreſces ſlowly when expoſed to the air, and is converted into ſulphate of lime on the ſurface. It is leſs ſoluble in water than the ſulphate of lime, requiring 800 parts of water to diſſolve it.

1189 Action of heat. 3. When it is expoſed to heat, it is deprived of ſome water, becomes white, and is reduced to powder. A ſtrong heat ſeparates ſome ſulphur, and it is then converted into ſulphate of lime.

1190 Compoſition. 4. The component parts of this ſalt are,

Sulphurous acid	48
Lime	47
Water	5
	100

3. Nitrate of Lime.

1191 Hiſtory. 1. This ſalt which is the compound of nitric acid and lime has been long known under the names of *calcareous nitre, mother water of nitre*, Baldwin's phoſphorus. It always accompanies nitre, and, as one of its names imports, remains in the ſolution from which nitre has been obtained.

1192 Preparation. 2. This ſalt may be prepared by diſſolving carbonate of lime in nitric acid, evaporating to the conſiſtence of ſyrup, and allowing the ſolution to cool ſlowly. It is thus obtained in the ſtate of cryſtals.

1193 Properties. 3. The cryſtals of nitrate of lime are in the form of ſix-ſided priſms, terminated by long pyramids. Sometimes they are in the form of long ſtriated needles, grouped together, of a ſilvery whiteneſs. The taſte is acrid, hot, and bitter. The ſpecific gravity is 1.6207.

1194 Action of water. 4. This is one of the moſt deliqueſcent ſalts. Expoſed to the air for a few hours, it is totally melted.

It is ſometimes employed in chemiſtry on account of this property of attracting moiſture, to deprive gaſes of the vapour of water with which they may be combined. For this purpoſe, the gaſes are made to paſs through tubes which contain dried nitrate of lime. It is owing to a mixture of this ſalt, that nitre is ſometimes deliqueſcent in the air. The nitrate of lime is extremely ſoluble in water. One part of cold water diſſolves four of this ſalt. Boiling water diſſolves ſtill more.

1195 Of heat. 5. When heated, this ſalt is very fuſible. It melts like oil, and after it becomes dry, it often acquires, during calcination, the property of becoming luminous in the dark. Hence the origin of one of its names. More ſtrongly heated, it is decompoſed; gives out red vapours of nitrous gas, oxygen and azotic gaſes, and there remains behind pure lime.

1196 Of acids. 6. This ſalt is decompoſed by the ſulphuric acid, partially by the phoſphoric, and by potaſh and ſoda. By double affinity it is decompoſed by the ſulphates of potaſh, of ſoda, and ammonia. Sulphate of lime, which is an inſoluble ſalt, is always precipitated.

1197 Compoſition. 7. By the analyſis of Bergman, the conſtituent parts of nitrate of lime are the following.

Acid,	43
Lime,	32
Water,	25
	100

By the analyſis of Mr Kirwan, when it is well dried in the air,

Acid,	57.44
Lime,	32.00
Water,	10.56
	100.00

This ſalt has not been applied to any uſe. It is recommended by Fourcroy as a ſubſtitute for nitre in the extraction of nitric acid *.

4. Nitrite of Lime.

When the nitrate of lime is expoſed to heat, till it give out ſome bubbles of oxygen gas, there remains behind a calcareous nitrite, which converts vegetable blues to green, and gives out a great quantity of red vapour by the action of acids. It ſeems to be in the ſtate of nitrite of lime, that this compound poſſeſſes the phoſphoreſcent property †.

5. Muriate of Lime.

1198 Names. 1. The compound of muriatic acid and lime has been known by the names of *calcareous marine ſalt*, *fixed ſal ammoniac*, and *Homberg's phoſphorus*. This ſalt is frequently found in ſolution in ſome mineral waters.

1199 Preparation. 2. It is prepared by ſaturating muriatic acid with carbonate of lime, and evaporating the ſolution to the conſiſtence of ſyrup. It cryſtallizes on cooling.

1200 Properties. 3. The muriate of lime cryſtallizes in ſix-ſided priſms, terminated by ſix-ſided pyramids. The taſte is acrid, bitter, and diſagreeable. It is extremely deliqueſcent in the air. Cold water diſſolves nearly double its weight. Its ſpecific gravity is 1.76.

1201 Action of heat. 4. Expoſed to heat, it becomes ſoft, melts, and ſwells up, and then is deprived of its water of cryſtallization. At a very high temperature it is alſo deprived of part of its acid. In this ſtate, with an exceſs of lime, it acquires the property of ſhining in the dark, from which it has been called *the phoſphorus of Homberg*.

1202 Of Acids. 5. This ſalt is decompoſed by the ſulphuric acid, by the nitric acid, which converts it into the oxymuriatic, and partially by the phoſphoric and fluoric acids.

1203 Compoſition. 6. According to the analyſis of Bergman, the conſtituent parts of this ſalt are,

Muriatic acid,	31
Lime,	44
Water,	25
	100

But according to Mr Kirwan, when it is dried in a red heat, it is compoſed of

Acid,	42
Lime,	50
Water,	8
	100

1204 Uſes. 7. This ſalt is only employed for chemical experiments, and particularly for the production of artificial cold, by mixing it with ſnow or pounded ice. Of all the ſalts employed for this purpoſe, it ſeems to have the greateſt effect, in conſequence of the rapid tranſition from the ſolid to the liquid ſtate. To prepare the ſalt for this purpoſe, it is moſt convenient to evaporate it to the conſiſtence of a pretty thick ſyrup; and then by ſtirring it conſtantly as it cools, it is obtained in a dry granulated ſtate, which ſhould be reduced to powder in the cold, and put up in bottles ſecured with ground ſtoppers.

6. Hyperoxymuriate of Lime.

1205 Preparation. This ſalt, which is the compound of hyperoxymuriatic acid and lime, is prepared by putting a quantity of pure white marble, reduced to powder, into one of the bottles of Woulfe's apparatus, half filled with water, and by paſſing a current of oxymuriatic acid gas into the liquid, till the efferveſcence ceaſes, and the powder has nearly diſappeared. It acquires a pungent ſtyptic taſte, with a reddiſh colour. It exhales the odour of oxymuriatic acid, and not of the hyperoxymuriatic acid. When ammonia is added to this ſolution, it is decompoſed, and there remains ordinary muriate of lime, from which circumſtance it ſeems doubtful whether there is at all formed a hyperoxymuriate of lime. According to Mr Chenevix, this ſalt is extremely deliqueſcent, melts at a low heat, in its water of cryſtallization, and is very ſoluble in alcohol. The component parts of this ſalt are,

1206 Compoſition.

Acid,	55.2
Lime,	28.3
Water,	16.5
	100.0 *.

---

* *Fourcroy Connaiſs. Chim.* iii. p. 133.

† *Ibid.* p. 159.

* *Phil. Tranſ.* 1802. p. 147.

1207 Uſes. This ſalt has been ſucceſsfully employed in the proceſs of bleaching.

7. Fluate of Lime.

1208 Hiſtory. 1. The compound of fluoric acid and lime has been long known under the names of *fluor ſpar*, *cubic ſpar*, and *phoſphoric ſpar*, from the figure of its cryſtals, or from ſome of its properties. This ſalt exiſts in great abundance in nature, and in a ſtate of conſiderable purity.

1209 Preparation. 2. It may be artificially prepared, by combining fluoric acid with lime in ſolution in water. The ſalt is depoſited in the form of powder in the bottom of the veſſel; and when it is taken out, it is to be well waſhed and dried.

1210 Properties. 3. When the fluate of lime is found native, it is generally cryſtallized in the form of cubes, the angles of which, and ſometimes the edges, are truncated. The primitive form of the cryſtal is the regular octahedron. The form of its integrant particle is the regular tetrahedron. It has frequently a conſiderable degree of tranſparency, and exhibits a great variety of colours. The ſpecific gravity is 3.15. It has no taſte, is not altered by expoſure to the air, and it is inſoluble in water.

1211 Action of heat. 4. When it is expoſed to heat, it decrepitates and becomes luminous in the dark; but when it has once given out this light, it cannot be reſtored, either by expoſing it to the ſun's rays, or by calcination with charcoal or any other combuſtible ſubſtance. From this circumſtance it appears, that this phoſphoreſcent property is owing to ſome volatile principle which has been a conſtituent part of the ſalt. The artificial fluate of lime alſo poſſeſſes the ſame property, and even, according to Scheele, in a higher degree. When it is ſtrongly heated, it melts into a tranſparent glaſs.

1212 Of acids. 5. This ſalt is decompoſed by the ſulphuric, nitric and muriatic acids, by the carbonates of potaſh and ſoda, and by moſt of the phoſphates. It is by decompoſing it by means of the ſulphuric acid, that the fluoric acid is obtained.

1213 Uſes. 6. The fluate of lime is much employed in ſmall pieces of ſculpture, and for ornamental purpoſes in the formation of cups, vaſes, and pyramids. It is employed alſo as a flux for mineral ſubſtances.

8. Borate of Lime.

This ſalt, which is a compound of boracic acid and lime, is prepared by pouring a ſolution of boracic acid into lime water, or by decompoſing the ſoluble alkaline borates by means of lime water. A precipitate is thus formed, of a ſalt nearly inſoluble, which is inſipid, and in the form of a white powder. Little is known of the properties of this ſalt.

9. Phoſphate of Lime.

1214 Hiſtory and preparation. 1. The compound of phoſphoric acid and lime, known under the name of *calcareous phoſphoric ſalt*, is one of the moſt intereſting diſcoveries of modern chemiſtry. This was made by Scheele and Gahn in 1774, when they proved that it formed the baſis of bones. To obtain this ſalt in a ſtate of purity, a quantity of bones is calcined to whiteneſs, reduced to powder, and well waſhed with water to ſeparate the carbonate of ſoda and other ſoluble ſalts which are generally combined with it. The phoſphate of lime is thus procured in the form of an inſipid white powder. In this ſtate it is generally mixed with a little carbonate of lime, which may be ſeparated by diluted acetic acid, and afterwards waſhing it with water.

1215 Properties. 2. By this proceſs the phoſphate of lime is procured in a ſtate of purity from the ſolid matter of bones. It has no taſte, and does not change the colour of vegetable blues. When it is prepared artificially, it is in the form of white powder, but as it exiſts in nature, it is found regularly cryſtallized. This is known to mineralogiſts under the name of *apatite*, of which there are ſeveral varieties. The primitive form of its cryſtal is the regular ſix-ſided priſm; the primitive form of the integrant molecule is a three-ſided priſm, whoſe baſes are equilateral triangles. It remains unaltered by expoſure to the air, and it is ſoluble in water.

1216 Action of heat. 3. When this ſalt is expoſed to heat, it ſcarcely undergoes any change; but when it is expoſed to the ſtrong heat of a glaſshouſe furnace, it is converted into a ſemitranſparent porcelain.

1217 Of acids. 4. The phoſphate of lime is decompoſed by the ſulphuric, nitric, muriatic, and other acids; but this decompoſition is only partial. Part of the lime only is abſtracted, and the ſalt is converted into an acidulous phoſphate of lime.

1218 Compoſition. 5. The component parts of phoſphate of lime, according to Fourcroy and Vauquelin, are,

Acid,	41
Lime,	59
	100

1219 Uſes. 6. The phoſphate of lime is of great importance in chemiſtry, for the purpoſe of extracting phoſphoric acid, to be decompoſed to obtain phoſphorus. It is alſo employed for making cupels, for poliſhing metals and precious ſtones, and for removing ſpots of greaſe from linen, paper, and ſilk. It is uſed in medicine as a remedy for rickets, to correct the ſuppoſed effects of acids in ſoftening the bones.

Superphoſphate of Lime.

1220 Hiſtory. 1. This ſalt, with an exceſs of acid, was diſcovered by Fourcroy and Vauquelin in 1795. Scheele had remarked, that the phoſphate of lime was diſſolved by an acid in human urine, but he had not aſcertained that this combination between the phoſphoric acid and the phoſphate of lime, conſtituted a permanent ſalt.

1221 Preparation. 2. It may be obtained artificially by the partial decompoſition of the phoſphate of lime by means of any acid, or by diſſolving this ſalt in phoſphoric acid. This laſt proceſs, Fourcroy obſerves, is the moſt certain; and when the phoſphoric acid has diſſolved as much as it can take up of the phoſphate of lime, the ſalt is in the ſtate of acidulous phoſphate, or ſuperphoſphate.

1222 Properties. 3. This ſalt cryſtallizes in ſmall ſilky threads, or in brilliant plates of a pearly luſtre, which are attached to each other, and ſeem to have the conſiſtence of honey or glue. It has a ſtrong acid taſte. Expoſed to the air, it is ſlightly deliqueſcent. It is ſoluble in water, and the ſolution produces cold. It is more ſoluble in boiling water, and cryſtallizes by cooling.

1223 Action of heat. 4. When this ſalt is expoſed to heat, it firſt melts, and then ſwells up and dries. If the temperature be increaſed, it undergoes the igneous fuſion, and is converted into a tranſparent glaſs. The phoſphoric acid in this ſalt is more readily decompoſed by charcoal than in the neutral phoſphate of lime. It is not decompoſed by any of the acids, excepting the oxalic. The proportions of its conſtituent parts are the following.

1224 Compoſition.

Acid,	54
Lime,	46
	100 *.

10. Phoſphite of Lime.

1225 Preparation. 1. This ſalt, compoſed of phoſphorous acid and lime, is formed by the direct combination of the acid with the earth, and when they are ſaturated, it falls to the bottom in the form of white powder. This powder is re-diſſolved with an exceſs of acid, and in this ſtate of acidulous phoſphite of lime, cryſtallizes by evaporating the ſolution.

1226 Properties. 2. When thus obtained, it is in the form of a white powder, if it is juſt neutralized; but with an exceſs of acid, it forms ſmall priſms or needles. This ſalt has no taſte; it is not changed by expoſure to the air; and it is inſoluble in water.

1227 Action of heat. 3. When it is expoſed to heat, it gives out a phoſphoric light, yields a ſmall quantity of phoſphorus, and is converted into a phoſphate. By the action of the blow-pipe it melts into a tranſparent globule.

1228 Of acids. 4. The neutral phoſphite of lime is ſoluble in acids, without being decompoſed. The proportions of its conſtituent parts are,

1229 Compoſition.

Phoſphorous acid,	34
Lime,	51
Water,	15
	100

11. Carbonate of Lime.

1230 Names. 1. This ſalt exiſts in great abundance in nature; and it is known by a great variety of names, as *limeſtone*, *marble*, *chalk*. 1231 Preparation. It may be prepared artificially, by directly combining carbonic acid with lime; but in this proceſs the proportions of the acid and earth muſt be accurately adjuſted; for, if there is too little acid, the firſt precipitate which is formed is re-diſſolved in the water, and ſeems to form carbonate with exceſs of lime. If there be too much acid, the carbonate firſt precipitated is alſo re-diſſolved, and diſappears in this exceſs of carbonic acid.

1232 Properties. 2. The carbonate of lime is perfectly taſteleſs. The ſpecific gravity is 2.7. It is frequently found cryſtallized, and exhibits a great variety of forms. When it is tranſparent and in the rhomboidal form, it has the property of double refraction. The primitive form of its cryſtals is an obtuſe rhomboid, whoſe angles are about 101½° and 78½°. The integrant molecule has the ſame form.

3. When it is expoſed to the air it undergoes no change. It is inſoluble in water.

1233 Action of heat. 4. Expoſed to a ſtrong heat, it decrepitates, and is deprived of its water of cryſtallization. It becomes white, opaque, and friable. If the heat be increaſed and continued, the whole of the carbonic acid is driven off in the ſtate of gas.

1234 Of acids. 4. The carbonate of lime is readily decompoſed by all the acids with effervеſcence, owing to the diſengagement of the carbonic acid in the ſtate of gas.

1235 Compoſition. 5. The component parts of carbonate of lime, as they have been aſcertained by the analyſes of Bergman and Kirwan, are the following.

	Bergman.	Kirwan.
Acid,	34	45
Lime,	55	55
Water,	11	00
	100	100

12. Arſeniate of Lime.

1236 Preparation. This ſalt, which is a compound of arſenic acid and lime, is prepared by dropping the acid into lime water. A precipitate is formed, which is ſoluble, either with an exceſs of the baſe, or the acid. Or it may be formed by diſſolving carbonate of lime in arſenic acid. The acidulous arſeniate of lime, when it is evaporated, affords ſmall cryſtals. 1237 Action of heat. When this ſalt is heated, it melts, but is not decompoſed *.

13. Tungſtate of Lime.

1238 Found native. The compound formed by tungſtic acid and lime, is found native. It is from the mineral called tungſten, that the metallic ſubſtance is obtained which bears this name. 1239 Preparation. When the ſolution of tungſtic acid is added to lime water, a precipitate of tungſtate of lime is formed, ſimilar to the native compound tungſten. This mineral is found cryſtallized. The primitive form of the cryſtal is the octahedron, which is compoſed of two four-ſided pyramids, applied baſe to baſe. It is of a yellowiſh colour, with ſome degree of tranſparency and conſiderable hardneſs. It is inſoluble in water, and is ſcarcely altered by the action of heat. The ſpecific gravity is about ſix. 1240 Compoſition. The component parts of this ſalt are,

Tungſtic acid	70
Lime	30
	100

14. Molybdate of Lime.

15. Acetate of Lime.

1241 Preparation. 1. The compound of acetic acid and lime is formed by diſſolving the carbonate of lime in the acid, till it is ſaturated. By evaporating the ſolution till a pellicle forms on the ſurface, it cryſtallizes on cooling.

1242 Properties. 2. The cryſtals of acetate of lime are in the form of ſmall priſms, with a ſhining ſilky luſtre. The taſte is bitter and ſour. It is not changed by expoſure to the air, but is ſoluble in water. The ſpecific gravity is 1.005.

1243 Action of heat. 3. When it is expoſed to heat, it is decompoſed, partly by the ſeparation of the acid, and partly by its decompoſition. 1244 Compoſition. The component parts of this ſalt, according to Dr Higgins, are,

Acetic acid and water	64.3
Lime	35.7
	100.0 †

16.

---

* *Fourcroy Connaiſs. Chim.* iii. p. 247.

* *Fourcroy Connaiſs. Chim.* v. p. 83.

† *Experiments*, p. 47.

16. Oxalate of Lime.

The oxalic acid ſaturated with lime, forms an inſoluble ſalt, which may be formed by dropping oxalic acid into any of the acid ſolutions of lime. The oxalate of lime thus formed, is a white powder, which converts the ſyrup of violets to a green. This ſalt cannot be decompoſed by any other acid, the affinity of oxalic acid for lime is ſo ſtrong. It is on this account that oxalic acid is employed as a teſt for lime, whether it is in a ſtate of combination, or uncombined. This ſalt may be decompoſed by expoſing it to heat. The acid itſelf is driven off, and undergoes decompoſition.

The component parts of this ſalt, according to Bergman, are,

Acid	48
Lime	46
Water	6
	100

17. Tartrate of Lime.

1245 Preparation. The compound of tartaric acid and lime may be formed, by diſſolving lime in the acid; or by adding a ſolution of lime in powder to a ſolution of tartar in boiling water, till it ceaſes to efferveſce, and to redden vegetable blues. The ſalt precipitates in the form of a white powder, which is inſoluble, excepting with an exceſs of acid. This ſalt is decompoſed by the ſulphuric, nitric, and muriatic acids.

18. Citrate of Lime.

1246 Preparation. This ſalt, which is a compound of citric acid and lime, may be formed by the direct combination of the acid and the earth. Small cryſtals are formed, which are precipitated, and are ſcarcely ſoluble in water, excepting with an exceſs of acid, and from this ſolution it may be obtained cryſtallized. 1247 Compoſition. The component parts of this ſalt are,

Citric acid	62.66
Lime	37.34
	100.00 *

19. Malate of Lime.

1248 Preparation. 1. The compound of malic acid and lime may be formed by combining the acid with the earth, and neutralizing them. Small irregular cryſtals are thus obtained, which are ſcarcely ſoluble in boiling water, but become very ſoluble with an exceſs of acid. In this ſtate it is the ſupermalate of lime. 1249 Exiſts in plants. This ſalt is found ready formed in ſome vegetables, as in houſe-leek and ſimilar ſucculent plants.

1250 Properties. 2. This acidulous malate of lime has an acid taſte. When it is evaporated, it forms a ſolid, ſhining ſubſtance, analogous to varniſh. It is decompoſed by the ſulphuric and oxalic acids, and alſo by the alkalies. Lime water added to a ſolution of this ſalt, combines with exceſs of acid, and precipitates the malate of lime.

20. Gallate of Lime.

The gallic acid combined with lime, forms a yellowiſh coloured, inſoluble ſalt, which, with an exceſs of baſe, becomes ſoluble.

21. Benzoate of Lime.

The compound of benzoic acid and lime, forms a ſalt which is very ſoluble in water. This ſalt cryſtallizes in an arboreſcent form on the ſides of the veſſel which contains the ſolution. It is decompoſed by the ſulphuric, nitric, and muriatic acids. It exiſts in great abundance in the urine of graminivorous quadrupeds.

22. Succinate of Lime.

The compound of ſuccinic acid and lime forms ſalts which are not very ſoluble in water, and are not altered by expoſure to the air.

23. Saccolate of Lime.

Saclactic acid and lime form an inſoluble ſalt.

24. Camphorate of Lime.

1251 Preparation. 1. This ſalt, which is a compound of camphoric acid and lime, is formed by adding lime water to cryſtallized camphoric acid. The ſolution is then to be boiled, filtered, and evaporated to three-fourths of its quantity. As it cools, the ſalt is depoſited.

1252 Properties. 2. The camphorate of lime has no regular ſhape, unleſs the evaporation has been properly managed, when it is found in the form of plates lying on each other. It is of a white colour, and has a ſlightly bitter taſte.

1253 Action of water and heat. 3. It effloreſces in the air, and falls down into powder. It is ſcarcely ſoluble in cold, and requires about 200 parts of boiling water for its ſolution. When it is expoſed to heat, if it be moderate, it melts and ſwells, but if thrown on red-hot coals, or heated in cloſe veſſels, the acid is decompoſed and ſublimed, and the lime remains pure.

4. It is decompoſed by the ſulphuric, nitric, and muriatic acids. With the ſulphuric acid there is formed an inſoluble precipitate. The nitric and muriatic acids precipitate the camphoric acid. This ſalt is alſo decompoſed by the carbonate of potaſh, and the phoſphate of ſoda.

5. The component parts of this ſalt are,

Camphoric acid	50
Lime	43
Water	7
	100 *.

25. Suberate of Lime.

1254 Properties. This ſalt, which is a compound of ſuberic acid and lime, does not cryſtallize, is perfectly white, has a ſlight ſaline taſte, and does not redden the tincture of turnſole. It is ſcarcely ſoluble in cold water. Boiling water diſſolves it more abundantly, but as it cools, a part of it is precipitated. 1255 Action of heat. When it is placed upon burning coals, it ſwells up, the acid is decompoſed, and the lime remains in the ſtate of powder. This ſalt is decompoſed by the ſulphuric, nitric, and muriatic acids, by potaſh and ſoda, and their carbonates, and by the phoſphate and borate of ſoda †.

26. Mellate of Lime.

The mellitic acid dropt into lime-water, forms a precipitate which is re-diſſolved by adding nitric acid.

---

* *Fourcroy* vii. p. 207.

* *Ann. de Chim.* xxvii. 23.

† *Ibid.* xxiii. p. 54.

Or when the mellitic acid is mixed with a ſolution of ſulphate of lime, a precipitate is formed of ſmall, gritty cryſtals, which do not affect the tranſparency of the water.

27. Lactate of Lime.

The compound of lactic acid and lime forms a deliqueſcent ſalt, which is ſoluble in alcohol.

28. Pruſſiate of Lime.

The compound of pruſſic acid and lime is formed by diſſolving the lime in the acid. The ſolution is then to be filtered, and the lime which has not combined with the acid is to be ſeparated by adding carbonic acid in water, in the proportion neceſſary to precipitate the lime from the ſame bulk of lime-water. The ſolution, after a ſecond filtration, muſt be preſerved in cloſe veſſels. By diſtillation the pruſſic acid is driven off, and the pure lime remains behind. This ſalt is decompoſed by all the other acids, and alſo by the alkalies.

29. Sebate of Lime.

When ſebacic acid is dropped into lime-water, the tranſparency of the water is not diſturbed, ſo that the compound of this acid with lime is ſoluble in water.

IV. Compounds of Lime with Inflammable Subſtances.

Lime does not enter into combination with alcohol or ether; but it forms compounds with the fixed oils which are known by the name of ſoaps. Lime combines alſo in ſmall quantity with the volatile oils, forming a ſimilar compound.

SECT. II. *Of BARYTES and its Combinations.*

1256 History. For the knowledge of this earth we are indebted to modern chemiſtry. It was diſcovered by Scheele in 1774; and its properties were inveſtigated by him, and in the following year by Gahn, who analyzed a mineral which had been diſtinguiſhed by the name of *ponderous ſpar*, on account of its weight, and found that it was compoſed of ſulphuric acid and the new earth. It received the name of *terra ponderoſa* from Bergman, who alſo examined its properties, and confirmed the experiments of Scheele and Gahn. Mr Kirwan gave it the name of *barytes*, from the Greek word βαρυς, which ſignifies heavy. Its properties were farther inveſtigated by Dr Hope, in 1793 [*], and by Pelletier, Fourcroy, and Vauquelin in 1797 [†].

1257 Preparation. 2. This earth may be obtained in a ſtate of purity by the following proceſs: A quantity of ſulphate of barytes, a mineral found in conſiderable abundance in nature, is firſt reduced to a fine powder. Mix it with $\frac{1}{8}$ of its weight of charcoal powder, and expoſe the mixture in a crucible to a ſtrong heat, for ſeveral hours. The ſulphuric acid, by this proceſs, is decompoſed, by being deprived of its oxygen, which combines with the carbone of the charcoal, and forms carbonic acid, which is driven off. The ſulphur remains in combination with the earth, forming a ſulphuret of barytes. This ſulphuret is to be diſſolved in water, and nitric acid poured into the ſolution. The nitric acid combines with the barytes, and forms nitrate of barytes, while the ſulphur is precipitated. The ſolution is to be filtered, and ſlowly evaporated till it cryſtallize. The cryſtals thus formed are then put into a crucible, and expoſed to a ſtrong heat. The nitric acid is decompoſed, and driven off, and the earth remains behind in a ſtate of purity.

Dr Hope has recommended another proceſs, which is more economical. By this proceſs the ſulphate of barytes is decompoſed as in the former. The ſulphuret which is obtained, is thrown into water, that all ſoluble matters may be diſſolved. To the ſolution, after filtration, a ſolution of carbonate of ſoda is to be added. A precipitate takes place in the form of a white powder. This powder is to be waſhed with water, made up into balls with charcoal, and expoſed to a ſtrong heat in a crucible. The balls are afterwards to be thrown into boiling water, when part of the barytes is found diſſolved, and, as the water cools, it cryſtallizes.

3. Barytes, as it is obtained by decompoſing the nitrate in the firſt proceſs, is in the form of ſmall, gray, porous maſſes, which are eaſily reduced to powder. It has a hot, burning taſte; and, when introduced into the ſtomach, is a deadly poiſon. Its ſpecific gravity is 4.00. It deſtroys the texture of all animal ſubſtances. It converts vegetable blues to a green colour. In many of its properties it is perfectly analogous to the fixed alkalies. 1258 Properties.

4. When it is expoſed to the air, eſpecially if the atmoſphere be loaded with moiſture, it ſwells up in a few minutes, becomes hot, and at laſt falls into a white powder. It is then deprived of part of its acrimony, and is increaſed in weight 0.22. This is owing to the abſorption of water from the atmoſphere. If a ſmall quantity of water be thrown upon barytes, it boils up, is ſtrongly heated, is enlarged in volume, and gives out a great quantity of heat. After being ſlaked in this manner, it is diluted with water, the earth cryſtallizes, and aſſumes the appearance of needle-formed cryſtals, which, at the end of ſome time, if expoſed to the air, ſpontaneouſly fall to powder. With a greater quantity of water the barytes is completely diſſolved. Cold water takes up about $\frac{1}{20}$ of its weight. This ſolution changes the ſyrup of violets to green, and at laſt deſtroys the colour. When this liquid is expoſed to the air, a thick pellicle is formed on the ſurface, which is owing to the abſorption of carbonic acid from the atmoſphere. Boiling water diſſolves $\frac{1}{2}$ its weight of pure barytes. The ſolution affords cryſtals as it cools. They are in the form of long, four-ſided priſms, tranſparent and white, which effloreſce in the air; but the form of the cryſtals varies according to the rapidity of the evaporation and cryſtallization. 1259 Action of water.

5. Light has no action on barytes. Heated on charcoal with the blow-pipe, it melts into an opaque, gray globule, which ſoon penetrates the charcoal. Expoſed to heat in a crucible, it melts, and attaches itſelf to the ſides of the veſſel, to which it adheres ſtrongly, forming a kind of greeniſh covering. Leſs ſtrongly heated, it hardens, and internally aſſumes a bluiſh green ſhade. There is no action between barytes and oxygen, azote, hydrogen, or carbone. 1260 Of heat.

---

[*] *Edin. Tranſ.* iv. 36.

[†] *Ann. de Chim.* xxi. 113.

I. Phoſphuret of Barytes.

1261 Preparation. 1. Barytes enters into combination with phoſphorus, forming the compound called *phoſphuret of barytes.* This is prepared by introducing a mixture of barytes and phoſphorus into a glaſs tube cloſed at one end, and expoſing the mixture to the heat of burning coals. The two ſubſtances rapidly combine together.

1262 Properties. 2. The phoſphuret of barytes, thus obtained, is of a dark or ſhining brown colour, having a metallic appearance, very fuſible, and exhaling, when it is moiſtened, a ſtrong fetid odour: in the dark it is luminous. When it is thrown into water, it is decompoſed, giving out phoſphorated hydrogen gas, and is gradually converted, by the action of the air and the water, into *phoſphate of barytes* *.

II. Sulphuret of Barytes.

1263 Preparation. A ſimilar combination alſo takes place between barytes and ſulphur. This combination may be formed by introducing barytes and ſulphur well mixed together, into a crucible, and expoſing them to a red heat. At that temperature the mixture melts, and the compound which is formed is the ſulphuret of barytes.

1264 Properties. This ſubſtance is very ſoluble in water, which it inſtantly decompoſes; and, when it is ſaturated with the ſulphurated hydrogen which is formed, it is converted 1265 Hydrogenated ſulphuret. into a hydrogenated ſulphuret of barytes, which depoſits by cooling, cryſtals of different forms, ſometimes in that of ſmall needles, ſometimes in that of large ſix-ſided priſms, ſometimes in the form of octahedrons, and often in that of ſmall, brilliant, hexagonal plates, which are cryſtals of ſulphurated hydrogen and barytes, denominated by Berthollet, *hydroſulphuret of barytes.* When the ſulphuret of barytes is diſſolved in water, it inſtantly exhales the fetid odour of ſulphurated hydrogen gas. The liquid which has depoſited cryſtals of hydroſulphuret of barytes, retains a hydrogenated ſulphuret in ſolution. When it is expoſed to the air, this ſolution becomes of an orange yellow. Cryſtals of hydroſulphuret of barytes, with ſpots or yellowiſh plates, are often obſerved in the midſt of the white maſſes.

3. The ſulphuret of barytes is moſt remarkable for the great rapidity with which it decompoſes water, and the great quantity of the ſulphurated hydrogen with which it combines, forming the hydroſulphuret of barytes; which latter is ſlowly, and with difficulty, decompoſed by the air, and the great proportion of ſulphurated hydrogen gas which is diſengaged by the action of acids, without any precipitation of ſulphur.

1266 Three compounds. 4. Thus, there are three different combinations of ſulphur with barytes. In the firſt, the ſulphur is directly combined with the barytes, as when they are expoſed to heat in the ſtate of dryneſs, which is the ſimple ſulphuret of barytes. In the other, the ſulphur combined with the hydrogen, is in the ſtate of hydroſulphuret of barytes. This compound is prepared by paſſing ſulphurated hydrogen gas into water holding barytes in ſolution, which, as it combines with the gas, becomes more ſoluble, and is condenſed and abſorbed by the water. The diſtinctive character between the latter combination and that of the ſulphuret of barytes is, that the firſt, by the action of acids, only gives out ſulphurated hydrogen gas, without any depoſition of ſulphur; and the ſecond, expoſed to heat, is deprived of its ſulphur, which is ſublimed, without affording ſulphurated hydrogen gas. Between theſe two ſtates, there is an intermediate combination, in which the ſulphuret of barytes holds in ſolution more or leſs ſulphurated hydrogen; ſo that, by the action of acids, it affords ſulphurated hydrogen gas, with a depoſition of ſulphur at the ſame time. To this intermediate compound, Berthollet has given the name of *hydrogenated ſulphuret of barytes* *.

III. Compounds of Barytes with the Acids.

1267 Affinities. Barytes enters into combination with the acids, and forms with them compounds, which are diſtinguiſhed by the name of *ſalts*. The order of affinities of barytes for the acids, according to Bergman, is the following.

Sulphuric acid,
Oxalic,
Succinic,
Fluoric,
Phoſphoric,
Saclactic,
Nitric,
Muriatic,
Suberic,
Citric,
Tartaric,
Arſenic,
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Carbonic,
Pruſſic.

1. Sulphate of Barytes.

1268 Found native. 1. This ſalt, which is a compound of ſulphuric acid and barytes, was formerly diſtinguiſhed by the name of *heavy ſpar*, *phoſphoric ſpar*, or *Bolognian ſtone*. It exiſts in great abundance in nature, particularly accompanying metallic veins; from which circumſtance, probably, and from its great weight, it was ſuppoſed to contain a metallic ſubſtance. It is rarely formed artificially, as that found in nature is ſufficiently pure.

1269 Properties. 2. The ſulphate of barytes is the heavieſt of all the ſalts, the ſpecific gravity being 4.4. It has neither taſte nor ſmell. Sometimes it is found cryſtallized, and ſometimes compact. There is a conſiderable variety among the forms of its cryſtals. The primitive form of ſulphate of barytes is a rhomboid, with right angles at the baſes, whoſe angles are $101\frac{1}{2}^\circ$ and $78\frac{1}{2}^\circ$. The integrant molecule is the ſame.

1270 Action of heat. 3. This ſalt remains unchanged in the air, and it is inſoluble in water. When it is ſuddenly heated, it decrepitates. By the action of a ſtrong heat, it melts with difficulty; and before the blow-pipe it fuſes, and is converted into a white opaque globule. It is decompoſed at a red heat by hydrogen and charcoal, and is converted into a ſulphuret which is phoſphoric. This was formerly called, from an accident, *Bolognian phoſphorus.*

---

* *Fourcroy Connaiſs. Chim.* ii. p. 191.

* *Fourcroy Connaiſs. Chim.* ii. p. 191.

phoſphorus. A piece of the ſulphate of barytes was found in the neighbourhood of Bologna, by a ſhoemaker of that city, who ſuſpecting that it contained ſilver, put it into the fire to ſeparate the metal. He found no ſilver, but he obſerved that by heating it acquired the property of ſhining in the dark, and thence it obtained the name of Bolognian ſtone or phoſphorus.

This ſalt is decompoſed by the carbonates of potaſh and ſoda, either by expoſing them to a ſtrong heat in a crucible, or by boiling them together in ſolution.

1271 Compoſition. According to the different analyſes which have been made to aſcertain the conſtituents of this ſalt, it appears that there is a conſiderable difference between the natural and artificial ſulphate of barytes, as in the following table.

	Native.	Artificial.
Acid	13	33
Barytes	84	64
Water	3	3
	100	100 *.

By another analyſis, when the artificial ſulphate was heated to redneſs, the component parts were found according to

	Thenard †.	Chenevix ‡.
Acid	25.18	24
Barytes	74.82	76
	100.00	100

2. Sulphite of Barytes.

1272 Preparation. 1. This compound of ſulphurous acid and barytes, is formed by paſſing ſulphurous acid gas into water, in which is mixed, or ſuſpended, carbonate of barytes in the ſtate of fine powder; or by the direct combination of ſulphurous acid and barytes, either ſolid or in ſolution. In whatever way it is prepared, the ſalt is depoſited in the form of powder, or cryſtallized.

1273 Properties. 2. The cryſtals of ſulphite of barytes are ſometimes in the form of ſmall, brilliant, and opaque needles, or very hard tranſparent cryſtals in the form of tetrahedrons, with truncated angles. It has little taſte. The ſpecific gravity is 1.6938. It is ſcarcely altered when expoſed to the air, and is inſoluble in water. When it is expoſed to heat, ſulphur is driven off, and there remains a ſulphate of barytes. It is decompoſed by the ſulphuric and muriatic acids, with the diſengagement of ſulphurous acid.

1274 Uſes. 3. This ſalt has been applied to no uſe, excepting for the chemical purpoſe of aſcertaining the purity of ſulphurous acid. It is employed in this way by Fourcroy. If there be any mixture of ſulphurous acid with the ſulphuric, it may be detected by this ſalt; for as there is a ſtronger affinity between ſulphuric acid and barytes than between ſulphurous acid and the ſame earth, the ſulphuric acid, if any be preſent, combines with the barytes, and forms with it an inſoluble ſalt, which is precipitated.

1275 Compoſition. 4. The following are the proportions of the conſtituent parts of this ſalt.

Sulphurous acid	39
Barytes	59
Water	2
	100 *

3. Nitrate of Barytes.

1276 Preparation. 1. This compound of nitric acid and barytes is prepared by ſaturating the acid with native carbonate of barytes; or, by the decompoſition of ſulphuret of barytes, by nitric acid. By filtration and evaporation this ſalt cryſtallizes.

1277 Properties. 2. The cryſtals of nitrate of barytes are in the form of regular octahedrons, or in ſmall brilliant plates. The ſpecific gravity is 2.9149. It has a hot, acrid, and auſtere taſte, and is little changed by being expoſed to the air. It is ſoluble in 12 parts of cold, and in about three or four parts of boiling water. When placed upon burning coals, it decrepitates, boils up, and becomes dry, and gives out ſparks round the points where it comes in contact with the burning coal. When it is heated in a retort, it gives out a little water, oxygen gas, and azotic gas; and there remains behind, the barytes in the form of a ſolid, gray, porous maſs.

1278 Compoſition. The conſtituent parts of this ſalt, according to Fourcroy, Vauquelin, and Kirwan, are the following.

	Fourcroy and Vauquelin †.	Kirwan ‡.
Nitric acid,	38	32
Barytes,	50	57
Water,	12	11
	100	100

This ſalt is only employed for detecting ſulphuric acid in nitric acid, and to be decompoſed for the purpoſe of obtaining pure barytes.

4. Nitrite of Barytes.

Nothing farther is known of this ſalt, than that it is formed when the nitrate of barytes is decompoſed in a retort by means of heat. If the operation be ſtopped at the time that a third part of the oxygen gas has been diſengaged, the nitrite of barytes remains.

5. Muriate of Barytes.

1279 Hiſtory. 1. This ſalt, which is a compound of muriatic acid and barytes, was firſt inveſtigated by Scheele and Bergman, and little more has been ſince added by the experiments and reſearches of other chemiſts.

1280 Preparation. 2. It is prepared by the direct combination of muriatic acid with the carbonate of barytes; or, by decompoſing the ſulphuret of barytes by the muriatic acid, filtering the ſolution, and evaporating till a pellicle appear on the ſurface. If it be allowed to cool ſlowly, cryſtals of muriate of barytes are formed. But the ſulphate of barytes, which is employed, ſometimes contains iron; ſo that a muriate of this metal is formed along with the muriate of barytes. To ſeparate the iron, the mixture is to be calcined, by which the acid is driven off, and the iron remains behind in the ſtate of oxide, which is inſoluble in water.

1281 Properties. 3. The primitive form of the cryſtals of this ſalt is

---

* *Fourcroy Connaiſs. Chim.* iii. p. 25.

† *Ann. de Chim.* xxxii. p. 266.

‡ *Nichol. Jour.* ii. 8vo. p. 196.

* *Fourcroy Connaiſs. Chim.* iii. p. 75.

† *Ibid.* iii. p. 106.

‡ *Nichol. Jour.* iii. p. 115.

a four-ſided priſm with ſquare baſes. The form of the integrant particle is the ſame. It cryſtallizes in tables, or in eight-ſided pyramids. The taſte is acrid, aſtringent, and metallic. The ſpecific gravity is 2.8257.

1282 Action of water. 4. It undergoes no change by expoſure to the air. It is ſoluble in five or ſix parts of cold water, but boiling water diſſolves more; and, on cooling, the ſalt cryſtallizes.

1283 Of heat. 5. When expoſed to heat, it decrepitates, loſes its water of cryſtallization, dries, falls down to powder, and at laſt melts; but no heat that can be applied decompoſes it.

1284 Of acids. 6. This ſalt is decompoſed by the ſulphuric and nitric acids, and a precipitation of nitrate or of ſulphate of barytes is formed.

1285 Compoſition. 7. The conſtituent parts of this ſalt, according to Mr Kirwan, are,

		When dried,
Acid,	20	23.8
Barytes,	64	76.2
Water,	16	00.0
	100	100.0

1286 Uſes. 8. This is one of the moſt delicate teſts for detecting ſulphuric acid in any ſolution. Water, which holds 0.0002 parts of ſulphuric acid, exhibits a viſible precipitate by a ſingle drop of the ſolution of muriate of barytes. Nay, there is a ſlight cloud in a few minutes produced by the addition of a ſolution of this ſalt to water, which holds 0.00009 parts of ſulphuric acid in ſolution. The muriate of barytes has been propoſed and recommended as a cure for ſcrophula; and it is ſaid, in ſome caſes in which it has been uſed, with good effect; but it ought to be adminiſtered with the utmoſt caution. The carbonate of barytes is one of the moſt active poiſons, and probably all the ſalts of this earth are poſſeſſed of ſimilar properties. The doſe ſhould not exceed five or ſix drops of the ſolution at firſt *.

6. Hyperoxymuriate of Barytes.

1287 Preparation. 1. The compound of hyperoxymuriatic acid and barytes was formed by Mr Chenevix. The proceſs which he followed was, to cauſe a current of oxymuriatic acid gas to paſs through a ſolution of a large quantity of barytic earth in warm water. This ſalt he found ſoluble in four parts of cold, and leſs of warm water; but as it cryſtallizes like the muriate of this earth, and has the ſame degree of ſolubility, he could not ſeparate the hyperoxymuriate from the muriate, which was formed at the ſame time. He therefore thought of obtaining it by double affinity, as in the following proceſs.

2. When phoſphate of ſilver is boiled with muriate of barytes, a double decompoſition takes place; muriate of ſilver and phoſphate of barytes are formed, both of which being inſoluble, are precipitated. But the phoſphate of ſilver does not decompoſe the hyperoxymuriate of barytes. When therefore the muriate and hyperoxymuriate of barytes are boiled with phoſphate of ſilver, the muriate of barytes only is decompoſed. The muriate of ſilver and the phoſphate of barytes are precipitated, and the hyperoxymuriate of barytes remains in ſolution. When this ſalt is decompoſed by the ſtronger acids it is accompanied with a flaſh of light, which Mr Chenevix conjectures, is owing to the relative proportionate affinities, and conſequently the greater rapidity of the diſengagement.

1288 Compoſition. The proportions of this ſalt are,

Hyperoxymuriatic acid,	47.0
Barytes,	42.2
Water,	10.8
	100.0 *.

7. Fluate of Barytes.

This compound of fluoric acid and barytes may be formed, by pouring fluoric acid into a ſolution of nitrate or muriate of barytes. A precipitate is formed, which is the fluate of barytes. This ſalt is decompoſed with effervеſcence by the ſulphuric acid, and it is precipitated by lime water. Of the proportions of its conſtituent parts and other properties nothing is known.

8. Borate of Barytes.

The compound of boracic acid and barytes is formed by pouring a ſolution of boracic acid into a ſolution of barytes. An inſoluble white powder is precipitated, which, according to Bergman, may be decompoſed, even by the weak vegetable acids.

9. Phoſphate of Barytes.

1289 Preparation. 1. The compound of phoſphoric acid and barytes, has been only examined by Vauquelin. It is prepared, either by the direct combination of phoſphoric acid with barytes, or the carbonate of barytes; or by precipitating a ſolution of nitrate or muriate of barytes, by means of an alkaline phoſphate. The phoſphate of barytes is precipitated in the form of powder.

1290 Properties. 2. This ſalt is in the form of white powder, without any appearance of cryſtallization. It is not altered by expoſure to the air, and is inſoluble in water. The ſpecific gravity is 1.2867.

1291 Action of heat. 3. This ſalt at a high temperature is fuſible. It is converted into a vitreous matter or gray enamel. Before the blow-pipe, on charcoal, it gives out a yellow phoſphoric light. The vitreous globules become opaque on cooling. It is decompoſed by the ſulphuric acid. The phoſphoric and phoſphorous acids, when added in exceſs, have the property of re-diſſolving the ſalts which they form with barytes.

10. Phoſphite of Barytes.

1292 Preparation. This compound of phoſphorous acid and barytes, is formed by the direct combination of the acid with the earth; or by precipitating the ſoluble phoſphites by a ſolution of barytes. By the laſt proceſs the ſalt is obtained in the greateſt purity.

1293 Properties. 2. The phoſphite of barytes is in the form of a white powder, which is inſipid, not altered by expoſure to the air, not very ſoluble in water, and without an exceſs of acid, by which means it is converted into the acidulous phoſphite.

1294 Action of heat. 3. The phoſphite of barytes melts under the blow-pipe into a globule, which is ſoon ſurrounded with a moſt brilliant light. The vitreous globule becomes, on cooling, white and opaque.

1295 Of acids. 4. This ſalt is decompoſed by moſt of the acids; by

---

* Fourcroy Connaiſſ. Chim. iii. p. 167.

* Phil. Tranſ. 1802. p. 147.

lime and lime water. The other alkaline and earthy baſes combine with the exceſs of phoſphorous acid, when it is in the ſtate of acidulous phoſphite, and there remains behind a neutral phoſphite.

1296 Compoſition. 5. The component parts of this ſalt are,

Phoſphorous acid,	41.7
Barytes,	51.3
Water,	7.0
	100.0 *

11. Carbonate of Barytes.

1297 Names. 1. This compound of carbonic acid and barytes has been known by the names of *aerated heavy ſpar*, *aerated baroſelenite* and *witherite* from the name of Dr Withering, who firſt diſcovered that it is a natural production. Its nature and properties were firſt inveſtigated by Scheele and Bergman, about the year 1776, and ſince that time by Kirwan, Hope, Klaproth, Pelletier, Fourcroy, and Vauquelin.

1298 Native. 2. The carbonate of barytes is found native in ſtriated, lamellated, ſemitranſparent maſſes. The primitive form of its cryſtals is the ſix-ſided priſm. The ſpecific gravity is 4.331.

1299 Prepared by art. 3. The carbonate of barytes may be prepared artificially, by expoſing a ſolution of pure barytes to the air; or, by paſſing carbonic acid gas into the ſolution. It may be prepared alſo in the dry way, by mixing together ſulphate of barytes and carbonate of potaſh or ſoda, and expoſing the mixture to ſtrong heat: or, by decompoſing by means of the carbonate of potaſh, ſoda, or ammonia, the nitrate or muriate of barytes in ſolution in water. By whatever proceſſes the carbonate of barytes is obtained, it is in the form of a white taſteleſs powder. When thus prepared, the ſpecific gravity is 3.763.

4. It undergoes no change by expoſure to the air. Cold water diſſolves $\frac{1}{4304}$; boiling water $\frac{1}{2304}$ part.

1300 Action of heat. 5. The carbonate of barytes undergoes little change when it is expoſed even to the ſtrongeſt heat. The artificial carbonate loſes about 0.28 of its weight by calcination, while the native carbonate becomes white and opaque, and is converted into a bluiſh green colour, without any perceptible loſs of weight; but if it be heated in a black lead crucible, or if it be formed into a paſte, with 100 parts of the ſalt to 10 of charcoal, the carbonic acid is ſeparated.

1301 Compoſition. 6. The component parts of the carbonate of barytes are the following:

Native Carbonate.

	Withering.	Fourcroy.
Acid	20	10
Barytes	80	90
	100	100

Artificial Carbonate.

	Bergman.	Pelletier.
Acid	7	22
Barytes	65	62
Water	28	16
	100	100

When both the natural and artificial are expoſed to a red heat, the component parts, as aſcertained by Mr Kirwan, are,

Acid	22
Barytes	78
	100

1302 Uſes. 7. This ſalt has been found native only in ſmall quantity, otherwiſe it is ſuppoſed, that it might be of great uſe for the preparation of barytic ſalts, which promiſe great ſervice in ſeveral arts and manufactures. It has been propoſed to employ it in medicine; but in experiments on animals, it has been found to act as a moſt deadly poiſon. Great caution, therefore, ſhould be obſerved in employing it as an internal remedy *.

12. Arſeniate of Barytes.

The compound of arſenic acid and barytes is formed by diſſolving the earth in the acid. It is an inſoluble, uncryſtallized ſalt; but with an exceſs of acid it becomes ſoluble, and is decompoſed by ſulphuric acid. It melts when expoſed to a ſtrong heat, but is not decompoſed.

13. Tungſtate of Barytes.

With the tungſtic acid barytes forms an inſoluble ſalt.

14. Molybdate of Barytes.

Barytes with the molybdic acid forms a ſalt which has very little ſolubility.

15. Chromate of Barytes.

It is little known, but ſaid to be inſoluble in water.

16. Columbate of Barytes.

17. Acetate of Barytes.

1303 Preparation. 1. This ſalt, which is a compound of acetic acid and barytes, may be prepared by directly combining the acid with the earth; or, by decompoſing ſulphuret of barytes by means of acetic acid. By evaporating the ſolution, it may be obtained cryſtallized.

1304 Properties. 2. The cryſtals of the acetate of barytes are in the form of fine tranſparent priſms. The ſpecific gravity is 1.828. This ſalt has an acid bitter taſte, effloreſces in the air, is very ſoluble in water, is decompoſed by the carbonates of the alkalies, but not by the alkalies themſelves, or the pure earths.

1305 Uſes. 3. This ſalt may be employed to detect the preſence and quantity of ſulphuric acid in ſolutions, particularly in vinegar, which may be adulterated with the addition of this acid †.

18. Oxalate of Barytes.

1306 Preparation. 1. The compound of oxalic acid and barytes is formed by adding the acid to a ſolution of barytes in water. A white powder precipitates, which is oxalate of barytes; it is inſoluble in water. With an exceſs of oxalic acid, this precipitate is diſſolved, and ſmall angular cryſtals are formed.

1307 Action of heat. 2. If theſe cryſtals are diſſolved in boiling water, they become opaque, and fall down in the form of an inſoluble

---

* Fourcroy Connaiſs. Chim. iii. p. 281.

* Fourcroy, iv. 10.

† Fourcroy, viii. 196.

inſoluble powder, for the water combines with the exceſs of acid, which held them in ſolution.

19. Tartrate of Barytes.

The compound of tartaric acid and barytes forms a ſalt in the ſtate of white powder, which has little ſolubility, excepting with an exceſs of acid. It is decompoſed by the ſulphuric, nitric, muriatic, and oxalic acids.

20. Citrate of Barytes.

1308 Preparation. 1. The compound of citric acid and barytes forms a ſalt, by adding the earth to a ſolution of the acid. A flocculent precipitate at firſt appears, which is diſſolved by agitation. The precipitate afterwards becomes permanent when the acid is ſaturated.

2. This ſalt, which is at firſt depoſited in the form of powder, ſhoots out afterwards into a kind of vegetation, of a ſilvery whiteneſs, with great brilliancy and beauty. It is ſoluble in a great proportion of water. This ſalt is compoſed of

Acid	50
Barytes	50
	100

21. Malate of Barytes.

The compound of malic acid and barytes is formed by adding the acid to a ſolution of the earth in water. A cryſtallized, ſoluble ſalt is precipitated.

22. Gallate of Barytes.

The compound of gallic acid and barytes is formed by the direct combination of the acid with the earth. A ſalt is thus formed, which is not very ſoluble, but with an exceſs of the baſe.

23. Benzoate of Barytes.

The benzoic acid combines with barytes, and forms a ſalt which is ſoluble in water, cryſtallizes, undergoes no change by expoſure to the air, and is decompoſed by heat and the ſtronger acids.

24. Succinate of Barytes.

Barytes forms, with ſuccinic acid, a ſalt which has little ſolubility.

25. Saccolate of Barytes.

This ſalt is inſoluble in water.

26. Camphorate of Barytes.

1309 Preparation. 1. The compound of camphoric acid and barytes is formed by adding the cryſtallized acid to the ſolution of the earth, and then boiling the mixture. It is afterwards to be filtered and evaporated to dryneſs. What remains is camphorate of barytes.

1310 Properties. 2. This ſalt does not cryſtallize; but when it is ſlowly evaporated, ſmall plates are depoſited, which ſeem tranſparent in the liquid, but become opaque when expoſed to the air. It has ſcarcely any taſte; but an impreſſion remains on the tongue, which is ſlightly acid and bitter.

3. This ſalt undergoes no change by expoſure to the air. It is only ſoluble in 600 parts of water at the boiling temperature.

1311 Action of heat. 4. When expoſed to the action of the blow-pipe, the acid is volatilized, and the earth is converted into a vitreous ſubſtance. The camphoric acid, as it burns, firſt exhibits a blue, then a red, and at laſt, a white flame.

5. This ſalt is decompoſed by the ſulphuric, nitric, and muriatic acids, and by the oxalic, tartaric and citric *.

27. Suberate of Barytes.

This ſalt does not cryſtallize, is only ſoluble in water with an exceſs of acid; when expoſed to heat, it ſwells up and melts, and is decompoſed by the ſulphuric, nitric, muriatic, and oxalic acids †.

28. Mellate of Barytes.

By adding mellitic acid to a ſolution of acetate of barytes, there is formed a flaky precipitate which is re-diſſolved with the addition of more acid. When the acid is poured into a ſolution of muriate of barytes no precipitate is formed; but a ſhort time afterwards a group of tranſparent needle-formed cryſtals is depoſited.

29. Lactate of Barytes.

Barytes forms with lactic acid, a deliqueſcent ſalt.

30. Pruſſiate of Barytes.

Pruſſic acid and barytes form a ſalt which is very little ſoluble in water, and is decompoſed, not only by the ſulphuric acid but even by carbonic.

31. Sebate of Barytes.

Sebacic acid added to a ſolution of barytes in water, forms no precipitate; from which it is inferred that the ſebate of barytes is ſoluble in water.

SECT. III. *Of Strontites and its Combinations.*

1312 Hiſtory. 1. This earth was not diſcovered till about the year 1791 or 1792. Dr Crawford, indeed, previous to this period, in making ſome experiments on what he ſuppoſed was a carbonate of barytes, and obſerving a ſtriking difference between this mineral, and the carbonate of barytes which he had been accuſtomed to employ, conjectured that it might contain a new earth; and he ſent a ſpecimen to Mr Kirwan for the purpoſe of analyzing it. This conjecture was fully verified by the experiments of Dr Hope ‡, Mr Kirwan, and M. Klaproth, who were all engaged in the ſame analyſis nearly about the ſame time. This earth is found native in combination with carbonic and ſulphuric acids. With the former it is found in conſiderable quantity in the lead mines of Strontian in Argyleſhire, from which it has derived its name *ſtrontites*, or *ſtrontian*, as it is called by others. The nature and properties of this earth have been ſtill farther inveſtigated by Pelletier, Fourcroy, and Vauquelin.

1313 Preparation. This earth may be obtained in a ſtate of purity, either by expoſing the carbonate of ſtrontites mixed with charcoal powder, to a ſtrong heat, by which the carbonic acid is driven off; or, by diſſolving the native

---

* *Ann. de Chim.* xxvii. p. 28.

† *Ibid.* xxiii. 52.

‡ *Edin. Tranſ.* iv. 3.

1314 Properties. ſalt in nitric acid, and decompoſing the nitrate of ſtrontites thus formed, by heat. Strontites obtained by either of theſe proceſſes, is in ſmall porous fragments of a greeniſh white colour. It has an acrid, hot, alkaline taſte, and converts vegetable blues to green. The ſpecific gravity is 1.647.

1315 Action of heat. 3. Light has no perceptible action upon this earth. When it is expoſed to heat, it may be kept a long time, even in a red heat, without undergoing any change, or even the appearance of fuſion. By the action of the blow-pipe it is not melted, but is ſurrounded with a very brilliant white flame.

1316 Of water. 4. When a little water is thrown on ſtrontites, it exhibits the ſame appearance as barytes. It is flaked, gives out heat, and then falls to powder. If a greater quantity of water be added, it is diſſolved. According to Klaproth it requires 200 parts of water at the ordinary temperature of the atmoſphere for its ſolution. Boiling water diſſolves it in greater quantity, and when the ſolution cools, it affords tranſparent cryſtals. Theſe cryſtals are in the form of rhomboidal plates, or in that of flattened ſilky needles, or compreſſed priſms. The ſpecific gravity is 1.46. Theſe cryſtals effloreſce in the air, and have an acrid hot taſte. The ſolution of this earth in water is acrid and alkaline, and converts vegetable blues to green. It is ſoon covered with a pellicle, by abſorbing carbonic acid from the atmoſphere.

5. Strontites has the property of communicating a purple colour to flame.

1317 Affinities. 6. The order of the affinities of ſtrontites is the following.

Sulphuric acid,
Phoſphoric,
Oxalic,
Tartaric,
Fluoric,
Nitric,
Muriatic,
Succinic,
Acetic,
Arſenic,
Boracic,
Carbonic.

I. Phoſphuret of Strontites.

The phoſphuret of ſtrontites is prepared in the ſame way as the phoſphuret of barytes.

II. Sulphuret of Strontites.

1318 Preparation. The ſulphuret of ſtrontites is formed by expoſing ſulphur and the earth in a crucible, to heat. This ſulphuret is ſoluble in water, by means of ſulphurated hydrogen, which is diſengaged by the decompoſition of the water. The ſtrontites thus combined with ſulphurated hydrogen, forms a hydroſulphuret of ſtrontites; and if this ſolution be evaporated, the hydroſulphuret of ſtrontites may be obtained in cryſtals, and the hydrogenated ſulphuret remains, as in ſimilar compounds, in ſolution. When the hydrogenated ſulphuret is decompoſed by means of an acid, the ſulphurated hydrogen gas which is diſengaged, burns with a beautiful purple flame, on account of holding in ſolution a ſmall quantity of the earth, which communicates this property.

III. Compounds of Strontites with the Acids.

1. Sulphate of Strontites.

1. The compound of ſulphuric acid with ſtrontites, may be formed by adding ſulphuric acid to a ſolution of ſtrontites in water, and it is obtained in the ſtate of a white powder. It is found native in different places, cryſtallized in fine needle-formed priſms. It has no taſte, and is ſcarcely ſoluble in water. It ſuffers no change in the air. By the action of the blow-pipe it gives out a yellowiſh purple light. It is not decompoſed by any of the acids; but it is decompoſed by the carbonate of potaſh and ſoda, by the barytic ſalts, by the ſulphates of potaſh and of ſoda, the phoſphates of potaſh, ſoda, and ammonia, and by the borate of ammonia.

2. The component parts of this ſalt, according to Vauquelin, are,

Acid,	46
Strontites,	54
	100

But according to Klaproth, Kirwan, and others,

Acid,	42
Strontites,	58
	100

2. Sulphite of Strontites.

This ſalt is yet unknown.

3. Nitrate of Strontites.

1. The compound of nitric acid and ſtrontites, is formed by precipitating, by means of the nitric acid, the ſulphuret of ſtrontites, obtained from the decompoſed ſulphate, or by diſſolving the carbonate of ſtrontites in the acid. By evaporation it may be obtained in cryſtals.

2. The cryſtals of nitrate of ſtrontites are in the form of octahedrons. The taſte of this ſalt is cool and pungent. It is not altered by expoſure to the air. The ſpecific gravity is 3.0061. It is ſoluble in 15 parts of cold water, and much more ſoluble in boiling water, in which it cryſtallizes on cooling. Expoſed to ſudden heat, it decrepitates. When it is ſubjected to heat in a crucible, it ſwells up, gives out oxygen and nitrous gas, and there remains behind pure earth. This ſalt has the property of communicating a purple flame to combuſtible ſubſtances with which it is mixed; as when a little of the ſalt in powder is thrown on the wick of a candle.

3. The component parts of this ſalt, are according to

	Vauquelin.	Kirwan.
Acid	48.4	31.7
Strontites	47.6	36.21
Water	4.0	32.72
	100.0	100.00

4. Nitrite of Strontites.

The properties of this ſalt have not been examined.

5. Muriate

5. Muriate of Strontites.

1319 Preparation. 1. The compound of muriatic acid and ſtrontites is prepared by diſſolving carbonate of ſtrontites in the acid. By evaporating the ſolution, the ſalt is obtained cryſtallized.

1320 Properties. 2. This ſalt cryſtallizes in long, ſlender hexagonal priſms. The taſte is cooling and pungent. The ſpecific gravity is 1.4402. It is not altered by expoſure to the air. It is very ſoluble in water. Three parts of the ſalt are diſſolved in two parts of cold water. Theſe cryſtals, which are ſoluble in alcohol, communicate a purple colour, which is the diſtinguiſhing characteriſtic of this ſalt. When heated, it melts, and parts with its water of cryſtallization, without being decompoſed, and there remains behind a ſemitranſparent enamel. This ſalt is decompoſed by a very ſtrong heat. It is decompoſed alſo by the ſulphuric, nitric, and phoſphoric acids; and by potaſh, ſoda, and barytes.

1321 Compoſition. 3. The conſtituent parts of this ſalt are, according to

	Vauquelin.	Kirwan.
Acid	23.6	18
Strontites	36.4	40
Water	40.0	42
	100.0	100

6. Hyperoxymuriate of Strontites.

1322 Preparation. 1. This combination of hyperoxymuriatic acid and ſtrontites, was prepared by Mr Chenevix, by a ſimilar proceſs to that which he employed in the formation of barytes with the ſame acid; and in many of its properties it is analogous.

2. The cryſtals of this ſalt are in the form of needles. They melt in the mouth, and give the ſenſation of cold. It is compoſed of

1323 Compoſition.

Acid	46
Strontites	26
Water	28
	100 *

7. Fluate of Strontites.

The properties of this ſalt have not yet been inveſtigated.

8. Borate of Strontites.

This compound of boracic acid and ſtrontites, is in the form of a white powder, and requires 130 parts of water for its ſolution. It converts the ſyrup of violets to a green colour, from which it is inferred, that it contains an exceſs of the earth.

9. Phoſphate of Strontites.

1324 Preparation. 1. The compound of phoſphoric acid and ſtrontites, is formed by diſſolving the carbonate of the earth in acid; or, by mixing together the ſolutions of muriate of ſtrontites, with thoſe of the alkaline phoſphates.

1325 Properties. 2. It is thus obtained in the form of white powder, which is perfectly taſteleſs. It is not altered by expoſure to the air. It is inſoluble in water, without an exceſs of acid. It melts under the blow-pipe into a white enamel, and gives out a purple, phoſphoreſcent light.

3. The conſtituent parts of this ſalt are,

Acid	41.24
Strontites	58.76
	100.00

10. Phoſphite of Strontites.

The nature of this ſalt is unknown.

11. Carbonate of Strontites.

1326 Found native. 1. This ſalt is found native; and, as we have already mentioned, was pointed out by Dr Crawford as different from the carbonate of barytes, with which it had been formerly confounded.

1327 Preparation. 2. It may be prepared artificially, by ſaturating a ſolution of ſtrontites in water with carbonic acid; or, by precipitating ſoluble ſalts with a baſe of this earth, by means of alkaline carbonates. The carbonate of barytes cryſtallizes in needles, or in ſix-ſided priſms. It has no taſte. The ſpecific gravity is 3.6750. It is not changed by expoſure to the air, and it is nearly inſoluble in water. 1328 Properties. When it is ſtrongly heated in a crucible, to produce fuſion, it is deprived of part of its carbonic acid. When heated under the blow-pipe, it melts into an opaque, vitreous globule, and gives out a purple flame.

1329 Compoſition. 2. The component parts of this ſalt, according to different chemiſts, are

	Hope.	Klaproth and Kirwan.	Pelletier.
Acid	30.2	30.	30
Strontites	61.2	69.5	62
Water	8.6	0.5	8
	100.0	100.0	100

12. Arſeniate of Strontites.

When arſenic acid is dropped into a ſolution of ſtrontites in water, a copious precipitate is formed, which is re-diſſolved when there is an exceſs of acid. When the arſeniate of ſtrontites is neutralized, it is only in a ſlight degree ſoluble in water *.

13. Tungſtate of Strontites.	unknown.
14. Molybdate of Strontites.	
15. Chromate of Strontites.	
16. Columbate of Strontites.	

17. Acetate of Strontites.

1330 Preparation. 1. This compound of acetic acid and ſtrontites is formed by diſſolving the carbonate in the acid. By evaporation the ſalt may be obtained cryſtallized.

1331 Properties. 2. The cryſtals remain unaltered by expoſure to the air. They change vegetable blues to green, and are equally ſoluble in hot and cold water †.

18. Oxalate of Strontites.

The compound of oxalic acid and ſtrontites is formed by the direct combination of the acid with the earth in ſolution. A precipitate appears in the form of a white powder, which is nearly inſoluble in water. It is decompoſed by heat.

---

* *Phil. Tranſ.* 1802.

* *Edin. Tranſ.* iv. 17.

† *Edin. Tranſ.* iv. p. 14.

The component parts of this ſalt are,

Acid	40.5
Strontites	59.5
	100.0

19. Tartrate of Strontites.

1. This ſalt is formed by diſſolving the earth in the acid. The cryſtals are in the form of ſmall triangular tables; they are not altered by the air, are inſipid to the taſte, and ſoluble in 320 parts of boiling water.

2. The conſtituent parts of this ſalt are,

Acid and water	47.12
Strontites	52.88
	100.0

20. Citrate of Strontites.

1. This combination of citric acid with ſtrontites may be formed by mixing together a ſolution of nitrate of ſtrontites and citrate of ammonia. A double decompoſition takes place, but no precipitate is formed. By ſlow evaporation, cryſtals of citrate of ſtrontites may be obtained.

2. This ſalt is ſoluble in water.

21. Malate of Strontites.

This ſalt is ſcarcely known.

22. Gallate of Strontites.

Little known alſo.

23. Benzoate of Strontites.

Unknown.

24. Succinate of Strontites.

Succinic acid combines with ſtrontites, and forms cryſtals, which may be obtained by ſlow evaporation.

25. Camphorate of Strontites.
26 Suberate of Strontites.
27. Mellate of Strontites.
28. Lactate of Strontites.
29. Pruſſiate of Strontites.
30. Sebate of Strontites.

unknown.

SECT. IV. *Of MAGNESIA and its Combinations.*

1332 History.

1. Magneſia was firſt known about the beginning of the 18th century, when it was ſold by a Roman canon, under the name of *magneſia alba*, or *white magneſia*, and *the powder of the count of Palma*, as a cure for diſeaſes; and like many new remedies, it was conſidered as univerſal. In the year 1707, Valentini diſcovered that this boaſted *panacea* was the produce of the calcined ley which remains after the preparation of nitre. He gave it the pompous name of *the laxative powder of many virtues*. In the year 1709, Slevogt deſcribed the method of obtaining it by precipitation, from the mother ley of nitre. Lanciſi and Hoffman examined ſome of its properties in 1717 and 1722; and although the latter diſcovered that it formed different combinations with acids from thoſe of lime, it was generally confounded with this ſubſtance.

But the nature of magneſia was not fully known, till Dr Black, in 1755, entered upon his celebrated inveſtigations of the different properties of this ſubſtance, lime and the alkalies, in the mild and cauſtic ſtate. Margraaf publiſhed the reſult of his experiments and reſearches on it in 1759, in which he gave many diſtinctive characters of this earth, and of its combinations; and, at laſt, by the obſervations of Bergman, publiſhed in 1775, and thoſe of Butini of Geneva in 1779, the nature and properties of magneſia were fully demonſtrated.

1333 Preparation.

2. Magneſia, although it exiſts in great abundance in combination with other ſubſtances, has never been found perfectly pure in nature. The proceſs by which it may be obtained in greateſt purity, is the following. A quantity of Epſom ſalt, which is a compound of ſulphuric acid and magneſia, is to be diſſolved in water, and then precipitated by potaſh. The precipitate which is formed, is to be well waſhed and dried, both with cold and hot water, to ſeparate any ſaline matters with which it may be mixed. The nature of this proceſs is obvious. The potaſh has a ſtronger affinity for ſulphuric acid than magneſia. It therefore combines with the acid, and the magneſia is precipitated.

1334 Properties.

3. Magneſia, when it is obtained pure, is in the form of a fine white powder, or in white friable cakes reſembling ſtarch. It has no ſmell, and no ſenſible taſte; but becomes dry, and leaves on the tongue a ſlight ſenſation of bitterneſs. Its ſpecific gravity, according to Kirwan, is 2.330. It gives a ſlight tinge of green to ſyrup of violets, or other delicate vegetable blues.

1335 Action of heat.

4. Magneſia is not acted upon by light. It is not melted when expoſed to the greateſt heat. By ſtrong calcination it becomes finer, whiter, and more friable. When it is expoſed to heat in the form of paſte with water, it contracts its dimenſions, and acquires a phoſphoreſcent property; for when it is ſtrongly rubbed on a hot iron plate, it becomes luminous in the dark. It is not altered by the action of the blow-pipe on charcoal, but gives out a flame of a ſlight yellow colour.

1336 Of air.

5. There is no action between magneſia and oxygen or azote. When expoſed to the air, it attracts a little moiſture from the atmoſphere, but this goes on very ſlowly.

Butini expoſed a quantity of magneſia for the ſpace of two years in a porcelain cup ſlightly covered with paper, and he found that it had acquired only $\frac{1}{144}$ part of its weight in addition, during that time.

6. There is no action between magneſia and hydrogen or carbone, and very little between it and phoſphorus.

1337 Of water.

7. Magneſia is very little ſoluble in water. According to Mr Kirwan, it requires near 8000 times its weight of cold water to diſſolve it. Butini found, that water boiled with this ſubſtance and left in contact with it for three months, had ſcarcely acquired $\frac{1}{10000}$ part of its weight; but water combines with magneſia in the ſolid ſtate. One hundred parts of magneſia, according to Bergman, thrown into water, and taken out and dried, acquired 18 parts of additional weight.

1338 Affinities.

8. Magneſia enters into combination with the acids, and

and forms with them peculiar ſalts. The order of its affinities is the following, according to Bergman.

Oxalic acid,
Phoſphoric,
Sulphuric,
Fluoric,
Arſenic,
Saclactic,
Succinic,
Nitric,
Muriatic,
Tartaric,
Citric,
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Carbonic,
Pruſſic.

1339 Of earths. 9. Magneſia does not enter into combination with the fixed alkalies; but in combination with ſome of the earths, it becomes fuſible by means of a ſtrong heat. With lime in certain proportions, it forms a greeniſh yellow glaſs.

1340 Uſes. 10. Magneſia is much employed in medicine as a gentle laxative, and as an abſorbent to deſtroy the acidity in the ſtomach. It is uſed in pharmacy to ſuſpend or aid the ſolution of reſinous and gummy ſubſtances, ſuch as camphor and opium, in water, which are otherwiſe little ſoluble.

I. Of Sulphuret of Magneſia.

1341 Preparation. 1. Magneſia enters into combination with ſulphur, either in the dry or humid way. Two parts of magneſia and one of ſulphur, put into a crucible, and expoſed to heat, form an orange yellow maſs, which is not very ſoluble in water, but emits the odour of ſulphurated hydrogen gas, when it comes in contact with that liquid, and which is very readily decompoſed by means of heat. The heat that is applied to obtain this ſulphuret muſt be very moderate, otherwiſe the ſulphur is driven off.

2. The ſulphuret of magneſia is formed with more difficulty in the humid way. When two parts of magneſia and one of ſulphur in powder, with 20 parts of water, are expoſed to heat on a ſand bath, the liquid becomes of a pale yellow colour, which is ſlightly fetid, but has nothing of the ſtrong odour of the other ſulphurets. There is formed very little of the ſulphuret of magneſia; for the greateſt part of the ſulphur and magneſian earth remains uncombined. There is very little ſulphurated hydrogen produced, the water ſcarcely exhaling the odour of this gas.

1342 Properties. 3. The ſolid ſulphuret of magneſia decompoſes rapidly, when expoſed to the air. It ſeems to abſorb very little ſulphurated hydrogen gas; ſo that the properties of the hydroſulphuret of magneſia are yet unknown *.

II. Compounds of Magneſia with Acids.

1. Sulphate of Magneſia.

1343 Hiſtory. The compound of ſulphuric acid and magneſia was formerly known under the name of *Epſom* and *Seidlitz ſalts*, becauſe it exiſts in the waters of theſe ſprings, and *ſal catharticus amarus*, *bitter purging ſalt*, on account of its properties. It was long confounded with ſulphate of ſoda, till its properties were inveſtigated by Black, Macquer, and Bergman, and its nature and compoſition fully aſcertained.

1344 Preparation. 2. This ſalt exiſts abundantly in nature. It is found in many mineral ſprings, and it forms a conſiderable proportion of the ſaline ingredients of ſea water. The bittern or mother water of common ſalt, that is, the water which remains after the cryſtallization, conſiſts chiefly of ſulphate of magneſia. It is therefore rarely prepared by art, by the direct combination of its conſtituent parts. It is eaſily purified by diſſolving the ſalt in water, and by evaporation and cryſtallization.

1345 Properties. 3. The ſulphate of magneſia thus prepared, is cryſtallized in four-ſided priſms, terminated by four-ſided pyramids. There is, however, ſome deviation from this form. The primitive form of the cryſtal is a quadrangular priſm with ſquare baſes. The integrant molecule is a triangular priſm, whoſe baſes are right-angled iſoſceles triangles. It has a cool, bitter taſte. The ſpecific gravity is 1.66.

1346 Action of water and heat. 4. Expoſed to the air, it effloreſces. It is ſoluble in its own weight of cold water: boiling water diſſolves more than two-thirds of its weight. Expoſed to heat, it undergoes the watery fuſion, and being deprived of its water of cryſtallization, it does not melt, nor is it decompoſed by the ſtrongeſt heat. By the action of the blow-pipe it melts with difficulty into an opaque, vitreous globule.

1347 Of alkalies. 5. The ſulphate of magneſia is decompoſed by the fixed alkalies, but with ammonia it forms a triple ſalt.

1348 Compoſition. The component parts of this ſalt are, according to

		Kirwan.	
	Bergman.	In cryſtals.	Dry.
Sulphuric acid	33	29.35	63.32
Magneſia	19	17.00	36.68
Water	48	53.65	00.00
	100	100.00	100.00 *.

1349 Uſes. 6. The ſulphate of magneſia is employed in medicine as a purgative. From this ſalt too, the earth of magneſia is uſually extracted.

2. Sulphate of Ammonia and Magneſia.

1350 Preparation. 1. This is a triple combination of ſulphuric acid with ammonia and magneſia. It is prepared by the partial decompoſition of the ſulphate of magneſia by means of ammonia. By evaporating the ſolution the triple ſalt is obtained in cryſtals.

1351 Properties. 2. This ſalt cryſtallizes in octahedrons. It has a bitter acrid taſte, does not effloreſce in the air, is leſs ſoluble in water than either of the ſalts of which it is compoſed, but it is more ſoluble in hot than in cold water, and it cryſtallizes on cooling. By heat it undergoes the watery fuſion. It then dries and is decompoſed. The component parts of this ſalt are,

Sulphate of magneſia,	64
of ammonia,	32
	100 *

---

* *Fourcroy Connaiſs. Chim.* ii. 161.—167.

* *Nichol. Jour.* iii. p. 215.

* *Fourcroy Connaiſs. Chim.* iii. 49.

3. Sulphite of Magneſia.

1352 Preparation. 1. The compound of ſulphurous acid and magneſia is formed by paſſing ſulphurous acid gas into two parts of water, with one of carbonate of magneſia. A violent efferveſcence takes place, with the evolution of heat. The ſulphite of magneſia is formed, and precipitated to the bottom in the ſtate of powder; but with an exceſs of acid it is re-diſſolved, and cryſtallizes.

1353 Properties. 2. The cryſtals of ſulphite of magneſia are in the form of depreſſed tranſparent tetrahedrons. It has a mild earthy taſte, which ſoon becomes ſenſibly ſulphureous; it has no ſmell. Its ſpecific gravity is 1.3802.

1354 Action of air, &c. 3. It effloreſces in the air, and is ſlowly converted into ſulphate of magneſia. It is ſoluble in 20 parts of cold water. Boiling water diſſolves a greater proportion, and from this it cryſtallizes on cooling. Expoſed to heat, this ſalt becomes viſcid, and by calcination it loſes 0.45 of its weight. If the heat be increaſed, it is decompoſed; the acid is driven off, and the pure earth remains behind.

The component parts of this ſalt are,

Sulphurous acid,	39
Magneſia,	16
Water,	45
	100

4. Sulphite of Ammonia and Magneſia.

1355 Preparation. 1. This triple ſalt is formed by decompoſing the ſulphite of ammonia by magneſia, or the ſulphite of magneſia by ammonia, in ſolution in the cold; or, by mixing together the ſolutions of the two ſalts.

1356 Properties. 2. This ſalt is in tranſparent cryſtals, the form of which has not been determined. When it is expoſed to the air, it is converted into ſulphate of ammonia and magneſia. 1357 Action of heat. It is leſs ſoluble in water than either of the two ſulphites of which it is formed. By the action of heat, ſulphurous acid is given out, acidulous ſulphite of ammonia is ſublimed, and there remains behind pure magneſia †.

5. Nitrate of Magneſia.

1358 Hiſtory and preparation. 1. This compound of nitric acid and magneſia was formerly called *nitre with baſe of magneſia*, and magneſian *ſaltpetre*. It is formed by the direct combination of the acid with the earth. By evaporation it is cryſtallized.

1359 Properties. 2. This ſalt cryſtallizes in four-ſided rhomboidal priſms, whoſe ſummits are oblique or truncated. Sometimes it is in the form of ſmall needles combined in groups. The taſte is penetrating and bitter. The ſpecific gravity is 1.736.

1360 Action of water. 3. It is deliqueſcent in the air, and is ſoluble in its own weight of cold water. It is more ſoluble in boiling water, in which it cryſtallizes on cooling; but it can only be obtained in regular cryſtals by ſlow evaporation from its ſolution in cold water.

1361 Of heat. 4. By the action of heat it undergoes the watery fuſion; the water is driven off, and it becomes dry. It is decompoſed in a ſtrong heat, gives out a little oxygen gas, then nitrous gas, and at laſt the nitric acid. The pure earth remains behind.

1362 Compoſition. The component parts of this ſalt are, according to

	Bergman.	Kirwan.
Acid,	43	46
Magneſia,	27	22
Water,	30	32
	100	100

6. Nitrate of Ammonia and Magneſia.

1363 Preparation. 1. This triple ſalt is formed, either by the direct combination of the ſolutions of nitrate of ammonia, and nitrate of magneſia, by which the ſalt is obtained pure and cryſtallized; or, by partially decompoſing the nitrate of ammonia by magneſia, or the nitrate of magneſia by ammonia.

1364 Properties. 2. The cryſtals of this ſalt are in the form of fine priſms. It has a bitter, acrid, and ammoniacal taſte. It is leſs deliqueſcent in the air than either of the conſtituent ſalts, and leſs ſoluble in water. It requires 11 parts of cold water to diſſolve it, but leſs of boiling water. It cryſtallizes on cooling.

1365 Action of heat. When it is rapidly heated, it inflames ſpontaneouſly. When ſlowly heated in cloſe veſſels, it gives out oxygen gas, azotic gas, a greater proportion of water than it contains, nitrous gas, and nitric acid, without the ſmalleſt trace of ammonia; which ſhows that it is decompoſed, that the hydrogen combines with the oxygen of the acid, and forms water.

1366 Compoſition. The component parts of this ſalt are,

Nitrate of magneſia,	78
——— ammonia,	22
	100 *

7. Nitrate of Magneſia.

Nothing is known of the properties of this ſalt.

8. Muriate of Magneſia.

1367 Found native. 1. This compound of muriatic acid and magneſia was formerly called *marine ſalt of magneſia*, and was confounded with the muriate of lime, with which it is frequently accompanied. The difference between theſe two ſalts was firſt pointed out by Dr Black, and Bergman afterwards examined the nature and properties of muriate of magneſia. The ſalt is obtained by diſſolving magneſia in muriatic acid till they are ſaturated, and then evaporating the ſolution. Small irregular cryſtals are obtained. This ſalt exiſts in the waters of the ocean, and in mineral waters, along with the muriates of ſoda and lime.

1368 Properties. 2. It is extremely difficult to obtain the muriate of magneſia in any regular form. It is either in the ſtate of powder, or very ſmall regular needles, or in a kind of jelly. It has a diſagreeable bitter taſte. The ſpecific gravity is 1.601.

3. It is very deliqueſcent in the air. Cold water readily diſſolves its own weight, and it is ſtill more ſoluble in boiling water.

1369 Action of heat. 4. It is completely decompoſed by heat; the acid is driven off, and the pure earth remains behind *.

1370 Compoſition. The component parts of this ſalt are,

	Bergman.	Kirwan.
Acid,	34	34.59
Magneſia,	41	31.07
Water,	25	34.38
	100	100.04 †

---

† *Ibid.* p. 89.

† *Fourcroy Connaiſs. Chim.* iii. 144.

* *Fourcroy*, iii. 204.

† *Nichol. Jour.* iii. 215.

9. Muriate of Ammonia and Magneſia.

1371 Preparation. This triple ſalt is formed by mixing the ſolutions of muriate of magneſia and muriate of ammonia; and by evaporating the ſolution the ſalt cryſtallizes in the form of ſmall polyhedrons. 1372 Properties. It has a bitter, ammoniacal taſte. It is little altered by expoſure to the air, and is ſoluble in ſix parts of cold water. It is decompoſed by heat. The muriate of ammonia is ſublimed, and the muriate of magneſia is deprived of its acid.

1373 Compoſition. The component parts of this ſalt are,

Muriate of magneſia,	73
——— ammonia,	27
	100

10. Hyperoxymuriate of Magneſia.

This is ſimilar in its chemical and phyſical properties to the hyperoxymuriate of lime, and it is prepared in the ſame way. It is precipitated by lime and ammonia.

1374 Compoſition. The component parts are,

Acid,	60
Magneſia,	25.7
Water,	14.3
	100.0 *

11. Fluate of Magneſia.

1375 Preparation. 1. This ſalt is formed by combining together fluoric acid and magneſia. According to Scheele, it precipitates in the form of a gelatinous maſs; but Bergman obſerves that great part of the ſalt is depoſited as the ſaturation approaches. 1376 Properties. By evaporating the ſolution, cryſtals in the form of ſix-ſided priſms, terminated by a low pyramid compoſed of three rhomboidal ſides, are obtained.

2. This ſalt is not decompoſed by the ſtrongeſt heat, or by any acid.

12. Fluate of Ammonia and Magneſia.

This triple ſalt is formed by mixing the ſolutions of the fluates of ammonia and magneſia. A precipitation is formed, which is the triple ſalt in cryſtals. The properties of this ſalt are unknown †.

13. Borate of Magneſia.

1377 Preparation. 1. This ſalt is formed by the direct combination of boracic acid with magneſia. The earth is ſlowly diſſolved, and when the ſolution is evaporated, cryſtals are obtained.

1378 Properties. 2. The cryſtals of this ſalt are very ſmall and irregular. It melts when expoſed to heat, without being decompoſed; but it may be decompoſed, it is ſaid, by alcohol ‡.

14. Borate of Magneſia and Lime.

1379 Found native. 1. This ſalt, which has been lately diſcovered native, is called by mineralogiſts *cubic quartz*. It was analyzed by Weſtrumb in 1788. It is an inſipid ſalt, and is regularly cryſtallized in polyhedrons of 22 faces. The ſpecific gravity is 2.566.

1380 Properties. 2. It is not altered by expoſure to the air, nor is it ſoluble even in boiling water. Expoſed to a ſtrong red heat, the cryſtals loſe their luſtre; and with a white heat they decrepitate, and at laſt melt into a yellow coloured glaſs.

1381 Compoſition. 3. The component parts of this ſalt are,

Acid,	73.5
Magneſia,	14.6
Lime,	11.9
	100.0

15. Phoſphate of Magneſia.

1382 Preparation. 1. This ſalt may be obtained by the direct combination of phoſphoric acid and carbonate of magneſia; or, it may be prepared by mixing together phoſphate of ſoda and ſulphate of magneſia in ſolution. In a few hours, large, tranſparent cryſtals are formed in the ſolution.

1383 Properties. 2. This ſalt cryſtallizes in ſix-ſided priſms with unequal ſides, but it is frequently in the form of powder. It has a cooling, ſweetiſh taſte. The ſpecific gravity is 1.5489.

1384 Action of water. 3. It effloreſces in the air, is not very ſoluble in cold water, and requires about 50 parts of boiling water for its ſolution, and part of it cryſtallizes on cooling. 1385 Of heat. When it is heated, it is eaſily deprived of its water of cryſtallization, and if the heat be moderate, it melts and falls down into a white powder. With a ſtronger heat, it is melted into glaſs.

16. Phoſphate of Ammonia and Magneſia.

1386 Found native. 1. This triple ſalt was diſcovered by Fourcroy in a calculous concretion, found in the colon of a horſe. The reſults of his experiments on this ſubſtance have been confirmed by Berthollet and Vauquelin.

1387 Preparation. 2. It may be prepared artificially, by mixing together a ſolution of phoſphate of magneſia with a ſolution of phoſphate of ammonia.

1388 Properties. 3. The cryſtals are in the priſmatic form, but cannot be accurately aſcertained. This ſalt has no taſte. In the concrete form, it is found in the cavities of animal bodies, and ſometimes it is cryſtallized, but moſt frequently lamellated and ſemitranſparent.

1389 Action of heat. 4. It is not changed by the action of the air, and is ſcarcely ſoluble in water. When it is heated moderately, it falls to powder. With a ſtronger heat it is deprived of the ammonia, and under the blow-pipe it melts into a tranſparent globule. It is decompoſed by the ſulphuric, nitric, and muriatic acids.

1390 Compoſition. The component parts of this ſalt found in the inteſtine of the horſe are,

Phoſphate of ammonia	33.3
——— magneſia	33.3
——— water	33.3
	100.0

17. Phoſphite of Magneſia.

1391 Preparation. 1. This ſalt may be prepared by directly combining phoſphorous acid with magneſia. Or it may be obtained in a purer ſtate, and cryſtallized, by mixing together ſolutions of phoſphites of ſoda or of potaſh, and ſulphate of magneſia, by which means it is obtained in brilliant milky flakes.

2. This

---

* *Phil. Tranſ.* 1802, p. 149.

† *Fourcroy*, iii. 308.

‡ *Ibid.* 319.

1392 Properties. 2. This ſalt, which has no ſenſible taſte, ſometimes cryſtallizes in the form of tetrahedrons. It effloreſces in the air, and is ſoluble in 400 parts of cold water. When expoſed to heat, it ſuddenly ſwells up, and melts into a glaſs. Under the blow-pipe it gives out a phoſphoric light, and becomes opaque on cooling.

The component parts of this ſalt are,

Acid	44
Magneſia	20
Water	36
	100

18. Phoſphite of Ammonia and Magneſia.

This ſalt is formed by the partial decompoſition of phoſphite of ammonia by means of magneſia, or by mixing together the ſolutions of the two phoſphites. If the ſolutions be ſufficiently concentrated, the triple phoſphite it readily depoſited. It forms cryſtals, and has little ſolubility in water. Its other properties are unknown.

19. Carbonate of Magneſia.

1393 Names and preparation. 1. This ſalt, which was firſt diſtinguiſhed by Dr Black, has been called *mild magneſia, aerated magneſia*. It is formed by mixing together ſulphate of magneſia and carbonate of potaſh in ſolution. Or it may be obtained by diſſolving pure magneſia in water ſaturated with carbonic acid. The ſalt, as the ſolution is evaporated, cryſtallizes.

1394 Properties. 2. The magneſia of commerce which is in the ſtate of powder, or light friable cakes, is not fully ſaturated with the acid. But when it is cryſtallized by the above proceſſes, it is in the form of tranſparent ſix-ſided priſms, terminated by a hexagonal plane. This ſalt has little taſte. The ſpecific gravity is 0.2941.

1395 Action of water and heat. 3. When it is cryſtallized, it ſoon loſes its tranſparency in the air. It is ſoluble in 48 parts of cold water. Expoſed to heat in a crucible, it ſlightly decrepitates, is deprived of its water and acid, and falls down into a powder. It is decompoſed by all the acids. 1396 Compoſition. The component parts of this ſalt are, according to

	Bergman.	Butini.	Fourcroy.
Acid	30	36	50
Magneſia	45	43	25
Water	25	21	25
	100	100	100

The magneſia of commerce is compoſed of

	Fourcroy.	Kirwan.
Carbonic acid	48	34
Magneſia	40	45
Water	12	21
	100	100

20. Carbonate of Ammonia and Magneſia.

This triple ſalt is prepared by decompoſing carbonate of ammonia by means of magneſia; or by precipitating a ſolution of carbonate of magneſia by means of pure ammonia. This ſalt, however, has not been particularly examined.

21. Arſeniate of Magneſia.

When arſenic acid is ſaturated with magneſia, a thick matter forms towards the point of ſaturation, which is ſoluble in exceſs of acid; but when it is evaporated, it does not cryſtallize. It aſſumes the form of a jelly. It is decompoſed by the alkaline arſeniates.

22. Tungſtate of Magneſia.

This acid, in combination with magneſia, forms a ſalt which appears in the form of brilliant ſcales. It is not altered by expoſure to the air, and it is ſoluble in water. It is decompoſed by acids, and a white powder is precipitated.

23. Molybdate of Magneſia.
24. Chromate of Magneſia. } unknown.
25. Columbate of Magneſia.

26. Acetate of Magneſia.

This ſalt is formed by the direct combination of magneſia with acetic acid. It does not cryſtallize, but a viſcid maſs remains when the ſolution is evaporated. It has a ſweetiſh taſte, leaving afterwards an impreſſion of bitterneſs. The ſpecific gravity is 1.378. It deliqueſces in the air, is very ſoluble in water, and is decompoſed by heat.

27. Oxalate of Magneſia.

This ſalt is formed by combining oxalic acid with magneſia, and evaporating the ſolution. A ſalt is obtained in the form of white powder, which is ſcarcely ſoluble in water. It is decompoſed by heat. The component parts of this ſalt are

Acid and water	65
Magneſia	35
	100

28. Tartrate of Magneſia.

This compound of tartaric acid and magneſia forms a ſalt which is inſoluble in water, without an exceſs of acid. When this is the caſe, it cryſtallizes by evaporation. The cryſtals are in the form of hexangular truncated priſms. It is firſt melted, and then decompoſed by heat.

29. Citrate of Magneſia.

This ſalt is obtained by diſſolving carbonate of magneſia in citric acid. From the thick ſolution of this ſalt, there is no cryſtallization; but after ſome days, by a ſlight agitation, it aſſumes the form of a white opaque maſs, which remains ſoft, as it ſeparates from the edges of the veſſel. The component parts of this ſalt are

Acid	66.66
Magneſia	33.34
	100.00 *

30. Malate of Magneſia.

This is a deliqueſcent ſalt, and very ſoluble in water.

---

* Fourcroy vii. 208.

31. Gallate of Magneſia.

Magneſia boiled with an infuſion of nut galls, affords a clear liquid, which aſſumes a green colour. This is ſoluble in an exceſs of acid.

32. Benzoate of Magneſia.

The combination of benzoic acid with magneſia affords plumoſe cryſtals which are eaſily ſoluble in water. This ſalt has a bitter taſte.

33. Succinate of Magneſia.

The ſalt which is formed by the combination of ſuccinic acid and magneſia, does not cryſtallize. It is a white glutinous maſs which is deliqueſcent in the air.

34. Saccolate of Magneſia.

This ſalt is inſoluble in water.

35. Camphorate of Magneſia.

1397 Preparation. 1. This ſalt is formed by mixing carbonate of magneſia with water, and adding cryſtallized camphoric acid. A ſlight efferveſcence takes place. The temperature ſhould be increaſed, to drive off the carbonic acid. The ſolution is filtered while it is hot, and evaporated to dryneſs. The maſs is diſſolved in diſtilled water, filtrated and evaporated by a gentle heat, till a pellicle appears on the ſurface. By cooling there are depoſited ſmall plates, which are heaped upon each other.

1398 Properties. 2. This ſalt, which does not cryſtallize, is white and opaque, and has a bitter taſte. In the air it is ſlightly effloreſcent. It is not very ſoluble in water. Boiling water diſſolves a little, but it is precipitated in cooling. When it is thrown on red-hot coals, the acid is volatilized, and pure magneſia remains behind. By the action of the blow-pipe it gives out a bluiſh flame. It is decompoſed by ſulphuric, nitric, and muriatic acids *.

* *Ann. de Chim.* xxvii. p. 37.

36. Suberate of Magneſia.

The compound of ſuberic acid and magneſia is in the form of powder. It has a bitter taſte, is deliqueſcent in the air, and ſoluble in water. It reddens the tincture of turnſole. Expoſed to heat, it ſwells up and melts. By the action of the blow-pipe, the ſalt is decompoſed, the acid is driven off, and pure magneſia remains behind. The ſulphuric, nitric, and muriatic acids, decompoſe it. It is alſo decompoſed by the alkalies, barytes, and lime †.

† *Ibid.* xxiii. p. 56.

37. Mellate of Magneſia.

Unknown.

38. Lactate of Magneſia.

A ſalt in ſmall deliqueſcent cryſtals.

39. Pruſſiate of Magneſia.

This ſalt may be prepared by directly combining pruſſic acid with pure magneſia; but the magneſia is precipitated when the ſolution is expoſed to the air. It is alſo decompoſed by the alkalies and lime.

SECT. V. *Of ALUMINA and its Combinations.*

1399 History. 1. *Alumina*, which is now employed to ſignify one of the ſimple earths, is derived from the word *alum*, of which this earth forms a conſtituent part, and from which it is obtained in greateſt purity. It was formerly denominated *argil* and *argillaceous earth*; but theſe names being expreſſive of mixtures of different earths, have been properly rejected. Pott and Margraaf were the firſt who diſtinguiſhed this earth from the calcareous earth or lime, and proved that this latter earth could not be obtained from it by calcination. In the year 1739 Hellot ſhewed, that the baſis of alum, ſeparated from this ſalt by an alkali, was pure argil, or alumina. In 1758 and 1762 Macquer examined this earth, and detailed its characteriſtic properties. Theſe were afterwards farther elucidated and confirmed by the experiments and reſearches of Bergman and Scheele, ſo that the nature and characters of this earth were completely developed, and it was univerſally admitted as diſtinct from all others hitherto known.

1400 Preparation. 2. Although alumina exiſts in great abundance in nature, yet it is rarely found uncombined, or in a ſtate of perfect purity. It may be obtained pure by the following proceſs.

Diſſolve a quantity of common alum in water, and add to the ſolution, a ſolution of potaſh or carbonate of potaſh, or what is ſuppoſed to be ſtill better, liquid ammonia. An abundant white precipitate is immediately formed. Continue the addition of the alkali as long as any precipitate appears. When the whole of the precipitate has collected at the bottom of the veſſel, pour off the fluid part, and waſh the precipitate repeatedly with large quantities of water, to free it from all ſaline matters which it may have retained. Dry the precipitate in a moderate heat, and the ſubſtance thus obtained is alumina in a ſtate of tolerable purity. If this precipitate retain any portion of ſulphuric acid, it may be ſeparated by adding muriatic acid in ſmall quantities at a time, till the whole is diſſolved. Evaporate the ſolution till a drop of it, when ſuffered to cool on a plate of glaſs, yields minute cryſtals. Then ſet by the ſolution till it cool, and cryſtals will be depoſited. Let theſe cryſtals be removed by pouring off the fluid, and continue the evaporation till no more cryſtals are formed. In this way the alum which the earth retained, may be ſeparated. The liquid which remains is to be mixed with ammonia as long as any precipitate appears. This precipitate, well waſhed and dried, is pure alumina.

1401 Properties. 3. The alumina obtained by this proceſs, is either in the form of friable fragments, or of very fine white powder, ſoft to the touch, and inſipid to the taſte. It has a peculiar odour, which is diſtinguiſhed by the name of *earthy ſmell*, and is only perceptible when it is breathed upon, or moiſtened (o). It adheres to the tongue in

---

(o) This ſmell, however, as it has been juſtly obſerved by Sauſſure, is owing to the oxide of iron with which the alumina in its ordinary ſtate of purification, is contaminated; for when it is perfectly pure, and no conſequence of its rapidly abſorbing moiſture. The ſpecific gravity is 2.

1402 Spongy alumina.

4. Sauſſure has obſerved, that alumina exhibits two different appearances, according to the quantity of water which has been employed in the ſolution of the aluminous ſalt. If the quantity of water does not exceed what is neceſſary for the ſolution of the ſalt, we obtain a light friable white earth, which is very ſpongy, and adheres to the tongue. This he calls *ſpongy alumina*. But when the ſalt is diſſolved in a large quantity of water, we obtain, after drying the precipitate in the ſame temperature, a yellowiſh brittle tranſparent maſs, which ſplits into ſmall fragments when held in the hand like ſolid ſulphur. It has a ſmooth conchoidal fracture, no earthy appearance, does not adhere to the tongue, and does not ſwell up when put into water. It occupies 10 or 12 times leſs volume than in the ſpongy ſtate, and has ſome appearance to gum arabic, or a dried jelly. This he diſtinguiſhes by the name of *gelatinous alumina* *.

1403 Gelatinous.

1404 Action of heat.

5. Alumina undergoes no change by being expoſed to light. When it is expoſed to heat, it is diminiſhed in bulk, in conſequence of being deprived of the water with which it is combined. Accordingly, Sauſſure has obſerved, that the ſpongy alumina expoſed to the ſame temperature, loſes a greater quantity of moiſture than the gelatinous alumina. The former, when expoſed to a red heat, loſes 0.58 parts of its weight; but the latter only 0.43 parts. When they are both expoſed to a very ſtrong heat, the ſpongy alumina is deprived of no more water than what it gives out with a red heat, while the gelatinous parts with only 0.4825. On this property of the contraction of bulk of alumina when expoſed to heat, depends the principle of the thermometer, or pyrometer, of Wedgwood, of which we ſhall immediately give a ſhort deſcription.

When alumina is expoſed to a very ſtrong heat ſuddenly applied, as by means of the blow-pipe, with a ſtream of oxygen gas, it is ſuſceptible of a kind of fuſion; and when it is cooled, it appears under the form of an enamel, of a greeniſh colour, and ſo hard, as to cut glaſs.

1405 Of water.

6. Alumina is not ſoluble in water, but it abſorbs and retains that fluid in conſiderable quantity. With a greater quantity of water it is diffuſed in it, and may be formed into a paſte, in which ſtate it is moulded with great facility into any form.

7. There is no action between alumina and oxygen, azote, hydrogen, or phoſphorus; and very little between it and ſulphur, except when they are in a ſtate of minute diviſion, or in combination with ſome other ſubſtances. Carbone combines with alumina, of which there are many natural compounds, among the claſs of bituminous foſſils; but even in theſe compounds, the carbone and alumina are mixed with other earths, and with the oxide of iron.

1406 Of carbone.

1407 Of acids.

8. Alumina enters into combination with almoſt all the acids, and forms ſalts which are more or leſs ſoluble, and ſuſceptible of cryſtallization. Some are inſoluble in water, and others require an exceſs of acid.

1408 Affinities.

9. The order of its affinity for the acids, is the following.

Sulphuric acid,
Nitric,
Muriatic,
Oxalic,
Arſenic,
Fluoric,
Tartaric,
Succinic,
Saclactic,
Citric,
Phoſphoric,
Lactic,
Benzoic,
Acetic,
Boracic,
Sulphurous,
Carbonic,
Pruſſic.

1409 Of alkalies

10. Alumina combines with the fixed alkalies. When they are heated together, an opaque maſs, which has little coherence, is formed. Fixed alkali diſſolved in water, with the aſſiſtance of heat, has the property of diſſolving alumina; but from this ſolution it may be precipitated by means of an acid, and then it is obtained in great purity. Liquid ammonia alſo holds a ſmall quantity of alumina in ſolution, if it has been recently precipitated.

1410 Of earths.

11. Alumina enters into combination with many of the earths, and particularly with lime and ſilica. Theſe compounds form the chief baſis of all kinds of pottery and porcelain. Alumina combines with lime, and enters into fuſion with it by means of heat. A compound is alſo formed with alumina and barytes, or ſtrontites, by expoſing them together in a crucible to a ſtrong heat; or, by boiling them together in water. Magneſia and alumina alone, do not enter into combination by means of the ſtrongeſt heat; but a porcelain is obtained from a mixture of lime, magneſia, and alumina. But in the proportions that are employed, it is neceſſary that the alumina be greateſt. The following table ſhews the reſults of experiments on theſe earths in different proportions *.

Alumina,	3	A porcelain.
Lime,	2	
Magneſia,	1	
Alumina,	3	A porcelain.
Magneſia,	2	
Lime,	1	
Alumina,	3	Porous porcelain.
Magneſia,	3	
Lime,	1	
Alumina,	3	Porous porcelain.
Magneſia,	3	
Lime,	2	

Alumina,

---

* *Jour. de Phyſique*, lii. p. 290.

* *Kirwan, Mineral.* i. p. 61.

traces of oxide of iron can be detected, it has no perceptible ſmell. To alumina which was perfectly inodorous, he communicated this ſmell, by triturating it with oxide of iron. *Journal de Phyſique*, lii. p. 287.

Alumina,	3	Porcelain.
Lime,	2	
Magneſia,	2	

1411 Uſes. 12. This is one of the moſt important of the earths, on account of the variety of purpoſes to which it is applied. It forms the baſes of all kinds of earthen ware, from the coarſeſt brick to the fineſt china. It is alſo chiefly employed in the pots or crucibles which are expoſed to very ſtrong heat, as in glaſs manufacture and caſt iron. It is employed alſo in dyeing and calico printing, and in the cleaning or ſcouring of woollen ſtuffs. It has been applied to a valuable uſe by the late Mr Wedgwood, in the conſtruction of an inſtrument capable of aſcertaining high degrees of temperature, to which the common thermometer cannot reach.

1412 Wedgwood's pyrometer. 13. This inſtrument is conſtructed on the principle of the contraction of pure clay, when it is expoſed to heat. Mr Wedgwood took a very pure clay, and formed it into ſmall ſhort cylinders, which were made exactly of the ſame ſize. They are then baked in a low red heat, to expel the whole of the air and moiſture which adhere to the clay. The cylinders are thus prepared for the meaſurement of ſtrong heats. For this purpoſe, one of the cylinders is introduced between two rulers, to which a ſcale is attached, and its bulk is exactly meaſured. It is then introduced into the furnace whoſe heat is to be tried, and the temperature is to be eſtimated according to the diminution of bulk which the cylinder has ſuſtained. The quantity of contraction is meaſured by means of two metallic rulers, which are fixed upon a plate. Theſe rulers are 24 inches in length, and are divided into 240 parts. The diſtance between the rulers at the upper extremity of the ſcale is 0.5 of an inch, and at the lower extremity 0.3 of an inch. The ſize of the clay cylinder, before it is introduced into the furnace, nearly fits the upper part of the ſcale; or at leaſt the degree at which it ſtands, before it is introduced into the furnace, is marked. After being heated, the clay cylinder is again applied to the ſcale, and the diminution of bulk is meaſured by the diſtance at which it ſtands between the rulers from the top of the ſcale, or from the degree at which it ſtood before it was expoſed to the heat.

1413 Scale of it. Mr Wedgwood connected the ſcale of his pyrometer with Fahrenheit's thermometer. The firſt degree of his ſcale which marks a red heat, correſponds to the 947° Fahrenheit; but to make this inſtrument better underſtood, we may ſtate a few of the correſponding degrees of the two inſtruments.

	Wedgwood.		Fahrenheit.
Red heat, - -	0	=	947
Fine ſilver melts -	28		4717
Fine gold melts -	32		5237
Welding heat of iron -	95		13427
Caſt iron melts -	130		17977
Greateſt heat in an air furnace eight inches ſquare	160		21877
Extremity of the ſcale, or higheſt temperature obſerved	240		32277

This inſtrument has been of conſiderable importance in ſome arts and manufactures, and it is undoubtedly fitted to give ſome information concerning thoſe intenſe heats which can be meaſured by no other inſtrument which has yet been contrived. But as the ſame kind of clay cannot always be obtained, and as it is probable that the contractions of the cylinders are not proportional to the temperatures, their eſtimation by this inſtrument can only be conſidered as an approximation to certainty.

I. Compounds of Alumina with Acids.

1. Sulphate of Alumina.

1414 Preparation. 1. This is a compound of ſulphuric acid and alumina. It may be formed by the direct combination of the acid with the earth. But in the preparation of this ſalt, the earth and the acid muſt be in a ſtate of purity, and muſt be ſaturated with each other. The ſolution is then evaporated to dryneſs; the ſalt is again diſſolved in diſtilled water, and evaporated ſlowly till it cryſtallizes.

1415 Properties. 2. The cryſtals of this ſalt are in the form of thin plates, ſoft and pliant, with a brilliant pearly luſtre, and of an aſtringent taſte. It is not altered by expoſure to the air; it is very ſoluble in water, but it does not cryſtallize readily. 1416 Action of heat, &c. When it is heated, it is infuſible; but by long calcination, it dries and falls down to powder. At a high temperature it is decompoſed, and the acid is driven off.

3. The ſulphuric acid readily combines with this ſalt, and forms with it an acidulous ſulphate of alumina. This ſalt has a more acid taſte than the former; it cryſtallizes with more difficulty, and the cryſtals have more brilliancy. It reddens vegetable blues, and frequently aſſumes the form of a thick gelatinous maſs.

4. All the alkaline and earthy baſes, except ſilica and zirconia, decompoſe either of theſe two ſalts. The ſaturated ſulphate of alumina, according to Bergman, is compoſed of

1417 Compoſition.

Sulphuric acid,	50
Alumina,	50
	100

2. Acidulous Sulphate of Alumina and Potaſh, or Alum.

1418 Hiſtory. 1. The alum of commerce, now of ſuch extenſive utility in many of the arts and manufactures, was imported into Europe from Aſia, previous to the 15th century, during which it was begun to be manufactured in Italy. Alum works were erected in Spain and Germany in the 16th century; and towards the end of it, a manufactory of this ſalt was eſtabliſhed in Yorkſhire in England. But the true nature of alum has been only of late underſtood. It is to the experiments and reſearches of Vauquelin, that we are indebted for the knowledge of its component parts.

1419 Preparation. 2. Alum is generally obtained by expoſing to the weather for ſome time, aluminous ſhiſtus, or what are called *aluminous ores*, which are natural productions, ſometimes found in the neighbourhood of volcanoes, and ſometimes, as in Britain, dug out of coal mines which abound with pyrites or ſulphuret of iron. When theſe ſubſtances, which are alſo mixed with a conſiderable

able proportion of clay, are expoſed to air and moiſture, the ſulphur combines with the oxygen of the air, or with that of the water, by decompoſing it, and is thus converted into ſulphuric acid. This combines with the alumina, and thus there is formed a ſulphate of alumina. The ſalt thus formed, is diſſolved in water, and muſt be purified by repeated boilings and cryſtallizations. This aluminous ſchiſtus is generally mixed with a conſiderable proportion of ſulphate of iron. From this it is to be ſeparated during the proceſs, and the potaſh or ammonia which is neceſſary to conſtitute the triple ſalt, muſt be added. Even before the component parts of alum were diſcovered, the addition of potaſh or ammonia was found to be neceſſary to complete the proceſs. This was well known to the manufacturers, who ſuppoſed that it was neceſſary to take up a quantity of acid, which being in exceſs, prevented the granulation, as it was called, or the cryſtallization of the alum.

1420 Properties. 3. Alum cryſtallizes in regular octahedrons; but this form is ſubject to conſiderable variety, according to the difference of proportion which is found to take place among its component parts. The primitive form of the cryſtal is the regular octahedron, and the integrant molecule the regular tetrahedron. It has a very aſtringent, ſtyptic, and ſomewhat ſweetiſh taſte. It uſually reddens vegetable blues. The ſpecific gravity is 1.7109.

1421 Action of water and heat. 4. It is little changed by expoſure to the air. By long contact there is a ſlight effloreſcence on the ſurface. Alum is ſoluble in 16 or 20 parts of cold water. Boiling water diſſolves a greater proportion. When expoſed to heat, it melts in its water of cryſtallization. It then ſwells up, enlarges in volume, and there remains behind a light, porous, dry maſs, which has a ſharp acid taſte, and reddens more ſtrongly vegetable blues. In this ſtate it is called *burnt* or *calcined alum*. When it is expoſed to a ſtronger heat, the acid is driven off.

1422 Varieties. 5. According to the experiments of Vauquelin, there are three kinds or varieties of alum, which, although they poſſeſs nearly the ſame properties, have different conſtituent parts, or different proportions of the ſame conſtituents. The firſt is ſulphate of alumina and potaſh with an exceſs of acid; which indeed is neceſſary to conſtitute alum. The ſecond conſiſts of alumina and ammonia, alſo with an exceſs of acid. The third variety which is moſt frequently found among the alum of commerce, is a mixture of both. It contains both potaſh and ammonia. When an additional quantity of potaſh is added, the alum cryſtallizes, not in its uſual form, but in the form of cubes, and hence it has been denominated *cubic alum*. If a ſtill greater quantity of potaſh be added, the cryſtallization is nearly interrupted; and it then appears in the form of flakes.

1423 Compoſition. The component parts of alum, are according to

Vauquelin.		Kirwan.	
Sulphate of alumina,	49	Acid,	17.66
——— Potaſh,	7	Baſe,	12.00
Water,	44	Water,	70.34
	100		100.00

1424 Action of charcoal. 6. The three varieties of alum are nearly decompoſed in the ſame way, by combuſtible ſubſtances. If alum be expoſed to a moderate heat with charcoal, it is converted into the ſtate of neutral ſalt, becauſe the charcoal acts on the exceſs of acid, before it can effect the decompoſition of the ſalt; but when it is ſtrongly heated, there is formed with the ſulphate of alumina and potaſh, a black ſubſtance, which ſpontaneouſly takes fire in the air. This ſubſtance has been diſtinguiſhed by the name of *pyrophorus*, and it is called *Homberg's pyrophorus*, becauſe it was diſcovered by that chemiſt.

1425 Pyrophorus. Pyrophorus is prepared by mixing together three parts of alum, and one of flower or ſugar, in an iron ladle, and expoſing the mixture to heat till it ceaſes to ſwell, and becomes black. It is then to be reduced to powder, put into a glaſs phial, and again expoſed to heat, till a blue flame proceeds from the mouth of the phial. After it burns for a minute, it is allowed to cool, and muſt be kept in a well-cloſed bottle.

1426 Properties. 7. The pyrophorus thus formed, contains a hydrogenated ſulphuret of potaſh and alumina, mixed with charcoal in a ſtate of minute diviſion. It kindles more readily in humid than in dry air. The oxygen gas of the atmoſpheric air is abſorbed. Part is converted into carbonic acid, and part combines with the ſulphur, and forms ſulphuric acid; ſo that when the pyrophorus is burnt, it no longer contains the hydrogenated ſulphuret as before, but ſulphate of alumina and potaſh; not in the ſtate of alum, becauſe it has been deprived of the exceſs of acid, which gives it its peculiar character.

8. Pyrophorus gives out a very fetid odour, when it is thrown into water, and leaves behind a ſulphuret of potaſh, and of hydrogenated alumina. It is inflamed by nitrous gas, and by oxymuriatic acid gas *.

1427 Uſes of alum. 9. The uſes of alum are very numerous. It is employed in medicine as an aſtringent and ſtyptic. It is employed in the arts of bleaching, of tanning, dyeing, calico-printing, and others. It is ſometimes uſed in preſerving animal matters from putrefaction, and it might be employed for the purpoſe of ſecuring wood from catching fire.

1428 Preparation. *Sulphate of alumina and potaſh.*—1. If a ſolution of cryſtallized alum be boiled with a ſolution of pure alumina, the ſaturated ſulphate of alumina and potaſh is formed. The exceſs of acid, it is obvious, in this proceſs, enters into combination with the alumina. The alum, as the earth is added, is gradually precipitated in the ſolution, in the form of a white powder.

1429 Properties. 2. This ſalt, ſaturated with alumina, never aſſumes any regular form. It has no taſte, is not changed by expoſure to the air, is not ſoluble in water, and when it is expoſed to heat, it is not altered, except at a very high temperature. This ſalt is leſs eaſily decompoſed than any of the other varieties of ſulphate of alumina. By the action of ſome of the acids it is converted into alum, which is owing to the acid combining with the additional portion of alumina, that ſaturated the exceſs of acid exiſting in the alum. This ſalt has been applied to no uſe.

3. Sulphite of Alumina.

1430 Preparation. 1. The compound of ſulphurous acid and alumina is

---

* Fourcroy, iii. p. 59.

is prepared by paſſing ſulphurous acid gas into water in which pure alumina is mixed or ſuſpended.

1431 Properties. 2. The ſulphite of alumina thus formed, is in the ſtate of a white, ſoft powder, which has at firſt an earthy taſte, and becomes afterwards ſulphureous. When it is expoſed to the air, for a long time, it is converted into the ſulphate of alumina, and more rapidly if it be combined with an exceſs of ſulphurous acid. It is inſoluble in water. Expoſed to heat, the acid is driven off, and partially decompoſed, for there remains behind a ſmall quantity of ſulphur. The component parts of this ſalt, are

1432 Compoſition.

Sulphurous acid	32
Alumina	44
Water	24
	100

4. Nitrate of Alumina.

1433 Preparation. 1. This ſalt was formerly known under the names of *nitre of argil*, and *nitrous alum*. It is formed by the direct combination of the nitric acid with alumina. It has been found impoſſible to neutralize the acid; and it cannot be obtained cryſtallized, excepting in the form of thin plates, and often only in a gelatinous maſs.

1434 Properties. 2. This ſalt has an auſtere and acid taſte. The ſpecific gravity is 1.645. It is deliqueſcent in the air, and extremely ſoluble in water. When it is heated, the acid is driven off, and the pure earth remains behind. It is readily decompoſed by the ſulphuric acid, which diſengages the nitric acid; and by the muriatic acid, which is converted into the oxymuriatic acid.

5. Nitrite of Alumina.

This ſalt is unknown.

6. Muriate of Alumina.

1435 Preparation. 1. This ſalt, which is a compound of muriatic acid and alumina, is formed by the direct combination of the acid with the earth; but it is never neutralized. The acid is always in exceſs.

1436 Properties. 2. This ſalt is rarely cryſtallized, but moſt frequently in the form of white powder, or in that of a gelatinous maſs. It has an aſtringent, acid, and ſharp taſte. It reddens the tincture of turnſole and of violets. It is extremely deliqueſcent in the air, and very ſoluble in water. When it is expoſed to heat it melts, and is decompoſed. The acid is ſeparated, and the pure alumina remains behind. It is decompoſed in the ſame way as the other muriates.

7. Hyperoxymuriate of Alumina.

1. This ſalt is prepared by paſſing oxymuriatic acid gas through water in which newly precipitated alumina is ſuſpended. The alumina diſappears, and when ſulphuric acid is poured into the ſolution, a ſtrong ſmell of hyperoxymuriatic acid gas is perceived.

2. This ſalt is deliqueſcent, and it is ſoluble in alcohol. Mr Chenevix could not aſcertain the proportion of its principles *.

8. Fluate of Alumina.

The combination of fluoric acid and alumina, affords a ſalt which cannot be cryſtallized, but which is in the form of a jelly. It has always an exceſs of acid, and an aſtringent taſte. It is decompoſed by all the earthy and alkaline baſes. With the latter it forms triple ſalts.

9. Borate of Alumina.

It is extremely difficult to form a compound of alumina and boracic acid by direct combination. This ſalt may be formed by mixing together a ſolution of borate of ſoda, with a ſolution of ſulphate of alumina. Its properties have not been examined.

10. Phoſphate of Alumina.

This ſalt is little known. By ſaturating phoſphoric acid with alumina, a white powdery maſs is obtained, which has little taſte, except there be an exceſs of acid, and then it ſeems to form an acidulous ſalt. It melts under the blow-pipe into a tranſparent globule, without decompoſition. It is decompoſed by the alkalies, ſome of the earths, and the acids.

11. Phoſphite of Alumina.

1. This ſalt is formed by the direct combination of phoſphorous acid with alumina. The ſolution is to be evaporated to a proper conſiſtence.

2. The phoſphite of alumina does not cryſtallize, but forms a thick, viſcid, gummy maſs, which becomes dry and ſolid in the air. It has an aſtringent taſte, is very ſoluble in water, ſwells up when it is heated, and gives out a phoſphoric light. It is decompoſed by all the alkaline and earthy baſes.

12. Carbonate of Alumina.

1437 This compound little known. Little is known of the combination of carbonic acid and alumina. Bergman had obſerved, when alum was precipitated by an alkaline carbonate, that very little or no effervescence took place; he therefore concluded, that the carbonic acid, not being driven off, muſt have combined with the alumina which was precipitated. And beſides he found, that the liquid contained a portion of carbonate of alumina, which is depoſited ſome hours or ſome days afterwards by the evaporation of the carbonic acid, which held it in ſolution.

Common clay, which is a mixture of alumina and ſilica, contains a certain portion of carbonic acid, which is diſengaged by the application of ſtrong heat. He obtained from one ſpecies of clay, ſeveral times its volume of this acid, mixed with a ſmall portion of hydrogen gas. It is owing to the ſame combination of carbonic acid, that clays, treated with acids, effervesce, without containing any carbonate of lime.

1438 The acid is combined with water. According to Sauſſure, alumina is diſſolved in water, which is ſaturated with carbonic acid; but when the ſolution is expoſed to the air, it is decompoſed.

13. Arſeniate of Alumina.

This ſalt is formed by diſſolving alumina in arſenic acid, and evaporating the ſolution to dryneſs. A thick maſs is thus obtained, which is inſoluble in water. It is decompoſed by the ſulphuric, nitric, and muriatic acids, as well as by the earthy and alkaline baſes.

14. Tungſtate of Alumina.

This ſalt has not been examined.

---

* *Phil. Tranſ.* 1802, p. 149.

15. Molybdate of Alumina.
16. Chromate of Alumina. } unknown.
17. Columbate of Alumina.

18. Acetate of Alumina.

The acetic acid enters into combination with alumina, and forms with it ſmall, needle-ſhaped cryſtals, which are ſoft, deliqueſcent, and have an aſtringent taſte. The ſpecific gravity of this ſalt is 1.245. Its other properties are unknown.

19. Oxalate of Alumina.

Oxalic acid very readily combines with alumina. When the ſolution is evaporated, a yellowiſh, ſoft, tranſparent maſs is obtained, but it does not cryſtallize. 1439 Properties. This ſalt has an aſtringent taſte, is deliqueſcent, and reddens the tincture of turnſole. When it is heated, it ſwells up, is deprived of its acid, and the alumina remains behind, ſlightly coloured. It is decompoſed by the ſtronger acids.

1440 Compoſition. The component parts of this ſalt are,

Acid and water	56
Alumina -	44
	100

20. Tartrate of Alumina.

Alumina enters into combination with tartaric acid, and forms an uncryſtallized, gelatinous maſs, which has an aſtringent taſte, is not deliqueſcent in the air, but is ſoluble in water.

21. Citrate of Alumina.

The properties of this ſalt have not been examined.

22. Malate of Alumina.

When malic acid is added to a ſolution, containing alumina, a precipitate is formed, which is ſcarcely ſoluble in water.

23. Gallate of Alumina.

If pure alumina be added to a ſolution of nut-galls, an inſoluble compound is formed with the tannin and extract. The liquid remained clear and white, and it afforded by evaporation, ſmall cryſtals, which are gallate of alumina with exceſs of acid *.

24. Benzoate of Alumina.

The compound of benzoic acid and alumina affords a ſalt, which cryſtallizes in an arboreſcent form. It has a bitter taſte, is deliqueſcent in the air, ſoluble in water, is decompoſed by the action of heat, and even by moſt of the vegetable acids.

25. Succinate of Alumina.

The compound of ſuccinic acid and alumina affords ſalts which cryſtallize in the form of priſms, and are eaſily decompoſed by heat.

26. Saccolate of Alumina.

This compound of ſaclactic acid and alumina forms a ſalt which is inſoluble in water.

27. Camphorate of Alumina.

1441 Preparation. 1. The compound of camphoric acid and alumina is formed by precipitating alumina by means of ammonia, waſhing the precipitate, and diluting it with diſtilled water. Cryſtals of camphoric acid are then to be added. The mixture is to be heated, filtered, and evaporated.

1442 Properties. 2. A white powder is thus obtained, which has a bitter, acid, and aſtringent taſte. It reddens vegetable blues. This ſalt is ſcarcely altered by expoſure to the air. Water diſſolves about $\frac{1}{200}$ part of its weight. Boiling water diſſolves it more readily; but on cooling, a precipitate is formed. When it is expoſed to heat, it ſwells up, and the acid is volatilized. By the action of the blow-pipe, a blue flame is produced, the ſalt is decompoſed, and the pure alumina remains behind. This ſalt is decompoſed by the mineral acids, and even by ſome of the vegetable acids. It is alſo decompoſed by the nitrates of lime and barytes *.

28. Suberate of Alumina.

The compound of ſuberic acid and alumina may be formed by evaporating the ſolution with a very moderate heat, in a large open veſſel. 1443 Properties. This ſalt does not cryſtallize; but the dried matter which is obtained, is tranſparent, of a yellowiſh colour, and has a ſtyptic, bitteriſh taſte. When too much heat is employed, the ſalt melts and blackens. It reddens the tincture of turnſole, and is ſlightly deliqueſcent in the air. Expoſed to the action of the blow-pipe, the acid is volatilized and decompoſed, and the alumina remains behind. It is decompoſed by the mineral acids, the earths, and the alkalies †.

29. Mellate of Alumina.

The properties of this ſalt are unknown.

30. Lactate of Alumina.

This is a deliqueſcent ſalt.

Sect. VI. *Of Silica and its Combinations.*

1444 Hiſtory. 1. Silica has been diſtinguiſhed by the names of *ſiliceous earth*, or *quartzy earth*, becauſe it is obtained from *ſilex*, or flint, and from the ſtone called *quartz*. This earth exiſts in great abundance in nature, and it conſtitutes the baſes of ſome of the hardeſt ſtones of which the nucleus of the globe conſiſts; and, on account of its great abundance, it has been regarded as the primitive or elementary earth, the baſe of all the other earths. Silica forms one of the conſtituent parts of moſt ſtony bodies; but it exiſts in greateſt abundance in agates, jaſper, flints, quartz, and rock cryſtal; in the latter it exiſts nearly in a ſtate of purity.

1445 Preparation. 2. But to obtain it perfectly pure, a quantity of quartz or rock cryſtal may be expoſed to a red heat. When it is taken from the fire, and while it is yet hot, it is ſuddenly immerſed in cold water. It is then to be reduced to powder; and, if tranſparent rock cryſtal has been employed, it is then in a ſtate of tolerable purity. To have it perfectly pure, mix one part of the pounded ſtone, with three parts of potaſh, and expoſe them in a crucible to heat, which is ſufficient for the fuſion of the mixture. The maſs thus obtained is ſoluble in water. Add a ſufficient quantity of water for its ſolution, and drop in muriatic acid, as long as there

---

* *Phil. Tranſ.* 1803, p. 244.

* *Ann. de Chim.* xxvii. p. 34.

† *Ibid.* xxiii. p. 56.

there is any precipitate. Let this be repeatedly waſhed with water, and dried. The ſubſtance thus obtained is pure ſilica.

1446 Properties.

3. It is in the form of a very fine white powder, which has neither taſte nor ſmell. The particles are rough and harſh to the feel, as when they are rubbed between the fingers, or touched with the tongue. The ſpecific gravity is 2.66.

1447 Action of heat, &c.

4. Light has no action on ſilica; and it is one of the peculiar characters of this earth, that it reſiſts, unchanged, the greateſt degree of heat.

5. There is no action between ſilica and oxygen, azote or hydrogen, nor is it changed by expoſure to the air. It is not acted upon by carbone, phoſphorus, or ſulphur. It is inſoluble in water; but in a ſtate of minute diviſion, it abſorbs a conſiderable portion, and forms with this liquid, a tranſparent jelly. When it is expoſed to the air, the whole of the moiſture is evaporated.

1448 Cryſtals.

6. Silica is frequently found in nature in the cryſtallized form, and then it is diſtinguiſhed by the name of *rock cryſtal*. It is moſt commonly in hexagonal priſms, terminated by hexagonal pyramids. Cryſtals of ſilica have alſo been formed artificially. In a ſolution of ſilica in fluoric acid which had remained at reſt for two years, Bergman found cryſtals, ſome of which were cubes, and ſome had truncated angles, at the bottom of the veſſel. Cryſtals of ſilica have alſo been formed, by diluting largely with water, the combination of ſilica and potaſh, and allowing it to remain for a long time. Profeſſor Seigling of Erfurt obtained cryſtals from a ſolution which had been kept eight years in a glaſs veſſel. A cruſt was formed on the top, compoſed of carbonate of potaſh and cryſtallized ſilica. The cryſtals of the latter were in the form of tetrahedral pyramids, perfectly tranſparent, and ſo hard as to ſtrike fire with ſteel.

1449 Action of Of acids.

7. Silica is only acted on by a very few of the acids. Theſe are, the phoſphoric and boracic, which combine with it by fuſion, and the fluoric, which diſſolves ſilica either in the gaſeous or liquid ſtate. When ſilica is held in ſolution in water by means of an alkali, it is alſo diſſolved by the muriatic acid.

1450 Of alkalies.

8. The alkalies have a very powerful action on this earth. In the preparation of the pure earth, it was combined with potaſh by means of fuſion. This compound is different in its nature and properties, according to the proportions of the ſilica and the alkali. Two or three parts of potaſh with one of ſilica, form a compound which is deliqueſcent in the air, and ſoluble in water. This was formerly diſtinguiſhed by the name *liquor ſilicum*, or *liquor of flints*. It is now called *ſilicated alkali*. When this ſolution is long expoſed to the air, the earth is depoſited in a flaky gelatinous form. It is decompoſed by acids, which combine with the alkali, and the pure earth falls to the bottom in the ſtate of fine powder. When the ſolution is largely diluted with water, and if a greater quantity of the acid be added than is ſufficient to ſaturate the alkali, the ſilica remains in ſolution. This is particularly the caſe when the muriatic acid is employed; but when the ſilica is in greater proportion, a compound is formed which is poſſeſſed of very different properties. The ſubſtance thus obtained is glaſs.

1451 Glaſs.

9. This earth alſo enters into combination with ſome of the earths. If to a ſolution of the liquor of flints, lime water be added, a precipitate is formed, which is found to be a compound of ſilica and lime. Silica alſo combines with lime by means of heat, and in certain proportions a glaſs is formed.

1452 Of earths.

The following table, drawn up by Mr Kirwan, exhibits the effects of heat on theſe earths in different proportions *.

Proportions.	Wedgw.	Effect.
50 Lime 50 Silica	150°	Melted into a maſs betwee porcelain and enamel, of white colour, ſemitranſparent at the edges, and which gave feeble ſparks with ſteel.
80 Silica 20 Lime	156°	Not melted, but formed a brittle maſs.
80 Lime 20 Silica	156°	Formed a yellowiſh-white, looſe powder.

10. Silica enters into combination with baryte The following table will ſhew the effect of different proportions of theſe earths, as they were aſcertained by Mr Kirwan †.

Proportions.	Wedgw.	Effects.
80 Silica 20 Barytes	155°	Formed a white brittle maſs.
75 Silica 20 Barytes	150°	A brittle hard maſs, ſemitranſparent at the edges.
66 Silica 33 Barytes	150°	Melted into a hard, ſomewhat porous, porcelain maſs.
50 Silica 50 Barytes	148°	A hard maſs not melted.
80 Barytes 20 Silica	148°	The edges melted into a pale greeniſh maſs, between a porcelain and an enamel.
75 Barytes 25 Silica	150°	Melted into a ſomewhat porous porcelain maſs.
66 Barytes 33 Silica	150°	Melted into a yellowiſh, and partly greeniſh white, porous porcelain.

11. Silica alſo enters into combination with ſtrontites. Three parts of ſtrontites and one of ſilica, ſtrongly heated in a ſilver crucible for an hour, afforded a gray, ſonorous, vitreous maſs, which has no taſte, and is inſoluble in water.

12. Siliceous earth enters with difficulty into combination with magneſia; but if equal parts of ſilica and magneſia be expoſed to very ſtrong heat, they melt into a white enamel.

---

* *Mineral.* i. p. 56.

† *Ibid.* 57.

13. But the moſt important compounds of all the earths are thoſe of ſilica and alumina. Theſe earths may be combined together, as appears from the experiments of Guyton, in the humid way. He mixed together equal parts of alumina diſſolved by means of potaſh, and of ſilica held in ſolution by the ſame alkali. When the ſolutions came into contact, a brown zone was immediately formed, which ſpread by agitation through the whole maſs, and communicated to it a yellowiſh colour. The mixture was no farther changed during the ſpace of an hour, although it was occaſionally ſtirred with a glaſs rod; but at the end of that time the whole maſs aſſumed the appearance of a thick, opaque, white jelly *. When the ſilica and alumina are mixed together, and formed into a paſte with water, and expoſed to heat, they ſtrongly cohere, and aſſume a conſiderable degree of hardneſs. This compound forms the baſes of all kinds of pottery and porcelain. 1453 Porcelain.

I. Compounds of Silica with Acids.

1. Muriate of Silica.

1454 Preparation. When muriatic acid is poured upon a ſolution of ſilicated potaſh, part of the ſilica remains in the ſolution combined with the acid. To this compound Fourcroy has given the name of *muriate of ſilica*. This ſolution which is perfectly tranſparent, is always acid. 1455 Properties. When it is concentrated by a ſlow evaporation, it aſſumes the form of a tranſparent jelly. But if the ſolution be boiled, it is decompoſed, and the ſilica is precipitated in the form of ſmall cryſtalline particles, ſo that it is totally ſeparated from the water and the acid †.

2. Fluate of Silica.

1456 Preparation. Fluoric acid combines with ſilica, either in the gaſeous or liquid ſtate. When it is diſengaged from lime in the ſtate of gas, by means of an acid, if the proceſs be performed in glaſs veſſels, they are corroded. The fluoric acid in the ſtate of gas combines with the ſilica, and retains it, even when it is condenſed by water. This earth may be precipitated from the liquid ſolution by means of an alkali. When fluoric acid gas is condenſed by water, part of the ſilica with which it was combined, is precipitated; but this portion is at laſt diſſolved by new additions of the acid, ſo that the ſalt is in the ſtate of an acidulous fluate. If this ſolution be evaporated, a quantity of ſilica, correſponding to the portion of acid diſengaged, is depoſited, and the liquid which remains, contains a portion in proportion to that of the acid which is left in the ſolution ‡.

3. Fluate of Potaſh and Silica.

This triple ſalt is formed, when a ſolution of fluate of potaſh is expoſed to heat in glaſs veſſels; or, when the fluoric acid which has been prepared in glaſs veſſels is combined with potaſh. But the nature of this triple ſalt has not been examined.

4. Fluate of Soda and Silica.

This triple ſalt is formed in the ſame way as the former.

5. Borate of Silica.

Boracic acid and ſilica combine together by means of a ſtrong heat, and form a tranſparent glaſs. To this Fourcroy has given the name of *borate of ſilica*. This compound has no taſte, is not altered by the air, nor is it ſoluble in water.

6. Phoſphate of Silica.

This compound of phoſphoric acid and ſilica is formed by means of fuſion; and the compound is a hard, denſe, tranſparent glaſs. When it is expoſed to ſtrong heat, it combines with the alkalies, and forms a triple ſalt. It is not decompoſed by any of the acids. This ſubſtance is employed in the fabrication of artificial gems.

Sect. VII. *Of Yttria and its Combinations.*

1. This earth was diſcovered by Gadolin in 1794; 1457 Hiſtory. and the account of his analyſis of the mineral from which it is obtained, was publiſhed in the memoirs of the Swediſh academy, and in Crell's Annals for the year 1796. In 1797 Ekeberg analyzed the ſame mineral, and confirmed the reſults of Gadolin. To the new earth found in this mineral, Ekeberg gave the name of *yttria*, derived from *Ytterby*, a place in Sweden where the ſtone is found. The ſame mineral was afterwards analyzed by Vauquelin and Klaproth, about the year 1800. The mineral from which this earth is obtained, has received the name of gadolinite, is of a black colour, has a vitreous fracture, and its ſpecific gravity is 4.0497. It is magnetic. When it is heated with borax, it melts, and communicates to the ſalt a yellowiſh colour inclining to violet. The component parts of this mineral are,

Yttria	.47
Silica	.25
Oxyde of iron	.18
Alumina	.04
	.94

1458 Preparation. 2. Yttria is obtained from this mineral, by reducing it to powder, and adding a mixture of nitric and muriatic acids, till the whole is decompoſed. The ſolution is then to be filtered, and evaporated to dryneſs. If then it be diluted with water, the ſilica will remain behind. The liquid which paſſed through the filter is alſo to be evaporated to dryneſs, and what remains is to be expoſed to a red heat in a cloſe veſſel. It is afterwards diſſolved in water, and filtered. The liquid which paſſes through the filter is tranſparent and colourleſs. By adding a ſolution of ammonia, a precipitate is formed, which being collected, is pure yttria.

1459 Properties. 3. This earth is in the ſtate of a white powder. It has neither taſte nor ſmell. It is not fuſible. It is not ſoluble in water, or in any of the cauſtic fixed alkalies, but it readily diſſolves in carbonate of ammonia. The ſpecific gravity of this earth is 4.842.

4. This earth undergoes no change by the action of light. It is not acted on by oxygen, azote, or hydrogen, nor does it combine with ſulphur. It forms compounds

---

* *Ann. de Chim.* xxxi. p. 248.

† *Fourcroy*, iii. 213.

‡ *Ibid.* iii. p. 310.

pounds with the acids. Theſe ſalts have a ſweetiſh, auſtere taſte, and ſome of them have a red colour.

I. Compounds of Yttria with the Acids.

1. Sulphate of Yttria.

1460 Preparation. 1. Sulphuric acid combines readily with yttria, and during the combination there is an evolution of caloric; and as the union goes on, the ſalt which is formed, cryſtallizes in ſmall brilliant grains.

1461 Properties. 2. Theſe cryſtals are ſometimes irregular, but often have the form of ſix-ſided priſms, terminated by four-ſided ſummits, and are of an amethyſt red colour. This ſalt has a ſweetiſh aſtringent taſte, ſomething like the ſalt of lead. The ſpecific gravity is 2.791. It undergoes no change by expoſure to the air. It is ſoluble in about 50 parts of cold water, but leſs ſo where there is not an exceſs of acid. This ſalt is partially decompoſed when expoſed to a red heat.

2. Sulphite of Yttria.

Unknown.

3. Nitrate of Yttria.

1462 Preparation. Nitric acid combines with yttria by diſſolving the earth in the acid. This ſalt cryſtallizes with difficulty. When it is evaporated by heat, if too much be applied, in place of becoming ſolid as other ſalts, it becomes ſoft, and aſſumes the appearance of a thick, tranſparent honey. When it cools, it becomes hard and brittle. It deliqueſces in the air. When ſulphuric acid is poured into a ſolution of nitrate of yttria, a precipitate is formed which cryſtallizes. Theſe are cryſtals of ſulphate of yttria [*].

4. Muriate of Yttria.

This ſalt, which is the compound of muriatic acid and yttria, reſembles the nitrate in many of its properties. It dries with difficulty, is fuſible with a moderate heat, and is deliqueſcent in the air. This ſalt is decompoſed by ammonia.

5. Fluate of Yttria.	unknown.
6. Borate of Yttria.	

7. Phoſphate of Yttria.

1463 Preparation. Phoſphoric acid does not precipitate yttria from its combination with the other acids; but the phoſphate of ſoda decompoſes the ſalts of yttria, and forms a phoſphate of yttria, which is precipitated in white, gelatinous flakes [†].

8. Phoſphite of Yttria.

Unknown.

9. Carbonate of Yttria.

1464 Preparation. This compound of carbonic acid and yttria was formed by Klaproth, by precipitating the earth by means of an alkaline carbonate, from its ſolution in acids. The carbonate of yttria is in the form of an inſipid white powder. It is inſoluble in water.

The component parts of this ſalt are,

Acid	18
Yttria	55
Water	27
	100

10. Arſeniate of Yttria.

This ſalt is formed by boiling the earth in the acid. A white powder is precipitated, which is arſeniate of yttria.

11. Tungſtate of Yttria.	unknown.
12. Molybdate of Yttria.	
13. Chromate of Yttria.	
14. Columbate of Yttria.	

15. Acetate of Yttria.

This ſalt is formed by the direct combination of the the earth with the acid. By evaporating the ſolution, a ſalt is obtained in cryſtals. Theſe cryſtals, which are of a red colour, are in the form of ſix-ſided plates obliquely truncated. This ſalt undergoes no change by expoſure to the air.

16. Oxalate of Yttria.

This ſalt is formed by adding oxalic acid to the ſolution of yttria in acids. A precipitate is formed in the ſtate of a white powder, which is inſoluble in water. It may be obtained alſo by employing the oxalate of ammonia.

17. Tartrate of Yttria.

This compound is formed by precipitating yttria from its ſolution in acids by means of tartrate of potaſh. This ſalt is ſoluble in water.

18. Citrate of Yttria.	unknown.
19. Malate of Yttria.	
20. Gallate of Yttria.	
21. Benzoate of Yttria.	

22. Succinate of Yttria.

If the ſuccinate of ſoda be added to a concentrated ſolution of muriate or acetate of yttria, a precipitate is formed, which is the ſuccinate of yttria in the ſtate of cubic cryſtals.

23. Saccolate of Yttria.	unknown.
24. Camphorate of Yttria.	
25. Suberate of Yttria.	
26. Mellate of Yttria.	
27. Lactate of Yttria.	

28. Pruſſiate of Yttria.

The pruſſiate of potaſh cryſtallized and re-diſſolved in water, cauſes a precipitate in the ſolution of yttria in acids. This is in the form of a white, gritty matter [*].

Sect. VIII. *Of Glucina and its Combinations.*

1465 History. 1. This earth was diſcovered by Vauquelin in the year 1798. He was requeſted by Haüy to analyze the the beryl, to aſcertain whether its conſtituent parts were

---

[*] *Ann. de Chim.* xxxvi. 143.

[†] *Ibid.* 158.

[*] *Ann. de Chim.* xxxvi. p. 158.

were the ſame with thoſe of the emerald, which the latter had conjectured, in obſerving a perfect correſpondence in ſtructure, hardneſs, and ſpecific gravity. In the courſe of this analyſis, Vauquelin diſcovered the new earth, to which, from its properties, he gave the name of *glucina*, from the Greek word γλυκος, which ſignifies ſweet. The ſame experiments were repeated by Klaproth and Bindheim, and the reſults which were obtained by Vauquelin confirmed.

1466 Preparation. 2. This earth is obtained by the following proceſs. One hundred parts of the beryl or emerald, reduced to a fine powder, are fuſed with 300 parts of cauſtic potaſh. The fuſed maſs is then diluted with diſtilled water, and diſſolved in muriatic acid. The ſolution is to be evaporated to dryneſs, taking care to ſtir it towards the end of the evaporation. Dilute the reſiduum with a large quantity of water, and filter it. The ſilica is thus ſeparated by means of the firſt proceſs. The filtered ſolution, which contains the muriates of alumina and glucina, is precipitated by carbonate of potaſh. The precipitate is to be well waſhed, and diſſolved in ſulphuric acid. Add to this ſolution, a quantity of ſulphate of potaſh, and evaporate to obtain cryſtallized alum. When by a new addition of ſulphate of potaſh, and by a new evaporation, the ſolution yields no more alum, add to it a ſolution of carbonate of ammonia in exceſs, and agitate it well. The glucina, after being depoſited, is diſſolved by means of the exceſs of this ſalt, and the ſmall quantity of alumina which may remain, is precipitated without being diſſolved. After ſome hours, when the aluminous precipitate is not diminiſhed in volume by a new addition of carbonate of ammonia and agitation, the ſolution is to be filtered, and boiled in a glaſs matraſs, and as the carbonate evaporates, there is precipitated a white, gritty powder, which is carbonate of glucina. The carbonic acid may be driven off, by expoſing the powder in a crucible to a red heat *.

1467 Properties. 3. Glucina prepared by this proceſs, is in the form of a ſoft powder, or light white fragments, inſipid to the taſte, and which adhere to the tongue. The ſpecific gravity is 2.967 †. It is altogether infuſible in the fire, and it neither contracts nor becomes harder, like alumina. It has no effect on vegetable colours.

4. There is no action between glucina and oxygen, azotic, or hydrogen gaſes. It is not changed by expoſure to the air, nor is it acted on by carbone, phoſphorus, or ſulphur. 1468 Hydroſulphuret. It combines with ſulphurated hydrogen. When ſulphurated hydrogen gas is made to paſs into water in which this earth is ſuſpended, it combines with it, and forms a hydroſulphuret, whoſe properties are ſimilar to thoſe of the other hydroſulphurets.

1469 Action of water. 5. Glucina is inſoluble in water; but it forms with this liquid in ſmall quantity, a paſte which is ſlightly ductile, but has leſs tenacity than that of alumina.

1470 Of acids. 6. Glucina combines readily with all the acids, and forms with moſt of them ſoluble ſalts, which are diſtinguiſhed by a ſweet and ſlightly aſtringent taſte. Its affinities are in the following order.

Sulphuric acid,
Nitric,
Muriatic,
Phoſphoric,
Fluoric,
Boracic,
Carbonic.

1471 Of alkalies. 7. This earth is ſoluble in ſolutions of the fixed alkalies. It is alſo ſoluble in carbonate of ammonia, but it is inſoluble in pure ammonia.

1472 Characteriſtic properties. 8. The characteriſtic properties of this earth are, according to Vauquelin, the following.

a. It forms with acids ſweetiſh and ſlightly aſtringent ſalts.

b. It is ſoluble in ſulphuric acid when a little in exceſs.

c. It decompoſes aluminous ſalts, by ſeparating the earth when it is boiled in their ſolutions.

d. The ſalts of glucina are completely precipitated by ammonia.

e. It is ſoluble in the liquid carbonate of ammonia.

f. The affinity of this earth for the acids is between that of magneſia and alumina *.

I. Compounds of Glucina with Acids.

1. Sulphate of Glucina.

1473 Preparation. 1. This ſalt, which was firſt diſcovered by Vauquelin, is prepared by the direct combination of ſulphuric acid with the earth, either in the pure ſtate, or in that of carbonate. The ſolution is to be evaporated to the conſiſtence of ſyrup, and cryſtals are obtained on cooling.

1474 Properties. 2. This ſalt cryſtallizes with difficulty in the form of ſmall needles; but their form has not been accurately aſcertained. It has a ſweet, and ſomewhat aſtringent taſte. It is not perceptibly altered by expoſure to the air, and is very ſoluble in water.

1475 Action of heat. 3. When it is expoſed to heat, it melts, ſwells up, and then dries. With a red heat it is entirely decompoſed, the acid is driven off in the ſtate of vapour, and the pure earth remains behind.

1476 Of acids, &c. 4. This ſalt is not decompoſed by any of the acids, but it is decompoſed by the alkaline and moſt of the earthy baſes. The infuſion of nut-galls added to a ſolution of this ſalt produces a yellowiſh white precipitate, which is characteriſtic of the ſalt †.

2. Sulphite of Glucina.

This ſalt is yet unknown.

3. Nitrate of Glucina.

1477 Preparation. 1. The compound of nitric acid and glucina is formed by the direct combination of the acid and earth in a ſtate of purity. The ſolution is evaporated by a moderate heat to dryneſs, and then the ſalt is obtained in the ſtate of powder.

1478 Properties. 2. The nitrate of glucina does not cryſtallize. It is either in the form of powder, or in that of a ſoft ductile maſs. The taſte is ſweetiſh and aſtringent.

1479 Action of heat. 3. It is extremely deliqueſcent in the air, and is very ſoluble in water. It readily melts when expoſed to heat, and if the heat be increaſed it is decompoſed; the acid is driven off in the gaſeous form, and the earth remains behind. It is only decompoſed by ſulphuric acid ‡.

4. Nitrite of Glucina.

Unknown.

---

* *Fourcroy*, ii. p. 157.

† *Annal. de Chim.* xliii. 277.

* *Fourcroy*, ii. 161.

† *Fourcroy Connaiſs. Chim.* iii. p. 49.

‡ *Ibid.* 146.

5. Muriate of Glucina.

This ſalt, according to Vauquelin, by whom only it has been deſcribed, comes very near the nitrate of glucina in its properties. It ſeems to cryſtallize with more facility, but the cryſtals are ſo ſmall that the form cannot be determined. It does not deliqueſce in the air. When it is diſſolved in alcohol, and diluted with water it affords a very agreeable ſweet liquor.

It is decompoſed by heat, by the ſulphuric acid, the nitric, and by the phoſphoric with the aſſiſtance of heat.

6. Fluate of Glucina, } unknown.
7. Borate of Glucina,

8. Phoſphate of Glucina.

1480 Preparation. 1. Vauquelin procured this ſalt by adding the phoſphate of ſoda to the ſolution of the nitrate, the ſulphate, or muriate of glucina. A copious mucilaginous matter is inſtantly precipitated. Or it may be obtained by heating together the muriate of glucina and phoſphoric acid in the ſtate of glaſs.

1481 Properties. 2. This ſalt does not cryſtallize, but is in the form of mucilage or of white powder. It has no perceptible taſte. It is not altered by expoſure to the air, and it is inſoluble in water without an exceſs of acid. It is not decompoſed by ſtrong heat. It melts under the blow-pipe into a tranſparent vitreous globule. It is decompoſed by the ſulphuric, nitric and muriatic acids.

9. Phoſphite of Glucina.

Unknown.

10. Carbonate of Glucina.

1482 Preparation. 1. The compound of carbonic acid and glucina, which was diſcovered by Vauquelin, and only examined by him, is prepared by expoſing the earth to the air, from which it attracts the acid, or by precipitating ſome of the ſoluble ſalts of glucina by means of an alkaline carbonate. The precipitate is to be waſhed with water, and dried in the air.

1483 Properties. 2. This carbonate is in the ſtate of a white powder, ſoft and greaſy to the touch. It has not the ſweet taſte of the other ſalts of glucina. It is not changed by expoſure to the air, and is inſoluble in water. When expoſed to heat, the acid is driven off, and the pure earth remains behind. It is decompoſed by all the acids with a briſk efferveſcence.

11. Carbonate of Ammonia and Glucina.

This triple ſalt is formed by adding the earth of glucina to a ſolution of carbonate of ammonia. It is ſoluble in the ſame quantity of water which holds the carbonate of ammonia in ſolution. Its other properties are unknown.

12. Arſeniate of Glucina,
13. Tungſtate of Glucina,
14. Molybdate of Glucina, } unknown.
15. Chromate of Glucina,
16. Columbate of Glucina,

17. Acetate of Glucina.

Glucina readily diſſolves in acetic acid. This ſalt does not cryſtallize; but by evaporation it is reduced to a gummy ſubſtance, which becomes ſlowly dry and brittle. For a long time it retains a kind of ductility. The taſte is ſweet and ſtrongly aſtringent.

18. Oxalate of Glucina,
19. Tartrate of Glucina,
20. Citrate of Glucina, } unknown.
21. Malate of Glucina,
22. Gallate of Glucina,
23. Benzoate of Glucina.

24. Succinate of Glucina.

This ſalt, according to Ekeberg, is formed by precipitating the earth from its ſolutions, by means of the ſuccinates. It is therefore, nearly inſoluble.

25. Saccolate of Glucina,
26. Camphorate of Glucina,
27. Suberate of Glucina,
28. Mellate of Glucina, } unknown.
29. Lactate of Glucina,
30. Pruſſiate of Glucina,
31. Sebate of Glucina,

SECT. IX. *Of* ZIRCONIA *and its Combinations.*

1484 Hiſtory. 1. The name of this earth is derived from a ſtone called *zircon* or *jargon*, which is found in the iſland of Ceylon. It was from this ſtone that Klaproth extracted the earth, ſome time before the year 1793. He ſoon after found the ſame earth in the oriental hyacinth. By this diſcovery, Guyton was led to analyze the hyacinths of France; and in thoſe which were collected in the river of Expailly, he detected the ſame earth. The experiments of Klaproth and Guyton were repeated by Vauquelin, and their reſults were confirmed, ſo that the nature and properties of this earth have been fully developed.

1485 Preparation. 2. Zirconia is extracted from this mineral, in which alone it has been found, by the following proceſs. A quantity of the mineral is to be reduced to fine powder, and fuſed with five or ſix times its weight of pure potaſh, in a ſilver crucible. The fuſed maſs is then diſſolved in water, by which means the alkali is ſeparated. The reſiduum is then diſſolved in muriatic acid, which is to be heated, to ſeparate the ſilica; and when no farther precipitate appears by means of heat, add a cauſtic fixed alkali. Another precipitate is formed which is to be well waſhed and dried. This is pure zirconia.

1486 Properties. 3. Zirconia thus prepared, is in the ſtate of fine white powder, which is nearly ſoft to the touch, and without taſte or ſmell. When it retains water, it aſſumes the form of a jelly, and is ſemitranſparent. The ſpecific gravity is 4.3.

1487 Action of heat. 4. Light has no action on this earth. When it is expoſed to the heat of the blow-pipe, it remains infuſible, but gives out a yellowiſh, phoſphoric light. Heated in a charcoal crucible, and ſurrounded with powdered charcoal, it undergoes a kind of fuſion, but without becoming tranſparent, or aſſuming a vitreous form. It becomes extremely hard, ſtrikes fire with ſteel, and ſcratches glaſs.

5. There is no action between zirconia and oxygen or azotic gaſes, nor is it changed by expoſure to the air.

air. It is not acted on by hydrogen, carbone, phoſphorus, or ſulphur.

1488 Of water. 6. This earth is inſoluble in water; but it mixes with a conſiderable portion of this fluid, and forms with it a tranſparent jelly. If in this ſtate it be ſlowly dried, it retains the water, and aſſumes a yellowiſh colour, and ſomething of the tranſparency of gum arabic*. When it is dried in a very high temperature, it loſes more than one-third of its weight. After having been expoſed to a red-heat, it becomes of a gray colour, harſh to the feel, and leſs ſoluble in acids.

1489 Of acids. 7. Zirconia combines with the acids, and forms with them peculiar ſalts. Many of theſe are inſoluble in water, and are diſtinguiſhed by an aſtringent taſte.

The order of the affinities of this earth, is the following:

1490 Affinities.

Vegetable acids,
Sulphuric,
Muriatic,
Nitric.

1491 Action of alkalies. 8. Zirconia does not combine with the alkalies by fuſion, and is inſoluble in liquid alkalies. It may be diſſolved, however, by the alkaline carbonates.

I. Compounds of Zirconia with the Acids.

1. Sulphate of Zirconia.

1492 Preparation and properties. 1. This ſalt is formed by the direct combination of the earth with ſulphuric acid. The ſolution is to be evaporated to dryneſs. The ſalt thus obtained is in the form of a white powder, which is very friable. Sometimes it is in the form of cryſtals like ſmall needles. It has no taſte, is not changed by expoſure to the air, and is inſoluble in water.

1493 Action of heat. 2. This ſalt is readily decompoſed by heat, the acid is driven off, and the earth remains behind. When it is boiled in water, the earth is precipitated, and the acid remains in the liquid. At a high temperature it is decompoſed by charcoal, and converted into a ſulphuret which is ſoluble in water, and the ſolution furniſhes by evaporation, cryſtals of hydroſulphuret of zirconia †.

2. Sulphite of Zirconia.

Unknown.

3. Nitrate of Zirconia.

1494 Preparation. 1. This ſalt is formed by the direct combination of zirconia with concentrated nitric acid; and by evaporation it is obtained in the form of a yellowiſh, tranſparent, viſcid maſs, which dries with difficulty.

1495 Properties. 2. This ſalt has a ſtyptic and aſtringent taſte, and leaves on the tongue a thick matter, which proceeds from a decompoſition of the ſalt by means of the ſaliva.

1496 Action of water and heat. 3. When nitrate of zirconia, after being evaporated, is put into diſtilled water, a very ſmall quantity only is diſſolved. The greateſt part remains under the form of gelatinous and tranſparent flakes. This ſalt is very readily decompoſed by heat.

1497 Of acids, &c. 4. It is alſo decompoſed by ſulphuric acid, which forms in the ſolution a white precipitate, ſoluble in exceſs of acid; by carbonate of ammonia, which produces a precipitate, ſoluble in an exceſs of this ſalt; and by an infuſion of nut galls in alcohol, which affords a white precipitate, ſoluble in an exceſs of this infuſion. But if the zirconia contain iron, the colour of the precipitate is bluiſh gray, of which a part remains in the ſolution, communicating to the liquor a pure blue colour. When this liquid is mixed with carbonate of ammonia, it affords a purple matter, by the refracted rays, but of a violet colour by reflected light. Cryſtallized gallic acid alſo precipitates the nitrate of zirconia, of a bluiſh gray colour. Moſt of the other vegetable acids alſo decompoſe this ſalt, and form combinations with the earth which are inſoluble in water ‡.

4. Nitrite of Zirconia.

Unknown.

5. Muriate of Zirconia.

1498 Preparation. 1. Of all the acids, the muriatic combines moſt readily with zirconia, when the latter is in the ſtate of carbonate. This ſalt was firſt formed by Klaproth, and its properties were afterwards more particularly inveſtigated by Vauquelin.

1499 Properties. 2. The muriate of zirconia has no colour, but poſſeſſes a very aſtringent taſte, is very ſoluble in water, and alſo in alcohol. By ſlow evaporation, it affords ſmall, tranſparent, needle-formed cryſtals, whoſe figure has not been determined. When muriate of zirconia contains any portion of ſilica, the cryſtals are cubical, have little conſiſtence, and reſemble a jelly. Theſe cryſtals expoſed to the air, gradually loſe their tranſparency, and are diminiſhed in volume. There are formed, in the middle of the maſs, white ſilky cryſtals in the ſhape of needles, which ariſe from the cubes.

1500 Action of heat. 3. Muriate of zirconia is decompoſed by heat, which drives off the acid. It is even decompoſed in the mouth by means of the ſaliva.

1501 Of acids, &c. 4. *a*. It is alſo decompoſed by ſulphuric acid, which forms a precipitate with the earth in heavy white flakes, while another part is retained in ſolution by the muriatic acid. But by the aſſiſtance of heat, the latter is diſſipated, and the remaining part of the ſulphate of zirconia is depoſited. If the evaporation be ſtopped before it is brought to a ſtate of dryneſs, it aſſumes the appearance of a jelly by cooling. The ſulphate of zirconia is then ſoluble in muriatic acid.

b. This ſalt is alſo decompoſed by the phoſphoric, citric, tartaric, oxalic, and ſaclactic acids, which forming with its baſe inſoluble compounds, precipitate in the form of white flakes.

c. The gallic acid precipitates the muriate of zirconia in the form of a white matter, if the ſalt has been pure, but of a grayiſh green if it contain iron. In the latter caſe, the precipitate becomes, when dry, of a ſhining black colour, which has the ſame appearance as china ink. The liquid, in which are formed the gallates of zirconia and iron, preſerves a green colour; and although new portions of gallic acid are added, no farther precipitation is produced. But the carbonate of ammonia throws down a copious flaky matter, which has a purple colour, and nearly reſembles that of lees of wine. Thus, it appears, that the gallic acid has a greater affinity for zirconia than the muriatic, and that the gallates of zirconia and iron are ſoluble in muriatic acid.

d. The

---

* *Ann. de Chim.* xxii. 197.

† *Ibid.* 199.

‡ *Annal. de Chim.* xxii. p. 199.

d. The carbonate of potaſh, when fully ſaturated, decompoſes the muriate of zirconia; and although this ſolution is attended with efferveſcence, the precipitate waſhed and dried in the air, retains a large proportion of carbonic acid; for when this earth is afterwards diſſolved in acids, it produces a briſk efferveſcence. The carbonate of ammonia at firſt forms a precipitate in the ſolution of muriate of zirconia. This precipitate is in great part re-diſſolved by new additions of the ammoniacal ſalt, and there is produced a triple ſalt, which may be decompoſed by heat.

e. A ſolution of ſulphurated hydrogen gas in water, mixed with a ſolution of muriate of zirconia containing iron, becomes turbid, and produces a reddiſh colour; but there is no real precipitate. Hydroſulphuret of ammonia inſtantly precipitates this earth of a fine green colour, which appears black when it is dry. When this precipitate is placed on burning coals, it emits the odour of ſulphurated hydrogen gas, and becomes of a purple blue colour when reduced to powder.

f. Pure alumina decompoſes the muriate of zirconia, with the aid of heat. The alumina is diſſolved, the liquid becomes milky, and aſſumes the form of a jelly as it cools. It has been remarked, when the muriate of zirconia contains iron, it remains in ſolution with the alumina, and the zirconia which has been precipitated in this way, contains no perceptible portion of this metal.

g. The pruſſiate of mercury produces in the ſolution of muriate of zirconia, a copious white precipitate, which is ſoluble in muriatic acid.

h. A plate of zinc introduced into a ſolution of muriate of zirconia, produces a ſlight efferveſcence. The liquid becomes milky, and aſſumes the appearance of a white ſemitranſparent jelly in a few days *.

6. Fluate of Zirconia,
7. Borate of Zirconia,
8. Phoſphate of Zirconia,
9. Phoſphite of Zirconia,

unknown.

10. Carbonate of Zirconia.

When an alkaline carbonate in ſolution is added to a ſolution of muriate of zirconia, the earth is precipitated without efferveſcence; and when this precipitate is expoſed to heat in cloſe veſſels, it gives out carbonic acid gas. It alſo enters into combination with the alkaline carbonates, and forms with them triple ſalts. This, Vauquelin obſerves, is one of the remarkable characters of this ſalt.

1502 Compoſition. The component parts of carbonate of zirconia, according to the ſame chemiſt, are,

Acid and water,	44.5
Zirconia,	55.5
	100.0

11. Arſeniate of Zirconia,
12. Tungſtate of Zirconia,
13. Molybdate of Zirconia,
14. Chromate of Zirconia
14. Columbate of Zirconia,

unknown.

16. Acetate of Zirconia.

1503 Properties. Acetic acid combines with zirconia, and forms with it a ſalt which does not cryſtallize. When the ſolution is evaporated to dryneſs, the acetate of zirconia remains in the ſtate of powder. This ſalt has an aſtringent taſte, is not altered by expoſure to the air, and is very ſoluble in water and in alcohol. This ſalt ſeems to have leſs tendency to be decompoſed by heat than the nitrate of zirconia *.

17. Oxalate of Zirconia,
18. Tartrate of Zirconia,
19. Citrate of Zirconia,
20. Malate of Zirconia,

unknown.

21. Gallate of Zirconia.

Gallic acid added to a ſolution of muriate of zirconia, it has been already mentioned, produces a precipitate of a white matter, which is the gallate of zirconia. The properties of this compound have not been examined.

22. Benzoate of Zirconia,
23. Succinate of Zirconia,
24. Saccolate of Zirconia,
25. Camphorate of Zirconia,
26. Suberate of Zirconia,
27. Mellate of Zirconia,
28. Lactate of Zirconia,
29. Pruſſiate of Zirconia,
30. Sebate of Zirconia.

unknown.

CHAP. XIV. OF METALS.

1504 Importance of metals. 1. THE metals, on account of their importance and utility, have always greatly occupied the attention of mankind. Indeed ſuch is their importance, that man could not take a ſingle ſtep in the improvement of even the ſimpleſt of the arts of life, without the aſſiſtance of ſome of the metals. In this view, the origin and improvement of many arts, and the knowledge of metallic ſubſtances, may be, in ſome meaſure, conſidered as coeval. The metals, therefore, became very early, and were probably the firſt objects of chemical inveſtigation. In the extraordinary purſuits of the alchemiſts, they were the ſubjects of their eager reſearches, in the diſcovery of the means of converting the more abundant and baſer metals, as they were called, into thoſe which were more valued, on account of their durability and ſcarcity. They failed of their purpoſe; but their labours were not in vain. The facts which they diſcovered in the progreſs of their inveſtigations, were of no ſmall importance to ſcience.

1505 Characters. 2. The metals are diſtinguiſhed from other ſubſtances by a number of characteriſtic properties. Theſe are, brilliancy, colour, opacity, denſity, hardneſs, elaſticity, ductility, malleability, tenacity, fuſibility, power of conducting caloric and electricity.

1506 Brilliancy. 3. Luſtre or brilliancy is one of the moſt ſtriking characteriſtic properties of metallic ſubſtances, and hence it has been denominated *metallic luſtre*. This is owing to the reflection of a great proportion of the rays of light by metallic ſurfaces. On account of this property, metals are employed in the conſtruction of mirrors. Other ſubſtances, indeed, exhibit the appearance of this brilliancy, which is the caſe with the mineral called *mica*; but in this ſubſtance, as well as every other which is not metallic, it is merely ſuperficial, and it entirely diſappears when the ſurface

---

* *Ann. de Chim.* xxii. p. 201.

* *Ann. de Chim.* xxii. p. 206.

is broken, or ſcratched with a ſharp-pointed inſtrument. But the metal, treated in the ſame way, becomes more brilliant. The following is the order in which the metals poſſeſs this luſtre:

Platina,
Steel,
Silver,
Mercury,
Gold,
Copper,
Tin,
Zinc,
Antimony,
Biſmuth,
Lead,
Arſenic,
Cobalt; and the other brittle metals.

1507 Colour. 4. Colour is one of the conſtant properties of metallic ſubſtances, while it is only accidental and variable in other minerals. And as the metals are the moſt opaque, and the denſeſt bodies in nature, colour in them is very intenſe, or rather confounded with their brillancy. The prevailing colour of metals is white; ſome however are yellow, and others reddiſh. Thoſe of a white colour were formerly diſtinguiſhed by the name of *lunar metals*, becauſe ſilver, which was called *luna*, being placed at the head of theſe metals, has a white colour. Gold, which was diſtinguiſhed by the name of *ſol*, having a yellow colour, gave the name of ſolar metals to ſuch as reſembled it. The colour of metals is permanent, while they remain unaltered, but it is often totally loſt when they enter into new combinations.

1508 Opacity. 5. It is generally admitted, that all metallic ſubſtances are perfectly opaque. Newton indeed obſerved, that gold-leaf when reduced to $\frac{1}{280000}$ of an inch thick, appeared of a green colour, from which he concluded that it tranſmits the green rays; and he ſuppoſed that other metals might alſo tranſmit light, if they were ſufficiently thin. But no metal has yet been found ſo malleable as to be reduced to that ſtate of thinneſs to permit light to paſs through it. Silver-leaf ſo thin as to be only $\frac{1}{160000}$ part of an inch, is quite opaque.

1509 Denſity. 6. The metals are particularly diſtinguiſhed from other ſubſtances by their denſity. Metallic ſubſtances have a greater ſpecific gravity than any other bodies in nature; that is, the quantity of matter contained in a given bulk, is greater in the metals than in other ſubſtances. Even the lighteſt of the metals poſſeſſes a greater denſity than the heavieſt bodies known of any other kind of matter. The particles of which they are compoſed muſt therefore be in cloſer contact than in any other body. To this greater denſity is owing their ſuperior luſtre.

1510 Hardneſs. 7. The metals differ from each other greatly in degrees of hardneſs. In general, metallic ſubſtances are not ſo hard as many other natural bodies. The degree of hardneſs does not depend on the denſity, for the hardeſt metals are by no means the heavieſt. This property, therefore, muſt be owing to the nature of the particles of which the metal is compoſed, or to ſome peculiar diſpoſition or arrangement of theſe particles. It is found that ſome of the metals can be hardened by art, merely by hammering, or by ſudden cooling after being heated. The hardneſs of metals too, is greatly increaſed by being combined with each other, or with other ſubſtances; as, for inſtance, when copper and tin are combined together, or iron and carbone in the formation of ſteel, the utility of which latter, as it is applied for cutting inſtruments, depends on its hardneſs. Metallic ſubſtances, in comparing their different degrees of hardneſs, have been divided into eight claſſes, which are arranged in the following order.

1ſt, Iron and manganeſe.
2d, Platina and nickel.
3d, Copper and biſmuth.
4th, Silver.
5th, Gold, zinc, and tungſten.
6th, Tin and cobalt.
7th, Lead and antimony.
8th, Arſenic.

Mercury being always fluid at the ordinary temperature of the atmoſphere, cannot be compared with regard to this property; and the degree of hardneſs which ſome of the other metals poſſeſs has not been aſcertained.

1511 Elaſticity. 8. The elaſticity of metals ſeems to follow the ſame order in which they poſſeſs the property of hardneſs. The elaſticity of ſome metals can be increaſed in the ſame way as their hardneſs, either by mechanical means, as by hammering, or by new combinations.

1512 Ductility. 9. One of the moſt important phyſical properties of the metals, is ductility. By this is meant that peculiar property which ſome metals poſſeſs, of being drawn out into wire, without deſtroying or diminiſhing the coheſive power of their particles. Some metals poſſeſs this property in a great degree, while others are entirely deprived of it; and ſome metals are extremely ductile, while they poſſeſs in a very ſmall degree another property, namely malleability. Iron is one of the moſt ductile metals, but is much leſs malleable than many others.

1513 Malleability. 10. Malleability is alſo one of the moſt valuable properties of metallic ſubſtances. By this property they can be reduced to any form or ſhape which may be wanted, for thoſe purpoſes to which they are to be applied. This property of malleability is ſuppoſed to depend on the form of the particles, or on the mode of their aggregation. Thoſe metals which poſſeſs this property of malleability or laminability, ſeem to be compoſed of ſmall plates, while the ductile metals ſeem to have their particles arranged in a fibrous form. When metallic ſubſtances are hammered, they become harder, denſer, and more elaſtic, which is owing to their particles being brought into cloſer contact.

1514 Tenacity. 11. Tenacity is expreſſive of the power of coheſion between the particles of metallic ſubſtances. Different metals poſſeſs this property in very different degrees. The method which has been adopted to eſtimate the different degrees of tenacity, is by ſuſpending wires of the ſame diameter of the different metals by one extremity, and attaching weights to the other, till the wires are broken. Iron, which has the greateſt tenacity of all the metals, when formed into wire, $\frac{1}{10}$ of an inch in diameter, will ſupport a weight of 500lb. without breaking, while a wire of lead of the ſame diameter,

ter, can only ſupport about 29lbs. The following is the order of the ductile metals, according to the degree of their tenacity.

Iron,
Copper,
Platina,
Silver,
Gold,
Tin,
Lead.

1515 Fuſibility. 12. Another property of the metals is fuſibility. When they are expoſed to a ſufficient degree of heat, they melt, and are reduced to the ſtate of liquidity. One of the metals, namely mercury, is always in the fluid ſtate, at the ordinary temperature of the atmoſphere. The different metals which are generally in the ſolid ſtate, require very different temperatures for their fuſion. Thus lead and tin require comparatively a lower temperature to be melted; while gold and platina can only be brought to the ſtate of fuſion, by the greateſt degree of heat that can be applied.

1516 Conductors of caloric and electricity. 13. Metallic ſubſtances are the beſt conductors of caloric, but the comparative degrees of this property have not been aſcertained. They are alſo found to be the beſt conductors of electricity.

14. The metals poſſeſs ſome properties in common with other ſubſtances, as taſte and ſmell, by which ſome of them are peculiarly diſtinguiſhed; and in being ſuſceptible of cryſtallization, which is the caſe with ſome, or of being volatilized, as happens to others.

1517 Oxidation in the air. 15. But metallic ſubſtances are not only of vaſt importance in the arts of civilized life, on account of the properties which we have now detailed, which belong to them in the metallic ſtate; but many of them are not leſs valuable in thoſe changes which they undergo by new combinations, and the new properties they acquire, in conſequence of theſe changes. One of the firſt and moſt ordinary changes to which metallic ſubſtances are ſubject, is their combination with oxygen. This is called in chemical language *oxidation*. When a metal, as, for inſtance, a piece of iron, is expoſed to the air, when it is moiſt, it ſoon undergoes a remarkable change. It loſes its metallic luſtre, and the ſurface it covered with a browniſh powder, well known by the name of *ruſt*. This change is owing to the combination of oxygen with the metal, and the ruſt of the metal in this ſtate is known in chemiſtry by the name of *oxide*. The proceſs by which this compound of oxygen and a metallic ſubſtance is formed, is called *oxidation*, and the product is denominated an *oxide*.

1518 By heat. 16. But this proceſs of oxidation is effected more rapidly when metals are expoſed to the action of heat; and indeed many metals require a very high temperature to produce the combination, while it cannot be accompliſhed in others by the greateſt degree of heat that can be produced. This proceſs was formerly called *calcination*, or calcining the metal; and the product, now denominated an *oxide*, was diſtinguiſhed by the name of *calx* or *calces*, from its being reduced to the ſtate of powder, in the ſame way as limeſtone, by burning.

1519 Are oxidated in different circumſtances. 17. Metals differ very much from each other in the circumſtances in which this oxidation takes place, as in the temperature which is neceſſary, the facility of the combination, the proportions of oxygen which combine, and the force of affinity between the conſtituent parts of the oxide. Some metals are oxidated in the loweſt temperature, as, for inſtance, iron and mangane ſe; while others require the greateſt degree of heat that can be applied. Such are ſilver, gold, and platina.

1520 In the air. 18. The facility with which oxidation takes place in ſome metals is ſo great, ſuch as iron, tin, lead, copper, and mangane ſe, that they muſt be completely defended from the action of oxygen; but in gold and platina, no perceptible change is obſerved, for whatever length of time they are expoſed to the atmoſphere.

1521 Proportion of oxygen determinate. 19. This oxidation and the quantity of oxygen abſorbed is proportional to the temperature. There are, however, many metals which combine with a determinate proportion of oxygen at certain temperatures, and from this may be eſtimated the quantity of oxidation from the degree of heat which has been applied. The rapidity of the oxidation is almoſt always increaſed by the elevation of temperature. In this way actual combuſtion or inflammation is produced. Thus filings of metals thrown upon a body in the ſtate of ignition, give out brilliant ſparks; and ſteel, ſtruck upon a flint, burns with a vivid flame in the air, in conſequence of the great heat which is communicated to it by percuſſion.

20. Metallic ſubſtances combine with very different proportions of oxygen; and this quantity varies according to the manner in which the proceſs has been conducted, or the temperature to which the metal has been expoſed.

1522 Different phenomena of oxidation. 21. In theſe different ſtates and conditions of oxidation, different phenomena are exhibited. Sometimes the metal becomes red hot, and is inflamed; ſometimes the oxidation takes place without fuſion, or does not combine with oxygen till after it has been melted; ſometimes it is covered with a brittle cruſt, or with a ſubſtance in the form of powder. At other times a pellicle, exhibiting different colours, forms on the ſurface; but, in all caſes, the metal is tarniſhed, loſes its brilliancy and its colour, and aſſumes another, which announces the change that has taken place.

1523 Different affinities. 22. Another difference which takes place among metals, is the different degrees of force with which the oxygen adheres to the metal. The knowledge of this, and the different degrees of affinity between oxygen and metallic ſubſtances, is of great importance in many operations and chemical reſults.

1524 Caloric given out during oxidation. 23. During the fixation of oxygen in metallic ſubſtances, it is abſorbed by ſome in its ſolid ſtate, and gives out a great deal of caloric. In others it is combined, without giving out the ſame quantity. This proportion of caloric given out correſponds to the facility with which oxides part with their oxygen, or are reduced to the metallic ſtate. Thoſe which have combined with oxygen with the greater proportion of caloric, are moſt eaſily reduced; but thoſe, on the contrary, in which the oxygen has been deprived of its caloric, are reduced to the metallic ſtate by a great addition of caloric,

caloric, and the greateſt number of oxides require the addition of ſubſtances whoſe affinity for oxygen is greater than that of the metal.

1525 Different oxides.

24. Metallic oxides are extremely different in different metals, and even in the ſame metal, according to the proportion of oxygen. They are, however, poſſeſſed of ſome common properties. They are all in the form of powder or earthy ſubſtance, or ſo brittle as to be eaſily reduced to this ſtate. They exhibit every ſhade of colour from pure white to brown and deep red, and they are heavier than the metals from which they have been obtained. Some oxides are revived, as it is called, or are reduced to the metallic ſtate, merely by being in contact with light or caloric. Some require the addition of a combuſtible ſubſtance and a high temperature; while others have ſo ſtrong an affinity for oxygen, that they cannot be deprived of it by the ſtrongeſt heat, but become fuſible in the fire, and afford a glaſſy matter more or leſs coloured, and even ſerve as a flux to the earths. Some oxides are volatile, but the greateſt number are fixed. Some have an acrid and cauſtic taſte, are more or leſs ſoluble in water, and even poſſeſs an acid quality; others are inſoluble and inſipid.

1526 Theory of Stahl.

25. Obſerving this remarkable change produced on metallic ſubſtances by the action of air or of heat, philoſophers began early to account for it. According to Becher and Stahl, the founders of chemical ſcience, metals are compoſed of earth and phlogiſton, and the proceſs which takes place during the calcination of a metal, is merely depriving it of its phlogiſton. This doctrine which had undergone various modifications, from the difficulties which it preſented in accounting for the phenomena of the calcination of metals, was finally overthrown by the celebrated experiments of Lavoiſier. In one of theſe experiments he introduced eight ounces of tin into a glaſs retort, and having hermetically ſealed it, after previous heating to expel ſome of the air, it was accurately weighed, and expoſed to heat. The tin melted; and a pellicle appeared on its ſurface, which was ſoon converted into a gray powder. The heat was continued for three hours, but no farther change appeared upon the metal. When the retort was cooled, it was found to have the ſame weight as before the operation. The point of the retort was then broken off, and a quantity of air ruſhed in. This was equal to 10 grs. which was the additional weight acquired by the retort. The whole of the metallic ſubſtance in the retort was 10 grains heavier than when it was introduced, ſo that he concluded, that the 10 grains of air which had diſappeared, had combined with the metal, and cauſed its increaſe of weight. The inference which he drew from this was, that the calcination of metals is not owing to their being deprived of any ſubſtance, but to their combination with air, and with the oxygen of the air; for it was found by future experiments, that the calcination or oxidation of metals could not be effected without oxygen; and when it took place in a given quantity of common air, it was only the oxygen which was abſorbed.

1527 Overturned.

26. But as a ſtill farther proof, that the calcination of metals is owing to the abſorption of oxygen, they are reduced by thoſe ſubſtances which have a greater affinity for oxygen. If charcoal in powder be mixed with a metallic calx or oxide, the oxygen combines with the carbone of the charcoal, forming carbonic acid, and the oxide is reſtored to the metallic ſtate. If this proceſs be performed in cloſe veſſels, the quantity of oxygen in the carbonic acid, correſponds to the quantity which was abſorbed by the metal during calcination.

1528 Metals combine with carbone, &c.

27. From theſe obſervations, therefore, it appears, that metallic ſubſtances combine with oxygen; and it has been obſerved, that not only different metals combine with it in different proportions, but the ſame metal forms compounds of one, two, and ſometimes three different portions. No combination takes place between azote or hydrogen and metallic ſubſtances; but ſome of them enter into combination with carbone, phoſphorus, and ſulphur, forming carburets, phoſphurets, and ſulphurets. The metals alſo combine with the acids, and form ſalts, ſome of which are of the utmoſt importance, not only in chemiſtry, but alſo in the arts of life. They alſo enter into combination with each other, forming a claſs of bodies which are diſtinguiſhed by the name of *alloys*.

1529 Diviſion.

28. Metallic ſubſtances were formerly divided into *noble* or *perfect*, and *imperfect metals*. The noble or perfect metals were platina, gold, ſilver, mercury; and the property on which this character was founded, was that of their being ſuſceptible of being reduced by being expoſed to heat. The other metals then known, were called *imperfect metals*, becauſe to reduce them to the metallic ſtate, the addition of ſome combuſtible ſubſtance was found to be neceſſary. They were alſo divided into *metals* and *ſemimetals*. Among the firſt were included thoſe metals which were malleable and ductile; the ſemimetals comprehended thoſe which poſſeſſed neither of theſe properties, and were therefore conſidered as leſs perfect. Theſe diſtinctions, however, are now neglected, becauſe they afford no well-founded or juſt marks of diſcrimination.

29. In the arrangement of the metals which we propoſe to follow, that of Fourcroy is adopted. He has divided them into five different claſſes, according to their ductility, and the proportions of oxygen with which they combine, or the facility with which that combination takes place. In the firſt claſs he includes thoſe metals which are brittle, and in ſome of their combinations with oxygen have acid properties. Theſe are,

Arſenic,
Tungſten,
Molybdena,
Chromium,
Columbium.

The ſecond claſs comprehends thoſe which are brittle and ſimply ſuſceptible of oxidation. Theſe are the following.

Titanium,
Uranium,
Cobalt,
Nickel,
Mangeneſe,
Biſmuth,
Antimony,
Tellurium.

The

The third claſs comprehends thoſe metals which have ſome degree of ductility, which are only two in number, viz.

Mercury,
Zinc.

The fourth claſs, which conſiſts of three metals, includes ſuch as are ductile, and eaſily oxidated. Theſe are,

Lead,
Iron,
Copper.

The fifth claſs is compoſed of three metals, which are characterized by being very ductile, but oxidated with great difficulty. Theſe are,

Silver,
Gold,
Platina.

1530 Natural hiſtory. 30. To theſe preliminary obſervations we have only to add, that metallic ſubſtances are found, either on the ſurface or in the interior of the globe, and either uncombined, or forming compounds with different ſubſtances. Some metals, as gold and platina, are generally found in ſmall grains, mixed with the ſoil. Theſe, as well as the matters with which they are accompanied, have proceeded from the decompoſition of the more ſolid parts of the globe. But metallic ſubſtances which are met with in greater abundance, exiſt in the interior of the globe, in veins which traverſe the other ſtrata of the earth in different directions. The metals moſt commonly found in veins are, lead, copper, ſilver, zinc, mercury, and antimony. Some exiſt in detached maſſes.

31. Metals, as they exiſt in the earth, are either in a ſtate of purity, or the metallic ſtate, when they are called *native* or *virgin metals*; or combined with each other, when they are ſaid to be *alloyed*. They are found alſo combined with other ſubſtances, very frequently with ſulphur; when they are ſaid to be mineralized: or, they are combined with oxygen, when they come under the denomination of *oxides*; or they are combined with acids in the ſtate of *ſalts*.

Sect. I. *Of Arsenic and its Combinations.*

1531 Hiſtory. 1. It would appear that the ancients were acquainted with arſenic in its ſtate of combination with ſulphur, which is a reddiſh coloured mineral, and was employed by them in painting; and although Theophraſtus arranged it among metallic ſtones, probably on account of its weight, it was not known to poſſeſs a metallic ſubſtance till the middle of the 17th century. Paracelſus, indeed, who lived at an earlier period, is ſaid to have known it in the metallic ſtate; but the proceſs of obtaining it from orpiment and arſenic, was only firſt deſcribed by Schroeder in 1649. Lemery alſo publiſhed a proceſs for extracting this metal in 1675. It was afterwards fully demonſtrated by Brandt in 1733, and by Macquer in 1746, that arſenic poſſeſſed peculiar properties, and is totally diſtinct from all other metals. Theſe facts were farther confirmed by Monnet in 1773, and by Bergman in 1777.

1532 Found native. 2. Arſenic is frequently found native, and is then in dark-coloured maſſes, which have little brilliancy, and exhibit no metallic luſtre, except at the fracture. It is frequently found combined with other metals. In this ſtate it is combined with iron, and is known by the name of *arſenical pyrites*, or *miſpickel*. One of the moſt frequent combinations of arſenic is with ſulphur, of which there are two principal varieties; the one is of a yellow colour, well known under the name of *orpiment*, and the other red, called *realgar*. It is alſo ſometimes found in the ſtate of white oxide, or arſenious acid, but this is a rare occurrence.

1533 Method of analyzing the ores. 3. In whatever ſtate arſenic is found, it can eaſily be detected, by throwing a little of it on burning coals. The white fume which ariſes, and the garlic ſmell which is exhaled, are ſufficiently characteriſtic of this metal. To obtain the metal from its oxide, it may be mixed with three times its weight of black flux. This mixture is put into a crucible, to which another crucible inverted is adapted. They are then to be luted together, to exclude the air. Apply heat to the lower crucible till it becomes red, defending the upper one as much as poſſible from the heat, by means of a plate of iron or copper, through which the lower crucible paſſes. When the apparatus has cooled, a cruſt of metallic arſenic is found in the upper crucible, in the form of cryſtals. This being detached and weighed, ſhows the quantity of pure metal in the mineral which has been tried.

In the humid way, Bergman recommends to treat native arſenic by diſſolving it in four parts of nitro-muriatic acid, concentrating the ſolution by evaporation, and precipitating the muriate of arſenic which is formed, by means of water. If there is any ſilver, it is firſt precipitated in the form of an inſoluble muriate, and iron is ſometimes found in the ſolution precipitated by water.

The ſulphurets of arſenic are to be treated by muriatic acid, adding a ſmall quantity of nitric acid, to ſeparate the ſulphur. The oxide of arſenic may then be precipitated by water. The pure metal may be obtained by immerſing a plate of zinc in the ſolution, having previouſly added a quantity of alcohol.

1534 Properties. 4. Arſenic is in the form of ſmall plates of a blackiſh gray, brilliant, and metallic colour, with conſiderable luſtre where there is a freſh fracture. The ſpecific gravity is 8.31. It is extremely brittle, and is therefore eaſily reduced to powder. It has neither ſmell nor perceptible taſte when it is cold; but when it is heated, and in the ſtate of vapour, it is remarkable for a ſtrong fetid odour of garlic. It ſublimes before it melts, ſo that its fuſing point is not known. It is the moſt volatile of all the metals. When ſlowly ſublimed, it cryſtallizes in the form of regular tetrahedrons, and ſometimes in that of octahedrons. The tetrahedron is the form of its integrant molecule.

1535 Action of air. 5. When arſenic recently prepared is expoſed to the air, it is ſoon tarniſhed, loſes its luſtre, becomes at firſt yellowiſh, and then paſſes to a black colour. It loſes at the ſame time its hardneſs, and becomes extremely friable. When it is heated in contact with air, or if it be thrown in the ſtate of powder on burning coals, it burns with a blue flame, and exhaling the ſtrong odour of garlic, is ſublimed in the form of a white, acrid, ſoluble maſs, which has been called the *white oxide of arſenic*, or *white arſenic*. By this latter name it is well known in the ſhops. To this oxide of arſenic, becauſe it poſſeſſes ſome acid properties, Fourcroy has given the name of *arſenious acid*. This acid bears the ſame relation to arſenic acid as the phoſphorous and ſulphurous acids do to phoſphoric and ſulphuric acids.

1536 Oxide or arſenious acid. 1537 Properties. 6. This oxide or acid is extremely volatile. When it is heated in cloſe veſſels, it is ſublimed in tranſparent, regular tetrahedrons. It is extremely acrid and cauſtic, corroding and deſtroying the organs of animals, ſo that it is the moſt violent poiſon known. The ſpecific gravity is between 4 and 5. It reddens vegetable blues, and when expoſed to the air, it is covered with a ſlight effloreſcence.

7. The arſenious acid is decompoſed by hydrogen, carbone, phoſphorus, and ſulphur. At a red heat, the hydrogen and carbone combine with the oxygen, and reduce it to the metallic ſtate. Phoſphorus and ſulphur are partly converted into phoſphoric and ſulphuric acids, and partly combine with the arſenic, forming a phoſphuret or ſulphuret of arſenic.

8. This acid is very ſoluble in water. It requires about 15 parts of boiling water for its ſolution, from which it may be obtained cryſtallized on cooling, or by ſlow evaporation. The cryſtals are in the form of regular tetrahedrons. The ſolution in water is extremely acrid, reddens vegetable blues, combines with earthy baſes, decompoſes the alkaline ſulphurets, and affords with them a yellow precipitate in which the arſenic returns to the metallic ſtate. The component parts of arſenious acid are,

Arſenic	75.2
Oxygen	24.8
	100.0

1538 Arſenic acid. 9. Arſenic combines with a greater proportion of oxygen; and in this compound it ſtill exhibits acid properties, and is known by the name of *arſenic acid*. The method of preparing this acid and its properties have already been deſcribed, in the chapter on acids; and the compounds it forms with the alkalies and earths, have been particularly detailed in the chapters which treat of theſe ſubſtances.

10. Arſenic does not decompoſe water. It may be kept for any length of time under water, without undergoing any change. There is no action between arſenic and carbone or azote. Arſenic, however, is ſoluble in hydrogen gas, to which it communicates a fetid odour and a poiſonous property.

1539 Phoſphuret. 11. Arſenic enters into combination with phoſphorus. When equal parts of phoſphorus and arſenic are diſtilled together with a moderate heat, there is ſublimed a dark-coloured brilliant ſubſtance, which burns on red-hot coals, with a mixed odour of arſenic and phoſphorus. This is the phoſphuret of arſenic, which muſt be preſerved under water. This compound may be formed under water at a boiling temperature in a matraſs. As the phoſphorus melts, it combines with the arſenic. The properties of this phoſphuret of arſenic have not been examined.

1540 Sulphuret. 12. Arſenic combines readily with ſulphur, either by fuſion or by ſublimation. The reſult of this combination is a yellow or red maſs. This compound of ſulphur and arſenic, which is a ſulphuret of arſenic, is found native. The red is known by the name of *realgar*, and the yellow by that of *orpiment*.

1541 Salts and alloys. 13. Arſenic enters into combination with the acids, and forms with them peculiar ſalts. It alſo combines with the metals, forming *alloys*. The following is the order of the affinities of arſenic and of its oxide, as they have been arranged by Bergman.

1542 Affinities.

ARSENIC.	OXIDE of ARSENIC.
Nickel,	Lime,
Cobalt,	Muriatic acid,
Copper,	Oxalic,
Iron,	Sulphuric,
Silver,	Nitric,
Tin,	Tartaric,
Gold,	Phoſphoric,
Platina,	Fluoric,
Zinc,	Saclactic,
Antimony,	Succinic,
Sulphur,	Citric,
Phoſphorus,	Lactic,
	Arſenic,
	Acetic,
	Pruſſic.

1543 Uſes. 14. Arſenic, in the metallic ſtate, is ſcarcely applied to any uſe, except for chemical purpoſes. It is ſometimes alloyed with the metals, by which means they acquire new properties. In the ſtate of white oxide, it is much employed in the arts. It has even been exhibited as an internal remedy in the diſeaſes of cancer and intermittent fevers; but in all caſes this terrible poiſon ought to be adminiſtered with the greateſt caution. To counteract the effects of arſenic when it has been accidentally taken into the ſtomach, one of the beſt antidotes is water impregnated with ſulphurated hydrogen gas, or ſome of the alkaline ſulphurets diſſolved in water *.

I. Salts of Arſenic.

1. Sulphate of Arſenic.

1544 No ſalt. Concentrated ſulphuric acid has no action on arſenic in the cold; but when they are boiled together, an effervescence takes place, ſulphurous acid gas is diſengaged, the arſenic is oxidated, and falls to the bottom in the ſtate of white powder. According to Fourcroy, this powder retains but a ſmall portion of ſulphuric acid, the whole of which is nearly carried off by waſhing with water; nor are cryſtals obtained from the ſolution. By evaporation the white oxide of arſenic is precipitated, and ſulphuric acid remains pure in the ſolution. There is no action between ſulphurous acid and arſenic.

2. Nitrate of Arſenic.

1545 Effect. Concentrated nitric acid produces a violent action with arſenic. Nitrous gas is diſengaged, and towards the end of the proceſs, azotic gas. The arſenic is converted at firſt into the white oxide, which, with a new addition of acid, paſſes to the ſtate of arſenic acid; and when a great quantity of nitric acid is employed, with the aid of heat, the metal is inſtantly converted into arſenic acid. There remains no oxide in the ſolution, and there is no nitrate of arſenic formed. But, according to Bergman, when the nitric acid is diluted, it diſſolves the oxide, and affords a cryſtallized ſalt like the white oxide.

---

* Fourcroy v. p. 80.

3. Muriate of Arſenic.

1546 Preparation. 1. Muriatic acid has no action on arſenic in the cold; but when they are boiled together, the ſolution takes place, and there is diſengaged a fetid gas, which ſeems to be arſeniated hydrogen gas. From this it appears, that muriatic acid enables the arſenic to decompoſe water. A little nitric acid added, promotes the ſolution; and this ſolution, heated and concentrated at firſt in cloſe veſſels, is entirely ſublimed in the form of a thick liquid, which was formerly called *butter of arſenic*. This ſalt is decompoſed by water alone, which precipitates the metal. The muriate of arſenic, therefore, can ſcarcely be conſidered as a permanent ſalt [*].

1547 Oxymuriatic acid. 2. When arſenic in the ſtate of powder is thrown into oxymuriatic acid gas, it inſtantly catches fire, burns with a very brilliant white flame, and is converted into white oxide. If arſenic be added to liquid oxymuriatic acid, it is converted into arſenic acid, while the acid returns to the ſtate of muriatic acid.

4. Fluate of Arſenic.

Fluoric acid combines with the white oxide of arſenic, and affords ſmall grains, which have a cryſtalline form; but their properties are unknown.

5. Borate of Arſenic.

Boracic acid alſo combines with the white oxide of arſenic, and affords a ſalt which is in the ſtate of white powder, or in the form of ſmall needles. Their properties are alſo unknown.

6. Acetate of Arſenic.

Acetic acid enters into combination with the white oxide of arſenic, and forms cryſtals, which are only known to be difficultly ſoluble in water.

7. Oxalate of Arſenic.

Oxalic acid, combined with arſenic, affords cryſtals in the form of priſms. Similar cryſtals are obtained by the combination of arſenic with the tartaric acid.

8. Benzoate of Arſenic.

Benzoic acid combines with the white oxide of arſenic, and by evaporating the ſolution, plumoſe cryſtals are obtained. This ſalt has an acid and acrid taſte, is ſoluble in water, ſublimes with a moderate heat, but with a ſtronger heat is decompoſed, and is not precipitated from its ſolutions by alkalies.

SECT. II. *Of TUNGSTEN and its Combinations.*

1548 Hiſtory. 1. The name of tungſten is derived from a white, tranſparent mineral, which contains this metal in the ſtate of acid united to lime. This mineral was analyzed by Scheele in 1781, and he found that one of its component parts is lime, and the other an earthy-like ſubſtance, to which he gave the name of *tungſtic acid*. His diſcovery was confirmed about the ſame time by Bergman, who conjectured that the baſis of the acid might be a metallic ſubſtance. This conjecture was verified by the experiments of Meſſieurs D'Elhuyart, two Spaniſh chemiſts, who diſcovered the ſame metal in the mineral call *wolfram*, and aſcertained ſome of its metallic properties. It has ſince been farther examined by Vauquelin and Hecht, and by Allen and Aiken of London.

1549 Found native. 2. This metallic ſubſtance has been only found in the ſtate of acid in combination with lime, iron, mangaueſe and lead. When it is combined with lime, it is the tungſten of the Swedes, and in combination with iron it is called wolfram.

1550 Method of obtaining it. 3. To obtain this metal from the acid, it is mixed with charcoal in a crucible, and expoſed to a very ſtrong heat. By this proceſs the metal was obtained in the form of a ſmall button at the bottom of the crucible in the firſt experiments which were made upon it by the German chemiſts. This crumbled to pieces between the fingers; and when it was examined with a magnifying glaſs, it was found to conſiſt of a number of metallic globules, none of which were larger than a pin head.

1551 Properties. 4. The colour of this metal is a ſteel gray. The ſpecific gravity is 17.6, or, according to others, 17.22. It is one of the hardeſt of the metals. It is alſo one of the moſt infuſible, requiring a temperature of 170° Wedgwood. It cryſtallizes on cooling.

1552 Action of heat. 5. When it is heated in the open air, it is readily converted into a yellow oxide, which afterwards, by a ſtronger heat, becomes of a black colour, and then by combining with a greater proportion of oxygen, it aſſumes the character of an acid, namely the tungſtic acid, whoſe properties and combinations with alkalies and earths, have been already deſcribed.

1553 Of phoſphorus, &c. 6. There is no action between tungſten and azote, hydrogen or carbone. Tungſten combines with phoſphorus, forming a phoſphuret, the properties of which are unknown. It alſo combines with ſulphur, forming a ſulphuret of a bluiſh black colour, and which may be cryſtallized. There is no action between this metal and ſulphuric, nitric, or muriatic acids. It is only acted on by nitro-muriatic acid at a boiling temperature, and nitrous gas is diſengaged. Nothing therefore is known of the combinations of tungſten with the other acids.

1554 Alloys. 7. This metal combines with the other metals, and forms alloys with them.

8. It is too little known, and has been produced in too ſmall quantity, to be able to aſcertain any thing of its uſes or applications.

SECT. III. *Of MOLYBDENA and its Combinations.*

1555 Hiſtory. 1. The mineral called *molybdena*, from which this metal is extracted, was analyzed by Scheele in 1778. He found that it contained ſulphur, and a ſubſtance which he diſcovered to be poſſeſſed of acid properties. Previous to this time, this mineral had been confounded with plumbago or black lead, which it reſembles in appearance. The acid which Scheele obtained from this ſubſtance, Bergman conjectured was a metallic oxide. Theſe experiments were repeated by Pelletier; and he proved that molybdena was a peculiar metal combined with ſulphur, and that in all the different proceſſes the ſulphur was ſeparated, and the metal oxidated. The metal has ſince been called *molybdena*, and

---

[*] *Fourcroy* v. p. 73.

and the mineral from which it is obtained *ſulphuret of molybdena.*

1556 Characters of the ore.

1557 Properties of the metal.

2. Molybdena has never been found, exiſting in any other but in the ſtate of ſulphuret, or in that of oxide. The ſulphuret of molybdena, it has been obſerved, was long confounded with plumbago, or the carburet of iron. It has, however, a leſs greaſy feel, more brilliancy, and inclining more to a blue colour. It ſtains the fingers leſs than carburet of iron, and leaves a bluiſh trace on paper. It is difficult to reduce it to powder, on account of the elaſticity of the plates or ſcales of which it is compoſed. The ſulphuret of molybdena, too, becomes electric by friction. When the ſulphuret of molybdena is treated with the blow-pipe, it exhales ſulphur, which is detected by its odour, and a white vapour which is condenſed on cold bodies in the form of plates or cryſtallized needles, of a yellowiſh colour, but which become blue by the contact of the interior flame. Molybdena has only been obtained in black, friable, agglutinated maſſes, which have ſome metallic brilliancy; and when broken, exhibit ſmall round grains, of a grayiſh brilliant appearance. The ſpecific gravity is about 7, and it is extremely infuſible; but ſince the experiments of Dr Hielm, which were made in 1781, this metal has been procured in ſuch ſmall quantity, that its characteriſtic metallic properties have not been aſcertained.

1558 Action of heat.

1559 Oxides.

1560 Acids.

3. When molybdena is expoſed to a high temperature in contact with air, it is converted into a white oxide, which ſublimes and cryſtallizes in the form of brilliant needles. This oxide has acid properties. When it is heated with combuſtible bodies, it aſſumes a bluiſh colour, with little brilliancy, as it approaches to the metallic ſtate. According to Mr Hatchet, who made a ſet of experiments on the compound of this acid with lead, the molybdate of lead, molybdena when it is not in the metallic ſtate, appears to ſuffer four degrees of oxigenation. The firſt is the black oxide, which contains the ſmalleſt proportion of oxygen. This oxide is obtained by expoſing to heat in a crucible, a mixture of molybdic acid and charcoal in powder. A black maſs remains, which is the oxide. The ſecond is the blue oxide, which may be obtained by the ſame proceſs, but it muſt not be continued ſo long. The third is the green oxide, which ſeems to be intermediate between an oxide and acid. Mr Hatchet propoſes to call it *molybdous acid.* The fourth degree of oxidation is the molybdic acid itſelf, which has at firſt a white colour; but when it is fuſed and ſublimed, is converted into a yellow colour. The properties of this acid and ſome of its combinations have been already deſcribed *.

1561 Action of phoſphorus.

4. Molybdena combines with phoſphorus; but the properties of this phoſphuret are not known. It alſo combines readily with ſulphur, and returns to the ſtate of ſulphuret of molybdena, in which it has only been found native.

1562 Of acids.

5. Molybdena enters into combination with the acids, forming with them peculiar ſalts.

1563 Of alkalies.

6. The alkalies have the property of diſſolving molybdena, and of promoting its oxidation. With the aſſiſtance of heat the alkalies form with the ſulphuret of molybdena, an alkaline ſulphuret which holds the metal in ſolution.

1564 Alloys.

7. Molybdena enters into combination with the metals, and forms alloys with them.

I. Salts of Molybdena.

1. Sulphate of Molybdena.

Sulphuric acid, with the aſſiſtance of heat, diſſolves molybdic acid, and affords a colourleſs ſolution; but when it is cold, it becomes of a deep blue. But neither this nor any other of the ſalts of molybdena ſeem diſpoſed to cryſtallize.

2. Nitrate of Molybdena.

Nitric acid converts the oxides of molybdena into molybdic acid, by giving up its oxygen.

3. Muriate of Molybdena.

Muriatic acid, when boiled with the oxide of molybdena, affords a ſolution of a deep blue colour, and there is formed a blue precipitate.

4. Fluate of Molybdena.

Fluoric acid forms a compound with the oxides of molybdena. The ſolution is of a greeniſh yellow colour, when it is hot; but when it is evaporated to dryneſs, it becomes of a greeniſh blue.

5. Phoſphate of Molybdena.

The oxide of molybdena is diſſolved by phoſphoric acid, with the aſſiſtance of heat, and a ſolution of a blue colour is obtained.

6. Acetate of Molybdena,
7. Oxalate of Molybdena,
8. Tartrate of Molybdena,
9. Benzoate of Molybdena.

All theſe ſalts in ſolution are of a blue colour, and when evaporated to dryneſs, afford a blue powder. They are formed by digeſting the ſeveral acids with the oxides of molybdena.

SECT. IV. *Of CHROMIUM and its Combinations.*

1565 Hiſtory.

1. This metal was diſcovered by Vauquelin in 1797, in a mineral called the *red lead ore of Siberia.* This ore had been formerly analyzed by ſeveral chemiſts, and even by Vauquelin himſelf; but their reſults of the nature of its compoſition only agreed, that lead was one of its conſtituent parts. Vauquelin by his laſt analyſis found that it contained lead, combined with the new acid, of which the baſis is a metal.

1566 Analyſis of the ore.

2. The proceſs which he followed was the following: He boiled one part of the red lead-ore of Siberia with two of carbonate of potaſh, in 200 parts of water. The potaſh combined with the new acid, while the carbonic acid united to the lead. The carbonate of lead precipitated to the bottom in the form of a white powder, and the new ſalt remained in ſolution. By adding nitric acid, the new ſalt was decompoſed; the acid combining with the potaſh. This mineral is completely diſſolved in muriatic acid. The ſolution aſſumes a deep green colour, and by evaporation affords muriate of lead. The fine green colour is owing to the oxide of the new metal having been deprived of part of its oxygen.

---

* *Phil. Tranſ.* 1796. p. 336.

oxygen by the muriatic acid, and being thus converted from an orange red to a green.

1567 Reaſon of the name of the metal. 3. The acid which is obtained by the firſt proceſs, and the oxide by the ſecond, being ſtrongly heated with charcoal in a crucible, afforded a metal different from any other formerly known. To this metal the name of *chromium* was given, from the Greek word χρωμα, on account of the remarkable property which it poſſeſſes of communicating colour to all its ſaline combinations.

1568 Properties. 4. The metal which was obtained, is of a grayiſh white colour, very hard and brittle, and extremely difficult of fuſion; but the ſmall quantity which has been hitherto obtained, precludes chemiſts from aſcertaining its properties.

1569 Found in different minerals. 5. This ſubſtance has been found in four different minerals, exiſting in two ſtates; in the ſtate of green oxide, combined with the oxide of lead, and in the ſame ſtate in the emerald; and, in the ſtate of acid, combined with the oxide of lead in the red-lead ore of Siberia, and alſo in the ſpinel ruby. It has alſo been diſcovered in the ſtate of chromic acid, combined with iron, forming a chromate of iron. It has alſo been diſcovered in France.

1570 Oxides. 6. Chromium, therefore, combines with oxygen in two different proportions; the green oxide, and the yellow, or the chromic acid. It is this acid which exiſts in the red-lead ore. When it is ſeparated from the lead, it is in the form of powder, of an orange-yellow colour, and is ſoluble in water. Its other properties have been already examined. The green oxide is prepared by expoſing the latter to heat in cloſe veſſels. The chromic acid is partially decompoſed; part of the oxygen is driven off, and the green oxide remains behind. Another oxide alſo, it is ſaid, which is intermediate between chromic acid and the green oxide, has been obtained.

1571 Action of acids. 7. Little is known of the action of acids on this metal; but in the few experiments which have been made, it appears, that it undergoes no change by means of ſulphuric and muriatic acids. Nitric acid diſtilled upon it ſeveral times ſucceſſively, changes it into green oxide, and at laſt into chromic acid. The ſame effect is produced more rapidly by means of the nitromuriatic acid.

SECT. V. *Of COLUMBIUM and its Combinations.*

1572 Hiſtory. 1. This metal was diſcovered by Mr Hatchet, in the year 1802, in a mineral, which he found in the Britiſh Muſeum. This mineral had been ſent along with ſpecimens of iron ores from Maſſachuſets in America, to Sir Hans Sloane, in whoſe catalogue it is deſcribed as a "very heavy black ſtone, with golden ſtreaks." Theſe ſtreaks, Mr Hatchet obſerves, proved to be yellow mica.

1573 Characters of the ore. This mineral is externally of a dark-browniſh gray colour; internally the ſame, inclining to iron gray. The longitudinal fracture is imperfectly lamellated; the croſs fracture ſhews a fine grain. The luſtre is vitreous, in ſome parts inclining to the metallic. It is moderately hard, but very brittle. The colour of the powder is dark chocolate brown. The particles are not attracted by the magnet. The ſpecific gravity is 5.918.

1574 Analyſis. 2. In the analyſis of this mineral, Mr Hatchet diſcovered, that it conſiſts of one part of oxide of iron, and three parts of a white-coloured ſubſtance, which exhibited the properties of an acid. This acid, under the name of *columbic acid*, with its combinations with the alkalies and earths, has been already deſcribed. Having found that it poſſeſſed properties different from all other acids, and alſo, that its baſe is metallic, he gave to the metal the name of *columbium*. In the attempts which Mr Hatchet made to reduce it to the metallic ſtate, even when it was expoſed to a very ſtrong heat with charcoal, the oxide was only found in the ſtate of powder, of a black colour. From theſe experiments it appeared, that this metal combines with oxygen in different proportions, and theſe oxides are diſtinguiſhed by different colours.

3. When the white oxide of this metal was added to phoſphoric acid in ſolution, and evaporated to dryneſs, the whole was put into a crucible, lined with charcoal, and expoſed to a ſtrong heat for half an hour. The incloſed matter had aſſumed a dark brown, ſpongy appearance, which had ſome reſemblance to the phoſphuret of titanium.

4. No ſulphuret was obtained when it was mixed and diſtilled with ſulphur.

5. Columbium combines with ſome of the acids, and forms ſalts, although few of theſe have been examined.

I. Salts of Columbium.

1. Sulphate of Columbium.

Boiling ſulphuric acid forms a tranſparent colourleſs ſolution with columbic acid. When water is added to this ſolution, it becomes turbid, aſſuming a milky appearance; and a white precipitate is gradually depoſited, which cracks as it becomes dry upon the filter, and, from white, it changes to a lavender blue colour; and, when completely dry, to a browniſh gray. It is then inſoluble in water, is ſemitranſparent, and breaks with a vitreous fracture. This precipitate obtained from the ſulphuric ſolution, by the addition of water, is a ſulphate of columbium.

2. Nitrate of Columbium.

The oxide of columbium ſeems to be perfectly inſoluble, and remains unchanged in colour, when digeſted in boiling concentrated nitric acid.

3. Muriate of Columbium.

Columbic acid, when recently ſeparated from potaſh, is ſoluble in boiling muriatic acid. This ſolution may be conſiderably diluted with water, without any change being produced. When evaporated to dryneſs, it left a pale-yellow ſubſtance, inſoluble in water, and which is diſſolved with great difficulty, when it is again digeſted with muriatic acid.

4. Phoſphate of Columbium.

A few drops of phoſphoric acid being added to a part of the ſolution of columbium in concentrated ſulphuric acid, at the end of about 12 hours converted the whole into a white, opaque, ſtiff jelly, which was inſoluble in water. When a ſmall quantity of phoſphoric acid was

was added to the muriatic ſolution of columbium, in a few hours a white flocculent precipitate was formed* (A).

Sect. VI. *Of Titanium and its Combinations.*

1575 History of its diſcovery. 1. This metal was diſcovered in 1793 by Klaproth. He obtained it from a mineral called *red ſchorl*. In this mineral he found the oxide of a metal different from any other then known. Previous to this time, indeed, the ſame oxide had been diſcovered by Mr Gregor, in a black ſand which is found in Menachan in Cornwal. To this, from the place, he gave the name of *menachine*, but he had not ſucceeded in reducing it to the metallic ſtate. Klaproth afterwards analyzed the *menachanite* of Mr Gregor, and found that it was preciſely the ſame as the oxide of the metal which he diſcovered in red ſchorl. To this metal he gave the name of *titanium*. The experiments of Klaproth were afterwards repeated by Vauquelin and Hecht in 1796. His reſults were confirmed, and they alſo ſucceeded in reducing a ſmall quantity of the oxide to the metallic ſtate.

1576 Natural hiſtory. 2. This metal has been found only in the ſtate of oxide. Red ſchorl conſiſts entirely of this oxide. It has been found in different countries, as in Spain, France, and Hungary. This oxide is diſſeminated in the fine ſpecimens of rock cryſtal which are brought from Madagaſcar, cryſtallized in long brilliant needles, the form of the primitive cryſtal being a ſix-ſided priſm with two-ſided ſummits; that of the molecule is a triangular priſm, with right-angled iſoſceles baſes. It is of a red colour of different ſhades. It is brittle, but the fragments are ſo hard as to ſcratch glaſs. The ſpecific gravity is from 4.180 to 4.246. The other mineral, to which Klaproth has given the name of *titanite*, is compoſed of oxide of titanium, ſilica and lime, nearly in equal proportions. Its ſpecific gravity is 3.510.

1577 Analyſis of its ore. 3. Titanium was obtained by Vauquelin, by reducing the native red oxide. He mixed together 100 parts of this oxide with 50 of calcined borax, and 50 of charcoal, formed into a paſte with oil; and expoſed the whole to the heat of a forge raiſed to 166° Wedgwood. By this proceſs he obtained a dark-coloured, agglutinated maſs, having a brilliant appearance on the ſurface.

1578 Properties. 4. Titanium obtained in this way is of a reddiſh yellow colour, ſhining and brilliant on the ſurface, and equally brilliant in ſome of its internal cavities. Its other properties, as it has been only procured in very ſmall quantity, have not been determined.

1579 Action of heat. 5. Titanium ſeems to be one of the moſt infuſible metals known. When the red oxide is expoſed to heat in a crucible, it loſes its luſtre. By the action of the blow-pipe it is deprived of its tranſparence, and becomes of a grayiſh white colour. On charcoal it becomes ſtill more opaque, and of a ſlate gray. The artificial carbonate of titanium expoſed to heat in a crucible, loſes $\frac{25}{100}$ of its weight, becomes yellow, and as it cools, reſumes its white colour.

1580 Phoſphuret. 6. Titanium enters into combination with phoſphorus, and forms with it a phoſphuret. This was prepared by Mr Chenevix, by expoſing a mixture of phoſphate of titanium, charcoal, and a little borax, in a crucible, to a very ſtrong heat. The phoſphuret which he obtained was in the form of a metallic button, of a pale white colour, brittle and granular, and infuſible by the action of the blow-pipe. Titanium has not been combined with ſulphur.

1581 Affinities. 7. This metal enters into combination with the acids, and forms ſalts with them. The affinities of the oxides of titanium, as they have been aſcertained by Lampadius, are in the following order.

Gallic acid,
Phoſphoric,
Arſenic,
Oxalic,
Sulphuric,
Muriatic,
Nitric,
Acetic †.

1582 Alloys. 8. In the experiments which were made by Vauquelin and Hecht, to combine titanium with other metals, they did not ſucceed with ſilver, copper, lead, or arſenic; but they formed an infuſible alloy with iron, of a gray colour, interſperſed with yellow-coloured, ſhining particles.

I. Salts

* Phil. Tranſ. 1802. p. 49.

† Ann. de Chim. xxvi. 91.

(A) Another metal has been more lately announced by Ekeberg, which, in ſome of its properties, ſeems to reſemble columbium. He obtained this metal from two minerals; to one of which he gave the name of *tantalite*, which is of a blackiſh gray colour, with ſome metallic luſtre, and ſome appearance of cryſtallization. This mineral is very hard; the ſpecific gravity is 7.953. When reduced to powder, it is of a browniſh gray colour, and is not attracted by the magnet. To the other mineral he gave the name of *yttrotantalite*. It was found in ſmall inſulated maſſes, in veins of feldſpar, and black mica. The fracture of this mineral is granular, of a gray metallic appearance, and may be ſcratched, although with difficulty, with a knife. It is not attracted by the magnet. The ſpecific gravity is 5.13. From theſe minerals this chemiſt extracted a ſubſtance, which he concluded to be a peculiar metal in the ſtate of oxide, having the appearance of a white powder. The following are the properties which he aſcertained.

1. It is not ſoluble in any of the acids. 2. The alkalies attract and diſſolve a conſiderable quantity of this ſubſtance, which may afterwards be precipitated by means of the acids. 3. The whole oxide of this metal undergoes no change of colour by the action of heat. 4. Its ſpecific gravity when it has been expoſed to a red-heat is 6.5. 5. It fuſes with phoſphate of ſoda, and borax, without communicating to them any colour. 6. The oxide of this metal, heated with charcoal powder, is reduced to the metallic ſtate, exhibits a brilliant fracture, of a dark gray colour. 7. It is again converted into a white powder by the action of the acids. The other properties of this ſubſtance have not been detailed *. To this metal Ekeberg has given the name of *tantalium*.

* Ann. de Chim xliii. p. 276.

I. Salts of Titanium.

1. Sulphate of Titanium.

1583 Salts. According to the experiments of Klaproth, ſulphuric acid has no action on the native red oxide of titanium from Hungary: but this acid is found to diſſolve the carbonate of titanium with efferveſcence; and when this ſolution is evaporated, the red oxide is converted into a white, opaque, gelatinous maſs. This was the reſult of Klaproth's experiment. In thoſe of Vauquelin and Hecht, ſulphuric acid being boiled with carbonate of titanium, aſſumed a milky appearance, and there were formed white, light flakes, which were diſſolved by a ſtronger heat; the fluid became tranſparent, but did not afford cryſtals.

2. Nitrate of Titanium.

Nitric acid has ſcarcely any perceptible action on titanium, but it combines with the carbonate, and forms a tranſparent ſolution, which aſſumes an oily appearance in the air, and affords tranſparent cryſtals in the form of elongated rhombs, having the oppoſite angles truncated, ſo as to repreſent hexagonal tables. But according to Vauquelin and Hecht, when they heated a mixture of nitric acid with carbonate of titanium, nitrous gas was diſengaged, and the liquid remained milky. Sugar added to the mixture cauſes a precipitate of the oxide, of a whiter colour than the carbonate; and if the nitric acid be employed diluted, the oxide of titanium is diſſolved, but the ſolution becomes turbid by means of heat, and thus the addition of caloric oppoſes the combination of this oxide with nitric acid, by oxidating it in a higher degree than what is ſoluble in this acid.

3. Muriate of Titanium.

The carbonate of titanium is ſoluble in muriatic acid; and according to Klaproth, the ſolution affords a yellowiſh, tranſparent jelly, which contains numerous tranſparent, cubic cryſtals. Vauquelin and Hecht found, that the carbonate of titanium is diſſolved with efferveſcence in concentrated muriatic acid; and the ſolution aſſumes a deep yellow colour, when it is made without the aſſiſtance of heat. When it was heated, it was reduced to a flaky maſs, which was neither rediſſolved by water, nor by new additions of the acid. A ſimilar ſolution which was not heated remained tranſparent; but when this ſolution was expoſed to a temperature of about 170°, it was converted into a yellow, tranſparent jelly, of an acid and very aſtringent taſte, which by cooling, depoſited a great number of ſmall cryſtals which effloreſced in the air. When this ſolution was boiled, oxymuriatic acid gas was diſengaged, the oxide was precipitated, and is no longer ſoluble in muriatic acid, till it is boiled for a long time with nitric acid; from which it appears, that the oxide of titanium muſt have a great proportion of oxygen, to combine with muriatic acid, and in this ſtate it can only combine with it in the cold, becauſe when it is expoſed to heat, the acid carries off a portion of its oxygen, which renders it inſoluble. The oxide of titanium, ſeparated from muriatic acid by the action of the blow-pipe, aſſumes a beautiful orange-yellow colour.

4. Carbonate of Titanium.

1584 Preparation. One part of the red oxide of titanium, and five parts of carbonate of potaſh, expoſed to a red heat in a crucible, were ſoon fuſed, and formed a ſolid maſs of a whitiſh gray colour, with ſmall needle-form cryſtals on the ſurface. When this was reduced to powder, and waſhed with warm water, there was depoſited a light white powder, which was found to be carbonate of titanium. The arſenic and phoſphoric acids cauſe a white precipitate of the oxide of titanium from its ſolution in acids. A ſimilar precipitate is produced by oxalic and tartaric acids; but it is inſtantly re-diſſolved, and the ſolution recovers its tranſparency.

1585 Salts of titanium decompoſed. The oxide of titanium is precipitated from its ſolution in acids; 1. By carbonate of potaſh, in the form of a white flaky matter, and by ammonia in the ſame way. 2. Pruſſiate of potaſh cauſes a copious precipitate of a mixed colour of green and brown. 3. Infuſion of nut-galls produces a very voluminous precipitate, of a reddiſh brown colour; and if the ſolution be not too much diluted with water, it coagulates like blood. A rod of tin introduced into a ſmall bottle with a ſolution of this oxide in muriatic acid, cauſed in a few minutes a pale roſe colour, in that part of the ſolution near the rod. This colour ſoon changed to a beautiful ruby. A rod of zinc firſt produced a violet colour, and afterwards that of indigo. 4. Sulphuret of ammonia combined with this ſolution, produced a pale green colour, and a precipitate of a bluiſh green.

SECT. VII. *Of URANIUM and its Combinations.*

1586 Diſcovery. 1. This metal was diſcovered by Klaproth in the year 1789. It was then announced as a metal more difficult to be reduced than manganeſe, externally of a gray colour, and internally of a clear brown, of conſiderable luſtre, and middling hardneſs; that it might be ſcratched and filed, and that its oxide gives a deep orange colour to porcelain.

1587 Natural hiſtory. 2. It has been obtained from three different minerals. The firſt is in the ſtate of ſulphuret, of a blackiſh colour, and of a ſhining fracture, and ſometimes lamellated. This has been called *pitch blende*. The ſpecific gravity is from 6.37 to 7.50. In this ſtate it is ſometimes combined with iron and ſulphurated lead. The uranium is in the metallic ſtate. The ſecond ore from which this metal is obtained, is the native oxide of uranium. It is always in the ſtate of yellow powder, on the ſurface of the ſulphuret. The ſpecific gravity is 3.24. When it is of a pure yellow colour, it is then a pure oxide. The third ore of the metal is the native carbonate of uranium. Of this there are two diſtinct varieties, the one of a pale green, and ſometimes of a ſilvery white colour. This contains but a ſmall quantity of the oxide of copper, and is very rare. The other is of a ſhining deep green, which is the green mica or *glimmer* of mineralogiſts. Klaproth ſuppoſed that it contained an oxide of uranium, mixed with the oxide of copper; but it has been ſince diſcovered to have carbonic acid in its compoſition. It is cryſtallized in ſmall ſquare plates, and ſometimes, though rarely, in complete octahedrons.

3. The

1588 Analyſis of the ore. 3. The proceſs by which Klaproth reduced this metal, is the following. He mixed the yellow oxide of uranium, precipitated from its ſolutions by an alkali, with linſeed oil, in the form of a paſte, and this being expoſed to a ſtrong heat, there remained a black powder, which had loſt rather more than one-fourth of its weight. It was then expoſed to the heat of a porcelain furnace, in a cloſe crucible, and the oxide was afterwards found in a coherent maſs, but friable under the fingers, and reduced to a black ſhining powder. It decompoſed nitric acid with efferveſcence. This black powder covered with calcined borax, was for the ſecond time expoſed to a ſtill ſtronger heat, by which a metallic maſs was obtained, conſiſting of very ſmall globules adhering together.

1589 Properties. 4. The colour of uranium is of a dark gray, and internally of a pale brown. It has little brilliancy, on account of the ſpongy maſs, in which ſtate it was obtained. It may be ſcratched with a knife, and is extremely infuſible. The ſpecific gravity is 6.440.

1590 Action of heat. 5. When uranium is expoſed to a red heat in the open air, or when it is acted on by the blowpipe, it undergoes no change. The yellow oxide of uranium does not melt. It acquires a browniſh gray colour when it is long heated in the air, but it has not been aſcertained whether it gains or loſes oxygen.

6. The oxide of uranium is reduced by means of charcoal, when it is expoſed to heat. Little is known of the combination of uranium with phoſphorus; but when the oxide was treated with blood, and a ſtrong heat applied, an acrid bitter maſs was obtained, which was ſuppoſed to owe its fuſibility to the phoſphorus which it contained.

7. Uranium has not been artificially combined with ſulphur, but it is not improbable that ſuch a combination might take place, ſince it is found native in this ſtate. Of the alloys of uranium with other metals nothing is yet known.

1591 Salts.

I. Salts of Uranium.

1. Sulphate of Uranium.

The yellow oxide of uranium is readily diſſolved in diluted ſulphuric acid; and the ſolution affords, by evaporation, a ſalt of a yellow colour, in the form of ſmall priſms. This ſulphate of uranium is different from all other metallic ſalts yet known, in colour, form, and other properties.

2. Nitrate of Uranium.

Nitric acid diſſolves with equal facility the oxide of uranium. The ſolution being ſlowly evaporated, yields large cryſtals in regular hexagonal tables, of a yellowiſh green colour. The cryſtals of nitrate of uranium are the moſt beautiful of all the metallic ſalts.

3. Muriate of Uranium.

Muriatic acid alſo diſſolves the oxide of uranium, and furniſhes ſmall yellowiſh cryſtals, which are deliqueſcent in the air.

4. Fluate of Uranium.

Fluoric acid combines with the oxide of uranium, and forms with it a cryſtallized ſalt, which is not altered by expoſure to the air.

5. Phoſphate of Uranium.

Phoſphoric acid enters into combination with the oxide of uranium, and forms with it yellowiſh white flakes, which are very little ſoluble in water.

6. Arſeniate of Uranium.

Arſenic acid may be combined with uranium, by decompoſing the nitrate by means of an alkali. A precipitate is obtained of a yellowiſh powder, which is the arſeniate of uranium.

7. Molybdate of Uranium.

In the ſame way molybdate of uranium may be obtained by adding a ſolution of molybdate of potaſh to the nitrate of uranium. It is obtained in the form of powder.

8. Acetate of Uranium.

The oxide of uranium is ſoluble in concentrated acetic acid, with the aſſiſtance of heat; and beautiful yellow cryſtals are obtained, in the form of long, ſlender, tranſparent, four-ſided priſms, terminated by four-ſided pyramids.

1592 Decompoſition of the ſalts of uranium. The ſolutions of the oxide of uranium in acids are precipitated by the alkaline ſulphurets, of a browniſh yellow, and their ſurface is covered at the ſame time with a gray metallic pellicle. The fixed alkalies precipitate from their ſolutions an oxide of uranium, of an orange yellow colour; ammonia occaſions a precipitate of a bright yellow; and the alkaline carbonates throw down a carbonate of uranium of a whitiſh yellow, which is rediſſolved in an exceſs of alkali. The infuſion of nut-galls thrown into one of theſe ſolutions, the exceſs of whoſe acid has been taken up by an alkali, produces a chocolate brown precipitate. Zinc, iron, and tin, introduced into theſe ſolutions, produce no change of colour, either in the cold or by heat.

SECT. VIII. *Of Cobalt and its Combinations.*

1593 Hiſtory. 1. The mineral called *cobalt* or *cobolt*, (B) ſeems to have

---

(B) The following curious information from Beckmann, with regard to the diſcovery of this mineral will, we doubt not, prove intereſting to the reader. "About the end of the 15th century, cobalt appears to have been dug up in great quantity in the mines on the borders of Saxony and Bohemia, diſcovered not long before that period. As it was not known at firſt to what uſe it could be applied, it was thrown aſide as a uſeleſs mineral. The miners had an averſion to it, not only becauſe it gave them much fruitleſs labour, but becauſe it often proved prejudicial to their health by the arſenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then firſt took its riſe. At any rate, I have never met with it before the beginning of the ſixteenth century; and Matheſius and Agricola ſeem to have firſt uſed it in their writings. Friſch derives it from have been firſt employed to give a blue colour to glaſs after the middle of the 16th century; but it was not till about the year 1732, that cobalt was diſtinguiſhed as a peculiar metal by Brandt, a Swediſh chemiſt, who extracted it from its ore, and examined ſome of its properties. In 1761 Lehman gave a particular account of the nature and properties of this ſubſtance; but his reſearches were chiefly limited to the mineral in the ſtate of ore. Bergman afterwards examined this metal, and pointed out the difference between it and nickel, mangancſe, and iron. The nature of it has been more lately inveſtigated by Taſſaert and Thenard, and ſome other French chemiſts.

1594 Ores. 2. Cobalt has never been found in nature in a ſtate of purity. It is either alloyed with arſenic, both metals being in the metallic ſtate; or it is combined with ſulphur and arſenic, or in the ſtate of oxide, or forming a ſalt with arſenic acid. 1. In the firſt ſtate when it is alloyed with arſenic, it is of a gray or whitiſh appearance, with ſome degree of brilliancy. The ſpecific gravity is 7.72. It is ſometimes cryſtallized in cubes, or octahedrons. When ſmall fragments of this mineral are expoſed to the action of the blow-pipe, or even to the flame of a candle, they give out a garlic ſmell. 2. The combination of ſulphur and arſenic with cobalt is denominated *gray cobalt ore*. The ſpecific gravity is from 6.33 to 6.45. The ſtructure is lamellated, and when it is heated, it emits no garlic ſmell. It cryſtallizes in octahedrons, dodecahedrons, and ſome other forms reſembling the ſulphuret of iron, with which it is frequently combined. 3. The third ſpecies of cobalt ore, is the oxide. It is found in black, friable maſſes, or in the ſtate of a black effloreſcence, which ſoils the fingers. This is a pure oxide of cobalt. 4. The fourth ſpecies is the arſeniate of cobalt, which has been diſtinguiſhed by the names of *flowers of cobalt*, *cobalt bloom*. It is of a peach-bloſſom colour, ſometimes in the ſtate of effloreſcence, ſometimes in the form of ſmall needles of a deep colour, which remains even after they are reduced to powder, and ſometimes in four-ſided priſms terminated by two-ſided ſummits. When it is placed on hot coals, it gives out a ſtrong garlic ſmell, loſes its colour, and becomes black.

1595 Analyſis of the ores. 3. To procure the pure metal from the ores of cobalt, the oxide in the ſtate of black powder, after being roaſted, is mixed with three times its own weight of black flux and a little common ſalt, put into a crucible lined with charcoal, and expoſed to a forge heat. When the fuſion is completed, the crucible is to be ſlightly agitated, to collect together the metallic globules into one maſs. Sometimes two metallic buttons are found under the vitreous ſcoriæ. The cobalt occupies the upper part, and the biſmuth being heavieſt, is loweſt. In this ſtate the cobalt is almoſt always combined with a ſmall portion of arſenic, nickel, or iron. But if the cryſtallized gray oxide of cobalt has been employed, the metal is obtained very pure, by the above proceſs; and when the ore is rich, it yields from 60 to 80 per cent.

By a different proceſs, cobalt may be obtained in the metallic ſtate, which conſiſts in treating the ore with nitric acid, which oxidates and diſſolves both the cobalt and the iron. Theſe oxides are precipitated by carbonate of ſoda, and well waſhed with water. They may be ſeparated by means of nitric acid, which diſſolves the oxide of cobalt, without touching that of the iron.

1596 Properties of cobalt. 4. Cobalt is of a gray colour, inclining to red, and of a very fine granulated texture. It is very brittle, ſo that it is eaſily reduced to a fine powder, which is of a gray colour, and with little brilliancy. The ſpecific gravity, according to Bergman, is 7.700; according to others, it is from 7.811 to 8.5384.

1597 Action of heat. 5. Cobalt is one of the moſt infuſible metals, requiring a temperature equal to 130° Wedgwood. It becomes red before it melts. When it is ſlowly cooled, and by pouring out a part of the fluid when it becomes ſolid at the edges, the cavity is found lined with priſmatic cryſtals. The ſame cryſtallization may be effected by inclining the crucible at the moment the ſurface becomes ſolid.

1598 Oxidation. 6. When cobalt is expoſed to a red heat in an open veſſel, it firſt loſes its colour and its brilliancy, becomes of a deep gray colour, and then paſſes to a black, or an intenſe blue. With a ſtill more violent heat, this laſt oxide melts into a bluiſh black glaſs. It appears from the experiments of Thenard, that cobalt combines with different proportions of oxygen, forming different oxides. When a ſolution of cobalt in acids is precipitated by an alkali; the precipitate which is formed is firſt of a lilach colour, and with an exceſs of baſe it becomes ſucceſſively blue and olive, and at laſt by drying it becomes entirely black. Theſe different changes depend on the different proportions of oxygen with which it combines.

He precipitated a ſolution of cobalt by pure potaſh. The oxide collected on a filter, was blue, and when expoſed to the air it became of an olive colour; and when waſhed with oxymuriatic acid, it changed from green to brown, and from this ſhade to the deepeſt black. The black oxide diſſolved with efferveſcence in muriatic acid; oxymuriatic acid gas was emitted in great abundance,

---

from the Bohemian word *kow*, which ſignifies metal; but the conjecture that it was formed from *cobalus*, which was the name of a ſpirit that, according to the ſuperſtitious notions of the times, haunted mines, deſtroyed the labours of the miners, and often gave them a great deal of unneceſſary trouble, is more probable; and there is reaſon to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, becauſe it thwarted them as much as the ſuppoſed ſpirit, by exciting falſe hopes, and rendering their labour often fruitleſs. It was once cuſtomary, therefore, to introduce into the church ſervice a prayer that God would preſerve miners and their works from *kobolts* and ſpirits."

" Matheſius, in his tenth ſermon, p. 501, where he ſpeaks of the *cadmia foſſilis*, ſays: 'Ye miners call it *kobolt*; the Germans call the black devil and the old devil's whores and hags old and black *kobel*, which by their witchcraft do injury to people and to their cattle.'—Whether the devil, therefore, and his hags gave this name to cobalt, or cobalt gave its name to witches, it is a poiſonous and noxious metal."

abundance, and when the muriatic acid was concentrated, the ſolution was of a green colour, which in the ſpace of 24 hours became purple. When the acid was diluted, it became inſtantly red. The oxide is ſoluble in ſulphuric and nitric acids, and the ſolution is of a red colour, accompanied with the evolution of bubbles, which ſeem to be oxygen gas.

The brown and coloured oxides produce with ſulphuric, nitric, and muriatic acids, ſimilar effects with the black oxide. With muriatic acid they both give out oxymuriatic acid, and form a ſolution of a green colour, which in time paſſes to a purple; or, if the acid be diluted with water, it becomes inſtantly red. The olive-coloured oxide is prepared by pouring potaſh into a ſolution of cobalt. There is formed a blue precipitate, which expoſed to the air becomes green. If this oxide be treated with diluted muriatic acid, oxymuriatic acid is obtained with a ſlight degree of heat, and the ſolution becomes more and more red, as this acid is diſengaged, ſo that the blue oxide combines with the oxygen of the air.

The blue oxide of cobalt, Thenard thinks, is moſt conveniently obtained by calcining the black oxide for half an hour in a cherry-red heat. It aſſumes a blue colour, by being deprived of part of its oxygen. This oxide diſſolves in acids, without the diſengagement of any gas. Its ſolution in concentrated muriatic acid is green, but if the acid be diluted with water, it is red. 1599 Oxides, four. Thenard concludes from his experiments, that there are four different oxides of cobalt; the blue, the olive, the brown, and the black; although he ſuppoſes that the brown may be a mixture of the olive and black oxides *.

7. There is no action between azote, hydrogen, or carbone, and cobalt.

1600 Phoſphuret. 8. Phoſphorus enters into combination with cobalt, by projecting bits of phoſphorus on ſmall pieces of cobalt, red-hot, in a crucible. The metal is inſtantly fuſed, and it abſorbs about $\frac{1}{15}$ of is weight of phoſphorus. A cruſt is formed at the ſame time on the ſurface, of a violet-red colour. This phoſphuret of cobalt has a metallic luſtre, is of a whiter colour than the metal itſelf, and is more brittle. It loſes its brilliancy in the air; and by the action of the blow-pipe, phoſphorus is diſengaged from the metallic globule, and inflames on the ſurface. There remains behind a vitreous globule of a deep blue colour.

1601 Sulphuret. 9. Sulphur combines with difficulty with cobalt, but the compound may be formed by the aid of the alkalies. This metal is ſoluble in the alkaline ſulphurets, and the reſult is a ſulphuret of cobalt, of a yellowiſh white colour, which is only decompoſed by means of the acids.

1602 Salts. 10. Cobalt enters into combination with the acids, and forms ſalts. It forms alloys alſo with moſt of the metals. The order of the affinities of cobalt and its oxides, according to Bergman, is the following:

Cobalt.	Oxide of Cobalt.
Iron,	Oxalic acid,
Nickel,	Muriatic,
Arſenic,	Sulphuric,
Copper,	Tartaric,
Gold,	Nitric,
Platina,	Phoſphoric,
Tin,	Fluoric,
Antimony,	Saclactic,
Zinc,	Succinic,
Phoſphorus,	Citric,
Sulphur,	Lactic,
	Acetic,
	Arſenic,
	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Cobalt.

1. Sulphate of Cobalt.

1603 Preparation. 1. Concentrated and boiling ſulphuric acid is decompoſed by cobalt, with the evolution of ſulphurous acid gas. A thick, grayiſh maſs, inclining to red, is formed. Water diſſolves the ſulphate of cobalt, and affords a grayiſh coloured liquid.

1604 Properties. 2. The ſulphate of cobalt cryſtallizes in ſmall needles, or in four-ſided rhomboidal priſms, terminated by two-ſided ſummits. It is of a reddiſh colour, and is ſoluble in 24 parts of water. It is decompoſed by heat, and there remains behind the black oxide of cobalt. By the action of the blow-pipe it ſwells up with efferveſcence. The alkalies alſo decompoſe it, by precipitating a reddiſh yellow oxide. One hundred parts of cobalt furniſh 140 parts of this precipitate by pure alkalies; but when the precipitation is effected by means of the alkaline carbonates, 160 parts are obtained.

2. Nitrate of Cobalt.

1605 Preparation. 1. Nitric acid combines with cobalt, with the aſſiſtance of a moderate heat. Nitrous gas is diſengaged, the metal is oxidated, and is diſſolved in the acid. The ſolution is of a fleſh-red colour, but when it is concentrated, of a brown colour. By evaporation it affords ſmall reddiſh coloured priſmatic cryſtals, which are deliqueſcent in the air, and which being placed on red-hot burning coals, ſwell up, and are decompoſed, leaving behind a deep red oxide.

1606 Enamels. 2. It is by the precipitation of this ſalt, that the oxide of cobalt is obtained for the purpoſe of enamels, and for giving a colour to porcelain. When the oxide is precipitated by means of an alkali, it is re-diſſolved when the alkali is added in exceſs.

3. Nitrate of Ammonia and Cobalt.

This triple ſalt was formed by Thenard by adding to a ſolution of cobalt in nitric acid, ammonia in exceſs. No precipitate is obtained. This ſolution being filtered and evaporated to dryneſs, and the reſidue being diſſolved in water, and again evaporated, yielded, on cooling, regular cubic cryſtals of a red colour, and of a pungent taſte. They were not changed by expoſure to atmoſpheric air. Being calcined in a crucible, they burned like nitrate of ammonia, with a vivid, yellowiſh white flame. The reſidue was a black ſubſtance, which had all the properties of cobalt. The ſolution of this ſalt in water is not precipitated by any of the alkalies or earths. It is ſtill more readily decompoſed by ſulphurated hydrogen, or the hydroſulphurets. When it is boiled with potaſh, ammonia

is

---

* Ann. de Chim. xlii. 210—215.

is diſengaged ; the oxide of cobalt is precipitated, and a nitrate of potaſh is formed *.

4. Muriate of Cobalt.

1607 Preparation. 1. Muriatic acid has no effect on cobalt in the cold ; but a ſmall quantity is diſſolved with the aſſiſtance of heat. But the black oxide of cobalt is readily diſſolved in muriatic acid. The ſolution is accompanied with efferveſcence, and the diſengagement of oxymuriatic acid gas. When this ſolution is concentrated by evaporation, it becomes of a fine green colour, which changes to red when it is diluted with water. By farther evaporation it is cryſtallized, and affords ſmall deliqueſcent cryſtals of muriate of cobalt in the form of needles.

1608 Sympathetic ink. 2. When theſe cryſtals are diſſolved in water, and ſo diluted that the ſolution is nearly colourleſs, characters marked with it on paper diſappear entirely ; but when heated, aſſume a fine green colour. This ſolution was one of the firſt known ſympathetic inks. In making experiments with this ſolution, the characters are written on paper, or, that the experiment may be more amuſing, a landſcape is drawn with a pencil, repreſenting the verdure of ſummer on a winter ſcene. Thoſe parts of the picture in which the ſympathetic ink has been uſed, are inviſible in the cold ; but when it is moderately heated, they become of a fine green colour, changing from the winter to the ſummer ſcene. When it is removed to the cold, the colour again diſappears, and if too much heat be not applied, the ſame change may be frequently repeated. When too much heated, the blue colour is converted to a brown, which becomes permanent.

1609 Theories. 3. Various theories have been propoſed to account for this remarkable change. According to ſome, it is owing to the moiſture of the atmoſphere being abſorbed that the colour diſappears ; and when this is driven off by heat, it is reſtored. But to this opinion it has been objected, that the ſame effect is produced, when paper, on which characters have been written with this ſolution, is entirely excluded from the atmoſphere, by being introduced into cloſe veſſels. According to others, the ſympathetic effect of this ſolution depends on the iron which is combined with the cobalt. Some ſuppoſe that the concentration of the ſolution, which takes place by the action of heat, is the cauſe of the appearance of the colour ; and its dilution, by abſorbing moiſture from the atmoſphere, the cauſe of its diſappearance ; while others are of opinion that it is partially deprived of its oxygen by being heated, and abſorbs it again in the cold, when the colour vaniſhes.

1610 Another proceſs. This ſympathetic ink may be eaſily prepared, by diſſolving the zaffre of commerce in nitro-muriatic acid.

5. Fluate of Cobalt.

Fluoric acid diſſolves the oxide of cobalt, and forms with it a yellow-coloured gelatinous ſolution ; or, by careful evaporation, it affords cryſtals, which are fluate of cobalt.

6. Borate of Cobalt.

Boracic acid has no action on cobalt ; but it combines with the oxide, by mixing a ſolution of nitrate of cobalt with a ſolution of borax.

7. Phoſphate of Cobalt.

Phoſphoric acid diſſolves the oxide of cobalt, and forms with it a reddiſh-coloured turbid ſolution, which affords a precipitate when the acid is ſaturated.

8. Carbonate of Cobalt.

This ſalt is formed by precipitating cobalt from its ſolutions in acids, by means of alkaline carbonates. One hundred parts of cobalt, which afford only 140 of precipitate by means of the pure alkalies, yield 160 parts, when the precipitate is effected by carbonate of ſoda.

9. Arſeniate of Cobalt.

This ſalt is formed by combining the nitrate of cobalt with the arſeniate of potaſh or of ſoda. It is ſometimes found native, and it exhibits the deepeſt and moſt beautiful red of all the ſalts of cobalt.

10. Tungſtate of Cobalt,
11. Molybdate of Cobalt,
12. Chromate of Cobalt,
13. Columbate of Cobalt,
} unknown.

14. Acetate of Cobalt.

This ſalt is readily formed, by diſſolving the oxide of cobalt in acetic acid. It does not yield cryſtals by evaporation, but is deliqueſcent in the air. It aſſumes a blue colour when it is heated, but is red in the cold, ſo that it forms a ſympathetic ink.

15. Oxalate of Cobalt.

This ſalt may be formed by precipitating the oxide of cobalt from its ſolution in acids, by means of oxalic acid. The precipitate, when it is dried, is in the form of a red powder, which is inſoluble in water, but may be diſſolved in exceſs of oxalic acid, and cryſtallized.

16. Tartrate of Cobalt.

The oxide of cobalt is ſoluble in tartaric acid, and forms a red-coloured ſolution, which affords cryſtals by evaporation.

II. Action of Alkalies, Earths, and Salts.

1611 Alkalies. 1. The alkalies have no action whatever on cobalt ; but when the oxides are ſuſpended in water, they ſeparate them from other matters.

1612 Earths. 2. Some of the earths, but particularly ſilica, enters into combination with the oxide of cobalt and the fixed alkalies, and forms a beautiful blue-coloured glaſs. The quantity of oxide muſt be ſmall, otherwiſe the glaſs will appear nearly black and opaque, on account of the intenſity of the colour.

1613 Salts. 3. Some of the neutral ſalts expoſed to a high temperature along with cobalt burn with a perceptible flame. It is by this means that the oxide is prepared for the purpoſe of enamels and colouring porcelain.

The hyperoxymuriate of potaſh, with one-third of its weight of cobalt in powder detonates by percuſſion.

---

* *Ann. de Chim.* xlii. 215.

1614 Uſes.

Cobalt is ſcarcely at all employed in the metallic ſtate. *Zaffre* is uſed for coarſe enamels and pottery ware. The purer oxides of cobalt are choſen for the purpoſes of porcelain. *Azure* is a vitreous blue in the ſtate of fine powder, which is prepared for ſimilar purpoſes. Zaffre is fuſed along with ſilica and an alkali, and thus forms a deep blue glaſs, which is known by the name of *ſmalt*. This is reduced to a powder, and mixed with a great quantity of water. The firſt portion which precipitates is called *coarſe azure*. Four different quantities are ſeparated in this way. The laſt, which is the fineſt, is called azure of four fires.

SECT. IX. *Of NICKEL and its Combinations.*

1615 Hiſtory.

The firſt mention which is made of this metal is by Hierne, a Swediſh chemiſt, in a work entitled *The art of diſcovering metals*, publiſhed in 1694. He particularly deſcribes the mineral from which nickel is extracted, and which was firſt called *kupfernickel*, or *falſe copper*, becauſe it was taken for an ore of copper, and none could be obtained from it. This was the opinion of Henckel and Cramer, who ſuppoſed it to be copper combined with arſenic or cobalt. This mineral was generally arranged among copper ores, till it was examined and analyzed by the celebrated Swediſh mineralogiſt Cronſtedt, in 1751, and 1754. In theſe experiments, the account of which was publiſhed in the memoirs of the Swediſh Academy, he proved that this mineral contains a new metal, different from all thoſe which had been hitherto known, to which he gave the name of *nickel*. This opinion was generally adopted, and objected to only by Monnet and Sage of France, who affirmed that this new metal was merely an alloy of cobalt, arſenic, iron, and copper. To remove theſe differences of opinion with regard to this ſubſtance, Bergman undertook an elaborate analyſis of the ores of nickel, and an accurate examination of its peculiar properties in the metallic ſtate. His experiments were detailed in a diſſertation which was publiſhed in 1775. The object of his reſearches was, to aſcertain if nickel was a peculiar metal; and from the reſult of his experiments it appeared, that it did not contain the ſmalleſt trace of copper, but that it is generally alloyed with cobalt, arſenic, and iron, from which indeed it can ſcarcely be completely ſeparated; but that it poſſeſſed peculiar and diſtinct properties from the other metals; and theſe properties became more ſtriking and characteriſtic in proportion to its purity.

1616 Ores.

2. Nickel is found in the ſtate of ſulphuret, when it is called *kupfernickel*. It is of a reddiſh yellow colour, with little brilliancy, ſomewhat ſimilar to tarniſhed copper, with which, from its appearance, it is frequently confounded. This mineral ſoon loſes its brilliancy in the air, becomes of a browniſh colour, and is covered at laſt with greeniſh ſpots. It is found forming veins in the earth, and is uſually combined with arſenic, cobalt, and iron. Nickel has been found alloyed with iron, when it is of a laminated texture, and compoſed of rhomboidal plates. The freſh fracture is of a pale yellow, which becomes black by expoſure to the air. Nickel is alſo found native in the ſtate of oxide, when it is of a bright green colour. In this ſtate it is generally on the ſurface of ſulphuret of nickel. Native nickel has alſo been found, according to Bergman, or at leaſt with a very ſmall proportion of ſulphur, but combined with iron, cobalt, and arſenic. He ſays, too, that it exiſts in combination with ſulphuric acid.

1617 Separation of the metal.

3. To obtain nickel from its ores in the ſtate of ſulphuret, they are firſt roaſted, by which means the ſulphur and arſenic are driven off. In this proceſs the mineral loſes one-third or one-half of its weight; and in proportion to the quantity of pure metal, which exiſts in the ore, it aſſumes a richer green. The roaſted ore is then mixed with two parts of black flux, put into a crucible covered with muriate of ſoda, and expoſed to a forge heat, to bring it to fuſion. When the apparatus has cooled, there is found under the brown, black, or blue ſcoriæ, a metallic button, which amounts to one-tenth, and ſometimes to one-half, of the mineral employed.

1618 Properties.

4. Nickel, in the pureſt ſtate in which it can be obtained, is of a yellowiſh white, or of a reddiſh white colour, with more or leſs luſtre, and of a granulated texture. The ſpecific gravity is 9 according to Bergman, but according to Guyton it is only 7.807. Bergman ſpeaks of it as poſſeſſing ſome degree of ductility; but this, it is ſuppoſed, is owing to its alloy with iron, which latter conſtitutes $\frac{1}{4}$ of its weight. It is alſo magnetic, and this property has alſo been ſuppoſed to depend on the ſame alloy. Nickel is a very infuſible metal, requiring a temperature equal to 150° Wedgwood. Its power of conducting caloric has not been aſcertained, nor has its taſte or its ſmell been recognized. It has never been obtained in cryſtals.

1619 Action of heat.

5. When nickel is expoſed to heat in an open veſſel, it combines with oxygen, and aſſumes a brown colour; but this requires a very high temperature. After long expoſure to the air, when it is moiſt, and in the cold, it becomes covered with an efflorеſcence of a bright green colour, of a peculiar and diſtinct ſhade. It is this efflореſcence which is found on the ſurface of the native ſulphurets of nickel, the ſhade of which is ſo remarkable, and ſo different from that of copper, that they can be eaſily diſtinguiſhed. This oxide is compoſed of

1620 Oxide.

Nickel,	77
Oxygen,	23
	100

6. There is no action between nickel and azote, hydrogen, or carbone; nor is it at all acted upon by water.

1621 Phoſphuret.

7. Nickel combines with phoſphorus, and forms with it a phoſphuret. This is prepared by decompoſing phoſphoric acid in the ſtate of glaſs, which is done by mixing phoſphoric glaſs, charcoal and nickel, and fuſing them together Or it may be prepared, by projecting bits of phoſphorus on the metal, while it is red-hot, in a crucible. It acquires an addition of one-fifth part to its weight; but it parts with a ſmall portion of phoſphorus as it cools. The phoſphuret of nickel is of a more brilliant and purer white than the metal itſelf. The texture reſembles a collection of ſmall needles heaped together. When it is heated under the blow-pipe,

pipe, the phoſphorus burns on its ſurface, and the metal is oxidated. The component parts of this phoſphuret, according to Pelletier, are

1622 Compoſition.

Nickel,	83.3
Phoſphorus,	16.6
	100.0 *

1623 Sulphuret. 8. Nickel combines readily with ſulphur, and forms with it a ſulphuret, which is ſomewhat different in its properties from the native ſulphuret. It is hard, of a yellowiſh colour, and in ſmall brilliant facets. When it is ſtrongly heated in the open air, it gives out luminous ſparks.

1624 Alloys. 9. Nickel enters into combination with ſeveral of the metals, and forms with them alloys; the properties of which are but little known. With cobalt and arſenic it forms native alloys. The alloy with the latter is of a reddiſh colour, has no magnetic property, is conſiderably hard, and its ſpecific gravity is leſs than the mean ſpecific gravity of the two metals.

1625 Salts. 10. Nickel enters into combination with the acids, and forms with them ſalts, which are diſtinguiſhed by peculiar properties.

1626 Affinities. 11. The order of the affinities of nickel and its oxide, as they have been aſcertained by Bergman, is the following:

NICKEL.	OXIDE of NICKEL.
Iron,	Oxalic acid,
Cobalt,	Muriatic,
Arſenic,	Sulphuric,
Copper,	Tartaric,
Gold,	Nitric,
Tin,	Phoſphoric,
Antimony,	Fluoric,
Platina,	Saclactic,
Biſmuth,	Succinic,
Lead,	Citric,
Silver,	Lactic,
Zinc,	Acetic,
Sulphur,	Arſenic,
Phoſphorus.	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Nickel.

1. Sulphate of Nickel.

1627 Preparation. Concentrated ſulphuric acid, with the aſſiſtance of heat, is decompoſed by nickel. Sulphurous acid gas is diſengaged, and there remains behind a gray maſs ſoluble in water, to which it communicates a beautiful green colour. By evaporating this ſolution, cryſtals of a pale emerald green are obtained, which are ſulphate of nickel. 1628 Properties. The oxide of nickel is alſo readily diſſolved by ſulphuric acid, from which alſo cryſtals are obtained. It cryſtallizes in the form of ſquare priſms, or in decahedrons, which are compoſed of two four-ſided pyramids, truncated at the ſummits.

2. Nitrate of Nickel.

Nitric acid oxidates and diſſolves nickel with the aſſiſtance of heat. The oxide is diſſolved by this acid, without effervescence. The ſolution has a blackiſh green colour, which affords rhomboidal, deliqueſcent cryſtals, that are decompoſed by heat, and leave, after being ſtrongly calcined, and giving out oxygen gas, a black oxide. When the nitrate of nickel is expoſed to a warm dry air, it is deprived of its water of cryſtallization, and even of its acid, ſo that there remains behind only an oxide of the metal.

3. Nitrate of Ammonia and Nickel.

This triple ſalt is formed, by adding ammonia in exceſs to the ſolution of nitrate of nickel. This ſalt is of a green colour. It is obtained in cryſtals by evaporation. The ſolution does not become turbid by the addition of alkalies, but the metal is precipitated by hydroſulphurets *.

4. Muriate of Nickel.

Muriatic acid diſſolves nickel and its oxide ſlowly, except with the aſſiſtance of heat. The ſolution is of a green colour, and affords irregular cryſtals. The muriate of nickel is decompoſed by heat, and by expoſure to the air.

5. Fluate of Nickel.

Fluoric acid diſſolves the oxide of nickel with difficulty, and affords cryſtals of a bright green colour.

6. Borate of Nickel.

The compound of boracic acid and nickel can only be formed by double affinity, by adding the borate of ſoda, for inſtance, to a ſolution of nickel in acids.

7. Phoſphate of Nickel.

Phoſphoric acid has not a very ſtrong affinity for the oxide of nickel. The ſolution which is formed is ſcarcely of a green colour, and does not afford cryſtals.

8. Carbonate of Nickel.

Liquid carbonic acid, expoſed to the contact of nickel, did not appear to Bergman, to combine with the metal. But when nickel is precipitated from its ſolutions by means of alkaline carbonates, the precipitate acquires a greater weight than when the pure alkali is employed; from which it is concluded, that part of the carbonic acid has combined with the oxide.

9. Arſeniate of Nickel.

Arſenic acid forms with the oxide of nickel a green ſaline maſs, which is obtained by precipitating the oxide of nickel from its ſolution in acids, by means of an alkaline arſeniate. The arſeniate of nickel is in the form of powder, which is ſcarcely ſoluble in water.

10. Tungſtate of Nickel. }
11. Molybdate of Nickel. } unknown.
12. Chromate of Nickel. }
13. Columbate of Nickel. }

14. Acetate of Nickel.

Acetic acid diſſolves the oxide of nickel, and forms a ſalt in rhomboidal cryſtals, which are of a deep green colour.

---

* Ann. de Chim. xiii. 135.

* Ann. de Chim. xlii. 217.

15. Oxalate of Nickel.

With the aſſiſtance of heat, oxalic acid acts upon nickel, and a pale-green powder precipitates. This ſalt is ſcarcely ſoluble in water. It may be formed alſo, by precipitating nickel from its ſolutions in ſulphuric, nitric, and muriatic acids, by means of oxalic acid.

16. Tartrate of Nickel.

This ſalt, and the combinations of the oxide of nickel with the other acids, are unknown.

II. Action of Alkalies.

1629 Fixed alkalies. The fixed alkalies diſſolve the oxide of nickel, but in ſmall quantity. They aſſume a yellow colour; 1630 Ammonia. but this oxide is very ſoluble in ammonia; the ſolution of which is of a deep-blue colour, and of a peculiar ſhade. When it is evaporated, it precipitates in the form of a blackiſh brown powder, which paſſes from a blue to green. Moſt of the metals ſeparate the nickel from this ſolution.

III. Action of the Earths.

1. Many of the earths, as ſilica and alumina, have no action on nickel; but others, as barytes and ſtrontites, convert the oxide in ſolution into an orange red. If it contain arſenic or cobalt, the glaſs, which is coloured with nickel, becomes of a blue or violet colour.

2. The nitrates and the hyperoxymuriates very readily decompoſe the ſalts of nickel, and reduce it to the ſtate of oxide. With the boracic and phoſphoric ſalts it aſſumes a pale red colour. The nitrate of potaſh detonates feebly with nickel, but has the property of detecting the ſmalleſt trace of cobalt, which could not have been diſcovered by any other reagent.

1631 Uſes. So far as is known, this metal has not been applied to much uſe. There is, however, little doubt, that it might be employed for enamels, and for colouring glaſs, porcelain and pottery. Fourcroy obſerves, that it is probably employed in ſome of the ſecret proceſſes of theſe manufactures, as it is brought from Saxony to Paris in conſiderable quantities.

Sect. X. *Of Manganese and its Combinations.*

1632 Hiſtory. 1. A ſubſtance was long employed in the manufacture of glaſs, which, on account of its property of depriving glaſs of its colour, was known under the name of *glaſſmaker's ſoap*; from its appearance it was called *black magneſia*, or *manganeſe*. But although it was long employed in manufactures, nothing was known of its intimate nature or conſtituent parts. It was generally conſidered as an ore of iron, becauſe it was found ſometimes combined with the oxide of this metal. By others it was arranged among the ores of zinc, ſuppoſing that it was ſome combination of this metal. To Bergman and Scheele we are indebted for the firſt accurate knowledge of its nature. Bergman, in a diſſertation which he publiſhed in 1774, announces it as a peculiar metal, on account of its weight, its property of colouring glaſs, and of affording a white precipitate with the alkaline pruſſiates. Scheele, in the ſame year, preſented to the academy of Stockholm, a memoir, containing his reſearches concerning the nature and peculiar properties of this mineral. From theſe experiments he concludes, that this mineral is the oxide of a peculiar metal, totally diſtinct from all others. Gahn, the pupil of Bergman, was the firſt who obtained the metal in its pure ſtate, from the native oxide of manganeſe. His experiments have been repeated by others, and the reſults of Scheele and of Bergman fully confirmed.

1633 Ores. 2. Manganeſe is moſt generally found in the ſtate of oxide. Of this there are three principal varieties, the white, the red, and the black. 1. The firſt, or the white ore of manganeſe, contains the ſmalleſt proportion of iron and of oxygen. Sometimes it is cryſtallized. This ore ſoon tarniſhes in the air by abſorbing oxygen. 2. The red ore of manganeſe contains more iron than the former. It is either friable, or hard as it is found in carbonate of lime, on ſhiſtus, or accompanying ores of iron; or in lamellated maſſes, radiated or cryſtallized in pyramids, rhomboids, or in ſhort brittle needles. 3. The black or the brown ore is frequently cryſtallized like the red. It is alſo found in ſolid maſſes having a metallic or dull earthy appearance, mixed with quartz and other ſtony bodies. The ſpecific gravity is 4.0. Manganeſe has been found native by Lapeyrouſe in ſome iron mines in France. It was in the form of ſmall, flattened, metallic buttons, of a lamellated texture. But it has been ſuppoſed that the manganeſe in this ſtate is alloyed with iron.

1634 Separation of the metal. 3. Manganeſe is procured in the metallic ſtate by the following proceſs. The native oxide of manganeſe is reduced to a fine powder, and formed into a paſte with water. Part of it is then made into a ball, and introduced into a crucible lined with charcoal. A thick ſtratum of charcoal is placed at the bottom of the crucible, and the ball of manganeſe is to be ſurrounded and covered with the ſame ſubſtance, and the crucible, which is inverted and luted to the other, is to be filled with it. The whole is then to be expoſed to a very ſtrong heat, not leſs than 160° Wedgwood, for more than an hour. When the apparatus cools the metal is found in the bottom of the crucible, or in the midſt of the ſcoriæ, in the form of globules, which amount to nearly one-third of the manganeſe employed. But if the heat has been too low it will be found in grains.

1635 Properties. 4. Manganeſe is of a grayiſh white colour, with conſiderable brilliancy, and of a granular texture. The ſpecific gravity is 6.850. It has neither taſte nor ſmell. In hardneſs it is equal to iron. It is one of the moſt brittle of the metals, and at the ſame time one of the moſt infuſible, requiring a temperature of 160° Wedgwood to melt it. When in the ſtate of powder it is often attracted by the magnet, on account of the iron, from which it can only be ſeparated with great difficulty.

1636 Action of air. 5. When this metal is expoſed to the air, it is ſoon tarniſhed. It becomes gray, brown, and black, and at laſt falls down into powder, which is found to have acquired conſiderable addition to its weight. But when it is heated in the open air, it paſſes more rapidly through the different changes of colour, in proportion as it combines with oxygen, to the abſorption of which theſe changes are owing. It appears, therefore, that manganeſe, like ſome of the other metals, combines with different portions of oxygen, forming different

ent oxides. The black oxide, which is manganeſe, combined with oxygen in the greateſt proportion, is found native in great abundance. 1637 Oxides. The red oxide is ſuppoſed to contain the oxygen in the next proportion. 1638 Black. This alſo exiſts native, and it may be formed by diſtilling the black oxide made into a paſte with concentrated ſulphuric acid in a retort to dryneſs. It is deprived of a great quantity of oxygen, which is given out in the ſtate of gas. The reſiduum is then to be mixed with water, which is to be filtered. This ſolution, 1639 Red. which is ſulphate of manganeſe, is of a red colour. By adding an alkali a precipitate is formed, which is the red oxide of manganeſe. The white oxide is alſo prepared by depriving the black oxide of part of its oxygen. This is effected by pouring nitric acid on the black oxide of manganeſe, with the addition of ſugar, which abſorbs the oxygen and converts it into the white oxide. The latter is then diſſolved in the acid, from which it may be precipitated by potaſh. 1640 White. The precipitate is in the form of a white powder. The proportions of manganeſe and oxygen in the white and brown oxides of manganeſe, according to Bergman, and in the black, according to Fourcroy, are,

	White Oxide.	Brown Oxide.	Black Oxide.
Manganeſe	80	74	60
Oxygen	20	26	40
	100	100	100

When theſe oxides are expoſed to the air, they abſorb oxygen, and are again converted into the black oxide with the greater proportion of oxygen.

1641 Furniſhes oxygen. It is from the black oxide of manganeſe that chemiſts generally procure oxygen gas. The moſt economical proceſs is that which has been already deſcribed in the chapter on oxygen. This is by expoſing it to a red heat in an iron bottle. The manganeſe is reduced to the ſtate of red oxide by being deprived of the difference of the quantity of oxygen between the black and the brown oxides. The ſame manganeſe may be employed after it has been for ſome time expoſed to the air, and occaſionally moiſtened with water. This proceſs, however, goes on much more ſlowly than is generally ſuppoſed. We have kept ſeveral quantities of manganeſe, which had furniſhed abundance of oxygen, and had ceaſed to give out more in a red heat, expoſed to the air for many months, and frequently moiſtened with water, but when it was again heated to redneſs, it did not yield above $\frac{1}{10}$ part of the original quantity from the native manganeſe.

7. Manganeſe does not enter into combination with azote, hydrogen, or carbone. It is by means of charcoal that the oxide of manganeſe is reduced, by being deprived of its oxygen; and what has been ſuppoſed to be a compound of manganeſe and carbone, is a carburet of iron, or carbone combined with the iron, with which manganeſe is almoſt always alloyed.

1642 Phoſphuret. 8. Phoſphorus combines very readily with manganeſe. Pelletier formed the phoſphuret of manganeſe by fuſing a mixture of equal parts of manganeſe, in the metallic ſtate and phoſphoric glaſs, with about $\frac{1}{6}$ part of charcoal in powder; or by fuſing equal parts of the two former without the charcoal; or by projecting ſmall bits of phoſphorus on manganeſe heated to redneſs in a crucible. The phoſphuret obtained by any of theſe proceſſes, is of a white colour, of a granulated texture and brittle, and much diſpoſed to cryſtallize. It undergoes no change by expoſure to the air. It was covered with an opake, vitreous matter of a yellowiſh colour. It is more fuſible than the manganeſe itſelf. When it is expoſed to the action of the blow-pipe, the phoſphorus burns, and the metal is oxidated *.

1643 Sulphuret. 9. Bergman failed in forming a compound with ſulphur and manganeſe by direct combination. But he ſucceeded in combining ſulphur with oxide of manganeſe. Three parts of ſulphur, and eight parts of the oxide, expoſed to heat in a glaſs retort, formed a greeniſh yellow maſs, which efferveſced with acids, and emitted ſulphurated hydrogen gas. Scheele has obſerved, that a part of the ſulphur is converted into ſulphurous acid during the proceſs.

1644 Affinities. 10. Manganeſe enters into combination with the acids, and forms ſalts with them. The order of the affinities of the oxides of manganeſe for the acids, according to Bergman, is the following:

Oxide of Manganese.

Oxalic acid,
Citric,
Phoſphoric,
Fluoric,
Muriatic,
Sulphuric,
Nitric,
Saclactic,
Succinic,
Tartaric,
Lactic,
Acetic,
Pruſſic.
Carbonic.

I. Salts of Manganeſe.

1. Sulphate of Manganeſe.

1. Concentrated ſulphuric acid acts on manganeſe, even in the cold; but the action is more powerful if the acid be diluted with two or three parts of water. Hydrogen gas is given out, and there remains behind in the liquid, a black, ſpongy maſs, which is the carburet of iron. The ſolution is colourleſs, and it affords by evaporation, tranſparent, colourleſs cryſtals. Sulphuric acid does not combine with the black oxide of manganeſe, till it is deprived of part of its oxygen, and reduced to the ſtate of red or white oxide; but the acid combines with either of the two latter oxides, forming ſalts poſſeſſed of diſtinct properties. 1645 Two ſulphates. There are, therefore, two ſulphates of manganeſe, which may be diſtinguiſhed, from the colour of the baſe or oxide, by the names of white and red ſulphates.

1646 With the white oxide. *White ſulphate of manganeſe.*—This is the compound of ſulphuric acid and the white oxide of manganeſe. This oxide combines with the acid without effervefcence, and forms a colourleſs ſolution, which yields by evaporation, tranſparent rhomboidal cryſtals, which have a very bitter taſte. This ſalt is decompoſed by heat; the acid is driven off, and oxygen gas is given out. It is decompoſed alſo by the pure alkalies, and a precipitate

---

* Ann. de Chim. xiii. 137.

tate is formed, of the white oxide of manganeſe, which ſoon becomes brown by expoſure to the air, in conſequence of the abſorption of its oxygen. The alkaline carbonates precipitate a carbonate of manganeſe, which does not abſorb the oxygen from the air, and does not become black like the former. It is the white ſulphate of manganeſe, which is obtained by diſſolving the metal in diluted ſulphuric acid. In this proceſs the manganeſe combines with the oxygen of the water, which is decompoſed, and is converted into the white oxide, which unites with the ſulphuric acid, to form the ſulphate. The hydrogen of the water is driven off in the ſtate of gas, ſo that the ſalt formed in this way, occaſions an efferveſcence. This ſalt may alſo be formed by diſſolving the black oxide in ſulphuric acid; but in this caſe it is neceſſary, as Scheele diſcovered, to add ſome vegetable matter, as ſugar, honey, or gum, to abſorb the ſuperabundant quantity of oxygen, which prevents the ſolution of the manganeſe in the acid. When, therefore, the black oxide is reduced to the ſtate of white oxide, by depriving it of part of its oxygen, it combines with the acid, and forms white ſulphate of manganeſe, as in the former proceſſes.

1647 With the red oxide.

Red Sulphate of Manganeſe.—If the black oxide of manganeſe be diſtilled to dryneſs with ſulphuric acid, diluted with half its weight of water, and if the reſiduum be waſhed with water, a reddiſh or violet-coloured ſolution, which is the red ſulphate of manganeſe, is obtained. By evaporation it affords thin cryſtalline maſſes, which have no regular form. Theſe are alſo of a reddiſh colour. The alkalies occaſion a red precipitate, which becomes black by expoſure to the air. This ſulphate may be alſo formed by the direct combination of the red oxide with the acid.

Bergman has obſerved, that the red oxide of manganeſe is intermediate between the black and the white; that it is more ſoluble in ſulphuric acid than the former, and leſs ſoluble than the latter; that the red forms a red-coloured ſulphate, while the white affords a colourleſs ſulphate.

Sulphurous acid acts feebly or ſcarcely at all on manganeſe; but it diſſolves the black oxide readily, and without efferveſcence. There is not formed, however, a ſulphite of manganeſe; for the ſulphurous acid deprives the black oxide of a portion of its oxygen, and thus converts it into a white oxide, while the acid itſelf is converted into ſulphuric acid. The white oxide is then diſſolved in the ſulphuric acid, and forms the white ſulphate of manganeſe.

2. Nitrate of Manganeſe.

1648 White oxide.

Nitric acid diſſolves manganeſe with efferveſcence, and with the evolution of nitrous gas. There remains behind a black, ſpongy maſs, which is carburet of iron, and inſoluble. The ſolution thus formed, is of a dark colour, on account of the iron which it contains; for it does not appear that the red oxide of manganeſe combines with nitric acid. The white oxide of manganeſe diſſolves very readily in nitric acid, and without efferveſcence, or the emiſſion of nitrous gas. This ſolution, if the oxide be pure, is colourleſs. It does not afford cryſtals, even by ſlow evaporation. The black oxide of manganeſe cannot be diſſolved in nitric acid, but by long digeſtion; but by adding ſome vegetable matters, as honey, ſugar, oils, or even ſome of the metals, to deprive the oxide of part of its oxygen, the combination is effected. Carbonic acid gas, which is formed by the union of the carbone of the vegetable matters with the oxygen of the manganeſe, is given out, during the proceſs.

2. Nitrous acid diſſolves the oxide of manganeſe much more readily than the nitric acid. No efferveſcence takes place, becauſe the oxygen of the manganeſe combines with the nitrous acid, and forms nitric acid, which latter combines with the oxide of manganeſe, reduced to the ſtate of white oxide; and thus there is formed, not a nitrite, but a nitrate of manganeſe.

3. Muriate of Manganeſe.

1649 White oxide.

Manganeſe is diſſolved with efferveſcence, and with the evolution of hydrogen gas, in liquid muriatic acid. The white oxide combines with the acid, without efferveſcence, and without the ſeparation of any gas, becauſe it is ſufficiently oxidated, to be diſſolved in this acid. The black oxide is diſſolved with equal facility in muriatic acid as in the other acids. In this caſe an efferveſcence takes place, with the diſengagement of oxymuriatic acid gas. The nature of this action is obvious. Part of the muriatic acid combines with part of the oxygen of the manganeſe, and forms oxymuriatic acid, which is diſengaged in the ſtate of gas. The black oxide is deprived of part of its oxygen, and converted into the white oxide, which latter diſſolves in the remaining part of the muriatic acid, and forms a muriate of manganeſe. This ſalt, being a compound of the white oxide of manganeſe and muriatic acid, may be called the *white muriate of manganeſe.* If any combuſtible matter be added, the ſolution of the black oxide of manganeſe in this acid goes on, without the production of oxymuriatic acid.

Oxymuriatic acid readily parts with its oxygen to manganeſe, which is thus converted into the white oxide. It combines alſo with the oxides of manganeſe, and forms ſolutions of a brown, red, or violet colour, which afford cryſtals of the ſame colour. There is, therefore, a red muriate of manganeſe.

It is from the black oxide of manganeſe, that oxymuriatic acid is obtained, either by adding to the oxide muriatic acid, part of which combines with the oxygen of the manganeſe, and is converted into oxymuriatic acid; or, by adding ſulphuric acid to a mixture of the black oxide of manganeſe and muriate of ſoda. The ſulphuric acid decompoſes the latter, and the muriatic acid being diſengaged, combines with part of the oxygen of the manganeſe, and forms oxymuriatic acid.

4. Fluate of Manganeſe.

Fluoric acid has little action on manganeſe or its oxides; but a fluate of manganeſe may be formed by double affinity, by adding an alkaline fluate to the nitrate or muriate of manganeſe. The fluate of manganeſe thus formed, is not very ſoluble in water. Its other properties are unknown.

5. Borate of Manganeſe.

This ſalt may be formed in the ſame way as the former.

former. It is equally ſoluble in water, and its other properties are alſo unknown.

6. Phoſphate of Manganeſe.

A phoſphate of manganeſe may be formed in the ſame way as the two former ſalts. It is not very ſoluble in water, and its other properties have not been examined.

7. Carbonate of Manganeſe.

Liquid carbonic acid diſſolves a ſmall portion of manganeſe, as well as of its black oxide. When this ſolution is expoſed to the air, the oxide is gradually precipitated, and appears on the ſurface in the form of a white pellicle. Bergman has remarked, that during the combination of manganeſe with carbonic acid, there is evolved an odour ſomewhat analogous to that of burnt fat.

8. Arſeniate of Manganeſe.

Arſenic acid combines with the white oxide of manganeſe, and forms an arſeniate. The arſenious acid, or white oxide of arſenic, deprives the black oxide of manganeſe of part of its oxygen, and paſſes to the ſtate of arſenic acid, and then combines with the manganeſe, now reduced to the ſtate of white oxide. When the arſenic acid is nearly ſaturated with the oxide, the ſolution becomes thick, and ſmall cryſtals make their appearance. This ſalt, when heated, does not melt, nor is the arſenic ſublimed, without the addition of charcoal.

9. Tungſtate of Manganeſe.
10. Molybdate of Manganeſe.
11. Chromate of Manganeſe.
12. Columbate of Manganeſe.
} unknown.

13. Acetate of Manganeſe.

1650 Proceſs for ſeparating iron.

Acetic acid diſſolves part of the black oxide of manganeſe, but acts very feebly on the metal itſelf. This acid may be employed to ſeparate manganeſe from iron; for when it is added to a ſolution containing both theſe metals, the acid combines with the manganeſe, for which it has a ſtronger affinity, and leaves the oxide of iron. Several ſucceſſive ſolutions and evaporations are neceſſary to ſeparate the whole of the iron, which is known when the ſolution becomes colourleſs, and when it affords a white precipitate with pruſſiate of potaſh. The ſolution of acetate of manganeſe does not cryſtallize, and when evaporated to dryneſs, it ſoon deliqueſces *.

14. Oxalate of Manganeſe.

Oxalic acid forms a ſalt with the oxide of manganeſe, which, when the ſolution is ſaturated, precipitates in the form of white powder. It may be formed alſo by adding oxalic acid to the ſulphate, nitrate, and muriate of manganeſe in ſolution.

15. Tartrate of Manganeſe.

This ſalt may be formed by double affinity, by adding tartrate of potaſh to the ſolution of manganeſe in ſulphuric or nitric acids. The black oxide of manganeſe is diſſolved in tartaric acid, and gives a black-coloured ſolution. When it is heated, an efferveſcence takes place; the acid is partially decompoſed, carbonic acid gas is evolved, and the ſolution at laſt becomes colourleſs.

16. Citrate of Manganeſe.

Citric acid, in its combination with the black oxide of manganeſe, exhibits the ſame phenomena as the former.

17. Benzoate of Manganeſe.

Benzoic acid readily combines with the white oxide of manganeſe. By evaporation, cryſtals in the form of ſmall ſcales are obtained, which are little altered by expoſure to the air, and are ſoluble in water.

II. Action of Alkalies on Manganeſe.

1651 Pure alkalies.

1. The pure alkalies favour the oxidation of manganeſe, and the decompoſition of water, becauſe they combine readily with this oxide. In the dry way, the fixed alkalies fuſe with manganeſe, and form a maſs of a deep green colour, which is ſoluble in water, and communicates to it the ſame colour. If this ſolution be kept in a cloſe veſſel, there is precipitated an oxide of iron, of a yellowiſh colour, and the green liquid changes to a blue. Water precipitates the alkaline ſolution, and converts it, firſt to a violet and then to a red colour. As the particles of the oxide collect together, the liquid becomes white. The addition of a few drops of acid, on expoſure to the air, produces the ſame precipitation, and the ſame ſhades of colour, by oxidating the manganeſe. The white oxide of arſenic, or arſenious acid, added to this alkaline ſolution, deprives it of the whole of its colour, and renders it white, by combining with the oxygen. By adding charcoal to the oxide of manganeſe which has been fuſed with an alkali, an efferveſcence takes place, with the evolution of carbonic acid, and the colour of the ſolution changes to a grayiſh white. The carbonic acid is here formed by the union of the carbone of the charcoal with the oxygen of the manganeſe, and this latter paſſes to the ſtate of white oxide. On account of theſe remarkable changes of colour, and the different ſhades which this liquid, treated in various ways, aſſumes, this compound has received the name of *mineral cameleon*.

1652 Mineral cameleon.

1653 Ammonia.

2. Scheele had obſerved the change which ammonia undergoes by the action of oxide of manganeſe, in the diſtillation of this oxide with the muriate of ammonia. He ſuſpected that the ammonia was partially decompoſed, and to this decompoſition he aſcribed the formation of a gas, which he obtained by this proceſs, and which he found to be different from carbonic acid. Berthollet has ſhewn, that in this proceſs, the hydrogen, leaving the ammonia which is decompoſed, combines with the oxygen of the oxide of manganeſe, and forms water; and the azote, the other component part of ammonia, is ſet at liberty.

1654 Curious experiment.

A very intereſting experiment was contrived by Dr Milner, which illuſtrates the reciprocal action, and decompoſitions of the oxide of manganeſe and ammonia. He filled a tube with oxide of manganeſe, expoſed it to a red heat, and made a ſtream of ammoniacal gas paſs through it. The gas was decompoſed, and its azote combining with the oxygen of the oxide, formed nitrous gas.

---

* Ann. de Chim. xli. p. 249.

Some of the alkaline ſalts have peculiar effects on the oxides of manganeſe and their compounds. The ſulphates have the property of deſtroying the colour of glaſs, which has been communicated by manganeſe; but for this effect a high temperature is neceſſary. The nitrates readily burn this metal, and oxidate it ſtrongly. Melted nitre gives a violet or red colour to glaſs, which has been rendered colourleſs, in reſtoring to it the oxygen of which it has been deprived by the fuſion of the glaſs. With the nitrate of potaſh and the black oxide of manganeſe, heated in a crucible to redneſs, a compound is formed, ſimilar to that which is the reſult of the direct combination of the oxide with the alkali.

The alkaline phoſphates and borates fuſed by means of the blow-pipe, with the oxide of manganeſe, produce various colours, according to the degree of oxidation, and the intenſity of the heat.

A white precipitate is formed, by adding hydroſulphuret of potaſh to the ſalts of manganeſe, and a yellowiſh-white precipitate is obtained, by means of the triple pruſſiate of potaſh.

III. Action of the Earths on Manganeſe.

1655 Colours glaſs.

There is no action between manganeſe and any of the earths; but its oxide combines with them, and forms vitreous matters, which are of different colours, according to the degree of oxidation of the manganeſe, and its mixture with iron. In general theſe colours are green, brown, black, or yellowiſh green.

1656 Uſes.

Manganeſe and its oxides are of great importance, both in chemiſtry and in the arts. This muſt be obvious, from the minute detail of its properties and combinations, which has now been given.

Sect. XI. *Of Biſmuth and its Combinations.*

1657 Hiſtory.

1. Biſmuth, it would appear, was known to the ancients, to the alchemiſts, and ſome of the earlieſt mineralogiſts; but it was conſidered merely as a variety of ſome other metal, and generally of tin and lead. Hence it was diſtinguiſhed by the name of *green tin*, *gray lead*, and *white antimony*. It was not till the year 1753, when its properties were particularly examined by Pott and Geoffroy the younger, that it was aſcertained to be a peculiar metal. Darcet and Rouelle afterwards inſtituted a ſet of experiments on this metal, and diſcovered more of its properties. Monnet and Beaume inveſtigated its principal combinations at ſtill greater length; and Bergman examined with more accuracy, ſome of its compounds and precipitates.

1658 Ores.

2. Biſmuth is found native in the ſtate of ſulphuret, and in that of oxide. Native biſmuth is eaſily diſtinguiſhed by its colour, brittleneſs and fuſibility. The ſulphuret of biſmuth is of a bluiſh gray, ſometimes with a yellowiſh ſhade, and is in irregular maſſes, or cryſtallized in the form of ſmall priſms. It has a brilliant, lamellated fracture. The native oxide of biſmuth accompanies the metal, or is found on the ſurface of the ſulphuret. It is of a greeniſh yellow colour.

1659 Analyſis in the dry way.

3. Biſmuth is eaſily extracted from its ores. The mineral, after being reduced to powder, and well waſhed, is mixed with about $\frac{1}{4}$ of its weight of black flux, is put into a crucible lined with charcoal, and well covered. It is then expoſed to a moderate heat, which muſt be quickly applied, to prevent the metal from being ſublimed. By this proceſs a metallic button is obtained.

1660 Humid way.

In the humid way, the ore of biſmuth being reduced to powder, is diſſolved in nitric acid, and precipitated from this ſolution by water. If the native biſmuth be combined with any other metals, they remain in the ſolution. The ſulphuret of biſmuth is alſo diſſolved in the ſame acid by boiling. The ſulphur is ſeparated, as the metal, being oxidated, combines with the acid. The native oxide is treated in the ſame way, and is precipitated by water.

1661 Properties.

4. Biſmuth is of a white colour, inclining to yellow, exhibiting a texture compoſed of large brilliant plates. Its ſpecific gravity is 9.822. It has ſcarcely either taſte or ſmell. By a violent ſtroke of the hammer it is broken, and divides into ſmall fragments of a lamellated ſtructure; the figure of its particles is the regular octahedron. It has conſiderable hardneſs; and by hammering, its denſity may be increaſed. It has very little elaſticity, and no ductility. Biſmuth is very fuſible. When it is expoſed to the temperature of 490°, according to Guyton, it melts; and, if after fuſion, it be allowed to cool ſlowly, it cryſtallizes in parallelopipeds, which croſs each other at right angles. This metal cryſtallizes more eaſily and more regularly than any other yet known. If the heat be long continued after the fuſion, and ſufficiently ſtrong; and if the proceſs be conducted in cloſe veſſels, it ſublimes, and attaches itſelf to the upper part of the apparatus, where it cryſtallizes in brilliant plates.

5. Biſmuth is but ſlightly affected by expoſure to the air in the cold. It loſes its brilliancy, and is covered with a fine powder of a yellowiſh gray colour; but, when it is heated in contact with air, the ſurface is ſoon covered with an irideſcent pellicle, which, by agitation and continuing the heat, is converted into a greeniſh gray or brown-coloured oxide. It acquires about $\frac{1}{12}$ of addition to its weight. By continuing the heat, and occaſionally ſtirring the fuſed metal, it becomes of an orange-yellow colour, and acquires a farther addition to its weight. If the metal in fuſion be expoſed to a red heat, it takes fire with a ſlight exploſion, burns with a bluiſh flame, and is ſublimed in the form of a yellowiſh vapour, which, being condenſed and collected, is known under the name of *flowers of biſmuth*. It appears then, that biſmuth combines with oxygen in two proportions. The firſt, or the ſmaller proportion, is that of the brown oxide; and the ſecond is the yellow oxide or flowers of biſmuth.

1662 Two oxides, brown and yellow.

1663 Phoſphuret.

6. There is no action between biſmuth and azote, hydrogen, or carbone. It combines but in very ſmall proportion with phoſphorus, forming a phoſphuret. When phoſphorus is dropped into biſmuth in fuſion, it ſeems to unite with it, according to Pelletier, in the proportion of four parts in the hundred. But the properties of the biſmuth are very little changed.

1664 Sulphuret.

7. Sulphur unites readily with biſmuth. When equal parts of biſmuth and ſulphur are heated together in a crucible, the fuſion of the metal is greatly retarded. It requires a higher temperature than when the metal is alone. This ſulphuret of biſmuth is of a ſhining dark gray colour, and cryſtallizes by proper cooling into needle-form priſms, ſhaded with ſplendid blue and

deep red colours. The cryſtals are obtained by piercing the ſurface when it becomes ſolid after fuſion, and pouring out the liquid parts : a cavity is thus left in which they are formed.

Sulphurated hydrogen gas occaſions a dark colour on the ſurface of biſmuth, and converts the oxides into a deep black colour, which is the commencement of reduction.

1665 Alloys and ſalts. 8. Biſmuth combines with many of the metals, and forms alloys ; but its combinations with the metals already deſcribed, are little or ſcarcely at all known. Biſmuth alſo combines with the acids, and forms ſalts.

1666 Affinities. 9. The affinities of biſmuth and its oxides are arranged by Bergman in the following order :

Bismuth.	Oxide of Bismuth.
Lead,	Oxalic acid,
Silver,	Arſenic,
Gold,	Tartaric,
Mercury,	Phoſphoric,
Antimony,	Sulphuric,
Tin,	Muriatic,
Copper,	Nitric,
Platina,	Fluoric,
Nickel,	Saclactic,
Iron,	Succinic,
Sulphur.	Citric,
	Lactic,
	Acetic,
	Pruſſic,
	Carbonic.

I. Salts of Biſmuth.

1667 Different from other metallic ſolutions. The ſolutions of biſmuth in the acids, and alſo the cryſtallized ſalts which are obtained from them, reſemble each other, but differ from almoſt all other metallic ſolutions, as well as from all other ſalts ; and particularly in one circumſtance, which is, that water in ſufficient quantity decompoſes them, and precipitates an oxide of biſmuth of a white colour. This ſhows that biſmuth is ſtrongly oxidated by the action of the acids, to which it adheres with no great affinity, and that it forms with them compounds which are not very permanent. It ſeems at the ſame time remarkable, that this metal ſhould be more oxidated in this way, than by the uſual proceſs of oxidation, by means of heat, and by the action of water ; and that it ſhould have a white colour, while in the uſual way, it is of a yellowiſh gray.

1. Sulphate of Biſmuth.

Concentrated ſulphuric acid has no action on biſmuth in the cold ; but this metal decompoſes the acid at a boiling temperature. Sulphurous acid gas is diſengaged, and the biſmuth is oxidated, and converted into a white powder. If the heat be ſtrong, ſulphur is ſublimed. When the remaining maſs is waſhed with water, it carries off the remaining acid and a ſmall quantity of the oxide of biſmuth. The ſolution, by proper evaporation, affords ſmall ſoft needle-formed cryſtals, which are ſulphate of biſmuth. This ſulphate is decompoſed by water, which ſeparates a white oxide.

2. Sulphite of Biſmuth.

Sulphurous acid has no action on biſmuth ; but it unites with its oxide, and forms a white ſulphite which is inſoluble in water, and even in its own acid ; of a ſulphureous taſte ; fuſible by the blow-pipe into a reddiſh yellow maſs, which is reduced on charcoal into metallic globules ; decompoſed with effervefcence by means of ſulphuric acid ; giving out by diſtillation ſulphurous acid, and leaving behind a pure white oxide.

3. Nitrate of Biſmuth.

1668 Violent action. 1. Nitric acid exhibits a very violent action with biſmuth. When the acid is a little concentrated, and the biſmuth in the ſtate of powder, there is a violent effervefcence, with the evolution of nitrous gas. There is at the ſame time great heat produced. The biſmuth is converted into white oxide at the expence of the acid, and when the action ceaſes, if no more acid be added than what is neceſſary to its oxidation, remains dry.

1669 Properties. 2. The nitric ſolution thus prepared, is colourleſs, and affords cryſtals by evaporation. It cryſtallizes in tetrahedral priſms, compreſſed into obtuſe three-ſided ſummits. It has ſometimes been obtained in flattened rhomboidal parallelopipeds, ſimilar to thoſe of Iceland cryſtal. When this ſalt is thrown on red-hot coals, it melts, boils, and froths up ; exhales nitrous vapour, and leaves behind a greeniſh yellow oxide. It dries in the air, and becomes moiſt when the air is humid. When it is brought into contact with water, it becomes turbid, is decompoſed, and a white oxide is precipitated. This decompoſition is effected with the nitric acid, which is poured gradually into a large quantity of water. The oxide which is thus obtained, was formerly called *magiſtery of biſmuth*. It is known in the ſhops by the name of *pearl white*. It becomes of a deep gray, brown, or even black colour, when it is expoſed to the action of ſulphurated hydrogen gas.

4. Muriate of Biſmuth.

1670 Preparation. Muriatic acid has but a feeble action on biſmuth. It is neceſſary to aſſiſt its action, that the acid be concentrated, and long digeſted with the metal, or diſtilled off it in the ſtate of powder. During the proceſs, a fetid odour is emitted, which is owing to the decompoſition of water, its oxygen combining with the metal, and the hydrogen being ſet at liberty. By evaporating this ſolution, ſmall needles of muriate of biſmuth are obtained ; but only in very ſmall quantity ; for the greateſt part of the oxide of biſmuth is ſeparated by water. The muriate is ſublimed by heat, into a thick, ſolid, fuſible matter, which was formerly called *butter of biſmuth*. It is deliqueſcent, and may be decompoſed by water, which ſeparates a very fine white oxide.

Oxymuriatic acid readily diſſolves biſmuth, and forms with the oxide which is previouſly produced, a ſalt ſimilar to the preceding.

5. Fluate of Biſmuth.

6. Borate of Biſmuth.

Theſe two ſalts may be formed by adding a fluate or borate of an alkali to a ſolution of nitrate of biſmuth. A white precipitate is formed of the fluate or borate of biſmuth; but little is known of their properties.

7. Phoſphate of Biſmuth.

This ſalt is formed by combining the acid with the oxide of the metal, when precipitated by an alkali. The phoſphate of biſmuth is in the ſtate of an inſoluble white powder.

8. Carbonate of Biſmuth.

This ſalt may be formed by precipitating the oxide of biſmuth from its ſolution in acids, by means of an alkaline carbonate.

9. Arſeniate of Biſmuth.

Arſenic acid acts upon biſmuth with the aſſiſtance of heat. A white powder appears on the ſurface of the metal, and the oxide is precipitated from the ſolution, by adding water. The arſeniate of biſmuth may be formed, by adding arſenic acid to a ſolution of the nitrate of biſmuth. The arſeniate of biſmuth falls to the bottom in the form of precipitate.

10. Tungſtate of Biſmuth.

Unknown.

11. Molybdate of Biſmuth.

Muriate of biſmuth is precipitated, if there be no exceſs of acid, by molybdic acid. The molybdate of biſmuth thus formed, is of a white colour.

12. Chromate of Biſmuth, } unknown.
13. Columbate of Biſmuth, }

14. Acetate of Biſmuth.

This ſalt may be formed, by adding a ſolution of acetate of potaſh to a ſolution of nitrate of biſmuth. A precipitate of acetate of biſmuth is formed. The addition of acetic acid to the nitrate of biſmuth, Guyton obſerves, prevented the latter from being precipitated by means of water.

15. Oxalate of Biſmuth.

Oxalic acid combines with the oxide of biſmuth, and forms with it a ſalt in the ſtate of white powder, which is ſcarcely ſoluble in water. Oxalic acid added to nitrate of biſmuth, occaſions a precipitate in the form of ſmall tranſparent cryſtals, which are oxalate of biſmuth.

16. Tartrate of Biſmuth.

Tartaric acid added to the ſolution of biſmuth in any of the mineral acids, precipitates the oxide in the form of a white powder, which is the tartrate of biſmuth, and is inſoluble in water.

17. Benzoate of Biſmuth.

Benzoic acid combines readily with the oxide of biſmuth. The ſolution, by evaporation, affords cryſtals in the form of needles. They undergo no change by expoſure to the air, are ſoluble in water, and decompoſed by ſulphuric and muriatic acids. This ſalt is alſo decompoſed by heat, which drives off its acid.

18. Succinate of Biſmuth.

Succinic acid combines with the oxide of biſmuth, at a boiling heat. By evaporating the ſolution, cryſtals of ſuccinate of biſmuth are obtained, in the form of plates, and of a yellow colour.

II. Action of Alkalies, Earths, and Salts, on Biſmuth.

1671 Alkalies. Scarcely any thing is known of the action of the alkalies on biſmuth. Ammonia, it is ſaid, communicates to it a yellow colour, and the oxide of biſmuth is ſoluble in ammonia in the liquid ſtate.

1672 Silica. The oxide of biſmuth combines by fuſion, with ſilica, to which it communicates a greeniſh yellow colour.

1673 Salts. Biſmuth is not changed by the action of the ſulphates or ſulphites. It is oxidated by the nitrates. When it is ſtrongly heated, and thrown into a red-hot crucible with nitrate of potaſh, it detonates feebly, and without much inflammation. It is reduced to the ſtate of oxide, of which one part combines with the potaſh. Biſmuth has no action on muriate of ammonia, but its oxide very readily decompoſes this ſalt. In the cold, it diſengages a little ammonia, by ſimple trituration; but when expoſed to heat, it is totally decompoſed, and there remains a muriate of biſmuth.

1674 Uſes. Biſmuth is applied to a great many uſes. It forms ſome important alloys with the ſofter metals, to give them hardneſs and conſiſtency. The oxides of biſmuth are of ſtill more extenſive utility. It is employed in this form by the manufacturers of porcelain, for the preparation of yellow enamels, and it is mixed with other oxides, to give variety of ſhade to their colours. It is ſometimes employed in the fabrication of coloured glaſſes, to communicate a greeniſh yellow. The white oxide, which is moſt commonly employed for theſe different purpoſes, is alſo employed as a paint for the ſkin, under the name of *pearl white;* but it is extremely improper for this purpoſe, for, beſides the injury which it does to the ſkin, it becomes black, when it is expoſed to the action of ſulphurated hydrogen gas. It is ſometimes uſed alſo, to give a black colour to the hair.

SECT. XII. *Of Antimony and its Combinations.*

1675 Hiſtory. 1. It does not appear that the ancients were acquainted with antimony as a diſtinct metal, although it is ſuppoſed that it was employed by them in alloys of other metals. It is ſaid, that they were acquainted with the oxide of antimony, and that it was employed as an external remedy in inflammation of the eyes. As a peculiar metal, it was not certainly known till the time of Baſil Valentine, who lived about the end of the 15th century. In his work, entitled *Currus Triumphalis Antimonii,* he has detailed all that was then known of this metallic ſubſtance, and he has particularly deſcribed the proceſs by which it is extracted from its ore.

No ſubſtance has been more the ſubject of inveſtigation than antimony, and on no ſubject, perhaps, has there been ſo much written. The alchemiſts regarded antimony as peculiarly appropriate to the object

ject of their reſearches. Their labours on this ſubject were almoſt incredible; and indeed this is ſcarcely to be wondered at, ſince it appears that they were inſpired with the hope of making, by its means, the fortunate diſcovery of the univerſal medicine. It was therefore tortured and tried in every poſſible way, to obtain the object of their reſearches; and on this account it is almoſt impoſſible to reckon up the number of medicinal preparations which were propoſed and employed with this metal and its ores. It is owing to theſe views and reſearches, concerning antimony, that its nature and properties are now ſo fully known.

2. About the end of the 17th century, Lemery publiſhed a treatiſe, which was the firſt correct and rational account of antimony. In this he arranged and detailed the diſcoveries of his predeceſſors, and added ſome of his own, with a number of curious experiments and accurate proceſſes for many of the preparations of antimony and its ſulphuret. Mender afterwards publiſhed a very complete hiſtory of all the facts that were then known concerning antimony; and it has been ſince examined by more modern chemiſts; among whom Bergman, Scheele, Berthollet, Prouſt, and Thenard, are the principal writers on this ſubject.

1676 Ores. 3. Antimony exiſts in nature in four different ſtates: In the ſtate of native antimony, that of ſulphuret, hydroſulphuret of the oxide of antimony, and muriate. Native antimony is eaſily diſtinguiſhed by its colour and brilliancy. It has been found in Sweden and in France. The moſt common ore of antimony is the ſulphuret, which is of a grayiſh colour, and ſtains the fingers. It is ſometimes cryſtallized in ſquare priſms, which are ſlightly rhomboidal, and terminated by four-ſided pyramids. The hydroſulphurated oxide of antimony is in ſhining filaments, of a deep red colour, diſpoſed in rays going from a common centre, adhering to the ſurface or cavities of the ſulphuret. The muriate of antimony, which is a rare production, is of a brilliant, pearly-white colour, in the form of ſmall divergent needles, ſomewhat reſembling radiated zeolite.

1677 Analyſis. 4. To obtain the pure metal from the ſulphuret of antimony, the ore is firſt roaſted, to ſeparate the greateſt part of the ſulphur. It is then mixed with its own weight of black flux, formed into a paſte with oil, and expoſed to a ſtrong heat in a crucible, at the bottom of which the metal is found reduced. By a ſhorter proceſs, eight parts of ſulphuret of antimony, ſix of tartar, and three of nitre, reduced to powder, and well mixed, are projected in ſmall quantities into a red-hot crucible. At each projection there is a ſtrong detonation; the tartar forms, by means of the nitre, a black flux, and the ſulphuret being burnt, the metal is fuſed, but not oxidated, on account of the charcoal of the tartar with which it is ſurrounded, and the liquid alkali which covers it. The whole is then fuſed in a conical iron pot; and, when it is cool, the metallic antimony is found at the bottom, marked on its ſurface with needle-ſhaped cryſtals, arranged in the form of a ſtar.

1678 Properties. 5. Antimony, in a ſtate of purity, is of a brilliant white colour, having a good deal of reſemblance to that of ſilver or of tin. It has a lamellated texture, compoſed of plates which croſs each other in all directions. It exhibits ſometimes perceptible traces of cryſtallization. The form of the cryſtals, which was diſcovered with difficulty by Hauy, on account of its complicated ſtructure, is the octahedron, compoſed of a great number of regular tetrahedrons. Antimony has a very perceptible taſte and ſmell, and particularly if it is rubbed for ſome time on the hands. The ſpecific gravity is 6.702. It is very brittle, ſo that it can be reduced to powder, which is of a grayiſh white colour.

1679 Action of water. 6. Antimony undergoes no change by being expoſed to the air, nor is there any perceptible action between antimony and water in the cold; but when water comes in contact with antimony red hot, it is inſtantaneouſly decompoſed, and accompanied with a violent detonation, and a very brilliant white flame. Accidents of this kind have happened, attended with conſiderable danger.

1680 Of heat. 7. When antimony is heated to the temperature of 808°, it melts. If the heat be continued after its fuſion, it is ſublimed, and if the proceſs be performed in cloſe veſſels, it is condenſed in ſhining cryſtallized plates. If it be allowed to cool ſlowly, and part of it be poured off when the ſurface becomes ſolid, the cavity is lined with pyramidal cryſtals, compoſed of ſmall octahedrons.

1681 Oxides. 8. When antimony is kept in fuſion in the open air, it riſes in the form of white vapour, which is precipitated on the ſurface of the metal or upper part of the crucible, and cryſtallizes in long priſms, or in ſmall, white, brilliant needles. This is an oxide of antimony, which was formerly called *argentine flowers*, or *ſnow of regulus of antimony*. By this proceſs it is found, that the antimony has acquired an addition of weight of about 50 per cent. This oxide may be obtained, by expoſing the antimony in a crucible to a white heat, and then by ſuddenly agitating it in contact with air, it takes fire with a kind of exploſion, and burns with a white light.

Thenard, in his reſearches concerning antimony, diſtinguiſhes ſix different degrees of oxidation of this metal. But in a memoir on the ſame metal by Prouſt, he conſiders that the oxides of antimony may be reduced to two. According to the experiments of this chemiſt, 100 parts of antimony treated with nitric acid in a retort, uniformly afford 130 of a yellow oxide in the ſtate of powder. It is reduced to 126 by waſhing with water before drying it, becauſe the nitric acid diſſolves a ſmall proportion. This oxide is not reduced by being expoſed to a red heat, but it is ſublimed, and condenſed in cloſe veſſels, in groups of cryſtals. It is inſoluble in water. It is the ſame oxide which was formerly diſtinguiſhed by the name of *argentine flowers*. The component parts of this oxide, according to Prouſt, are,

Antimony	77
Oxygen	23
	100 *

The oxide with a ſmaller proportion of oxygen, is formed by diſſolving antimony in muriatic acid; and by adding water to the ſolution, a white powder is precipitated, which being waſhed, is ſeparated from any acid that may adhere to it. To purify it ſtill more, it is to be boiled with carbonate of potaſh, and afterwards waſhed, and dried on a filter. This oxide is of a yellowiſh white colour, and has little brilliancy; it

---

* *Jour. de Phyſique*, lv. p. 330.

melts at a moderate red heat, and when it is allowed to cool, it cryſtallizes on the ſurface. The cryſtals are of a yellowiſh white colour, which are thrown together in heaps, in a radiated form. This oxide was formerly known by the name of *powder of algaroth*. Its component parts are,

Antimony	81.5
Oxygen	18.5
	100.0 *

9. There is no action between antimony and azote, hydrogen, or carbone.

1682 Phoſphuret.

10. Antimony enters into combination with phoſphorus, and forms with it a phoſphuret. Equal parts of phoſphoric glaſs and antimony are fuſed together in a crucible, or with the addition of $\frac{1}{8}$ of charcoal, or by projecting pieces of phoſphorus on the metal in fuſion in a crucible; and thus a phoſphuret of antimony is obtained. This phoſphuret has a metallic luſtre, is brittle, and has a lamellated fracture. When it is placed on burning charcoal, it melts, gives out a ſmall green flame, and is converted into the white oxide of antimony, which is ſublimed.

1683 Sulphuret.

11. Antimony combines very readily with ſulphur, and forms with it an artificial ſulphuret, which is exactly ſimilar to the native ſulphuret. It is formed by mixing the antimony and the ſulphur together, and fuſing them in a crucible. This ſulphuret is of a brilliant gray colour, is more fuſible than the metal itſelf, and by ſlow cooling, may be obtained in cryſtals. The component parts of the ſulphuret, according to Prouſt, are,

Antimony,	75.1
Oxygen,	24.9
	100.0

1684 Oxides with ſulphur.

12. The yellow oxide of antimony combines with different proportions of ſulphur, and forms compounds of different colours, and which were formerly diſtinguiſhed by different names. With eight parts of the oxide and one part of ſulphuret, a red coloured, ſemitranſparent maſs is obtained, which was formerly called *glaſs of antimony*. When two parts of ſulphuret are added to eight parts of the oxide, a yellowiſh maſs is formed, which was known by the name of *crocus metallorum*. Six parts of oxide and one of ſulphur, form a dark red, opaque maſs, with a vitreous fracture, which is the true *liver of ſulphur*. In theſe combinations, the ſulphur deprives the oxide of part of the antimony, and combines with it, forming a ſulphuret. This ſulphuret then combines with the oxide ‡.

1685 Affinities.

13. Antimony enters into combination with the acids, and forms ſalts. It alſo forms alloys with many of the metals. The affinities of antimony and of its oxides are, according to Bergman, in the following order:

ANTIMONY.	OXIDE OF ANTIMONY.
Iron,	Muriatic acid,
Copper,	Oxalic,
Tin,	Sulphuric,
Lead,	Nitric,
Nickel,	Tartaric,
Silver,	Saclactic,
Biſmuth,	Phoſphoric,
Zinc,	Citric,
Gold,	Succinic,
Platina,	Fluoric,
Mercury,	Arſenic,
Arſenic,	Lactic,
Cobalt,	Acetic,
Sulphur.	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Antimony.

1. Sulphate of Antimony.

Sulphuric acid has no action on antimony in the cold. At a boiling temperature the acid is decompoſed; ſulphurous acid gas is emitted with effervеſcence, and if diſtilled in a retort to dryneſs, ſulphur is ſublimed. There remains a white oxide of antimony. If this maſs be waſhed with water, the acid which adheres to it is carried off, with a ſmall portion of the oxide, and what remains is the white oxide, which is inſoluble. By adding a large quantity of water to the ſolution, the oxide which it had carried off is precipitated; but this ſolution being evaporated yields no cryſtals. It is decompoſed by the earths and the alkalies, which precipitate a white oxide. Sulphuric acid, therefore, oxidates antimony, but does not ſeem to have the property of forming a ſalt.

2. Sulphite of Antimony.

Sulphurous acid with the aſſiſtance of heat, is decompoſed by antimony. The metal is oxidated, and there is formed a ſulphite of antimony. This ſalt may be alſo obtained by adding ſulphurous acid to the ſolution of antimony in muriatic acid. A white precipitate appears, which is inſoluble, of an acrid, bitter taſte, and is decompoſed by heat. When it is diſtilled in cloſe veſſels, it yields a little ſulphurous acid, then ſulphuric acid, and the reſiduum is a reddiſh brown maſs, which is ſoluble in fixed alkali, and may be precipitated by means of muriatic acid, into a hydroſulphuret of antimony.

3. Nitrate of Antimony.

Nitric acid is rapidly decompoſed by antimony, even in the cold. There is evolved a great quantity of nitrous gas, and ſometimes the rapidity of the oxidation is ſuch, that it is accompanied with actual combuſtion. The water alſo is partially decompoſed. The antimony is converted into white oxide. The hydrogen of the water combines with the azote of the acid, and forms ammonia, which combines with part of the nitric acid, and the compound is nitrate of ammonia. The ſmall quantity of oxide of antimony which is diſſolved in nitric acid, is precipitated by water, ſo that it adheres very ſlightly to the acid.

4. Muriate of Antimony.

Muriatic acid acts on antimony very feebly. By digeſting the metal with the acid for a long time, it diſſolves a ſmall quantity, and the ſolution becomes of a yellowiſh colour. The white oxide is more ſoluble in this

---

* *Journ. de Phyſique*, lv. p. 330.

‡ *Ibid.* lv. p. 330.

this acid, and forms with it a colourleſs ſolution. The firſt ſolution yields cryſtals by evaporation, in the form of ſmall needles, which are deliqueſcent, and ſublimed by heat, and are precipitated and decompoſed by water. The ſolution formed with the oxide is fixed in the fire, and cryſtallizes in brilliant plates. It is alſo decompoſed by water. Muriatic acid diſſolves more readily the ſulphuret of antimony, for it does not require the aid of heat. There is diſengaged a ſtrong odour of ſulphurated hydrogen gas. When the mixture is heated, the whole of the metal is diſſolved.

Nitromuriatic acid diſſolves antimony more readily than any of the acids which have been mentioned. This ſolution is colourleſs. The muriate of antimony which remains after the evaporation, by being diſtilled, comes over of a thicker conſiſtence, in proportion as it is concentrated. This muriate of antimony was formerly called *butter of antimony*. It is of a grayiſh white colour, and ſometimes cryſtallizes in four-ſided priſms. It is deliqueſcent in the air, and extremely cauſtic and corroſive. When it is diluted with water, a white powder is precipitated, which is the *powder of algaroth*.

5. Fluate of Antimony.

6. Borate of Antimony.

Fluoric and boracic acids have no action on antimony, but combine with its oxide, or precipitate it from its ſolution in acids, in the form of white powder, forming a fluate or borate of antimony.

7. Phoſphate of Antimony.

Phoſphoric acid combines with the oxide of antimony. The ſolution, by evaporation, yields a blackiſh green maſs.

8. Phoſphate of Lime and Antimony.

1686 James's powder. This triple ſalt is formed by calcining together equal parts of ſulphuret of antimony and the aſhes of bones; or, according to the proceſs recommended by Mr Chenevix, by diſſolving white oxide of antimony and phoſphite of lime in equal parts in muriatic acid; and then by adding this ſolution to a ſufficient quantity of diſtilled water, which contains pure ammonia. A precipitate is formed in the ſtate of white powder. This powder is nearly inſoluble in water. It has been long known as a diaphoretic and emetic, under the name of *James's powder*. According to the analyſis of Dr Pearſon, it is compoſed of

Phoſphate of lime,	43
Oxide of antimony,	57
	100

9. Carbonate of Antimony.

Unknown.

10. Arſeniate of Antimony.

By digeſting together arſenic acid and antimony, a white powder is obtained, which is arſeniate of antimony. Muriatic acid diſſolves this powder, but it may be ſeparated by adding water. This ſalt may be formed alſo, by adding an alkaline arſeniate to the ſolution of antimony in muriatic, tartaric, or acetic acids.

11. Molybdate of Antimony.

Muriate of antimony is precipitated by molybdic acid; and if the acid be not in exceſs, the precipitate is white.

12. Acetate of Antimony.

Acetic acid diſſolves a ſmall portion of the oxide of antimony, and according to ſome, yields ſmall cryſtals. The acetate of antimony has been employed as an emetic.

13. Oxalate of Antimony.

Oxalic acid combines with the oxide of antimony, and the ſolution affords cryſtals in the form of ſmall grains, which are ſcarcely ſoluble in water.

14. Tartrate of Antimony.

Tartaric acid alſo combines with a ſmall portion of the oxide of antimony, and affords a ſalt which aſſumes the form of jelly.

15. Tartrate of Potaſh and Antimony.

This triple ſalt was formerly prepared by boiling together the preparation of what was called crocus metallorum, and tartar, in water. 1687 Tartar emetic. But if the white oxide be mixed with its own weight of tartar, and the mixture boiled in 10 or 12 parts of water, till the tartar be ſaturated, and the ſolution filtered and evaporated, cryſtals are obtained, which are cryſtals of the tartrate of potaſh and antimony, which have been long and better known by the name of *tartar emetic*. This ſalt is of a white colour, and it cryſtallizes in regular tetrahedrons. It effloreſces by expoſure to the air, and is ſoluble in 80 parts of cold, and in half that quantity of water at the boiling temperature. When it is expoſed to heat, it is decompoſed. It is alſo decompoſed by the alkalies and their carbonates.

According to the analyſis of Thenard, this ſalt is compoſed of

Antimony,	38
Acid,	34
Potaſh,	16
Water,	8
	96, loſs 4.*

This ſalt has been greatly employed as a diaphoretic and emetic, from which property it has derived its name. An account of the mode of preparing a ſimilar powder, which, it is ſaid, was invented by an earl of Warwick, and became famous in Italy as a powerful and effectual medicine, was publiſhed in Italy, in the year 1620. The preparation of tartar emetic itſelf was firſt publiſhed in 1631.

16. Benzoate of Antimony.

Benzoic acid combines with the oxide of antimony, and by evaporating the ſolution, cryſtals are obtained. This ſalt is not altered by expoſure to the air, but it is readily decompoſed by heat.

II. Action of Alkalies, &c. on Antimony.

1688 Alkalies. 1. All the alkalies have a peculiar action on the ſulphuret of antimony. Sulphuret of antimony and potaſh

---

* *Ann. de Chim.* xxxviii. p. 39.

potaſh form a preparation which is known by the name of *kermes mineral*, a name which it derives from the red animal called *kermes*. This is prepared in the dry way by mixing together one part of ſulphuret of antimony and two of potaſh, and in proportion to the quantity of ſulphuret, add a ſixteenth part of ſulphur. Fuſe the mixture in a crucible, and pour it into an iron mortar. When it is cool reduce it to powder, and boil it in water; filter the liquid, and as it cools, a reddiſh brown powder is depoſited. Waſh the precipitate, firſt with cold, and then with boiling water, till it comes off inſipid. It may be prepared in the humid way, by boiling 10 or 12 parts of pure liquid alkali with two of ſulphuret of antimony, for half an hour, and then filtering the liquid; the kermes is depoſited as it cools.

The compound which is firſt formed, is a hydroſulphuret of potaſh and antimony. When boiling water is added in ſufficient quantity, the whole is diſſolved, but the ſolution becomes turbid by cooling, and divides into two parts; the one which is depoſited in the form of a reddiſh brown powder, is the kermes mineral, and the other, which remains in ſolution, containing a ſmaller proportion of ſulphur and oxide of antimony than the former, has been diſtinguiſhed by the name of *golden ſulphur*. The cauſe of the ſeparation is, that the alkali, if it is not in great quantity, cannot hold the ſulphurated oxide of antimony in ſolution while it is cold. What remains in ſolution after the ſpontaneous precipitation, contains a greater proportion of ſulphur, and leſs of the oxide of antimony. When an acid is added to this ſolution, another precipitate is formed, which is of an orange yellow colour, from the greater proportion of ſulphur, and on this account has been called *golden ſulphur*. Kermes mineral, or the hydroſulphuret of antimony, according to Thenard, contains the following proportions.

Brown oxide of antimony,	72.760
Sulphurated hydrogen,	20.298
Sulphur,	4.156
Water and loſs,	2.786
	100.000

From the analyſis of the ſame chemiſt, the golden ſulphur or *ſulphur auratum*, is alſo a hydroſulphuret, having a greater proportion of ſulphur, and a ſmaller proportion of the oxide. The component parts are the following.

Brown oxide of antimony,	68.300
Sulphurated hydrogen,	17.877
Sulphur,	12.000
	98.177 *

1689 Earths

2. The oxide of antimony has the property of combining with ſome of the earths during their vitrification, and communicating to them different ſhades of colour, more or leſs yellow and orange.

1690 Salts.

3. Moſt of the ſalts have a peculiar action on antimony or its ſulphuret. By fuſing in a crucible two parts of ſulphate of potaſh and one of antimony, the metal diſappears, and a vitreous maſs of a yellow colour is formed, which has a cauſtic property. Diſſolved in hot water, it affords, on cooling, a hydroſulphuret of antimony. The antimony has carried off the oxygen of the acid, and combined in the ſtate of oxide, with the ſulphuret of potaſh, which is formed by the ſulphur of the acid uniting with the potaſh during the proceſs.

The nitrates have a powerful action on antimony and its ſulphuret. A mixture of two or three parts of nitrate of potaſh and one of antimony in fine powder, well rubbed together in a mortar, produces a lively detonation, by throwing it on burning coals, or projecting it into a red-hot crucible, or heating it to redneſs in a cloſe veſſel. This detonation is accompanied with a bright white flame; and the antimony is ſtrongly oxidated by the oxygen of the nitre, which is decompoſed, and reduced to its alkaline baſe. The reſiduum of this detonation is a white ſcorified maſs, which being waſhed with water, leaves a portion of the oxide of antimony united to a ſmall quantity of potaſh, and affords beſides, another compound, with more of the alkali. The white matter which is firſt depoſited, has been called *waſhed diaphoretic antimony*. The water which remains holds in ſolution a portion of metallic oxide, united to the potaſh of the nitre. The oxide in this caſe performs the part of an acid. This compound has been found ſuſceptible of cryſtallization. It is decompoſed by acids, and the precipitate from it, which is an oxide of antimony, has been diſtinguiſhed by the names of *ceruſe of antimony*, *magiſtery of diaphoretic antimony*, and *pearly matter of Kerkringius*.

When equal parts of nitre and ſulphuret of antimony are treated in the ſame way, a vitrified maſs is obtained, ſimilar to what has been already deſcribed, by the name of *liver of antimony*.

III. Alloys.

Antimony enters into combination with the metals, and forms alloys with them, ſome of which are of conſiderable importance. But the alloys of antimony, with the metals already deſcribed, are either little known, or have been applied to no uſe. The alloys of cobalt and nickel, with antimony, have not been examined. With mangeneſe antimony forms but an imperfect alloy, and the compound of antimony and biſmuth is very brittle.

1691 Uſes of antimony.

Beſides the various preparations of antimony uſed in medicine, which are now comparatively but few in number, it is much employed in many arts. In the metallic ſtate it is of the greateſt importance as an alloy with other metals which will be afterwards mentioned. In the ſtate of oxide, it is much uſed in the fabrication of coloured glaſs, and of enamels for pottery and porcelain; particularly in forming different ſhades of brown, orange, and yellow colours. The oxide is mixed with different other metallic oxides, to produce various ſhades of colour.

Sect. XIII. *Of Tellurium and its Combinations.*

1692 Hiſtory.

1. In the year 1782, Muller of Richenſtein, in examining a gold ore, diſtinguiſhed by the names of *aurum paradoxum* and *aurum problematicum*, conjectured that it

---

* Ann. de Chim. xxxii. p. 277.

it contained a peculiar metal. Bergman, to whom this mineralogiſt had ſent a ſpecimen of the mineral, could not, from the ſmall quantity which he had received, aſcertain whether it was really a new metal, or merely antimony, with which it poſſeſſes ſome common properties. He inclined however to the former opinion. This mineral was analyzed by Klaproth in the end of the year 1797, the account of which was publiſhed in 1798. By this analyſis the conjecture of Muller was verified, and to the new metal Klaproth gave the name of *tellurium*.

2. This metal has been found in four different minerals. Firſt, in that in which Klaproth firſt detected it, which is called *white gold ore*, a mineral found in the mountains of Fatzbay in Tranſylvania. In this mineral the tellurium is combined with iron and gold. The ſecond is what is called *graphic gold ore*, which is compoſed of tellurium, gold, and ſilver. The third is known by the name of *yellow gold ore of Nagyag*. This mineral contains, beſides tellurium, gold, ſilver, and a little ſulphur. The fourth is a variety of the laſt, and is denominated *gray gold ore*. Beſides the metals in the former, it contains a little copper. To obtain the metal from the ore, a quantity of it is ſlightly heated with ſix parts of muriatic acid, and having added three parts of nitric acid, it is then boiled. A conſiderable efferveſcence takes place, and the whole is diſſolved. The ſolution being diluted with diſtilled water, is mixed with a ſolution of cauſtic potaſh, to diſſolve the precipitate; and there remains only a brown, flaky matter, formed of the oxides of gold and iron. The alkaline ſolution of the oxide of tellurium is mixed with muriatic acid, to ſaturate the potaſh, and there is depoſited a copious, very heavy, white powder. By forming this powder into a paſte with oil, and heating it to redneſs in a ſmall glaſs retort, the metal is obtained, partly fuſed and cryſtallized at the bottom of the retort, and partly ſublimed at the upper part.

1693 Properties. 4. Tellurium is of a white colour, ſomewhat reſembling lead, and has a conſiderable luſtre. It is very brittle, and may be eaſily reduced to powder. It has a lamellated texture, ſimilar to antimony. By ſlow cooling it aſſumes a cryſtalline form, eſpecially on the ſurface. Its ſpecific gravity is 6.115. It is one of the moſt fuſible of the metals, and when heated in cloſe veſſels, it boils readily, and is ſublimed in the form of brilliant globules, which adhere to the upper part of the veſſels.

1694 Action of heat. 5. When tellurium is heated by the action of the blow-pipe on charcoal, it burns, after being melted, with a lively flame, of a blue colour, and green at the edges. It is entirely volatilized in the form of a grayiſh white ſmoke, diffuſing a fetid odour, which Klaproth compares to that of radiſhes.

The oxide of tellurium is very fuſible. By heating it in a retort, a yellow, ſtraw-coloured maſs is obtained, which aſſumes a radiated texture on cooling. When the oxide is heated on charcoal, and ſurrounded with it, it is ſo rapidly reduced, that it is accompanied with a kind of exploſion.

1695 Sulphuret. 6. Tellurium enters into combination with ſulphur, and forms with it a ſulphuret. This ſulphuret is of a grayiſh colour, of a radiated ſtructure, and is eaſily cryſtallized.

I. Salts of Tellurium.

1. Sulphate of Tellurium.

One part of tellurium mixed in the cold, in a cloſe veſſel, with 100 parts of concentrated ſulphuric acid, communicates to it a beautiful crimſon colour. By adding water drop by drop to this ſolution, the colour vaniſhes, and the metal is depoſited in the form of black flakes. When the ſolution is heated, the colour alſo diſappears, and the oxide of tellurium is gradually precipitated in the ſtate of white powder; but when diluted ſulphuric acid is employed, with the addition of a ſmall quantity of nitric acid, a larger portion of tellurium is diſſolved. The ſolution is tranſparent and colourleſs, and is not decompoſed by adding water.

2. Nitrate of Tellurium.

Nitric acid readily diſſolves tellurium, and forms a tranſparent, colourleſs ſolution, which being concentrated, ſpontaneouſly affords ſmall, light, white, needle-ſhaped cryſtals, diſpoſed in a dendritical form.

3. Muriate of Tellurium.

Nitromuriatic acid very readily diſſolves tellurium, which is precipitated by adding a conſiderable quantity of water in the form of oxide. This is a white powder, which is ſoluble in muriatic acid.

The infuſion of nut-galls added to ſolutions of tellurium in acids, occaſions a flaky precipitate, which is of a yellow colour.

II. Action of Alkalies and Earths.

1696 Alkalies. 1. All the pure alkalies precipitate the ſolutions of tellurium in acids, in the form of white oxide. With an exceſs of alkali the precipitate is re-diſſolved. With the alkaline carbonates a precipitate is obtained, which is much leſs ſoluble in exceſs of alkali.

2. The alkaline ſulphurets added to ſolutions of tellurium in acids, produce a brown or black precipitate, as the metal is more or leſs oxidated. This precipitate ſometimes reſembles the hydroſulphurets of antimony. The hydroſulphuret of tellurium thus formed, expoſed to heat on burning coals, burns with a ſmall blue flame, and is volatilized in white ſmoke. No precipitate is formed by the pruſſiate of potaſh.

1697 Earths. 3. The action of the oxide of tellurium with the earths is not known; but from its great fuſibility, it has been ſuppoſed that it is ſuſceptible of forming a vitreous matter with the earths, and communicating to them a ſtraw colour.

III. Action of Metals.

The alloys of tellurium are unknown.

1698 Precipitated by zinc and iron. Tellurium is ſeparated from its ſolutions in acids, by zinc and iron, in the form of ſmall, black flakes, which may be reduced to the metallic ſtate on burning charcoal, or even by ſimple friction. Antimony cauſes a ſimilar precipitation in a ſolution of nitrate and ſulphate of tellurium. Tin produces a ſimilar effect.

1699 Uſes. Tellurium has hitherto been found in ſuch ſmall quantity, that it has not yet been applied to any uſe. Were it found in abundance, it has been ſuppoſed, from its eaſy fuſibility, that it might be of conſiderable importance in ſome of the arts.

Sect. XIII. *Of Mercury and its Combinations.*

1700 Hiſtory. 1. Mercury appears to have been known from the earlieſt ages. By comparing its properties with ſilver, and being in the fluid ſtate, it has been called *quickſilver*. Mercury was long the ſubject of the reſearches of the alchemiſts, with the view of diſcovering the method of tranſmuting it into gold or ſilver. It was ſuppoſed to approach ſo near to theſe metals, particularly to the latter, in its nature, that all that was wanted for this tranſmutation, was to fix it, or to bring it to the ſolid ſtate. In conſequence of the numerous experiments to which it was ſubjected, and the great varieties of forms it aſſumed, they regarded it as the principle of all other bodies, and one of the elements of nature. It was ſuppoſed to exiſt in all metals, and alſo to form one of the component parts of many bodies. Hence, according to this theory, there were two kinds of mercury; the one the principle of a great number of bodies, and the other common mercury, or the metal known by that name. Hence, according to Beccher, it was called *the mercurial principle*, or *the mercurial earth*. But however extravagant the reſearches of the alchemiſts may now be conſidered to have been, it is to their labours that chemiſtry is indebted for the knowledge of many important properties and combinations of this metal.

1701 Ores. 2. Mercury is found in four different ſtates. In the metallic ſtate, alloyed with other metals, combined with ſulphur, and with muriatic acid. 1. Native or virgin mercury is found in the cavities or clefts of rocks, in ſtrata of clay, or of chalk, in the form of liquid globules, which are eaſily diſtinguiſhed by their brilliancy. 2. It is found more frequently alloyed with other metals, or, as it is called when mercury is combined with a metal, *amalgamated*, and moſt frequently with ſilver. 3. A frequent ore of mercury is the red ſulphuret, which is known by the name of *cinnabar*. The ſulphuret of mercury is of various colours, from vermilion red to brown. Sometimes it effloreſces on the ſurface of the ore, when it is called *flowers of cinnabar*, or *native vermilion*. 4. The fourth ore of this metal is the muriate. This ſalt is white and brilliant, and of a lamellated ſtructure.

1702 Analyſis. 3. Native mercury is frequently alloyed with other metals; it is therefore of importance to be able to aſcertain the proportions. For this purpoſe it is to be diſſolved in nitric acid. If it contain gold, this metal remains in a ſtate of powder at the bottom of the veſſel. If alloyed with biſmuth, it may be precipitated with water, which does not ſeparate the oxide of mercury. Silver is detected by precipitating the ſolution by means of muriate of ſoda. The muriate of ſilver and the muriate of mercury fall down together; but the latter being more ſoluble in water than the former, may be eaſily ſeparated.

The ſulphuret of mercury may be decompoſed by boiling it with eight times its weight, of a mixture of three parts of nitric, and one of muriatic acid; the metallic part is diſſolved, and the ſulphur remains in the ſtate of powder.

1703 To diſcover its purity. It may be known whether the mercury has been adulterated with other metals, by its dull and leſs brilliant luſtre, and by its ſoiling the hands, or white bodies on which it is rubbed, and by its dividing with more difficulty into round globules, which appear flat and uneven, adhere to the veſſels in which they are agitated, and when poured along a ſmooth ſurface, by their *dragging* a tail. Mercury is alſo impure, when the globules do not readily run together, and when it is agitated with water, ſeparating from it a black powder.

1704 Purification. To procure mercury in a ſtate of purity, or to revive it, as it is called, two parts of cinnabar and one of filings of iron are well triturated together, and diſtilled in an iron retort, introducing the beak of the retort into a receiver, with water. The iron has a greater affinity for the oxygen and the ſulphur of the mercury than the latter. The mercury, therefore, riſes in vapour, and is condenſed by the water. There remains in the retort a ſulphuret of iron, in which the metal is a little oxidated. The mercury thus obtained, being dried and paſſed through a ſkin, is very pure and brilliant.

1705 Properties. 4. Mercury is of a white colour, is one of the moſt brilliant of the metals, and when its ſurface is clean and not tarniſhed, makes a good mirror. Next to gold, platina, and tungſten, it is the heavieſt of the metals, having a ſpecific gravity $=13.568$. It has no perceptible taſte or ſmell.

5. At the ordinary temperature of the atmoſphere mercury is always in the liquid ſtate; but when it is expoſed to a degree of cold equal to -39° it becomes ſolid. This was firſt diſcovered in the year 1759 by the academicians of Peterſburgh. Similar experiments have ſince been frequently repeated. In 1772, Pallas ſucceeded in the congelation of mercury at Kraſnojark, by a natural cold equal to $-55\frac{1}{2}^\circ$ Fahrenheit. Mercury was alſo congealed by a natural cold in 1775 at Hudſon's bay. The freezing of mercury is now a common experiment by means of artificial cold, and the method of producing this has been already deſcribed, in treating of freezing mixtures. In ſome experiments which have been made on the congelation of mercury, it was remarked, that a ſlight ſhock was communicated to the perſon who held the tube containing the metal, by its ſudden contraction at the moment it became ſolid. Mercury cryſtallizes in very ſmall octahedrons. It appears to be malleable, for by ſtriking it with a hammer in the ſolid ſtate, it was flattened and extended.

1706 Action of heat. 6. At the temperature of 660° mercury boils, and is then converted into vapour. This vapour, like common air, is inviſible and elaſtic. 1707 Oxides. When mercury is expoſed to the air, the ſurface becomes tarniſhed, and is covered with a black powder. This change is owing to the abſorption of the oxygen of the air, and the converſion of the mercury into an oxide. This proceſs is greatly promoted by applying heat to the mercury, or by ſhaking it, ſo that it may be brought in contact with the air. 1708 Black. To this black powder, which is the firſt degree of the oxidation of the metal, the name of *ethiops per ſe* was formerly given, becauſe it is obtained without the aſſiſtance of any other ſubſtance. According to Fourcroy, this oxide contains

Mercury,	96
Oxygen,	4
	100

1709 Red.

By a ſtrong heat the oxygen is driven off, and the mercury is reduced to the metallic ſtate: but when this oxide is expoſed to a more moderate degree of heat, it combines with more oxygen, and is converted into the red oxide, ſo called from its colour. This oxide may alſo be obtained, by expoſing a quantity of mercury for ſome length of time in a veſſel provided with a long narrow neck, by which means the vapours of the mercury are prevented from eſcaping, while the air is admitted. By this proceſs the mercury is alſo converted into the red oxide; and, obtained in this way, it was formerly called *precipitate per ſe*, or *red precipitate*. This oxide may alſo be obtained by diſſolving mercury in nitric acid, evaporating to dryneſs, and expoſing the maſs to a very ſtrong heat, to drive off the acid. What remains being reduced to powder, is the red oxide of mercury, or red precipitate. This oxide, according to Fourcroy, contains one-tenth of its weight of oxygen. It is of an acrid diſagreeable taſte, and has ſo powerful an effect upon animal matters, that it may be conſidered as a poiſon. It corrodes the ſkin with which it comes in contact. When this oxide is expoſed to heat, it is decompoſed; part of its oxygen is given out, and it is converted into the black oxide. Even by expoſure to the light of the ſun, this change is effected, as it paſſes through different ſhades of colour.

1710 Action of hydrogen.

7. Mercury does not enter into combination with azote, hydrogen, or carbone; but if hydrogen gas be kept in contact with the red oxide, it is gradually converted into the black oxide. If hydrogen gas be made to paſs through a tube heated to redneſs, containing red oxide of mercury, a detonation takes place. The oxygen and hydrogen combine together to form water, while the mercury is reduced to the metallic ſtate. This oxide may be alſo reduced by means of charcoal, with the aſſiſtance of heat. The oxygen of the oxide combines with carbone, and forms carbonic acid, and the mercury is revived.

1711 Phoſphuret.

8. Phoſphorus combines with mercury with difficulty. Pelletier took equal parts of phoſphorus and red oxide of mercury, and introduced them into a matraſs, to which he added a little water, to cover the mixture. It was expoſed to the heat of a ſand bath, and agitated from time to time. The oxide ſoon became black, and united to the phoſphorus. The water retained phoſphoric acid; ſo that it appears to be a compound of phoſphorus and the black oxide of mercury. The phoſphuret of mercury thus formed, becomes ſoft in boiling water, and acquires ſome conſiſtence in the cold. When it is heated, it is decompoſed. The phoſphorus and the mercury are ſeparately emitted. Expoſed to a dry air, it diffuſes white vapours, which have the odour of phoſphorus.

1712 Sulphuret.

9. Mercury combines readily with ſulphur, either by ſimple trituration in the cold, or by the action of heat. One part of mercury and two of ſulphur, triturated together in a mortar, the mercury ſoon diſappearing, form a black powder, which was formerly diſtinguiſhed by the name of *ethiops mineral*. Fourcroy is of opinion, that in this proceſs the mercury is oxidated, and the ſulphur is combined with the black oxide; in ſupport of which, he ſtates that the ſulphur cannot be ſeparated from the mercury, but by ſome chemical action. Berthollet ſuppoſes that this ſubſtance contains ſulphurated hydrogen, and hence it is concluded that *ethiops mineral* is a hydrogenous ſulphuret of mercury, compoſed of mercury, ſulphur, and ſulphurated hydrogen.

1713 Cinnabar.

When this compound is heated in an open veſſel, the ſulphur, which is in a ſtate of minute diviſion, takes fire, and is ſoon reduced to ſulphurous acid gas. The mercury is at the ſame time more ſtrongly oxidated; is converted to a deep violet-coloured powder; and if in this ſtate it be heated in a matraſs, it is ſublimed in the form of a deep red cake, of a brilliant, cryſtalline appearance. This ſubſtance was formerly called *artificial cinnabar*, or, in the preſent language of chemiſtry, *red ſulphurated oxide of mercury*. Various proceſſes have been given for the preparation of this ſubſtance. Seven parts of mercury ſqueezed through leather to purify it, are to be fuſed with one part of ſulphur in an earthen veſſel, agitating the mixture till it is completely reduced to the black ſulphurated oxide. Introduce this into a matraſs, placed in a crucible furniſhed with ſand, and expoſe it gradually to the heat of a furnace, which is to be increaſed till the matter is ſublimed, and collected at the top of the veſſel. It is then removed, and when the veſſel is broken, a red maſs is obtained, with a degree of beauty and brilliancy in proportion to the temperature which has been employed, and the ſmall quantity of ſulphur which it retains. Fourcroy conſiders this as a compound of ſulphur and the red oxide of mercury, but according to Prouſt, it is a ſulphuret of mercury; that is, a compound of ſulphur and metallic mercury. Its component parts are,

Mercury	85
Sulphur	15
	100

1714 Properties.

This ſulphuret is of a fine ſcarlet colour. It is not altered by expoſure to the air, and is inſoluble in water. The ſpecific gravity is 10. When a ſufficient degree of heat is applied to it, it takes fire, and burns with a blue flame. When reduced to powder, it is then called vermilion, which is well known as a paint.

1715 Vermilion.

1716 Affinities.

10. The order of the affinities of mercury is the following.

Mercury.	Oxide of Mercury.
Gold,	Muriatic acid,
Silver,	Oxalic,
Tin,	Succinic,
Lead,	Arſenic,
Biſmuth,	Phoſphoric,
Platina,	Sulphuric,
Zinc,	Saclactic,
Copper,	Tartaric,
Antimony,	Citric,
Arſenic,	Sulphurous,
Iron.	Nitric,
	Fluoric,
	Acetic,
	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Mercury.

1. Sulphate of Mercury.

1717 Different ſulphates.

1. Sulphuric acid forms ſalts with the different oxides of mercury, and with different proportions of theſe oxides, ſo that there is a conſiderable variety of the ſulphates of mercury. This ſeems to depend on the nature of the action between ſulphuric acid and mercury, according to the temperature in which the combination is made, and the quantity of acid employed.

1718 Preparation.

2. Sulphuric acid has no effect on mercury in the cold; but if two parts of mercury and three of ſulphuric acid be introduced into a retort, and expoſed to heat, an effervescence takes place, with the evolution of ſulphureous acid gas. If the proceſs be ſtopped, when the mercury is converted into a white maſs, and there yet remains part of the liquid, it is found to be acrid and corroſive, and it reddens vegetable blues. This is the ſulphate of mercury with exceſs of acid. This acidulous ſulphate of mercury contains very different proportions of ſulphuric acid, according to the original quantity employed. If this ſulphate be waſhed with a ſmaller quantity of water than is neceſſary for its complete ſolution, and if this be repeated till the water no longer changes vegetable blues, there remains a white ſalt without acidity, and which is much leſs acrid and corroſive than the ſaline maſs from which it is obtained. This may be conſidered as a neutral ſulphate of mercury.

1719 Properties.

3. It is of a white colour, cryſtallizes in plates, and in fine, needle-ſhaped priſms. The taſte is not acrid. It is ſoluble in 500 parts of cold water, and in one half that quantity of boiling water. When cryſtallized, it is compoſed of

Mercury	75
Oxygen	8
Sulphuric acid	12
Water	5
	100

It is ſoluble both in cold and hot water, without being decompoſed. The pure alkalies and lime water, occaſion a precipitate of a grayiſh-black powder. When ſulphuric acid is added, it is then reduced to the ſtate of acidulous ſulphate, and its ſolubility increaſes in proportion to the additional quantity of acid. A twelfth part of acid renders it ſoluble in 157 parts of cold water, and in 33 of boiling water. But if $\frac{1}{4}$ of this quantity of cold water be added, it combines with the whole exceſs of acid, and forming a liquid of greater denſity than when it is diluted with 157 parts of water neceſſary for its complete ſolution, it diſſolves much more of the ſulphate of mercury, and brings the ſalt to a ſtate of greater acidity. It then requires 500 parts of water for its ſolution.

1720 A different ſalt by continuing the heat.

4. But if the ſame proportions of ſulphuric acid and mercury, namely, three parts of acid, and two of mercury, be expoſed for a longer time to the action of heat, a greater proportion of ſulphuric acid is decompoſed, and the mercury combines with a greater proportion of oxygen. The ſalt thus obtained, poſſeſſes different properties from the former. It cryſtallizes in ſmall priſms, and when it is neutralized, it is of a dirty-white colour; but if it be obtained in the dry ſtate, it is pure white, and in this ſtate it is combined with an exceſs of acid. It is then deliqueſcent in the air; but, in the neutral ſtate, it undergoes no change. When hot water is added to this ſalt, it is converted into a yellow powder, which has been long diſtinguiſhed by the name of *turpeth mineral.*

5. It was formerly ſuppoſed that turpeth mineral, which is obtained by the addition of warm water to this ſalt, was a ſimple oxide of mercury, without any portion of ſulphuric acid. Fourcroy mentions, that Rouelle firſt conjectured, that it was combined with a certain portion of the acid, and that his experiments have verified and confirmed this conjecture; for in treating turpeth mineral, after being well waſhed with muriatic acid, this ſolution precipitates by means of muriate of barytes, a ſulphate of barytes from this baſe. Fourcroy denominates this ſalt *ſulphate of mercury with exceſs of acid*, or *yellow ſulphate of mercury.* It is ſoluble in 600 parts of boiling water; but another ſulphate of mercury remains in the ſolution. This contains an exceſs of acid, and is therefore more ſoluble in water.

1721 Three ſulphates.

6. From a ſeries of experiments which Fourcroy made on this ſubject, he concludes, that there are three diſtinct ſulphates of mercury. 1. The firſt is the neutral ſulphate of mercury, which cryſtallizes, is ſoluble in 500 parts of cold water, and forms a copious precipitate with the alkalies, which is not decompoſed by nitric acid, but forms a mild muriate of mercury with the addition of muriatic acid. 1722 Acidulous ſulphate. 2. The acidulous ſulphate of mercury, which is more ſoluble than the former, is precipitated of an orange colour by means of the alkalies. The exceſs of acid is removed, and alſo a portion of the ſalt, with $\frac{1}{4}$ of the water neceſſary for its complete ſolution. The neutral ſulphate of mercury remains behind, and is not decompoſed by means of the nitric acid. 1723 Subſulphate. 3. The third ſulphate of mercury contains an exceſs of baſe, or of the oxide of mercury. It is of a yellow colour, ſoluble in 200 parts of water, and is precipitated of a gray colour by the alkalies. It is decompoſed by the nitric acid, and the muriatic acid converts it into a hyperoxymuriate of mercury.

2. Sulphate of Ammonia and Mercury.

1724 Preparation.

This triple ſalt is formed by adding ammonia to a ſolution of neutral ſulphate of mercury. A copious gray precipitate is thrown down, which, being expoſed to the light of the ſun, is partly reduced to the metallic ſtate, and partly to that of a gray powder. This laſt is the ſulphate of ammonia and mercury. It is ſoluble in ammonia; and by evaporation, brilliant polygonal cryſtals are formed. Or, if a large quantity of water be added to the ſolution, it becomes white and milky, and there is precipitated the ſame ſalt, but without any regular form. 1725 Properties. This ſalt has a pungent, auſtere taſte. When it is heated, it gives out ammonia, azotic gas, a ſmall quantity of metallic mercury, and a little ſulphite of ammonia. There remains in the retort yellow ſulphate of mercury. 1726 Compoſition. According to the analyſis of Fourcroy, this triple ſalt is compoſed of

Sulphuric

Sulphuric acid	18
Mercury	39
Ammonia	33
Water	10
	100

3. Nitrate of Mercury.

1727 Preparation.

1. Nitric acid is rapidly decompoſed by mercury. It is accompanied with efferveſcence, and the evolution of nitrous gas. The mercury combines with part of the oxygen of the acid; it is thus oxidated, and is then diſſolved in the remaining portion of the acid. This ſolution of mercury in nitric acid, when it is made in the cold, is colourleſs, very heavy, and ſo extremely cauſtic, that it has been employed as an eſcharotic, under the name of *mercurial water*. It produces an indelible browniſh black ſpot on all animal and vegetable ſubſtances. By ſpontaneous evaporation it affords regular tranſparent cryſtals, compoſed of two four-ſided pyramids, truncated near their baſes, and on the four angles which reſult from the union of the pyramids. But different cryſtals are formed, according to the nature of the ſolution, and the evaporation, whether it has been more ſlowly or more rapidly conducted. When this ſolution of mercury in nitric acid is made in the cold, the compound formed is a nitrate of mercury without exceſs of the oxide or baſe; but if mercury be added to this ſolution, and the action be aided by heat, a new portion of the oxide is diſſolved. It is then a nitrate of mercury with exceſs of baſe. Fourcroy diſtinguiſhes three nitrates of mercury. 1728 Three nitrates. 1. Nitrate of mercury neutralized. From this regular cryſtals are obtained, and it is not precipitated by water. 2. The acidulous nitrate of mercury, or with exceſs of acid. This is obtained by diſſolving the firſt in water containing nitric acid, or by adding this acid to the other nitrates. 3. The nitrate of mercury with exceſs of oxide. This exiſts in the ſolution precipitated by water, or by expoſing the other nitrates to the action of heat. In this way is produced what was formerly called *nitrous turpeth*.

2. Theſe different nitrates of mercury poſſeſs many common properties, but are ſufficiently diſtinguiſhed by others, and particularly by their decompoſition. When the nitrate of mercury is placed upon burning coals, it detonates feebly, although with a vivid white flame, when it has been ſufficiently dried; but when it is moiſt it melts, blackens, extinguiſhes that part of the coal which it touches, and throws out ſmall red ſparks, with a ſlight decrepitation about the dried edges of the maſs. The nitrate of mercury with exceſs of oxide poſſeſſes a ſtill more feeble detonating property. The nitrate of mercury with exceſs of acid boils up, melts very rapidly, ſwells greatly, and exhales red vapours, with very little detonation. If the nitrate of mercury, neutralized, be heated in a crucible without any combuſtible matter, it melts, exhales nitrous gas, becomes of a deep yellow colour, then paſſes to an orange, and at laſt is converted into a deep red. In this ſtate it was formerly called *red precipitate*. It is the red oxide of mercury, which is obtained by the decompoſition of the nitrate.

3. The pure nitrate of mercury expoſed to the air in the ſtate of cryſtals, is ſoon changed. It gradually abſorbs oxygen from the atmoſphere, and paſſes from a white to a yellow colour. This is the *nitrous turpeth*. It is a yellow oxide of mercury combined with a ſmall portion of nitric acid, or a nitrate of mercury with exceſs of baſe. The yellow colour becomes deeper with the addition of boiling water. The nitrous turpeth, it has been obſerved, contains a greater quantity of oxygen than that which is prepared by ſulphuric acid, and from this circumſtance it is more readily converted into red oxide by the action of heat.

1729 Decompoſition.

4. The nitrate of mercury is decompoſed by all the alkalies, but with different phenomena, according to the ſtate of the combination, and particularly the degree of oxidation of the baſe. Bergman has diſtinguiſhed the two ſolutions of mercury, that which is not precipitated by water, from that which is precipitated by the different products which are obtained by means of alkalies. The nitrate of mercury affords with potaſh, a yellowiſh white oxide; with carbonate of potaſh, a white oxide; and with ammonia, an oxide of a dark gray colour. Sulphuric acid and the ſulphates occaſion a precipitate in form of a white powder. Muriatic acid and the muriates give a thick maſs reſembling curd. But the ſolution which is precipitated by water, and which is more acrid, and leſs diſpoſed to cryſtallize, affords precipitates by means of the fixed alkalies, of a deeper yellow or brown colour. By means of ammonia, a white precipitate is formed. By means of the ſulphuric acid and the ſulphates, a yellow precipitate, and by the muriatic acid, a more copious, curdled matter. Fourcroy has obſerved in the decompoſition of nitrate of mercury with exceſs of acid, that a precipitate in the ſtate of black powder is formed, with a great addition of the alkali; but if it be added in ſmall quantity, the precipitate is white or gray. A copious precipitate is obtained, from the clear ſupernatant ſolution, by diluting it with water. The ſame white precipitate is obtained, by mixing together nitrate of mercury and nitrite of ammonia. By evaporating the liquid, which is rendered turbid by the addition of water, ſix-ſided priſmatic cryſtals are depoſited, as the ammonia is volatilized. The white precipitate is a brittle ſalt, which has very little ſolubility, having an exceſs of oxide, of mercury, and ammonia. 1730 Compoſition. The component parts of this ſalt, according to Fourcroy are,

Acid and water	15.80
Oxide of mercury	68.20
Ammonia	16.00
	100.00

1731 Howard's fulminating powder.

5. From a ſolution of mercury in nitric acid, Mr Howard prepared a fulminating powder poſſeſſed of peculiar properties; the proceſs which he found to anſwer beſt, is the following:

1732 Preparation.

“ One hundred grains, or a greater proportional quantity, of quickſilver (not exceeding 500 grains) are to be diſſolved, with heat, in a meaſured ounce and a half of nitric acid. This ſolution being poured cold upon two meaſured ounces of alcohol, previouſly introduced into any convenient glaſs veſſel, a moderate heat is to be applied until an efferveſcence is excited. A white fume then begins to undulate on the ſurface of the liquor; and the powder will be gradually precipitated, upon the ceſſation of action and re-action. The precipitate is to be immediately collected on a filter, well waſhed with diſtilled water, and carefully dried in a heat not much exceeding that of a water bath. The immediate edulcoration of the powder is material, becauſe it is liable to the re-action of the nitric acid; and, whilſt any of that acid adheres to it, it is very ſubject to the influence of light. Let it alſo be cautiouſly remembered, that the mercurial ſolution is to be poured upon the alcohol.

"I have recommended quickſilver to be uſed in preference to an oxide, becauſe it ſeems to anſwer equally, and is leſs expenſive; otherwiſe, not only the pure red oxide, but the red nitrous oxide and turpeth may be ſubſtituted; neither does it ſeem eſſential to attend to the preciſe ſpecific gravity of the acid or the alcohol. The rectified ſpirit of wine and the nitrous acid of commerce never failed, with me, to produce a fulminating mercury. It is indeed true, that the powder prepared without attention, is produced in different quantities, varies in colour, and probably in ſtrength. From analogy, I am diſpoſed to think the whiteſt is the ſtrongeſt; for it is well known, that black precipitates of mercury approach the neareſt to the metallic ſtate. The variation in quantity is remarkable; the ſmalleſt quantity I ever obtained from 100 grains of quickſilver being 120 grains, and the largeſt 132 grains. Much depends on very minute circumſtances. The greateſt product ſeems to be obtained, when a veſſel is uſed which condenſes and cauſes moſt ether to return into the mother liquor; beſides which, care is to be had in applying the requiſite heat, that a ſpeedy and not a violent action be effected. One hundred grains of an oxide are not ſo productive as 100 grains of quickſilver.

1733 Properties. This powder, ſtruck on an anvil with a hammer, explodes with a ſtunning diſagreeable noiſe, and with ſuch force, as to indent both the hammer and the anvil. Half a grain or a grain, if quite dry, is as much as ought to be uſed on ſuch an occaſion. 1734 Decompoſition. The ſhock of an electric battery, ſent through five or ſix grains, produces a very ſimilar effect. The powder explodes at the 368th degree of Fahrenheit's thermometer. A quantity of it, ſufficient to diſcharge a bullet from a gun, with a greater force than an ordinary charge of gunpowder, always burſts the piece. Ten grains of the powder, exploded in a glaſs globe, produce only four cubic inches of air, conſiſting of carbonic acid gas and nitrogene, or azotic gas.

This powder is decompoſed by ſulphuric, nitric, and muriatic acids. When concentrated ſulphuric acid is poured upon it, an immediate exploſion takes place. According to the experiments of Mr Howard, this powder conſiſts of oxalate of mercury, and nitrous etheriſed gas. 1735 Compoſition. But it appears that the nature of the component parts varies with the different modes which are followed in its preparation. When it is prepared with little heat, it conſiſts of nitric acid, oxide of mercury, and a peculiar vegetable ſubſtance; but by continuing the heat during the fermentation, a greeniſh colour is communicated to the powder. It is then found to be compoſed of ammonia, oxide of mercury, and a greater proportion of the vegetable matter. Its detonating power is more feeble, and it gives out a blue flame when placed on hot coals. By boiling the mixture for half an hour, it is compoſed of oxalate of mercury, and a ſmall proportion of vegetable matter; does not detonate, but decrepitates when it is heated. *

4. Muriate of Mercury.

1736 This compound long known. 1. Muriatic acid has no action whatever on mercury; but it combines readily with its oxides, and forms ſalts which have been the ſubject of reſearch among chemiſts, almoſt in every age. The muriates of mercury were known to the Arabians in the 10th and 11th centuries. They were the firſt objects of ſtudy and examination with the alchemiſts, in their ſearch after the philoſophers ſtone; and ſince chemiſtry aſſumed the form of a ſcience, they have greatly occupied the attention of philoſophers, in diſcovering their nature and properties.

1737 Two muriates. 2. There are two compounds of muriatic acid and the oxides of mercury, which poſſeſs very different properties, according to the degree of oxidation of the mercury.

1738 Preparation. 3. Muriatic acid precipitates the oxides of mercury from their ſolutions in ſulphuric and nitric acids. If muriatic acid be added to the yellow ſulphate of mercury, or to the nitrate of mercury which is precipitable by water, a muriate of mercury is obtained, which is ſoluble in water, and which, on account of its properties, was formerly called *corroſive ſublimate*, or *corroſive muriate of mercury*. But if muriatic acid be added to the acidulous ſulphate of mercury, or to the nitrate of mercury which affords no precipitate with water, a white, inſoluble, inſipid precipitate is obtained, which was formerly called *ſweet mercury* or *calomel*, and is now known by the name of *ſubmuriate*, and ſometimes *ſweet muriate of mercury*.

1739 Of the muriate. 4. The muriate of mercury, or corroſive ſublimate, may be prepared by the following proceſs. Boil two parts of mercury with two and a half of ſulphuric acid in a matraſs, with the heat of a ſand bath, to dryneſs. Let this dry maſs be mixed with four parts of dried muriate of ſoda, and let the whole be ſublimed in a glaſs veſſel, by gradually increaſing the heat. In the firſt part of this proceſs, part of the ſulphuric acid is decompoſed; the mercury combines with the oxygen and forms an oxide, which is diſſolved in the undecompoſed part of the ſulphuric acid, and a ſulphate of mercury is thus obtained. The muriate of ſoda being mixed with this ſalt, produces another decompoſition. The muriatic acid combines with the mercury, forming the muriate of mercury, which is ſublimed; and the ſulphuric acid of the ſulphate of mercury combines with the ſoda, forming a ſulphate of ſoda, which remains behind.

1740 Properties. 5. The muriate of mercury thus obtained, forms a beautiful white, ſemitranſparent maſs, which is found to be compoſed of ſmall priſmatic cryſtals in the form of needles. It may be obtained by evaporation, in the form of cubes or rhomboidal priſms, or four ſided priſms, having the alternate ſides narrower, and terminated by two-ſided ſummits. The taſte is extremely acrid and cauſtic, and the metallic impreſſion remains long on the tongue. The ſpecific gravity is 5.1398. It is ſoluble in 20 parts of cold water, and in leſs weight of boiling water. This ſalt is not altered by expoſure

---

* *Phil. Tranſ.* 1800,

to the air ; and, when it is ſublimed by heat, it remains unchanged. It is ſoluble in ſulphuric, nitric, and muriatic acids, and, when theſe ſolutions are evaporated, the muriate of mercury is obtained unaltered. It is precipitated by all the alkalies and earths, of an orange-yellow colour, which gradually changes to a brick-red. The carbonates of the fixed alkalies afford a permanent yellow colour. Ammonia forms with it a triple ſalt. The component parts of this ſalt, according to Mr Chenevix, are,

1741 Compoſition.

Oxide of mercury	82
Acid	18
	100

Muriate of mercury is one of the moſt violent poiſons known. When taken internally, it produces nauſea and vomiting, with ſevere pain, and, in a ſhort time, corrodes the ſtomach and bowels. Externally, it is employed as an eſcharctic for deſtroying fungous fleſh. It ſublimes readily when heated, and is extremely injurious in the ſtate of vapour, to thoſe who breathe it.

1742 Preparation.

Submuriate of Mercury.—This ſalt is prepared by triturating together in a glaſs mortar, four parts of muriate of mercury or corroſive ſublimate, with three of mercury, till the latter diſappear. When this is formed into an uniform maſs, it is put into a matraſs, of which it ſhould fill $\frac{1}{3}$, and it is to be ſublimed with the heat of a ſand bath. When the proceſs is finiſhed, the phial is broken ; and the white matter at the upper part of the veſſel, and the red matter at the bottom, are to be ſeparated, and the remaining part of the maſs is to be ſublimed, and afterwards reduced to a fine powder, which is to be well waſhed with boiling water.

In this proceſs, it is obvious, that the mercury which is added, combines with part of the oxygen of the oxide of mercury, formerly combined with the muriatic acid ; and the whole of the oxide of mercury having now a ſmaller proportion of oxygen, is combined with a ſmaller proportion of muriatic acid. This will appear from the proportions of its component parts, as they have been aſcertained by Mr Chenevix.

1743 Compoſition.

Oxide of mercury in calomel contains,

Mercury	89.3
Oxygen	10.7
	100.0

Calomel is compoſed of

Oxide of mercury	88.5
Muriatic acid	11.5
	100.0

1744 Properties.

Submuriate of mercury, or calomel, is generally in the form of a white, ſolid maſs ; but it is ſuſceptible of cryſtallization in four-ſided priſms, terminated by pyramids. It has ſcarcely any taſte, has no poiſonous property, and is very little ſoluble in water. The ſpecific gravity is 7.1758. It becomes dark coloured by expoſure to light, is phoſphoreſcent when rubbed in the dark, and requires a higher temperature for its ſublimation than the muriate of mercury. It is converted into the muriate or corroſive ſublimate, by the nitric and oxymuriatic acids.

1745 Different names.

This ſalt, which is now generally known in the ſhops, by the name of *calomel* or *ſweet mercury*, was formerly deſcribed under a great variety of names, derived from its effects, or the mode of its preparation. In the beginning of the 17th century, it was regarded as an important ſecret. But, in the year 1608, Beguin deſcribed it very accurately, in his *tyrocinium chemicum*, under the name of *the dragon tamed*, on account of the corroſive ſublimate from which it was prepared, being deprived of its poiſonous and deſtructive qualities. At different periods it was diſtinguiſhed by other names, as *aquila alba*, *aquila mitigata*, *manna metallorum*, *panchymagogus quercitanus*, &c. The uſe of this ſalt as a purgative, and indeed in all caſes where mercurial preparations are required, is well known.

5. Muriate of Ammonia and Mercury.

1746 Preparation.

If ammonia be added to a ſolution of muriate of mercury, or corroſive ſublimate, a white precipitate is obtained, which is a triple ſalt, formed by the combination of the ammonia with the muriate of mercury. This white precipitate has at firſt an earthy taſte, which becomes afterwards metallic and diſagreeable. It ſeems to be inſoluble in water. Sulphuric acid forms with this triple ſalt, corroſive ſublimate, and ſulphate of ammonia and mercury. Nitric acid converts it into corroſive ſublimate and nitrate of ammonia and mercury. It is completely ſoluble in muriatic acid, and there is formed a muriate of mercury and ammonia. This preparation was known to the alchemiſts, and diſtinguiſhed by the names of *ſal alembroth*, and *ſalt of wiſdom*. The component parts of this ſalt, according to Fourcroy, are

Acid,	16
Oxide of mercury,	81
Ammonia,	3
	100 *

6. Hyperoxymuriate of Mercury.

1747 Preparation.

This ſalt was formed by Mr Chenevix, by paſſing a current of oxymuriatic acid gas through water, in which there was red oxide of mercury. The oxide became of a dark brown colour, and a ſolution appeared to have taken place. The liquor was evaporated to dryneſs, and a ſalt was obtained which conſiſted partly of corroſive ſublimate, and partly of hyperoxymuriate of mercury. By ſeparating the latter, and cryſtallizing it again, it was obtained nearly pure. This ſalt is more ſoluble than corroſive ſublimate, four parts of water retaining it in ſolution. Hyperoxymuriatic acid is given out by the addition of ſulphuric, or even weaker acids, and the liquid aſſumes an orange colour †.

1748 Properties.

7. Fluate of Mercury.

Fluoric acid combines only with the oxide of mercury ; or the ſoluble fluates mixed with a ſolution of nitrate of mercury, produce a precipitate of a white colour, which is the fluate of mercury, of which the properties are little known.

---

* *Fourcroy* v. 309—342.

† *Phil. Tranſ.* 1802. p. 260.

8. Borate of Mercury.

Boracic acid has no direct action on mercury, but by mixing together a ſolution of the borate of ſoda with a ſolution of nitrate of mercury, a yellowiſh precipitate is obtained, which is the borate of mercury. This ſalt acquires a greeniſh colour by expoſure to the air. Lime water forms a precipitate of a red powder.

9. Phoſphate of Mercury.

Phoſphoric acid has no action on mercury, but it combines with its oxide. This ſalt may be prepared by precipitating the nitrate of mercury in ſolution, by means of phoſphate of ſoda. A white precipitate is formed, which is phoſphate of mercury. This ſalt is inſoluble in water, phoſphoreſces when rubbed in the dark, and is decompoſed by heat, giving out phoſphorus.

10. Carbonate of Mercury.

By precipitating the ſolutions of mercury on the other acids by means of the alkaline carbonates, a white precipitate is obtained, which is a carbonate of mercury.

11. Arſeniate of Mercury.

When arſenic acid is diſtilled in a retort with mercury, it is partially decompoſed. Arſenious acid is ſublimed, with a portion of metallic mercury and a ſmall quantity of yellow oxide. There remains behind a yellow maſs, which is arſeniate of mercury. It is inſoluble in water, and in ſulphuric and nitric acids. It is ſoluble in muriatic acid, and affords by evaporation and ſublimation, the muriate of mercury, or corroſive ſublimate. Arſenic acid precipitates the ſulphate and nitrate of mercury in the form of a white powder, which is alſo arſeniate of mercury.

12. Tungſtate of Mercury.

This ſalt is formed by adding to a ſolution of nitrate of mercury, an alkaline tungſtate. The ſalt is decompoſed, and the tungſtate of mercury is precipitated in the form of a white inſoluble powder.

13. Molybdate of Mercury.

Molybdic acid precipitates mercury from its ſolution in nitric acid, in the form of a white flaky powder. It is alſo inſoluble in water.

14. Chromate of Mercury.

An alkaline chromate in ſolution, added to a ſolution of nitrate of mercury, forms a precipitate of a fine reddiſh purple colour. This is the chromate of mercury, which is inſoluble in water, and which Vauquelin, who diſcovered it, ſuggeſts to be employed as a pigment.

15. Columbate of Mercury.

Unknown.

16. Acetate of Mercury.

1749
Combines with two oxides.

1. Acetic acid combines with the oxides of mercury, and forms different ſalts, according to the oxide which enters into the combination. With the red oxide of mercury it forms a ſalt which does not cryſtallize; but when the liquid is concentrated, and evaporated to dryneſs, it affords a yellow deliqueſcent maſs. When this ſalt is diſſolved in water, it divides into two parts; the one falls down in the ſtate of yellow powder, which is the acetate of mercury with exceſs of baſe; and the other part remains in ſolution, becauſe it contains an exceſs of acid.

2. But when the nitrate of mercury is precipitated by means of alkalies, and the precipitate is diſſolved in acetic acid, the ſolution yields by evaporation and cooling, acetate of mercury, in thin brilliant flakes. This ſalt may alſo be formed by mixing together ſolutions of acetate of potaſh and nitrate of mercury. The acetate of mercury appears in the form of large flat cryſtals, which have an acrid taſte, and are ſcarcely ſoluble in water. This latter ſalt is a compound of acetic acid and the oxide of mercury, with a ſmaller proportion of oxygen. It is employed in medicine, and forms the principal ingredient of *Keyſer's pills*.

17. Oxalate of Mercury.

Oxalic acid combines with the oxide of mercury, and forms an oxalate in the ſtate of white powder, which is ſcarcely ſoluble in water. It becomes black by expoſure to the light. When it is heated it detonates. This ſalt may alſo be obtained, by adding oxalic acid to a ſolution of the nitrate or ſulphate of mercury.

18. Tartrate of Mercury.

Tartaric acid forms an inſoluble ſalt of a white colour, with the oxide of mercury, which becomes yellow by expoſure to the light.

19. Tartrate of Potaſh and Mercury.

This triple ſalt may be prepared by boiling together in water, one part of oxide of mercury, and ſix of tartar. Cryſtals of the triple ſalt are obtained by evaporating the liquid.

20. Citrate of Mercury.

Citric acid produces an efferveſcence with the red oxide of mercury, changes into a white colour, and then unites it in one maſs. This ſalt is ſcarcely ſoluble in water. It has a metallic taſte, and is decompoſed by nitric acid.

21. Malate of Mercury.

When malic acid is added to a ſolution of nitrate of mercury, a white precipitate is formed, which is malate of mercury.

22. Benzoate of Mercury.

Benzoic acid forms with the oxide of mercury, a ſalt in the ſtate of white powder, which is inſoluble in water, and is ſcarcely altered by expoſure to the air. It is decompoſed by heat.

23. Succinate of Mercury.

Succinic acid combines with the oxide of mercury with the aſſiſtance of heat, and forms with it an irregular maſs in which ſome cryſtals are obſerved.

24. Saccolate of Mercury.

By adding ſaclactic acid to a ſolution of nitrate of mercury, a white precipitate is formed, which is ſaccolate of mercury.

25. Mellate of Mercury.

Mellitic acid added to a ſolution of nitrate of mercury, produces a copious precipitate, which is re-diſſolved by the addition of nitric acid *.

26. Pruſſiate of Mercury.

This ſalt is obtained by boiling the red oxide of mercury with Pruſſian blue. It forms cryſtals in four-ſided priſms, terminated by four-ſided pyramids. The ſpecific gravity is 2.7612. It forms triple ſalts with ſulphuric and muriatic acids, the properties of which are not known.

II. Action of Alkalies, &c.

There is no action between mercury and the alkalies or alkaline earths; but the alkalies combine with the oxides of mercury, and form with them compounds in which the latter ſeem to act the part of acids. Some of theſe compounds have been already treated of, in ſpeaking of the action of ammonia on ſome of the mercurial ſalts.

Salts formed with the alkalies and earths, have no action on mercury or its oxides, if we except the muriates. By diſſolving the muriate of mercury in a ſolution of muriate of ammonia, a triple ſalt, which is muriate of ammonia and mercury, and which has been already deſcribed, is obtained.

1750 Uſes. Mercury is one of the metals of the moſt extenſive utility. In the metallic ſtate it is applied to the conſtruction of meteorological inſtruments, as the barometer and thermometer. Mercury is alſo applied to a great variety of purpoſes in the arts; in gilding with ſilver and gold; in forming an amalgam with tin for covering the back of mirrors; and in metallurgy for the purpoſe of ſeparating gold and ſilver from their ores. Mercury is alſo of conſiderable importance for the purpoſes of chemiſtry. Many of its preparations form ſome of the moſt effectual and moſt certain remedies in different diſeaſes.

Sect. XV. *Of Zinc and its Combinations.*

1751 Hiſtory. 1. Paracelſus is the firſt who ſpeaks of zinc under its preſent name. It is ſuppoſed that the Greeks were acquainted with this metal in the ſtate of compound with copper, which formed the famous Corinthian braſs; but it does not appear that they made any diſtinction between it and other metals. It is particularly mentioned by Albertus Magnus, who died in 1280, and he ſeems to have known that it inflamed, and communicated a colour to metals with which it was combined. The method of obtaining zinc from the ore called *calamine*, is mentioned by Henckel in his pyrotology in 1721. Swab extracted it by diſtillation in 1742, and Margraaf was occupied with this proceſs in 1746. Zinc was ſuppoſed by the earlier chemiſts to be a variety or compound of ſome of the other metals. Lemery thought it was a kind of biſmuth, and Homberg took it for a mixture of iron and tin; while others ſuppoſed that it was tin rendered brittle by ſulphur, or that it was a coagulated mercury.

1752 Ores. 2. Zinc is found in four different ſtates: In the ſtate of oxide, in the ſtate of ſulphuret, in that of ſulphate, and in that of carbonate. 1. In the ſtate of oxide it is known by the name of *calamine*, or *lapis calaminaris*, depoſited in a regular form, or in that of incruſtations and ſtalactites, in the cavities of metallic veins. 2. The ſulphuret of zinc, known by the name of *blende*, is ſometimes diſpoſed in ſcales, and ſometimes cryſtallized in tetrahedrons, or octahedrons. It is frequently found in lead mines, accompanying the ores of lead. 3. The ſulphate of zinc, which is found native, is readily known by its white colour and tranſparency, its ſtrong acrid taſte, and ſolubility in water. It is generally found in a ſtalactitical form, or in fine ſilky cryſtals, like thoſe of amianthus. 4. The native carbonate of zinc, which is ſometimes confounded with the oxide or calamine, forms another ore of zinc. It is tranſparent, white, or yellowiſh. It is inſipid and inſoluble in water, and diſſolves with efferveſcence in nitric and muriatic acids.

1753 Analyſis. 3. To reduce oxides of zinc to the metallic ſtate, the ore is pulverized and mixed with charcoal, and the mixture is heated in a crucible covered with a plate of copper. The zinc is ſublimed in the metallic ſtate, and combines with the copper, which it converts into braſs; and in this rude proceſs the richneſs of the ore is aſcertained by the intenſity of the colour. The ſulphurets of zinc are reduced by roaſting, by which proceſs the ſulphur is ſeparated, and the reſiduum is then treated in the ſame way as the oxides. In the humid way Bergman has propoſed to analyze the oxides of zinc by means of ſulphuric acid, and then by precipitating the oxide by carbonate of ſoda, he has aſcertained that 193 parts of this precipitate give 100 parts of the metal.

1754 Properties. 4. Zinc is of a brilliant white colour with a bluiſh ſhade, which is very perceptible in its metallic ſtate, and of a diſtinct lamellated texture; but the plates of which it is compoſed are ſmaller than thoſe of biſmuth and antimony. The ſpecific gravity is 7.190. Zinc is not quite ſo brittle as the preceding metals. It requires a ſmart and ſudden blow to ſeparate its fragments. It is ſuſceptible of a ſlight degree of malleability, for by gradual and cautious preſſure, it may be formed into thin plates, which have ſome degree of elaſticity. It has a ſlight odour, and a peculiar taſte, which is communicated to the fingers when they are rubbed on this metal.

1755 Action of heat. 5. When zinc is expoſed to a heat of about 700° it melts, and by increaſing the heat it evaporates, ſo that in cloſe veſſels it may be diſtilled. When allowed to cool ſlowly after being in fuſion, it cryſtallizes in fine needles. When zinc is expoſed to the air, it undergoes very little alteration in the cold. Its brilliancy is ſlightly tarniſhed, and it becomes at length covered with a thin gray oxide. 1756 Oxidation. When zinc is fuſed in cloſe veſſels and expoſed to heated air, at the moment it becomes ſolid on the ſurface, it exhibits a great variety of ſhades of colour, which is the commencement of oxidation. When it is kept in fuſion, in the open air, the ſurface becomes covered with a gray pellicle, which being removed, is ſucceeded by another, till the whole

---

* Klaproth Eſſays, II. 102. Tranſl.

of the zinc is converted into this gray-coloured matter, which is an oxide of zinc. This proceſs may be promoted by agitating the veſſel, ſo that the metal in fuſion may be expoſed to the air. By heating together the gray pellicles which have been collected in an open veſſel, the whole is converted into a uniform gray powder, which at laſt aſſumes a yellowiſh colour. The yellow oxide, thus formed, has acquired an additional weight of about 17 per cent of the metallic zinc.

When this metal is heated to redneſs in an open veſſel, by agitating the veſſel, it ſuddenly takes fire, and burns with a very brilliant white, and ſomewhat greeniſh flame. Zinc is at the ſame time reduced to a ſtate of vapour, which is condenſed in the air, in light, filamentous, white flakes, of a very delicate texture. This is an oxide of zinc. It has been diſtinguiſhed by different names, as *flowers of zinc*, *nihil album* or *white nothing*, *lana philoſophica*, or *philoſophic wool*.

1757 Oxides two. Thus, there are two oxides of zinc; the gray oxide, which conſiſts of about 88 parts of zinc, and 12 of oxygen, and the white oxide, which, according to Prouſt, is compoſed of 80 parts of zinc, and 20 of oxygen.

1758 Action of hydrogen. There is no action between azote and this metal. Hydrogen gas, it is ſuppoſed, diſſolves a ſmall quantity of zinc; for by diſſolving zinc in diluted ſulphuric acid, the hydrogen gas which is obtained by the decompoſition of the water, has been found to hold a little zinc in ſolution, which is depoſited on the ſides of the jars 1759 Of carbone. containing the gas. It is ſuppoſed too, that zinc is ſometimes combined with carbone, becauſe hydrogen gas obtained by the above proceſs, is ſometimes contaminated with carbonated hydrogen gas.

1760 Phoſphuret. 7. Zinc combines with phoſphorus, and forms a phoſphuret. This may be prepared by adding ſmall bits of phoſphorus to zinc in fuſion, but previouſly throwing in a little reſinous matter, to prevent the oxidation of the zinc. This was the proceſs by which Pelletier formed the phoſphuret of zinc. This phoſphuret is of a white colour and metallic luſtre. It has ſome degree of malleability. When it is hammered, it emits 1761 Phoſphorated oxide. the odour of phoſphorus, and when expoſed to a ſtrong heat, it burns like zinc. Phoſphorus alſo enters into combination with the oxide of zinc, and forms with it a phoſphorated oxide. This is formed by diſtilling in an earthen-ware retort, equal parts of oxide of zinc, and phoſphoric glaſs, with one-ſixth of charcoal powder. A ſtrong heat is applied, and a metallic ſubſtance of a ſilvery white colour is ſublimed, which has a vitreous fracture. When it is heated by the blow-pipe, the phoſphorus burns, and there remains behind a vitreous matter, which is tranſparent while in fuſion, but becomes opaque when it is cold.

1762 Sulphuret. 8. Zinc has not been combined directly with ſulphur. When they are heated together in a crucible, the ſulphur ſeparates without producing any other change on the zinc than that of being a little more infuſible; but it has been obſerved that ſulphur and zinc, when fuſed together in a crucible, enter into combination, as the zinc is oxidated. This compound aſſumes a browniſh gray colour. Guyton afterwards diſcovered that ſulphur and the oxide of zinc readily unite together by fuſion, and that the compound is of a gray colour, ſimilar to the native ſulphuret of zinc, as it has been called, or the ſulphurated oxide of zinc, according to this experiment; but according to Prouſt, the ore of zinc, which is known by the name of *blende*, is a ſulphuret, that is, ſulphur combined with zinc in the metallic ſtate.

1763 Affinities. 9. The order of the affinities of zinc and its oxide is the following:

Zinc.	Oxide of Zinc.
Copper,	Oxalic acid,
Antimony,	Sulphuric,
Tin,	Muriatic,
Mercury,	Saclactic,
Silver,	Nitric,
Gold,	Tartaric,
Cobalt,	Phoſphoric,
Arſenic,	Citric,
Platina,	Succinic,
Biſmuth,	Fluoric,
Lead,	Arſenic,
Nickel,	Lactic,
Iron.	Acetic,
	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Zinc.

1. Sulphate of Zinc.

1764 Preparation. 1. Sulphuric acid diluted with water, acts very powerfully on zinc. A violent efferveſcence takes place; the mixture is ſtrongly heated, and a great quantity of hydrogen gas is evolved. In this proceſs, which is uſually followed for obtaining the pureſt hydrogen gas for chemical purpoſes, the water is decompoſed; its oxygen combines with the metal and forms an oxide, which is then diſſolved in the ſulphuric acid, and forms a ſulphate of zinc, while the hydrogen, the other component part of the water, eſcapes in the form of gas. A black powder is ſometimes obſerved floating in the ſolution, which is carburet of iron, with which the zinc is frequently contaminated. As the effervefcence ceaſes, a white powder is formed, which gradually diſappears towards the end of the proceſs, and with the addition of water forms a tranſparent ſolution. By evaporation and cooling, the ſulphate of zinc is obtained cryſtallized.

1765 Properties. 2. The ſulphate of zinc is frequently contaminated with other metals, as with lead, iron and copper; but when it is pure, it cryſtallizes in four-ſided priſms, terminated by pyramids with four faces. This ſalt has an acrid, aſtringent, and ſtrongly metallic taſte. When it is expoſed to the air it effloreſces. It is ſoluble in leſs than two and a half parts of cold water, and more ſoluble in boiling water. The ſpecific gravity of the cryſtallized ſalt is 1.912; but as it is generally met with in the ſhops, it is only 1.3275. When heated in a retort, it melts, loſes its water of cryſtallization, and part of its acid in the ſtate of ſulphurous acid, and a little water. It is decompoſed and precipitated in the ſtate of white oxide by all the alkalies; and if the precipitate is formed by means of the carbonates, a white pigment is obtained. The ſulphate of zinc is alſo decompoſed with the aſſiſtance of heat, by means of nitre. The alkaline ſulphurets and hydroſulphurets alſo precipitate the ſulphate of zinc,

zinc, of a deep orange or brown colour. The component parts of this ſalt are, according to

1766 Compoſition.

	Bergman.	Kirwan.
Acid,	40	20.5
Oxide,	20	40.0
Water,	40	39.5
	100	100.0

1767 White vitriol. 3. The ſalt, known in commerce by the name of *white vitriol*, is a ſulphate of zinc, and is ſuppoſed to contain an exceſs of acid. It is in the form of white granular maſſes, reſembling ſugar, and often marked with yellow ſpots. This ſalt is uſually prepared by roaſting the ſulphuret of zinc, or blende, by which means the ſulphur is converted into ſulphuric acid. It is then diſſolved in water, which is purified and evaporated, and the ſalt is cryſtallized by ſudden cooling. Part of its water of cryſtallization is afterwards driven off by heat, ſo that it is obtained in a regular, ſolid, and granulated maſs. It is generally contaminated with iron and other metals; but it may be purified from theſe, by adding filings of zinc, which precipitate the other metals, and leave a pure ſulphate of zinc.

2. Sulphite of Zinc.

1768 Preparation. Concentrated ſulphurous acid readily combines with the white oxide of zinc, without any effervescence, but with the evolution of heat, and the acid being deprived of its odour. When the ſaturation is completed, white cryſtals appear on the ſurface of the liquid. This ſalt has a pungent, aſtringent taſte. It cryſtallizes readily. 1769 Properties. It is decompoſed by the acids, with effervescence. It is inſoluble in alcohol. It forms white precipitates with the alkalies, and when expoſed to the air, it is readily converted into ſulphate of zinc.

1770 Combines with ſulphur. *Sulphurated ſulphite of Zinc.*—When ſulphurous acid is added to zinc in the ſtate of powder or filings, a great degree of heat is produced; ſulphurated hydrogen gas is diſengaged; the liquid becomes at firſt brown, ſometimes muddy, and aſſumes a yellow colour, and towards the end of the proceſs it becomes tranſparent. The ſolution has an acrid, aſtringent, and ſulphureous taſte. Sulphuric and muriatic acids diſengage with effervescence, ſulphurous acid gas, and precipitate a yellowiſh-white powder. Nitric acid at firſt ſeparates ſulphurous acid gas, and afterwards a flaky precipitate, which is pure ſulphur. When this ſolution is expoſed to the air, it becomes thick like honey, and affords cryſtals in the form of needles or fine four-ſided priſms, terminated by four-ſided pyrimids. Theſe are cryſtals of ſulphurated ſulphite of zinc, which become white by expoſure to the air, and form a white powder inſoluble in water. 1771 Properties. When this ſalt is heated by the blow-pipe, it ſwells up, gives out a bright light like burning zinc, and forms dendritical ramifications. This ſalt is partly ſoluble in alcohol. The part not diſſolved, only gives out ſulphurous acid gas by means of ſulphuric acid, whilſt the part which is diſſolved affords, beſides ſulphurous acid gas, a copious precipitate of ſulphur. When it is diſtilled in a retort, it gives out water, ſulphurous acid, ſulphuric acid, and ſulphur ſublimed. There remains behind oxide of zinc, mixed with a little of the ſulphate.

1772 Theory of the proceſs. In the ſolution of zinc in liquid ſulphurous acid, water, and part of the ſulphurous acid itſelf, are decompoſed; for ſulphurated hydrogen gas is diſengaged, which is compoſed of the hydrogen of the water and part of the ſulphur of the ſulphurous acid. There is no precipitation of ſulphur during the ſolution, for it combines with the ſulphite of zinc, as it is formed; but this is not completely ſaturated, ſince alcohol diſſolves only the portion of ſulphurated ſulphite which it contains, and ſeparates the ſulphite *.

3. Nitrate of Zinc.

1773 Preparation. 1. Concentrated nitric acid produces a violent action with zinc, and ſometimes even inflames it. To effect this ſolution, with a moderate action, the acid ſhould be diluted with water. Great heat is produced, with violent effervescence and the evolution of nitrous gas. The acid is decompoſed; its oxygen combining with the metal, forms an oxide, which combines with the acid as it is formed.

1774 Properties. 2. This ſolution is of a greeniſh-yellow colour, and extremely cauſtic. By evaporation it affords cryſtals, in the form of four-ſided, compreſſed, and ſtriated priſms, terminated by four-ſided pyramids. The ſpecific gravity is 2.096. This ſalt is deliqueſcent in the air. When it is heated on burning coals, it melts, and detonates with a ſmall red flame. When heated in a crucible, it gives out red vapour, and aſſumes a deep colour and gelatinous conſiſtence. When cooled in this ſtate, it retains its ſoftneſs for ſome time. By continuing the heat, it dries, gives out nitrous and oxygen gaſſes, and leaves behind a yellow oxide.

4. Muriate of Zinc.

1775 Preparation. Muriatic acid produces a rapid action on zinc. It is diſſolved with effervescence, and with the evolution of pure hydrogen gas. The ſolution of zinc in muriatic acid is colourleſs; it does not cryſtallize, but aſſumes the form of a tranſparent jelly. It affords by diſtillation a ſmall quantity of fuming acid, and a ſolid muriate of zinc, which is fuſible with a moderate heat, and was formerly known by the name of *butter of zinc.* When this muriate of zinc is ſublimed by heat, it becomes of a fine white colour, compoſing a maſs of cryſtals in the form of ſmall priſms. 1776 Properties. It is decompoſed by ſulphuric acid, and is precipitated by the alkalies. It is ſoluble in water, attracts moiſture from the atmoſphere, and is ſoon converted into a tranſparent jelly. The ſpecific gravity is 1.577.

5. Muriate of Ammonia and Zinc.

This triple ſalt is formed by boiling white oxide of zinc in a ſolution of muriate of ammonia. The oxide of zinc is diſſolved; part of which is afterwards depoſited, when the ſolution cools, but what remains in the ſolution is not precipitated by the alkalies or the alkaline carbonates.

6. Fluate of Zinc.

Fluoric acid produces a violent action with zinc; there is conſiderable effervescence, with the evolution

---

* Fourcroy, v. p. 380.

of hydrogen gas. The metal is oxidated, and then diſſolves in the acid; but the properties of this ſalt are little known.

7. Borate of Zinc.

Boracic acid combines with the oxide of zinc, by adding the borate of potaſh or ſoda to the ſolution of zinc in nitric or muriatic acid. This ſalt is inſoluble in water.

8. Phoſphate of Zinc.

1777 Preparation. Phoſphoric acid diluted with water, acts upon zinc with the evolution of hydrogen gas, owing to the decompoſition of water. A white powder is depoſited, which is phoſphate of zinc. By expoſing phoſphoric glaſs and zinc to a ſtrong heat, a phoſphuret of zinc is formed, by the decompoſition of the acid.

9. Carbonate of Zinc.

1778 Preparation. Zinc reduced to a fine powder, and added to liquid carbonic acid, is oxidated and copiouſly diſſolved in the acid, at the end of 24 hours. This ſolution, expoſed to the air, is covered with a pellicle of carbonate of zinc of different colours. The carbonate of zinc is found native, and has been diſtinguiſhed by the name of *calamine*, thus confounding it with the oxide of zinc. Carbonate of zinc, according to the analyſis of Bergman, is compoſed of

Acid	28
Oxide	66
Water	6
	100

10. Arſeniate of Zinc.

When arſenic acid is added to zinc, it produces an efferveſcence, with the evolution of hydrogen gas, holding arſenic in ſolution. A black powder is depoſited, which is metallic arſenic. In this proceſs, the zinc decompoſes part of the water, and combines with its oxygen, and at the ſame time deprives the arſenic acid of its oxygen, by which it is reduced to the metallic ſtate. The arſeniate of zinc may be obtained by adding a ſolution of an alkaline arſeniate to a ſolution of the ſulphate of zinc. A white precipitate is formed, which is the arſeniate of zinc. It is inſoluble in water.

11. Tungſtate of Zinc.

12. Molybdate of Zinc.

Theſe ſalts may be formed by a ſimilar proceſs. A white powder is obtained, which is inſoluble in water.

13. Chromate of Zinc.

This ſalt is obtained by combining an alkaline chromate with a ſolution of zinc in nitric acid. A precipitate is formed of an orange red colour, which is chromate of zinc.

14. Columbate of Zinc.

Unknown.

15. Acetate of Zinc.

1779 Preparation and properties. Acetic acid diſſolves zinc, and the ſolution by evaporation cryſtallizes in the form of rhomboidal or hexagonal plates. This ſalt has a bitter metallic taſte, is not altered by expoſure to the air, and is ſoluble in water. It burns with a blue flame when thrown on burning coals. When diſtilled, it yields water, an inflammable liquid, and ſome oil. At the end of the proceſs, when the ſalt is completely decompoſed, the oxide of zinc is ſublimed, which being brought in contact with a candle, burns with a fine blue flame. The reſiduum is in the ſtate of pyrophorus, but it has little combuſtibility.

16. Oxalate of Zinc.

Oxalic acid acts upon zinc with efferveſcence, and the evolution of hydrogen gas. Water is decompoſed, and as the zinc is oxidated, it combines with the acid, forming an oxalate of zinc. It is in the ſtate of white powder, of an acrid taſte, and but little ſoluble in water.

17. Tartrate of Zinc.

Tartaric acid combines with zinc with efferveſcence, and the evolution of hydrogen gas. The properties of this ſalt have not been examined.

18. Citrate of Zinc.

Citric acid acts upon zinc with efferveſcence and the evolution of hydrogen gas. At the end of 24 hours the action ceaſes, and the liquid depoſits on the ſides of the veſſel and on its ſurface, ſmall, brilliant cryſtals in the form of plates, which are inſoluble in water. The citrate of zinc has an aſtringent, metallic taſte. It is compoſed of equal parts of acid and of oxide of zinc.

19. Malate of Zinc.

Malic acid diſſolves zinc, and by evaporating the ſolution, cryſtals may be obtained.

20. Benzoate of Zinc.

Benzoic acid readily diſſolves zinc, and by evaporation the ſolution affords needle-ſhaped cryſtals. The benzoate of zinc is ſoluble in water and alcohol. When it is expoſed to heat, the acid is ſublimed.

21. Succinate of Zinc.

Zinc is diſſolved in ſuccinic acid with efferveſcence. By evaporation the ſolution affords ſlender, foliated cryſtals.

22. Lactate of Zinc.

Zinc is ſoluble in lactic acid with efferveſcence, and by evaporating the ſolution, the ſalt may be obtained cryſtallized.

II. Action of Alkalies, &c. on Zinc.

1780 Fixed alkalies. 1. When zinc is immerſed in a ſolution of potaſh or ſoda, it is tarniſhed, and becomes black, and when it is boiled in the ſolution, hydrogen gas is evolved. The ſolution aſſumes a dirty-yellow colour, from which an oxide of zinc may be precipitated by acids.

2. Ammonia

1781 Ammonia. 2. Ammonia has a ſtill more powerful action on zinc. Hydrogen gas is more copiouſly evolved, and the oxide which is formed is more abundantly diſſolved in the liquid, and at the end of ſome time a conſiderable quantity of white oxide is depoſited. Theſe alkaline ſolutions become turbid by expoſure to the air; its oxygen and carbonic acid, acting at the ſame time, precipitate the oxide.

1782 Sulphates. 3. The alkaline and earthy ſulphates are readily decompoſed by zinc, with the aſſiſtance of heat. It attracts the oxygen of the ſulphuric acid, and thus decompoſing it, ſeparates the ſulphur, which combines with the baſes of the ſulphates. Alum boiled in ſolution with zinc, is decompoſed, and there is formed a triple ſalt, which is ſulphate of zinc and alumina.

1783 Nitrates. 4. The nitrates produce a vivid inflammation with zinc at a red heat. The acid is decompoſed, its oxygen combines with the metal, and by this rapid combination, a violent detonation is produced. The azotic gas is diſengaged, and the zinc is fully oxidated. Three parts of nitre well dried, and one of zinc in fine powder, well mixed together and projected into a red-hot crucible, produce a very brilliant inflammation. The burning matter is ſometimes thrown out to a conſiderable diſtance; ſo that the experiment ſhould be made with caution. This compound is ſometimes employed in fire works.

1784 Muriates. 5. Zinc has a conſiderable action on the muriates. Triturated with the muriate of ammonia, the ſalt is decompoſed, and ammonia is diſengaged. By diſtilling this ſalt with zinc, ammoniacal and hydrogen gaſes are obtained; the latter is obviouſly owing to the decompoſition of the water contained in the ſalt, by means of the zinc, which combines with the oxygen, and then forms a muriate of zinc with the muriatic acid.

1785 Phoſphates, &c. 6. The phoſphates and borates combine by fuſion with the oxide of zinc, which communicates to the glaſs thus formed a greeniſh-yellow colour.

7. Zinc decompoſes the greateſt number of the metallic ſalts from their ſolutions, by its ſtrong affinity for oxygen. They are precipitated in the metallic form, or in the ſtate of oxide, but deprived of a portion of oxygen.

1786 Uſes. 8. Zinc is employed in many of the arts. It forms uſeful alloys with ſome of the other metals, ſome of which will be mentioned afterwards. It is alſo employed in medicine. The ſulphate of zinc is ſometimes exhibited as an emetic, and frequently uſed in ſolution as an eye-waſh. The oxide of zinc, or the flowers of zinc, have been preſcribed as an antiſpaſmodic, and particularly in caſes of epilepſy.

Sect. XVI. *Of Tin and its Combinations.*

1787 Hiſtory. 1. Tin has been known from the earlieſt ages. It was much employed by the Egyptians in the arts, and by the Greeks as an alloy with other metals. Pliny ſpeaks of it under the name of white lead, as a metal well known in the arts, and even applied in the fabrication of many ornaments of luxury. He aſcribes to the Gauls the invention of the art of tinning, or covering other metals with a thin coat of tin. The alchemiſts were much employed in their reſearches concerning tin. They gave it the name of *Jupiter*, from which the ſalts or preparations of tin were called *jovial*. Since their time, the nature and properties of tin have been particularly inveſtigated by many chemiſts, and it has proved the ſubject of ſome important diſcoveries in chemical ſcience. So early as the year 1630, John Rey threw out a conjecture, that the air was fixed in this metal during its calcination. Boyle, towards the end of the ſame century, attempted to account for the increaſe of weight which this metal acquired during this proceſs; but this was only fully aſcertained by Lavoiſier, who repeated the experiment of Boyle, and calcined the metal in cloſe veſſels; but the method of conducting this experiment and the reſult of it, have been already detailed.

1788 Ores. 2. Tin exiſts in nature in three different ſtates. It is found native, in the ſtate of oxide, and in that of ſulphurated oxide. Native tin is in brilliant plates, or regularly cryſtallized. The native oxide of tin, which is the moſt common ore of this metal, exiſts under a variety of forms. It is generally found cryſtallized. The ſulphuret of tin is of a pale or dark gray colour, and when pure, has ſome reſemblance to an ore of ſilver.

1789 Analyſis. 3. To obtain the metal from its ores, they are firſt roaſted, and then treated with a flux, to reduce the metal. It has been recommended by ſome, to mix a ſmall quantity of pitch with the fuſed maſs, to prevent the oxidation of the tin. After the ore is roaſted, it fuſes readily with three times its weight of black flux, and a little decrepitated muriate of ſoda.

In the humid way, native tin may be diſſolved in nitric acid, which readily oxidates, and reduces it to the ſtate of white powder, which is an oxide of tin; and if it contain iron and copper, theſe two metals remain in the ſolution.

1790 Properties. 4. Tin is of a white colour, nearly as brilliant as ſilver. The ſpecific gravity of tin is 7.291. It is one of the ſofteſt of the metals. It may be ſcratched with the nail, and eaſily cut with a knife. It is extremely flexible, and produces a peculiar noiſe when it is bent or folded. It is ſo malleable, that it can be eaſily beaten out to $\frac{1}{1000}$ part of an inch, which is the thickneſs of tinfoil. It has little elaſticity or tenacity. A wire of this metal about $\frac{1}{10}$ of an inch in diameter ſupports a weight of about 30lbs. without breaking.

1791 Action of heat. 5. Tin is ſuſceptible of very conſiderable expanſion by means of caloric, and on this account it has been propoſed to employ it as a pyrometer. Tin is one of the moſt fuſible of the metals, and melts at the temperature of 442°, but it requires a very high temperature to raiſe it in vapour. If it be allowed to cool ſlowly, and when the ſurface becomes ſolid by pouring out part of the liquid metal, cryſtals are formed, in large rhomboids, compoſed of a great number of ſmall needles.

1792 Odour, &c. 6. Tin is a good conductor of electricity. It poſſeſſes a peculiar odour, which is communicated to the hands by friction. It has alſo a perceptible taſte.

1793 Oxidation. 7. When this metal is expoſed to the air, it is ſoon tarniſhed, and aſſumes a grayiſh white colour; but it undergoes no farther change. When it is melted in an open veſſel, it is ſoon covered with a grayiſh pellicle, which is the commencement of the oxidation of the

the metal. When this pellicle is removed, another forms, and ſo on ſucceſſively till the whole is oxidated. By continuing the heat, and by agitation, the proceſs goes on more rapidly, and the metal is converted into a whitiſh powder. This oxide contains about 20 parts of oxygen in 100 of the metal. With the addition of lead to promote the oxidation, this oxide is the *putty of tin*. It contains about two parts of oxide of lead, and one part of oxide of tin. But when tin is ſtrongly heated, it is converted into a fine white oxide, which during the proceſs gives out a vivid white flame. This oxide is condenſed in the cold, and cryſtallizes in ſhining tranſparent needles.

1794 Two oxides.

According to Prouſt, tin combines with two proportions of oxygen, thus forming two oxides. The yellow oxide, which has the ſmaller proportion of oxygen, may be prepared by diſſolving tin in nitric acid diluted with water, without the aid of heat. By precipitating the oxide with pure potaſh, it is obtained in the form of a yellowiſh powder. Its component parts are thoſe already ſtated, namely,

20 oxygen,
80 tin,
———
100

By diſſolving tin in concentrated nitric acid, with the aſſiſtance of heat, the whole is converted with effervеſcence into a white powder, which falls to the bottom of the veſſel. The component parts of this oxide are, 28 oxygen, and 72 of tin.

8. There is no action between tin and azote, hydrogen, or carbone, nor is there any perceptible action between tin or its oxides and water.

1795 Phoſphuret.

9. Phoſphorus combines very readily with tin, by projecting bits of phoſphorus on melted tin in a crucible. A phoſphuret of tin is thus obtained, which cryſtallizes on cooling. This compound is of a ſilvery white colour, may be cut with a knife, and extended under the hammer, but ſoon ſeparates into plates. The filings of this phoſphuret are like thoſe of lead, and when they are thrown on red-hot coals, they take fire, and burn with the ſmell and flame of phoſphorus. By the action of the blow-pipe the phoſphorus only burns, and the ſmall metallic button which remains is ſurrounded with a tranſparent glaſs. Pelletier diſtilled this phoſphuret often with hyperoxymuriate of mercury, and obtained a fuming muriate of tin, with the mercury reduced to the metallic ſtate, and phoſphorated hydrogen gas, which exploded as it came in contact with the air. There remained in the retort a ſpongy inflammable matter, which he ſuppoſed to be a compound of tin and phoſphorus.

1796 Sulphuret.

10. Sulphur combines very readily with tin, by adding the ſulphur to the metal while in a ſtate of fuſion. This compound forms a grayiſh or bluiſh matter, which has a metallic luſtre, a lamellated ſtructure, and cryſtallizes in cubes, or in octahedrons.

1797 Compoſition.

It is decompoſed by acids with effervеſcence. The component parts are, according to

	Bergman.	Pelletier.
Tin,	80	85
Sulphur,	20	15
	100	100

1798 Sulphurated oxide.

11. If equal parts of oxide of tin and ſulphur be fuſed together in a retort, ſulphurous acid and ſome ſulphur are diſengaged, and there remains in the veſſel a compound of a brilliant golden colour. It cryſtallizes in ſix-ſided plates. It is not acted on by the acids. When it is ſtrongly heated, it gives out ſulphurous acid and ſulphur, and there remains behind a black maſs which is ſulphuret of tin. This compound, which is a ſulphurated oxide of tin, was formerly diſtinguiſhed by the name of *aurum muſivum*, *muſicum*, or *moſaicum*. The component parts of this ſulphurated oxide of tin are,

Oxide of tin,	60
Sulphur,	40
	100

12. Tin enters into combination with many of the metals, and forms alloys with them, ſome of which are of great importance. It alſo combines with acids, and forms ſalts. The affinities of tin and its oxides are in the following order.

1799 Affinities.

Tin.	Oxide of Tin.
Zinc,	Tartaric acid,
Mercury,	Muriatic,
Copper,	Sulphuric,
Antimony,	Oxalic,
Gold,	Arſenic,
Silver,	Phoſphoric,
Lead,	Nitric,
Iron,	Succinic,
Manganeſe,	Fluoric,
Nickel,	Saclactic,
Arſenic,	Citric,
Platina,	Lactic,
Biſmuth,	Acetic,
Cobalt,	Boracic,
Sulphur.	Pruſſic.

I. Salts of Tin.

1. Sulphate of Tin.

1800 Two ſulphates.

1. Sulphuric acid acts very feebly on tin in the cold. The acid, however, is at laſt decompoſed; its oxygen combines with the metal, ſulphurous acid gas is emitted, and the oxide falls to the bottom in the ſtate of white powder. In this caſe, the oxide has the ſmaller proportion of oxygen, and then the ſolution is more permanent. There is no precipitation by water.

2. But when the ſolution of tin in ſulphuric acid is promoted by the action of heat, the acid is ſtill farther decompoſed; a greater quantity of ſulphurous acid is given out, and ſulphur is depoſited. In this caſe the white oxide of tin is formed. This compound, when evaporated, aſſumes the form of a jelly, and does not cryſtallize by the addition of water. It is precipitated in the form of white powder. The firſt might be called the yellow ſulphate of tin, and the ſecond the white ſulphate of tin.

2. Sulphite of Tin.

When tin is immerſed in liquid ſulphurous acid, it aſſumes a yellow colour. At the end of ſome days it becomes

becomes black like charcoal, and there is depoſited in the liquid a black powder. In this proceſs part of the ſulphurous acid is decompoſed; its oxygen combining with the metal, forms an oxide, which enters into combination with another part of the acid, and forms the ſulphite of tin. A portion of ſulphur is depoſited along with the white ſulphite, which is not very ſoluble, and another portion remains in ſolution with part of the ſulphite, forming a ſulphurated ſulphite. A third portion of the ſulphur combines with part of the metallic tin, and forms a black ſulphuret, on which the acid has no action *.

3. Nitrate of Tin.

1801 History. 1. Nitric acid produces a very violent action with tin. It is accompanied with great heat, and the evolution of nitrous gas. The metal is converted into a white oxide, which gives to the liquid the appearance of coagulated milk. It had been long obſerved by chemiſts, that the ſolution of tin in nitric acid was not permanent, for by evaporating or concentrating the ſolution, the oxide is always precipitated. This difficulty has been ſolved by the diſcoveries of modern chemiſtry.

1802 Preparation. 2. If tin be diſſolved in nitric acid, diluted with water, and the great increaſe of temperature moderated by the application of cold, as by immerſing the veſſel in cold water, a ſolution of a ſmall quantity of the oxide of tin is effected. The ſolution is of a yellow colour, and contains the oxide of tin, with a ſmaller proportion of oxygen, which is the yellow oxide. In this proceſs the tin is chiefly oxidated by the decompoſition of the water. In this proceſs too, ammonia is formed from the azote of the acid combining with the hydrogen of the water. This becomes perceptible by adding potaſh to the liquid. When the ſolution is heated, the oxide of tin is ſeparated in great abundance.

1803 In different proportions. 3. But when nitric acid is more concentrated, a more violent action takes place between this acid and tin. The metal is oxidated, and the whole of it ſeparates from the liquid. To one part of pure nitric acid Guyton added $1\frac{1}{2}$ of tin in a retort, when a violent efferveſcence took place, but no gas was given out. In this experiment a quantity of ammonia equal to $\frac{1}{20}$ of the weight of the acid and tin employed, was formed. The acid and the water are decompoſed, and the oxygen of both combines with the tin, and forms an oxide, while the azote of the acid and the hydrogen of the water combine together and form ammonia. In this ſtate of oxidation, the tin does not combine with the acid.

4. Muriate of Tin.

1804 Preparation. 1. Concentrated muriatic acid diſſolves tin, either in the cold or with the aſſiſtance of a gentle heat. The acid is ſoon deprived of its fuming property, and of its yellow colour. A ſlight efferveſcence takes place, which is owing to the decompoſition of water, and the evolution of a fetid hydrogen gas. This peculiar odour is ſuppoſed to be occaſioned by the hydrogen gas holding in ſolution a portion of the metal. Muriatic acid diſſolves more than $\frac{1}{2}$ its weight of tin. No precipitate is formed, as with the other acids. When it is

1805 Properties. evaporated, it furniſhes cryſtals in the form of brilliant needle-ſhaped priſms, which are deliqueſcent in the air.

1806 Decompoſition. 2. This muriate of tin is precipitated by the alkalies in the form of a copious white oxide, which is re-diſſolved with an exceſs of alkali. The alkaline ſolution is of a browniſh yellow colour. The ſulphuret of ammonia precipitates this ſalt in the form of powder, which becomes black as it dries, and by diſtillation yields ammonia and *aurum muſivum*. The ſulphuret of potaſh produces a yellow precipitate, which, by diſtillation furniſhes ſulphurous acid and ſulphur, and what remains is converted into *aurum muſivum*, or the ſulphurated oxide of tin. This oxide precipitated by means of ſoda, and diſtilled with its weight of ſulphur, yields ſulphurous acid gas, ſulphur, and the reſiduum is *aurum muſivum*.

1807 Abſorbs oxygen. 3. This ſolution of tin abſorbs oxygen, with the evolution of heat, from oxymuriatic acid, which is deprived of its odour. With nitric acid, a violent efferveſcence takes place. Nitrous gas is diſengaged, and in both theſe caſes, the oxide of tin combines with an additional portion of oxygen. With the addition of ſulphurous acid, this ſolution of tin depoſits the yellow ſulphurated oxide of a fine bright colour. This ſolution converts

1808 Forms an oxymuriate. arſenic acid into the metallic ſtate, and it produces the ſame effect on the molybdic and tungſtic acids, by combining with their oxygen. The red oxide of mercury, the hyperoxymuriate of mercury, the white oxide of antimony, the oxides of zinc and ſilver, are all reduced to the metallic ſtate by being deprived of their oxygen by the muriate of tin. This muriate alſo precipitates from the ſolution of gold, *the purple powder of Caſſius*, by attracting that portion of oxygen which renders the oxide of gold ſoluble. In all theſe proceſſes, the reſults of which were aſcertained by Pelletier, the muriate of tin is converted into an oxymuriate.

1809 Formed by another proceſs. 4. This oxymuriate of tin is formed by making a ſtream of oxymuriatic acid gas paſs into a ſolution of muriate of tin. It is alſo prepared by triturating equal parts of an amalgam, conſiſting of two parts of tin, and one of mercury, and muriate of mercury, or corroſive ſublimate, and diſtilling this mixture in a glaſs retort, with a very moderate heat. A colourleſs liquor firſt paſſes over, which is followed with the ſudden evolution of a white vapour, which lines the inſide of the receiver. This vapour is condenſed into a tranſparent liquid, which, in the air, exhales a copious, heavy, white vapour, from which this liquid has been called *the ſmoking liquor of Libavius*, or the *oxymuriate of tin*. When this liquor is included in a veſſel, it no longer gives out any viſible vapour, but it depoſits at the top of the veſſel needle-ſhaped cryſtals, while ſimilar cryſtals are precipitated to the bottom. Water does not precipitate the fuming muriate of tin. When it is thrown into water, it produces a noiſe ſimilar to that which is occaſioned by concentrated ſulphuric acid. A number of tranſparent bubbles of air being evolved from the mixture, collect on the ſurface, and become white by the contact of air. By agitating the water, they are more readily diſſipated, and the liquid fumes no longer.

1810 In nitromuriatic. 5. Nitromuriatic acid, which is compoſed of one part of nitric acid, and two or three of muriatic acid, very readily diſſolves tin. A ſtrong heat is produced, which

---

* Fourcroy Connaiſs. Chim. vi. p. 30.

which may be moderated by immerſing the veſſel, in which the ſolution is made, in cold water. The metal ſhould be added in ſmall portions, and one part ſhould be diſſolved before the addition of another. In this way the acid will diſſolve half its weight of tin. It is by this proceſs that the muriate of tin is obtained for the purpoſe of dyeing ſcarlet; but it is found to vary conſiderably in its effects, which, no doubt, depends on the ſtrength of the acids employed, and the different proportions in the mixture. This ſolution is almoſt always coloured. Sometimes it affords a gelatinous maſs on cooling, which becomes in time more ſolid. Sometimes it is of a white colour like milk. This ſolution has not the fetid odour of the ſimple ſolution of tin in muriatic acid. It often happens, that it does not aſſume the viſcid or ſolid form, without the addition of $\frac{1}{2}$ its weight of water. It is then ſlightly opaque, which is owing to the precipitation of part of its oxide. When this ſolution is heated, an effervescence take place; the tin is more ſtrongly oxidated, and it is generally after this proceſs that it aſſumes the form of a tranſparent jelly.

5. Fluate of Tin.

Fluoric acid has very little action on tin, but it diſſolves its oxide, and forms with it a ſolution which aſſumes a gelatinous form. The fluate of tin may be alſo obtained by adding a ſolution of an alkaline fluate to a ſolution of tin in muriatic acid.

6. Borate of Tin.

By a ſimilar proceſs boracic acid combines with the oxide of tin, and forms a borate of tin, which is inſoluble.

7. Phoſphate of Tin.

This ſalt may be formed by precipitating the oxide of tin from its ſolution in muriatic acid, by means of an alkaline phoſphate. A phoſphate of tin is thus obtained, which is inſoluble in water.

8. Carbonate of Tin.

This ſalt is prepared by precipitating the oxide of tin from its ſolution in muriatic acid, by means of the carbonates of the alkalies. When this carbonate of tin is diſſolved in an acid, it effervesces; but, according to Bergman, the oxide of tin, precipitated by an alkaline carbonate, is not found to have received any ſenſible addition of weight, ſo that the effervescence occaſioned by the action of an acid, on what is ſuppoſed to be a carbonate of tin, probably depends on the decompoſition of the acid itſelf.

9. Arſeniate of Tin.

Arſenic acid, with a moderate heat, diſſolves a ſmall quantity of tin, and the ſolution aſſumes the form of a jelly. Arſeniate of tin is formed, by adding to a ſolution of tin in muriatic acid, an alkaline arſeniate. A precipitate is formed, which is arſeniate of tin in the ſtate of inſoluble powder.

All the metallic acids are decompoſed by means of tin. They alſo combine with the oxide of tin, and form ſalts in the ſtate of powder, which has little ſolubility.

10. Acetate of Tin.

Acetic acid diſſolves only a ſmall portion of tin; but when the acid is boiled on tin, the action is more powerful, and the ſolution, which is of a whitiſh colour, affords by evaporation ſmall cryſtals. The ſolution of tin in acetic acid ſometimes does not cryſtallize, but affords only a gelatinous maſs; ſo that, by the action of acetic acid on tin, the metal is either in different degrees of oxidation, or there are different proportions of the acid and baſe.

11. Oxalate of Tin.

Oxalic acid added to tin in thin plates or filings, firſt blackens the ſurface, which is afterwards covered with a white powder. The oxalate of tin, which is ſoluble in water, has an auſtere metallic taſte. By ſlow evaporation it furniſhes needle-ſhaped or priſmatic cryſtals. When it is more rapidly evaporated, it affords a tranſparent maſs like horn.

12. Tartrate of Tin.

Tartaric acid diſſolves the oxide of tin, but the nature of this ſalt has not been examined.

13. Tartrate of Potaſh and Tin.

This triple ſalt may be obtained by boiling together the oxide of tin and tartar, in water. It is a ſoluble ſalt, and cryſtallizes with difficulty. It is not precipitated by the alkalies or the alkaline carbonates.

14. Benzoate of Tin.

This ſalt is formed by adding to a ſolution of tin in muriatic acid, benzoate of potaſh. The benzoate of tin is precipitated, which is ſoluble in water, with the aſſiſtance of heat.

15. Succinate of Tin.

The oxide of tin is diſſolved by ſuccinic acid with the aſſiſtance of heat. When the ſolution is evaporated, it affords thin tranſparent cryſtals of ſuccinate of tin.

II. Action of Alkalies, &c. on Tin.

1811 Alkalies. 1. Tin in the metallic ſtate is little changed by the action of the alkalies; but the oxides of tin readily combine with theſe bodies. The combination of the oxide of tin with the fixed alkalies is effected, either in the dry or humid way; and with the aſſiſtance of heat the oxide of tin combines with liquid ammonia. This combination takes place moſt readily when the oxide is recently precipitated, when it is in the ſtate of minute diviſion.

1812 Earths. 2. The oxide of tin combines with the earths by fuſion; and with the addition of a fixed alkali, forms an opaque vitreous maſs, which is employed for the purpoſes of enamel.

1813 Salts. 3. Moſt of the ſalts are decompoſed by means of tin,
in conſequence of the ſtrong affinity of this metal for
oxygen. All the ſulphates, when heated with this
metal, are more or leſs rapidly converted into ſulphu-
rets. Equal parts of ſulphate of potaſh and tin, heated 1814 Sulphates.
together in a crucible, afford a greeniſh coloured maſs,
which has no metallic appearance, and which ſeems to
be a ſulphuret of potaſh and tin. The nitrates pro- 1815 Nitrates.
duce

duce deflagration with this metal, with the aſſiſtance of heat. If the tin be melted in a crucible, and brought to a red-heat, and dried nitre in powder be projected into it, a white brilliant flame is produced, and when the detonation has entirely ceaſed, the tin is found to be oxidated. This experiment may be alſo made, by mixing together tin filings with three parts of nitre in powder, and projecting the mixture into a red-hot crucible. 1816 Muriates. Muriate of ammonia is decompoſed by tin; and by adding ſulphur, the ſulphurated oxide of tin, or *aurum muſivum*, is obtained. Eight parts of tin united to eight parts of mercury, with ſix of ſulphur, and four of muriate of ammonia, afford, according to the proceſs of Pelletier, a very beautiful *aurum muſivum*.

It was obſerved by this philoſopher, that during the proceſs, ſulphurated hydrogen gas, ſulphuret of ammonia, and muriate of tin, were produced; that the tin oxidated and united to the ſulphur, formed aurum muſivum; and that a part of this matter, compoſed of the different ſubſtances, in a ſtate of vapour, was depoſited in lamellated, hexangular cryſtals in the upper part, and in the neck of the retort.

The alkaline hyperoxymuriates, but eſpecially that of potaſh, produce a violent detonation with this metal. Three parts of this ſalt mixed with one of tin in fine powder, rapidly deflagrates when brought into contact with a burning body. During this combuſtion, there is a brilliant and ſudden flame, and the metal is reduced to the ſtate of vapour. The ſame mixture by percuſſion produces a violent detonation with a conſiderable flame in the dark.

Many of the metallic ſolutions and metallic ſalts are decompoſed by means of tin, and are either reduced to the metallic ſtate, or deprived of a conſiderable portion of their oxygen.

III. Alloys.

1817 Arſenic. 1. Tin and arſenic form an alloy by fuſion. The compound, when the proportion of arſenic is conſiderable, is white, brittle, more ſonorous and harder than tin. In the proportion of 15 parts of tin and one of arſenic, the alloy cryſtallizes in large plates, is more infuſible than tin, and more brittle than zinc. By expoſure to the air, and with the aſſiſtance of heat, the arſenic is driven off.

1818 Cobalt. 2. With cobalt tin forms an alloy which is in ſmall grains, and of a light violet colour.

1819 Biſmuth. 3. Tin combines with biſmuth. The tin is then harder, more ſonorous and brighter. The compound in certain proportions becomes more fuſible than either of the two metals. The alloy of equal parts of tin and biſmuth melts at 280°. Eight parts of tin and two of biſmuth melt at 390°, and two of tin and one of biſmuth at 330°.

1820 Antimony. 4. Tin combines with antimony, and forms an alloy which is white and brittle, and has a ſpecific gravity leſs than that of the two metals taken ſeparately. The antimony gives hardneſs to the tin, and changes its texture. This alloy is employed in many arts, and particularly for the plates on which muſic is engraved.

1821 Mercury. 5. Tin combines very readily with mercury, and in all proportions. The tin is even diſſolved when the quantity of mercury is conſiderable. This union takes place in the cold, but it is greatly promoted by means of heat. The heated mercury is poured upon the tin in fuſion. The amalgam of tin is ſuſceptible of cryſtallization in the form of cubes. Sage obſerved the cryſtals of this amalgam in gray brilliant plates, thin towards the edges, and leaving between them polygonal cavities.

This amalgam is employed for covering mirrors. In applying it, tinfoil is ſpread on a ſmooth flat ſtone or table, and mercury in which a certain proportion of tin has been already diſſolved, is poured upon it. It is then ſpread equally over the whole with a feather or a piece of cloth. The plate of glaſs, one ſide of which is to be covered, is then applied to the edge of the table, and cautiouſly moved along the tinfoil, ſo that the redundant part of the mercury may be carried before it. What remains enters into union with the tin. The glaſs is then to be equally loaded with weights, to preſs out any part of the mercury which may yet remain uncombined with the tin. In the courſe of a few hours the amalgam of the two metals adheres ſo firmly to the glaſs, that the weights may be removed.

1822 Zinc. 6. Zinc readily forms an alloy with tin by fuſion. The compound affords a hard metal with ſmall grains, the ductility of which correſponds to the quantity of tin. The alloy of tin and zinc forms part of the compound which is known by the name of *pewter*.

1823 Uſes. Tin is applied to a great many important purpoſes. In the arts and domeſtic economy, it is formed into a great variety of veſſels and inſtruments. The alloys of tin with other metals are not leſs important. It forms a component part of type metal, and bell metal. The oxides of tin are employed for the purpoſe of poliſhing glaſs and metallic ſubſtances, and combined with the earths and alkalies for the fabrication of enamels. The ſalts of tin are employed for the preparation of colours in dyeing, or as a valuable mordant for fixing certain colours. Tin in the metallic ſtate has been exhibited as a remedy againſt worms. It is then granulated by conſtant agitation while it cools after fuſion; but it is ſuppoſed, if it produces any effect as a vermifuge medicine, that it is merely by its mechanical action.

SECT. XVII. *Of LEAD and its Combinations.*

1824 Hiſtory. 1. Lead has been known from the earlieſt ages. Pliny ſpeaks of it under the name of black lead, probably to diſtinguiſh it from tin, with the properties of which he was alſo acquainted, for he obſerves that it was ſometimes the practice to contaminate tin with lead.

1825 Ores. 2. Lead is found in great abundance in many parts of the world, and in a great variety of forms and combinations. Lead has rarely, if ever, been found native, and it is doubted whether it has yet been diſcovered in the ſtate of oxide. The moſt common form of lead is in the ſtate of ſulphuret, when it is combined with ſulphur. In this ſtate it is of a gray, brilliant colour, of a lamellated texture, very brittle, and breaks into cubes. This is the moſt frequent combination of lead, and it is generally found in this ſtate in veins. Lead is alſo frequently met with combined with ſeveral of the acids. The carbonate, phoſphate, and arſeniate of lead are not uncommon productions in the cavities of the veins of ſulphuret of lead. The chromate, molybdate, and ſulphate of lead are more rare.

1826 Analyſis. 3. The ſulphuret of lead, which is the moſt common ore, is reduced by roaſting, and then fuſing with black flux. The other ores of lead are to be analyzed according to the nature of the acid with which they are combined. To obtain lead in a ſtate of purity, it may be diſſolved in nitric acid, and precipitated by means of ſulphate of ſoda. The precipitate, which is ſulphate of lead, is well waſhed, and reduced in a crucible, by fuſing it with three times its weight of black flux.

1827 Properties. 4. Lead is of a grayiſh or bluiſh white colour. It has conſiderable brilliancy, but it ſoon tarniſhes when expoſed to the air. The ſpecific gravity of lead is 11.352. It gives out a peculiar odour when it is rubbed; it has at firſt ſcarcely any perceptible taſte; but a diſagreeable impreſſion after ſome time remains on the tongue. When it is taken internally, it produces violent effects on the animal economy, even in very ſmall quantity. The colica pictonum or dry bellyach of the Weſt Indies, or, as it is called in this country, *mill-reek*, which is a violent affection of the bowels, is occaſioned by this metal being taken internally, either combined with ſome liquid, or in the ſtate of vapour. This terrible diſeaſe often terminates in palſy. Lead ſtains the finger or paper of a bluiſh colour. It is one of the ſofteſt of the metals. It may be ſcratched with the nail or cut with a knife. It poſſeſſes conſiderable malleability, and may be reduced to plates thinner than paper. It has no great ductility, and its tenacity is leſs than that of the other metals. A lead wire of about $\frac{1}{12}$ of an inch in diameter can ſupport only a weight of about 18lb.

1828 Action of heat. 5. Lead is very fuſible. It melts at the temperature of 540°, or, according to the eſtimation of Guyton, at 594°. When it is kept a long time melted, and at a red heat, it ſublimes, and evaporates in the air. By ſlow cooling it cryſtallizes in quadrangular pyramids compoſed of octahedrons.

1829 Oxidation. 6. When lead is expoſed to the air, it ſoon tarniſhes, is deprived of its luſtre, and becomes firſt of a deep gray, and afterwards of a grayiſh white colour; but this proceſs is extremely ſlow, for the white cruſt which is formed on the ſurface defends the metal from the action of the air, and its farther oxidation by abſorption of oxygen.

1830 Gray oxide. When lead is melted in the open air, and heat continued, an irideſcent pellicle is formed on the ſurface, which afterwards aſſumes a uniform gray colour. When this is removed, another pellicle is formed, and in this way the whole may be converted into an oxide. When theſe pellicles are heated and agitated together, the whole is converted into a grayiſh powder, mixed with yellowiſh or greeniſh ſpots. This is the gray oxide of lead, which is the firſt ſtate of its oxidation.

1831 Yellow. When the gray oxide of lead is more ſtrongly heated in contact with air, it abſorbs a greater quantity of oxygen, and is converted into a yellow oxide, which is known in the arts by the name of *maſſicot*. It contains about nine parts of oxygen in the hundred. This oxide which is much employed in ſome of the arts, is prepared in the large way, by conſtantly agitating it while heated, in contact with air, without applying ſo great a heat as to reduce the metal to the ſtate of the next oxide.

1832 Red. If this oxide of lead be reduced to a fine powder, and expoſed to a ſtrong heat in a furnace for about 50 or 60 hours, it is converted into a red powder which is well known by the name of *minium*, or *red lead*. The heat neceſſary for this converſion is that of a cherry-red, in a reverberatory furnace.

1833 Brown. Lead is ſuſceptible of combining with another portion of oxygen, and of forming another oxide. If a quantity of red oxide of lead, according to the proceſs of Prouſt and Vauquelin, be put into a veſſel with water, and oxymuriatic acid gas be paſſed through it, the oxide aſſumes a deeper colour, and is diſſolved. By adding potaſh to the ſolution, the lead is precipitated of a brown colour, which is the brown oxide of lead. It is of a ſhining brown colour, and is compoſed of

Lead	79
Oxygen	21
	100

By the action of the blow-pipe it becomes yellow, and melts. On burning coals it is reduced, and when heated in a retort, gives out pure oxygen gas, and is converted into a vitreous matter. It inflames ſulphur by triturating it with the oxide, and gives out a bright flame.

1834 Litharge. 7. When lead has been converted into an oxide, and when this oxide is expoſed to a more violent heat, it melts into a kind of glaſs, or ſemivitrified matter. In this ſtate it is known by the name of *litharge*. It conſiſts of ſmall reddiſh brilliant ſcales, which from the colour is called *litharge of gold*. When it has been expoſed to a greater degree of heat, and is more vitrified, it is diſtinguiſhed by the name of *litharge of ſilver*.

8. There is no action between lead and azote, hydrogen or carbone. Water has no action on lead, but it ſeems to promote the oxidation of this metal, when it is in contact with air. Leaden veſſels which are frequently moiſtened with water, are covered with a white cruſt when expoſed to the air.

1835 Phoſphuret. 9. Lead combines with phoſphorus, and forms with it a phoſphuret. This may be prepared by projecting phoſphorus on lead melted in a crucible, or by diſtilling phoſphorus with lead in a retort. The phoſphuret of lead is of a ſilvery white colour, with a little of a bluiſh ſhade. It is of a lamellated ſtructure, and may be ſeparated in plates by hammering. It is ſo ſoft that it may be cut with a knife. It is ſomewhat leſs fuſible than the component parts. During its fuſion, a ſmall quantity of phoſphorus ſeparates, and takes fire on the ſurface. The component parts of this phoſphuret are,

1836 Compoſition.

Lead	88
Phoſphorus	12
	100

1837 Sulphuret. 10. Sulphur combines readily with lead, either by melting ſulphur and lead together in a crucible, or by throwing ſulphur on melted lead. A black matter is thus obtained, of a brilliant appearance, fibrous texture, and leſs fuſible than lead. This compound is brittle, and reſembles the native ſulphuret of lead, or *galena*. The component parts of this ſulphuret are,

Lead

Lead	86.8
Sulphur	13.2
	100.0

1838 Affinities. 11. Lead enters into combination with the metals, and forms alloys, and with the acids, and forms ſalts. The order of the affinities of lead and of its oxide is the following.

Lead.	Oxide of Lead.
Gold,	Sulphuric acid,
Silver,	Saclactic,
Copper,	Oxalic,
Mercury,	Arſenic,
Biſmuth,	Tartaric,
Tin,	Muriatic,
Antimony,	Phoſphoric,
Platina,	Sulphurous,
Arſenic,	Suberic,
Zinc,	Nitric,
Nickel,	Fluoric,
Iron,	Citric,
Sulphur.	Lactic,
	Acetic,
	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Lead.

1. Sulphate of Lead.

1839 Preparation. Sulphuric acid has no action on lead in the cold, but when lead is boiled with the acid concentrated, it decompoſes it, and ſulphurous acid gas is diſengaged with effervescence. The lead is converted into a white thick maſs, which remains at the bottom of the veſſel. Sulphate of lead may alſo be obtained by adding ſulphuric acid or an alkaline ſulphate to acetate of lead. This ſalt is precipitated in the ſtate of a white powder. The white maſs obtained by the firſt proceſs, being waſhed with water ſeparates into two portions, one of which is oxide of lead containing a little ſulphuric acid, and the other portion, which is ſulphate of lead, is ſoluble in water, and may be obtained cryſtallized in needles. The ſpecific gravity of this ſalt is 1.8742. It has ſcarcely any taſte. It is found native, and cryſtallized in regular octahedrons, or four-ſided pyramids, or tranſparent tables. The component parts of native ſulphate of lead are, according to

1840 Compoſition.

	Kirwan.	Klaproth.
Oxide,	75.00	70.50
Acid,	23.37	25.75
Water,	1.63	2.25
	100.00 *	98.50 †

This ſalt is deprived of great part of its acid by means of the alkalies.

2. Sulphite of Lead.

1841 Preparation. Sulphurous acid has no action on lead, but it combines readily with the oxide of lead, with a ſmaller proportion of oxygen. The red oxide of lead added to liquid ſulphurous acid, ſoon becomes white; the acid is deprived of its odour, and there is formed a ſaline maſs of ſulphate and ſulphite of lead. The ſulphite of lead cannot be obtained ſeparately, but by treating the white oxide of lead ſeparated from the nitrate by means of ſulphurous acid. The ſulphite of lead is taſteleſs and inſoluble. 1842 Action of heat. By the action of the blow-pipe on charcoal, it melts, gives out a phoſphoric flame, and becomes of a pale yellow colour on cooling. When it is heated for a longer time, it ſwells up and is entirely reduced to the metallic ſtate. When diſtilled in cloſe veſſels, it gives out water, ſulphurous acid, and ſulphur, and there remains behind, ſulphate of lead of a greeniſh yellow colour. 1843 Decompoſition. It is decompoſed with effervescence and the evolution of ſulphurous acid, by means of ſulphuric and muriatic acids. It is not decompoſed by nitric acid, but is converted into a ſulphate, and red fumes of nitrous gas are given out. If, in place of treating the red oxide with ſulphurous acid, this oxide be expoſed to a red-heat, along with ſulphite of ſoda, the oxide is reduced, and the ſulphite of ſoda is converted into a ſulphate, but with exceſs of ſoda, becauſe the ſulphuric acid formed, cannot ſaturate the ſame quantity of ſoda. Hence it appears, that the red oxide of lead gives up part of its oxygen to the ſulphurous acid when it is uncombined, and the whole of its oxygen to the acid, when it is in combination with potaſh or ſoda *.

3. Nitrate of Lead.

1844 Preparation. 1. Nitric acid, a little diluted with water, acts upon lead, oxidates it, and diſſolves it with effervescence. If the acid be too ſtrong, there remains behind a dry oxide. This oxide is equally ſoluble in nitric acid. No precipitate is formed in the ſolution by the addition of water. It has at firſt a ſweetiſh, then an aſtringent, acrid taſte. By evaporating this ſolution, it affords on cooling, regular cryſtals in the form of flat triangles; and by ſlow, ſpontaneous evaporation, the angles are truncated. 1845 Properties. Sometimes ſix-ſided truncated pyramids are obtained, with the faces alternately broad and narrow. Theſe cryſtals decrepitate ſtrongly on burning coals, and give out brilliant ſparks. The ſalt is decompoſed, and a yellow or red oxide of lead remains behind. Nitrate of lead is decompoſed by the alkalies, and precipitated in the form of white oxide. It is precipitated of a black colour, by means of the ſulphurets and hydroſulphurets; it is alſo decompoſed by ſulphuric acid and the ſulphates, which form a thick, white, ſoluble precipitate of ſulphate of lead. Sulphurous acid alſo precipitates this ſalt in the form of ſulphate of lead.

1846 With the white oxide. 2. The former ſalt is a compound of nitric acid and the yellow oxide; but when nitric acid combines with the white oxide, the ſalt cryſtallizes in yellow coloured brilliant ſcales, which are very ſoluble in water. This ſalt may alſo be prepared by boiling together a quantity of nitrate of lead with the yellow oxide, along with lead in the metallic ſtate. The lead deprives the yellow oxide of part of its oxygen, and the whole is converted into the white oxide, and combines with the acid.

1847 Action on red oxide. 3. But if nitric acid be poured on the red oxide of lead, heat is produced, the oxide becomes white, part is diſſolved, and part falls to the bottom in the form of

---

* Min. Wat. p. 274.

† Eſſays, ii. 131. Tranſl.

* Fourcroy, viii. 86.

a black powder. This powder is the brown oxide of lead, with the greateſt proportion of oxygen, part of which it has derived from the red oxide, which is then converted into the white. About $\frac{6}{7}$ of the red oxide are diſſolved in the acid, but are previouſly reduced to the ſtate of white oxide, and the oxygen which has been given out, combines with the remaining $\frac{1}{7}$, and converts it to the ſtate of brown oxide. Thus it appears, that the red and the brown oxides of lead do not form compounds with nitric acid. They muſt be deprived of a portion of their oxygen, and converted into the white or yellow oxides, before they are ſoluble in this acid.

4. Muriate of Lead.

1849 Preparation. Muriatic acid acts feebly on lead or its oxide; but when it is heated with the latter, part of the oxide combines with the acid, becomes ſoluble with exceſs of acid, and affords cryſtals in the form of ſhining ſilky needles, which are not deliqueſcent in the air, but are ſoluble in water, and have an aſtringent taſte. This ſalt may be formed by adding an alkaline muriate to a ſolution of nitrate of lead. A white thick precipitate is immediately formed. The muriate of lead thus obtained, has a ſweetiſh taſte, and is ſoluble in about 30 times its weight of water. When heated, it readily melts, and gives out a white vapour, which condenſes into a cryſtalline powder. When this ſalt is melted, it aſſumes the appearance of a ſemivitreous, ſhining, grayiſh maſs, which has been called *plumbum corneum*, or *horny lead*. This ſalt is decompoſed by ſulphuric acid.

1848 Compoſition. Its component parts are, according to

Klaproth.		Kirwan.	
Acid,	13.5	Acid,	18.23
Oxide of lead,	86.5	Oxide of lead,	81.77
	100.0		100.00

1849 With red oxide. 2. When muriatic acid is ſlightly heated with the red oxide of lead, the acid is converted into oxymuriatic acid; while the oxide, deprived of part of its oxygen, unites to another portion of the acid, and forms muriate of lead in the ſtate of white powder.

5. Hyperoxymuriate of Lead.

1850 Preparation. When oxymuriatic acid gas is made to paſs through water, having a white, yellow, or red oxide of lead, it is abſorbed. The oxide becomes at firſt black or brown, and is then diſſolved. The hyperoxymuriate which is formed, remains in ſolution of a yellow colour. This ſolution being precipitated with potaſh or ſoda, the oxide of lead is depoſited, of a reddiſh brown colour. This ſalt may be obtained by pouring oxymuriatic acid on nitrate of lead. No precipitate is at firſt formed, but in the end a browniſh red powder appears. This ſalt is more ſoluble than muriate of lead, and is readily decompoſed.

1851 Properties. The brown oxide of lead, which is obtained by decompoſing this ſalt, according to the experiments of Vauquelin, poſſeſſes very different properties from thoſe of the other oxides of this metal. It is of a deep, ſhining, velvet-brown colour. Heated with the blow-pipe, it becomes yellow, and melts. On red-hot coals it is reduced; it gives out pure hydrogen gas, when it is heated in a retort, and there remains behind a litharge of lead. It diſſolves in nitrous acid, but is inſoluble in nitric acid. The addition of ſugar, honey, or ſome vegetable matter, by depriving it of part of its oxygen, renders it ſoluble in this acid.

6. Fluate of Lead.

This ſalt may be formed by pouring a ſolution of an alkaline fluate into a ſolution of nitrate of lead. An inſoluble inſipid ſalt is thus formed, which is decompoſed by ſulphuric, nitric, and muriatic acids.

7. Borate of Lead.

This ſalt is formed in the ſame way as the laſt, and is in the ſtate of white powder. It melts before the blow-pipe, into a colourleſs glaſs.

8. Phoſphate of Lead.

1852 Preparation. 1. Liquid phoſphoric acid acts very ſlowly upon lead, and converts it into a white, inſoluble phoſphate. It may be formed, however, by adding an alkaline phoſphate to the nitrate of lead. With an exceſs of acid this ſalt becomes fuſible by heat, and when it cools, aſſumes the form of regular polyhedrons. It is decompoſed by red-hot charcoal, which converts it into phoſphorus and lead, while the carbone of the charcoal is converted into carbonic acid. It is decompoſed by ſulphuric, nitric, and muriatic acids, and by the alkaline carbonates.

1853 Native. This ſalt is frequently found native, cryſtallized in ſix-ſided priſms, of a green or yellow colour. It is ſoluble in pure ſoda, but inſoluble in water. The component parts of a phoſphate of lead from Wanlockhead in Scotland, according to the analyſis of Klaproth, are the following.

Oxide of lead,	80.00
Phoſphoric acid,	18.00
Muriatic,	1.62
	99.62 *.

9. Carbonate of Lead.

1854 Preparation. 1. Carbonic acid which has no action on lead, combines with its oxide, which is converted into the carbonate of lead; or this ſalt may be prepared by the decompoſition of a ſoluble ſalt of lead by an alkaline carbonate. Thus precipitated, it is in the ſtate of white powder, which has neither taſte nor ſmell, and is inſoluble in water, but it is ſoluble in pure potaſh.

1855 Native. 2. This ſalt is frequently found native, of a whitiſh colour, and cryſtallized in tables, in ſix-ſided priſms, or in regular octahedrons. The ſpecific gravity is 7.2357. It is inſoluble in water. By the action of the blow-pipe on charcoal, the acid is driven off, and the lead is revived. The component parts of carbonate of lead, are, according to

	Bergman.	Klaproth.
Acid,	16	16.33
Yellow oxide,	84	83.67
	100	100.00

1856 White lead. 3. Ceruſe or white lead, which is employed as a paint, is a carbonate of lead, combined with a certain proportion

---

* *Eſſays*, ii. 125. *Tranſl.*

proportion of oxide. It is prepared by expoſing thin plates of lead to the vapour of vinegar. A range of pots are placed on tanners bark or horſe dung, that they may receive a moderate heat. Theſe are covered with plates of lead, which are full of holes. Another range of pots is placed above theſe, covered in like manner with plates of lead, and ſo on, till the whole chamber is filled. The acid is decompoſed; part of the lead remains in the ſtate of oxide, while the greateſt proportion is converted into a carbonate, which is the white lead of commerce.

10. Arſeniate of Lead.

When lead is digeſted in a ſolution of arſenic acid, the ſurface is blackened, and becomes covered with a white powder. When lead filings are diſtilled with double their weight of ſolid arſenic acid, the mixture melts into a tranſparent maſs. A ſmall quantity of arſenious acid is ſeparated, and there remains behind a whitiſh glaſs, which being diluted with water, lets fall a white powder, whilſt part of the arſenic acid is diſſolved. The lead in this caſe has deprived the arſenic acid of part of its oxygen, and in the ſtate of white oxide has combined with another portion of the acid. The arſeniate of lead is not ſoluble in water. By heat it fuſes into a white glaſs. This ſalt is found native, and by the analyſis of Mr Chenevix it is compoſed of 1857 Compoſition.

Acid,	33
White oxide,	63
Water,	4
	100

11. Tungſtate of Lead.

Tungſtic acid ſeparates the oxide of lead from its ſolution in nitric acid, and forms a tungſtate of lead, in the form of a white powder.

12. Molybdate of Lead.

When molybdic acid is added to the ſolution of lead in nitric acid, it forms a copious white precipitate, which is molybdate of lead. This ſalt is found native, and cryſtallized in cubes or rhomboidal plates. It is of a yellow colour, inſoluble in water, but ſoluble in fixed alkalies and nitric acid. It is decompoſed by muriatic acid. The component parts, as aſcertained by Klaproth, are,

Acid,	34.7
Oxide,	65.3
	100.0

13. Chromate of Lead.

An alkaline chromate mixed with the ſolution of nitrate of lead, forms a precipitate in the ſtate of red powder, which is chromate of lead. This ſalt is found native, of a reddiſh yellow colour, and cryſtallized in four-ſided priſms, terminated by four-ſided pyramids. The ſpecific gravity is about 6. It is ſoluble in the fixed alkalies, but inſoluble in water. It is decompoſed by muriatic and ſulphuric acids, but diſſolves without decompoſition in nitric acid. According to the analyſis of Vauquelin, it is compoſed of

Acid,	34.9
Oxide,	65.1
	100.0

14. Acetate of Lead.

1858 Names. 1. The combination of acetic acid and lead was formerly known by the names of *extract of Saturn*, *ſalt of Saturn*, *ſugar of Saturn*, or *ſugar of lead*. This acid oxidates lead, and diſſolves the oxides with great facility. 1859 Preparation. It is formed by diſſolving carbonate of lead or ceruſe in acetic acid, or by expoſing thin plates of lead to the action of acetic acid in earthen veſſels. After the acid has been ſufficiently ſaturated, and the ſolution concentrated by evaporation, the acetate of lead is depoſited in ſmall cryſtals.

1860 Properties. 2. This ſalt is in the form of ſmall cryſtals, which are flat, four-ſided priſms, terminated by two-ſided ſummits. It has an aſtringent ſweetiſh taſte. The ſpecific gravity is 2.345. It is not very ſoluble in water, without an exceſs of acid. It undergoes no change by expoſure to the air. By its ſolution in water, a ſmall quantity is depoſited in the form of white powder, which is a carbonate of lead, formed by the carbonic acid which exiſts in the water.

1861 Decompoſition. 3. Acetate of lead is decompoſed by ſulphuric, muriatic, fluoric, and phoſphoric acids. It is decompoſed by heat. By diſtillation it affords, according to the experiments of Prouſt, from 160 parts of the ſalt, 12 parts of ſlightly acidulated water; with a greater heat, 72 parts of a yellow liquid, having the odour of alcohol, which had ſomething of an empyreumatic ſmell. Ammonia was diſengaged, by adding lime to the liquid; and when the liquid was ſaturated with potaſh, and remained at reſt for 24 hours, a third part of oil ſeparated, and floated on the ſurface. This oil, which had a ſtrong odour, was removed, and the liquid diſtilled with a moderate heat. The firſt part that came over mixed with water like alcohol, and was almoſt as volatile as ether. When it was brought into contact with a burning body, it gave out a white flame.

15. Oxalate of Lead.

Oxalic acid very readily tarniſhes lead, and at laſt corrodes it. It readily diſſolves the oxide; and when it is ſaturated, the ſolution becomes thick, and depoſits ſmall ſhining cryſtals, which become readily opaque by expoſure to the air. This ſalt may be formed by pouring oxalic acid into the ſolutions of nitrate, muriate, or acetate of lead. It is ſcarcely ſoluble in water, without an exceſs of acid. The component parts are,

Acid,	41.2
Oxide,	58.8
	100.0

16. Tartrate of Lead.

Tartaric acid combines with the oxide of lead, or forms a precipitate in the ſtate of an inſoluble white powder,

powder, from the ſolution of lead in nitric and muriatic acids. It is compoſed of

Acid,	34
White oxide,	66
	100 *.

17. Tartrate of Potaſh and Lead.

This triple ſalt is obtained by boiling the oxide of lead in tartar with water. It is inſoluble, and is not decompoſed by the alkalies.

18. Citrate of Lead.

By adding citric acid to a ſolution of acetate of lead, a citrate of lead precipitates in the form of powder, which is ſcarcely ſoluble in water.

19. Malate of Lead.

This ſalt is obtained by adding malic acid to a ſolution of the nitrate or acetate of lead. The malate of lead precipitates in the form of fine light flakes. It is ſoluble in acetic and diluted nitric acids.

20. Benzoate of Lead.

Benzoic acid has but a feeble action on lead. By evaporating the ſolution, cryſtals of a brilliant-white colour are obtained, which are benzoate of lead. This ſalt undergoes no change by expoſure to the air, is ſoluble in water and alcohol, is decompoſed by heat, and by the ſulphuric and muriatic acids.

21. Succinate of Lead.

Succinic acid combines with the yellow oxide of lead, and yields ſlender foliated cryſtals, which are nearly inſoluble in water, but ſoluble in nitric acid.

22. Saccolate of Lead.

When ſaclactic acid is added to ſolution of nitrate of lead, a white precipitate is obtained, which is ſaccolate of lead.

23. Suberate of Lead.

Suberic acid forms a precipitate when added to the ſolution of lead in acetic and nitric acids.

24. Lactate of Lead.

Lactic acid, after it has been digeſted upon lead for ſome days, diſſolves a portion of it. The ſolution has a ſweet, aſtringent taſte, but it does not cryſtallize.

II. Action of the Alkalies, &c. on Lead.

1862 Promote its oxidation. The alkalies and earths have no action whatever on lead. The alkalies, however, promote its oxidation by the air, on account of the attraction which they poſſeſs for the oxide of lead.

1863 Combine with the oxide. 2. The alkalies and alkaline earths unite readily with the oxide of lead. Lime water digeſted ſome time with oxide of lead in the ſtate of litharge, diſſolves this oxide better than the red. When the ſolution is evaporated, it affords ſmall, tranſparent, irideſcent cryſtals, not more ſoluble than lime. The alkaline ſulphates decompoſe this compound of oxide of lead and lime. It is alſo decompoſed by ſulphurated hydrogen gas, and by ſulphuric and muriatic acids, which latter convert the lead into a ſulphate and muriate. This ſolution blackens wool, the nails, hair, the white of an egg; but has no action, and produces no change on ſilk, on the ſkin, or the yolk of an egg. It has been obſerved, that the ſimple mixture of red oxide of lead and of lime, which latter converts it to white, produces a black colour on animal matters. It is ſometimes employed for dyeing the hair. It had formerly been obſerved by Bergman, that the cauſtic fixed alkalies diſſolve the oxide of lead, which takes place when theſe bodies are added in exceſs to the precipitates of this metal from its ſolution.

1864 Earths. 3. The earths, but eſpecially alumina and ſilica, readily combine with the red oxide of lead, by the action of heat; and, when the proportion of oxide is conſiderable, the compound is a heavy, uniform, vitreous maſs, which has been called *glaſs of lead*. It is on account of the ſtrong tendency of the oxide of lead to vitrification, and which it communicates to earthy matters, that it is employed in the compoſition of glaſs in the proportion of from $\frac{1}{5}$ to $\frac{1}{6}$. This oxide was only employed formerly, for the preparation of enamels, and for glazing pottery and ſtone ware; but it is now generally uſed after the example of the Engliſh manufacturers, in the fabrication of glaſs, in moſt countries of Europe.

1865 Sulphates, &c. 4. Lead has no action on the ſulphates. It burns ſlowly with the aſſiſtance of the nitrates. When nitre, in the ſtate of fine powder, is thrown into melted lead, raiſed to a red heat, there is ſcarcely any perceptible flame; and, when the action has ceaſed, the oxide is found in ſmall yellowiſh ſemivitrified ſcales, ſimilar to thoſe of litharge.

1866 Muriates. 5. There is a perceptible action between lead and the muriates, ſome of which have given riſe to ſeveral important proceſſes in chemiſtry, and in the arts. It had been long obſerved, that a plate of lead immerſed in water, ſaturated with muriate of ſoda, was ſoon covered with a cruſt of white oxide. It was alſo known, that the red oxide of mercury and litharge became white when kept in contact with muriate of ſoda diſſolved in water. This proceſs, which is promoted by agitation, is one of the great deſiderata of modern chemiſtry, to be able to decompoſe common ſalt for the purpoſe of obtaining the ſoda. It was at firſt ſuppoſed, that this was a partial decompoſition, from which a ſmall quantity of muriate of lead only was obtained; that the decompoſition was aided by heat; and that it was by this proceſs that a brilliant yellow muriate of lead, much employed in painting under the name of *Engliſh yellow*, was prepared.

1867 Decompoſition of muriate of ſoda. This ſubject has been greatly elucidated by the experiments and reſearches of Vauquelin. He took ſeven parts of litharge reduced to powder, and one of muriate of ſoda mixed together, and moiſtened with a ſufficient quantity of water, to reduce them to the liquid ſtate, and then agitated the mixture for ſeveral hours to promote the reciprocal action. The oxide became white, and increaſed in volume, and the mixture abſorbing the water, became of a more ſolid conſiſtence. Having added new quantities of water during four days, and diluted the whole in ſeven or eight parts of this

---

* Ann. de Chim. xxxviii. 37.

this liquid, it was filtered. The liquid, which was now ſenſibly alkaline, contained a little muriate of lead, but no trace of muriate of ſoda. When it was evaporated to $\frac{1}{10}$ of its bulk, it yielded cryſtals of carbonate of ſoda, which were opaque, by being contaminated with muriate of lead. The oxide of lead which remained, had increaſed about $\frac{1}{8}$ of the weight; it became of a fine citron-yellow colour, with a moderate heat, and loſt 0.025 of its weight. It was inſoluble in water. Soda diſſolved a portion of this oxide, as did alſo diluted nitric acid. By this means the muriate of lead was ſeparated pure and cryſtallized; and the maſs which remained after the action of muriate of ſoda and lead, exhibited the characters of a muriate of lead containing an exceſs of oxide.

From theſe experiments Vauquelin concludes, that the litharge which has been employed in the decompoſition of ſea ſalt, is a muriate of lead with exceſs of oxide; that the cauſtic alkalies diſſolve this ſalt, but do not decompoſe it; that the affinity of muriate of lead for an exceſs of the oxide of this metal, is the cauſe of the decompoſition of muriate of ſoda by means of litharge; that the exceſs of oxide gives to the muriate of lead the property of aſſuming a brilliant yellow colour by heat, a property which the ſimple muriate of lead does not poſſeſs; that the ſame exceſs of lead renders it inſoluble in water, and that this exceſs may be taken up by the nitric acid, which reduces it to the ſtate of ordinary muriate of lead. The ſame philoſopher has confirmed theſe inferences, by ſhewing that cauſtic ſoda decompoſes the common muriate of lead, only by bringing it to the ſtate of muriate with exceſs of oxide, which is characterized by being in the form of powder, and the yellow colour, which is communicated by heat, and its decompoſition by nitric acid, which converts it into nitrate of lead, and ſimple muriate of lead. Thus, it appears, that the oxide of lead decompoſes the muriate of ſoda, by double affinity; namely, by the affinity of the oxide for muriatic acid, and that of the muriate of lead for an exceſs of oxide. A conſiderable quantity of the latter, therefore, is neceſſary for the complete decompoſition. Five-ſixths at leaſt are required to form the muriate with exceſs of oxide. Litharge then decompoſes ſea ſalt completely, when in ſufficient quantity, while ſoda only decompoſes the muriate of lead partially, and reduces it to the ſtate of muriate with exceſs of oxide; but the carbonate of ſoda effects the entire decompoſition of this ſalt.

1868 Muriate of ammonia. 6. The decompoſition of muriate of ammonia by lead, and eſpecially by its oxide, has been long known. The oxides of lead triturated with this ſalt in a mortar in the cold, diſengage ammonia, which is very perceptible by its ſmell. By diſtilling a mixture of one part of red oxide of lead and two of muriate of ammonia in a retort, very pure cauſtic ammonia is obtained. If the red oxide has remained for any length of time expoſed to the air, it gives out, during the proceſs, a little carbonate of ammonia. The hyperoxymuriate of potaſh produces a detonation with lead. A mixture of three parts of this ſalt with one of lead, gives out a vivid flame by percuſſion. The other ſalts, as the phoſphates, fluates, &c. have no effect on lead. By the action of the blow-pipe, they combine with its oxides, and form yellowiſh, or gray, opaque, or tranſparent glaſſes.

III. Alloys.

1869 With arſenic. 1. Lead combines with arſenic by fuſion, and the compound is a brittle lamellated alloy. When the oxides of theſe metals are combined together by means of heat, a vitreous maſs of a red colour is formed.

2. The alloys of lead with tungſten, molybdena, and the newly diſcovered metals, are not known.

1870 Cobalt. 3. Cobalt ſeems to have little affinity for lead. Equal parts of the two metals being fuſed together, were found, when the maſs cooled, to be in ſeparate maſſes. The heavieſt metal occupied the inferior part of the veſſel, and the lighter the upper part. An alloy of lead and cobalt has been formed by introducing cobalt in powder within plates of lead, and covering them with charcoal, to exclude the air. A brittle maſs, which aſſumed a better poliſh than lead, was obtained from equal parts of the two metals, by the application of heat. The two metals in different proportions afforded an alloy which differed in hardneſs, ſpecific gravity and malleability, according as the one or the other metal predominated.

1871 Biſmuth. 4. Lead forms with biſmuth an alloy of a cloſe grain, and a dark gray colour. This alloy, when the biſmuth is not in great proportion, poſſeſſes conſiderable ductility. Biſmuth has the property of increaſing the tenacity of lead. The ſpecific gravity of the alloy of lead and biſmuth is greater than the mean.

1872 Antimony. 5. When lead is combined with one-eighth of its weight of antimony, it forms an alloy which poſſeſſes great tenacity. When they are combined in equal parts, the alloy is very brittle. Two parts of lead with one of antimony, give a brittle alloy in ſmall grains ſimilar to thoſe of iron. Four parts of lead with one of antimony, afford an alloy of greater ductility, and in larger grains. Four parts of lead with one-half of antimony, give a very ſoft metal in fine grains like ſteel, and having the ſame colour. The alloy of 16 parts of lead and one of antimony, differs only from lead in hardneſs. This alloy has a greater ſpecific gravity than the mean, and poſſeſſes conſiderable tenacity. It is employed in the fabrication of printing types.

1873 Mercury. 6. Mercury combines with lead very readily, and in all proportions. An amalgam of lead and mercury may be formed by triturating the former in filings with the latter; or, by adding heated mercury to lead in fuſion. This amalgam varies in ſolidity, according to the proportion of the two metals. It is of a white colour, is altered by expoſure to the air, and affords cryſtals by cooling. The mercury is driven off by ſtrong heat, and when it is triturated with water, a black powder, which is oxide of lead, ſeparates. The amalgam of lead and mercury becomes very liquid, when it is triturated with the amalgam of biſmuth. 1874 And biſmuth. To equal parts of lead and biſmuth melted in an iron veſſel, half the quantity of the whole maſs of hot fluid mercury was added, and the mixture was agitated till it cooled. A fluid amalgam was thus obtained, which does not become ſolid by reſt, or expoſure to the air, and which almoſt entirely paſſes through leather like mercury itſelf. This liquidity of lead and biſmuth is aſcribed to their increaſed capacity for caloric in a ſtate of combination. When mercury is thus ſophiſticated, it may be detected by obſerving

the

the ſmaller ſpecific gravity, and ſubjecting it to the teſt formerly mentioned, of pouring it along a ſmooth ſurface, when it is found to *drag a tail*.

1875 Zinc. 7. An alloy of zinc and lead in equal parts is harder and whiter than lead, and is malleable. The lead is rendered volatile by the zinc, while the latter is in the proportion of 10 or 12 parts to one of the former; but if the zinc be in ſmaller proportion, it ſeparates from the lead. The ſpecific gravities of the alloys of zinc and lead are ſaid to be greater than the mean of the two metals.

1876 Tin. 8. Lead combines with tin in all proportions. Lead, in general, is found to increaſe in denſity and hardneſs, when alloyed with tin. Three or four parts of tin with one of lead, according to Muſchenbroek, form an alloy which poſſeſſes twice the hardneſs of pure tin. The alloy of three parts of tin and one of lead poſſeſſes the greateſt tenacity of any proportion of theſe metals. Two parts of lead and one of tin, 1877 Solder. compoſe an alloy which is more fuſible than either of the metals. This is the compoſition of common ſolder. Tinfoil is a compound of tin and lead; and the ſheet lead employed for lining the boxes in which tea is brought from China to Europe, contains a certain portion of tin, which gives it hardneſs. This, however, is alſo found to be alloyed with zinc and biſmuth.

1878 Tin and biſmuth. One of the moſt ſingular alloys of lead is that with biſmuth and tin, which has been called from its eaſy fuſibility, the *fuſible alloy*. Eight parts of biſmuth, five of lead and three of tin, are the proportions propoſed by Darcet for this alloy, which is ſo fuſible, that it remains liquid at the temperature of boiling water. This alloy cryſtallizes by ſlow cooling.

1879 Uſes of lead, &c. Lead and its various preparations are applied to a great variety of purpoſes in the arts. In the metallic ſtate it is employed in the conſtruction of numerous veſſels. In the ſtate of oxide it is uſed as a paint, and in the fabrication of enamels for porcelain and pottery, and in the preparation of coloured glaſs and artificial precious ſtones. Some of its ſalts are of great importance in the arts, as the acetate in dyeing, and the carbonate or ceruſe in painting.

The greateſt caution ought to be obſerved, however, in the uſe of leaden veſſels in domeſtic economy, in which ſubſtances are preſerved which are to be taken internally, particularly thoſe which contain acids that are apt to diſſolve the lead; and as the effects of lead are ſo deleterious to the animal economy when taken internally, this caution cannot be too ſtrictly obſerved.

SECT. XVIII. *Of IRON and its Combinations.*

1880 Hiſtory. 1. Iron is one of the moſt important and moſt uſeful of the metals, and it is fortunately one of the moſt abundant. It is ſuppoſed that it was not ſo early known as ſome of the other metals, which, on account of their ſcarcity and durability, have been held in higher eſtimation, and dignified with the name of *precious metals*. But perhaps the difficulty of extracting and working iron prevented it from being ſo generally applied to thoſe purpoſes to which, on account of its valuable properties, it is peculiarly appropriated.

1881 Very abundant. 2. Iron, as it is the moſt uſeful of the metals, ſo, as it has been obſerved, it is the moſt abundant, and at the ſame time the moſt univerſally diffuſed. Iron exiſts in five different ſtates, but in theſe it exhibits the greateſt variety of any other of the metals. It is found in the metallic ſtate, in that of alloy with other metals; in the ſtate of ſulphuret, in the ſtate of oxide, and combined with the acids forming ſalts. 1882 Ores. 1. Iron has only been found native in inſulated maſſes, one of which, diſcovered by Pallas in Siberia, and another, which was found in South America, long occupied the attention of philoſophers in ſpeculations and diſcuſſions concerning their origin. This point remained unſettled till the diſcovery of numerous other facts with regard to ſimilar productions, which have proved, whatever may have been their origin or mode of formation, that theſe metallic maſſes have fallen from the atmoſphere. 2. Iron is frequently found in the ſtate of alloy with other metals; but in this ſtate it is generally in very ſmall proportion. 3. Combined with ſulphur. This compound, or ſulphuret of iron, which is known to mineralogiſts by the name of *pyrites*, is a frequent production among the ores of iron. Sulphuret of iron is found cryſtallized in a great variety of forms. Iron is alſo frequently found combined with carbone. This compound, now diſtinguiſhed by the name of *carburet of iron*, was formerly known by the name of *black lead*, or *plumbago*. 4. But the moſt ordinary ſtate of iron is that of oxide, and in this ſtate it exhibits a great variety of forms. It is ſometimes in irregular and inſulated maſſes; ſometimes regularly cryſtallized, and diſpoſed in veins. 5. The native ſalts of iron are very numerous. It has been found in the ſtate of ſulphate, phoſphate, carbonate, tungſtate, and pruſſiate, and there is reaſon to believe, that it exiſts in combination with many other acids.

1883 Analyſis. 3. The method of aſſaying iron ores, or of extracting the metal from theſe ſubſtances with which it is combined, varies according to the nature of the ore. It is firſt reduced into powder, and expoſed to heat, to ſeparate the moiſture or ſulphur, or other volatile matters. Four parts of the ore are then to be mixed with an equal quantity of decrepitated muriate of ſoda, and the ſame quantity of a mixture of equal parts of fluor ſpar and lime, with one-half part of charcoal. This mixture is expoſed to a red-heat in a crucible nearly an hour, after which the iron is found in the metallic ſtate at the bottom of the crucible. In the humid way, a given quantity of iron ore may be reduced to powder, and digeſted with ſix parts of muriatic acid, which combines with the iron, and other ſubſtances ſoluble in that acid, but leaves the ſulphur and ſiliceous earth behind. The ſolution is then to be ſaturated with potaſh, by which the iron is precipitated in the ſtate of oxide, along with the earths with which it had combined. The precipitate is to be well dried, and ſubjected to a red-heat. It is then to be reduced to powder, and digeſted with diluted nitric acid. The acid combines with the earths, but leaves the iron, becauſe it is too highly oxidated to be ſoluble in this acid. The oxide, after being well waſhed, is mixed with charcoal, and expoſed to a ſtrong heat in a crucible, by which the oxygen is driven off, and the iron remains behind in the metallic ſtate.

1884 Properties. 4. Iron has a peculiar metallic brilliancy. It is of a grayiſh or bluiſh-white colour. The ſpecific gravity of iron is from 7.6 to 7.89, and according to ſome, even 8.16. It has an aſtringent taſte, and when it is rubbed, gives out a peculiar ſmell. One of the ſingular properties of iron, is that of poſſeſſing the magnetic virtue, or of being attracted by the magnet. Iron poſſeſſes a conſiderable degree of malleability, but in this property it is inferior to gold or ſilver. It is extremely ductile. It may be drawn out into wire almoſt as fine as hair. The tenacity of iron is very great. A wire .078 of an inch in diameter will ſupport a weight, without breaking, equal to more than 500 lib. avoirdupois *. The texture of iron ſeems to be fibrous, and to this, it is ſuppoſed, are owing its great ductility and tenacity.

1885 Action of heat. 5. Iron is one of the moſt infuſible of the metals. It is ſaid that it requires a temperature equal to more than 150° Wedgwood for its fuſion. It becomes red long before it melts, and different degrees of temperature are diſtinguiſhed by the different ſhades of red which it exhibits. The firſt is called a *dull red*, the ſecond a *cherry red*, the third a *bright red*, and the fourth a *white heat* or *incandeſcence*.

1886 Oxidation. 6. When iron is expoſed to the air, the ſurface ſoon becomes tarniſhed, and is covered with a brown powder, which is called *ruſt*. This proceſs is greatly promoted by the moiſture of the atmoſphere. This is the oxidation of the metal, and its converſion into an oxide, by combining with the oxygen of the atmoſphere. The proceſs of ruſting, then, is the oxidation of the iron, and it is owing to the ſtrong affinity which exiſts between iron and oxygen. But ruſt is not merely a combination of oxygen. It has combined with a certain proportion of carbonic acid. This was formerly called *ſaffron of mars*.

1887 Oxides two. 7. There are two oxides of iron; the firſt, or that which contains the greateſt proportion of oxygen, is common ruſt, or, as it is denominated from its colour, 1888 Red oxide. brown or red oxide of iron. This oxide may be formed by expoſing iron filings in an open veſſel to a red heat, and agitating them till they are converted into a red powder. This oxide conſiſts of

Oxygen,	48
Iron,	52
	100

The red oxide of iron cannot be decompoſed by heat; but when it is expoſed to heat with its own weight of iron filings, there is no evolution of any gas, but the iron filings are converted into a black powder, and the 1889 Black. red oxide is converted into a ſimilar powder. This is the black oxide of iron, which contains the ſmaller proportion of oxygen. This oxide is compoſed of

Oxygen,	27
Iron,	73
	100

This oxide may alſo be obtained by heating iron filings for ſome time in water at a temperature not under 70°, or by making the vapour of water paſs through a red-hot tube containing iron wire, or ſmall fragments of iron. The water in theſe caſes is decompoſed, the hydrogen eſcapes in the form of gas, and the oxygen combines with the iron. This oxide was formerly called *martial ethiops*. It is this oxide which is obtained by burning iron wire in oxygen gas.

8. There is no action between iron and azote. Hydrogen gas, which is obtained from the decompoſition of water by means of iron filings and ſulphuric acid, holds a ſmall quantity of iron in ſolution. When hydrogen gas is brought into contact with the red oxide of iron; it deprives it of that proportion of oxygen which it contains above the black oxide, and converts it into this oxide.

1890 Carburet. 9. Iron combines very readily with carbone, and forms a carburet. When the charcoal combines with one-tenth of its weight of iron, it conſtitutes a carburet, which is found native, and diſtinguiſhed by the name of *plumbago*, or *black lead*. This compound has a metallic luſtre, is of a bluiſh or dark-gray colour, has a greaſy feel, and ſtains the fingers. It is well known as the ſubſtance of which black-lead pencils are compoſed. But there is another combination of iron with carbone, which forms one of the moſt important compounds, on account of its valuable properties, and the numerous uſes to which it is applied. This is ſteel. The different ſtates of iron are owing to its being perfectly free from contamination with other ſubſtances, or to its combination with carbone in different proportions. In theſe different ſtates it is diſtinguiſhed by the names of *caſt* or *crude iron*, *wrought iron*, and *ſteel*.

1891 Proceſs for obtaining. *Crude* or *caſt iron*. When iron is firſt extracted from its ores, it is in the ſtate of what is called crude iron. Iron is generally obtained from ores in the ſtate of oxide, and this is frequently mixed with clay. It muſt therefore be ſeparated from theſe ſubſtances. This is accompliſhed by reducing the ore to ſmall pieces, and mixing it with a flux compoſed of limeſtone and charcoal. It is then expoſed to a very ſtrong heat. For this proceſs, furnaces are conſtructed in ſuch a way, that the heat can be raiſed to a very high temperature. The nature of this proceſs muſt be obvious. The carbone of the charcoal combines with the oxygen of the iron, and forms carbonic acid, which is driven off in the ſtate of gas. By the ſtrong heat to which the lime and the clay are ſubjected, they are fuſed together, and form a vitreous matter, which being lighter than the iron, riſes to the ſurface. The iron alſo is in a ſtate of fuſion at the bottom of the furnace. When the proceſs is finiſhed, a hole is opened, through which the fluid iron flows, and is received into moulds. This is crude or caſt iron, or in the language of the workmen, *pig iron*. In this ſtate it is extremely brittle and hard, and poſſeſſes ſcarcely any malleability. It ſtill contains a conſiderable proportion of carbone, and it is not entirely free from oxygen.

1892 Soft iron. *Wrought Iron.*—The next proceſs in the manufacture of iron, is to deprive it of thoſe ſubſtances which alter its properties, and prevent its application to the purpoſes of pure or malleable iron. The crude iron is again introduced into a furnace, where it is melted by the flame of combuſtible ſubſtances, which is directed to its ſurface, and while it is in the ſtate of fuſion, it is conſtantly ſtirred, that the whole of it may be uniformly brought into contact with the air. At laſt it ſwells, and gives out a blue flame, and when this is continued for about an hour, the iron begins to acquire ſome conſiſtency, and at laſt becomes ſolid. While it is hot, it is removed from the furnace, and hammered

hammered by the action of machinery. It is then in the ſtate of wrought or ſoft iron.

Steel.—This is ſoft iron or wrought iron combined with a certain portion of carbone. There are different proceſſes for the preparation of ſteel; and the ſteel prepared by theſe proceſſes has received different names.

1893 Natural ſteel.

What is called natural ſteel, is prepared by expoſing caſt iron to a ſtrong heat in a furnace, while its ſurface is covered with ſcoriæ. In this proceſs part of the carbone of the crude iron combines with the oxygen, from which it is not entirely free, and is driven off in the ſtate of carbonic acid gas. The iron remains combined with a ſmall proportion of carbone. The ſteel prepared in this way is of an inferior quality.

1894 Of cementation.

Steel of cementation is prepared by arranging bars of pure iron and charcoal in powder in alternate layers, in large troughs or crucibles, which are carefully cloſed up with clay. Theſe are expoſed to heat in a furnace for the ſpace of eight or ten days, when the bars of iron are found converted into ſteel. This is ſometimes called *bliſtered ſteel* from bliſters which appear on the ſurface, or tilted ſteel, when it is drawn out into ſmaller bars by the hammer. By breaking it into pieces, and repeated welding in a furnace, and afterwards drawing it out into bars, it is converted into what is called *German* or *ſheer ſteel*. Steel formed in this way is generally of a ſuperior quality to natural ſteel.

1895 Caſt.

Caſt ſteel is prepared by fuſing natural ſteel with charcoal powder, and pounded glaſs, in a cloſe crucible; or by melting together 30 parts of iron, one of pounded glaſs, and one of charcoal. By this proceſs the beſt kind of ſteel is obtained, and it is this which is generally uſed for the finer kinds of cutting inſtruments. Different opinions have been entertained concerning the proportions of iron and carbone in the compoſition of ſteel. According to ſome, the proportion of carbone amounts to $\frac{1}{32}$ part, though, according to others, it does not exceed $\frac{1}{140}$ part.

1896 Properties of ſteel.

Steel poſſeſſes very different properties from iron. It is extremely hard and brittle, does not yield to the file, and retains the magnetic virtue for any length of time. When it is hammered, its ſpecific gravity is greater than that of iron. It is not malleable when cold, but it has this property when red-hot, and it may be reduced to thinner plates than iron.

1897 Diſtinguiſhed from iron.

There is a very eaſy teſt by which ſteel may be diſtinguiſhed from iron. If a drop of diluted nitric acid be let fall on ſteel, and allowed to remain for a few minutes, it leaves behind, after it is waſhed off, a black ſpot, which is owing to the converſion of the carbone of the ſteel into charcoal, by combining with the oxygen of the acid. But if nitric acid is dropt on iron, a whitiſh gray ſpot remains.

1898 Phoſphuret.

10. Iron combines with phoſphorus, and forms with it a phoſphuret. It may be formed by melting in a crucible 16 parts of phoſphoric glaſs with 16 parts of iron, and one-half part of charcoal in powder. The phoſphuret of iron is of a white colour when it is broken, and it is obſerved cryſtallized in ſome points in rhomboidal priſms. It is of a ſtriated and granulated texture, and is magnetic. This phoſphuret may be formed alſo, by dropping ſmall bits of phoſphorus into iron filings heated red-hot. This is the *ſiderite* of Bergman, in which he ſuppoſed he had diſcovered a new metal, to which he gave the name of *ſiderum*.

1899 Cold ſhort iron.

What is called *cold ſhort iron*, from its being brittle when cold, but malleable when it is heated, contains a certain portion of phoſphate of iron, to which this property is owing. It was in the inveſtigation of the nature of this iron, that Bergman obtained, by means of ſulphuric acid, a white powder, which was converted into a brittle metal of a dark-gray colour. By the experiments of Klaproth and Scheele it was proved, that cold ſhort iron is a compound of phoſphoric acid and iron.

1900 Sulphuret.

11. Iron combines with ſulphur by different proceſſes. A ſulphuret of iron may be prepared by fuſing together in a crucible, equal parts of powdered ſulphur and iron filings. This is a maſs which is remarkably brittle and hard, and of a deep-gray colour. If this maſs be reduced to powder, and moiſtened with water, the water is decompoſed, its oxygen combines with the ſulphur, which is converted into ſulphuric acid, and the iron is oxidated. If equal parts of ſulphur and iron-filings be well mixed together by trituration, and a ſufficient quantity of water be added, to form the whole into a paſte, and if this mixture be expoſed to the air, it ſoon becomes hot, ſwells up and cracks, exhaling the vapours of ſulphurated hydrogen gas, and ſometimes is ſpontaneouſly inflamed. During this action the water is decompoſed, the iron is oxidated, and the ſulphur is converted into ſulphuric acid, while the hydrogen of the water combines with a portion of ſulphur, and forms ſulphurated hydrogen gas. By obſerving the phenomena of this proceſs, which alſo take place, it is ſaid when the mixture is buried under ground, Lemery ſuppoſed that he could explain the nature and cauſe of volcanic eruptions.

If a mixture of three parts by weight of iron filings, and one of powdered ſulphur, be put into a glaſs veſſel on burning coals, a ſulphuret of iron is obtained, with ſome remarkable phenomena. It firſt melts, and then all at once becomes red-hot, and ſometimes, when the quantity is conſiderable, is accompanied with an exploſion, at the moment when the combination takes place. According to the experiments of Prouſt, the component parts of ſulphuret of iron are,

Sulphur	60
Iron	40
	100

1901 Pyrites.

According to the experiments of the ſame chemiſt, pyrites, which is found in great abundance in nature, and uſually cryſtallized in cubes, is ſulphuret of iron combined with an additional portion of ſulphur. The component parts of pyrites are

Sulphuret of iron	80
Sulphur	20
	100

12. Iron enters into combination with the acids, and forms ſalts, and with the metals, and forms alloys.

1902 Affinities.

The affinities of iron and its oxides are, according to Bergman, in the following order.

IRON.

Iron.	Oxide of Iron.
Nickel,	Oxalic acid,
Cobalt,	Tartaric,
Manganeſe,	Camphoric,
Arſenic,	Sulphuric,
Copper,	Saclactic,
Gold,	Muriatic,
Silver,	Nitric,
Tin,	Phoſphoric,
Antimony,	Arſenic,
Platina,	Fluoric,
Biſmuth,	Succinic,
Lead,	Citric,
Mercury.	Lactic,
	Acetic,
	Boracic,
	Pruſſic,
	Carbonic.

I. Salts of Iron.

1. Sulphate of Iron.

1903 Preparation. 1. Concentrated ſulphuric acid has ſcarcely any action on iron. When it is heated, the acid is decompoſed, part of its oxygen combines with the iron, and ſulphurous acid gas is evolved. But when diluted ſulphuric acid is added to iron filings, a violent efferveſcence takes place, and hydrogen gas is diſengaged. In this proceſs, the water, with which the acid is diluted, is decompoſed, the oxygen of which combines with the iron, and converts it into an oxide, while the hydrogen eſcapes in the ſtate of gas. 1904 Properties. The ſolution is of a green colour; and, by evaporation, it affords cryſtals of ſulphate of iron, which are tranſparent, of a fine green colour, in the form of rhomboidal priſms, and having an acrid, aſtringent taſte. This ſalt almoſt always reddens vegetable blues. It is very ſoluble; two parts of cold water, and leſs than its weight of boiling water, are ſufficient for its ſolution.

1905 Found native. 2. This ſalt is, in many places of the world, a natural production. It is obtained from the decompoſition of pyrites, which it is ſometimes found neceſſary 1906 Manufacture. to promote by art. This is done by throwing them together into heaps, and watering them occaſionally. Sometimes previous roaſting is neceſſary, either to render them more brittle, and to ſeparate the additional portion of ſulphur above what is neceſſary to conſtitute a ſulphuret. After a certain time an effloreſcence takes place, and the ſurface is covered with the ſulphate of iron, which is diſſolved in water, concentrated by boiling, and evaporated, and then allowed to cool and cryſtallize. 1907 Names. This ſalt, which was known to the ancients, was denominated *miſy*, *ſory*, and *calchantum*. It is diſtinguiſhed in commerce by a great variety of names, as *martial vitriol*, *roman vitriol*, and moſt commonly by the names of *green copperas*, or *green vitriol*.

1908 Action of heat. 3. When ſulphate of iron is ſtrongly heated, it melts, and is deprived of its water of cryſtallization. Sulphurous acid gas is then given out, it aſſumes a red colour, and is reduced to the ſtate of powder. This was formerly called *colcothar*, and *colcothar of vitriol*. It is the ſalt almoſt entirely decompoſed. Part of the iron is ſtrongly oxidated, and to this the red colour is owing. It is alſo mixed with ſulphate of iron; but the iron in this caſe is alſo converted into the red oxide, with the greater proportion of oxygen. This change, it is obvious, depends on the ſtrong affinity of iron for oxygen; for, by the action of heat, the ſulphate of iron of which the green oxide forms the baſe, is decompoſed; the oxygen of the acid combines with the iron, and converts it into the red oxide; part of which, as it is formed, unites with the acid, before the whole of it is decompoſed; and in this way the product of this proceſs is the red oxide of iron mixed with red ſulphate.

1909 Compoſition. The component parts of this ſalt are, according to Bergman,

Acid	39
Oxide	23
Water	38
	100

Theſe properties vary, according to the eſtimation of Mr Kirwan, who makes this ſalt to be compoſed of

Acid -	26
Oxide -	28
Water of compoſition	8
of cryſtallization	38
	100

This diſtinction made by Mr Kirwan between the water of compoſition and that of cryſtallization is, that the former is combined with the oxide, and the latter with the ſalt.

1910 Action of air. 4. When this ſalt is expoſed to the air, it becomes of a yellowiſh colour, opaque, and a powder forms on the ſurface. The ſame thing takes place, if the ſalt in ſolution in water be expoſed to the air. From a fine tranſparent green colour, it becomes turbid, and is converted into a yellowiſh-red liquid, and there is precipitated a powder of the ſame colour. This change is owing to the abſorption of oxygen, and the converſion of the green oxide with the ſmaller proportion of oxygen, into the red oxide with the greater proportion. This proceſs is greatly promoted by the direct combination of oxygen, or by the addition of thoſe ſubſtances which are readily decompoſed, and give out their oxygen. When oxymuriatic acid is added to the ſolution, it becomes inſtantly yellow, and there is formed a red precipitate. The ſame change takes place when the ſalt is diſſolved in water impregnated with carbonic acid. The iron decompoſes the acid, and combines with its oxygen. Thus it appears, that the decompoſition of the ſulphate of iron is owing, in all theſe caſes, to the abſorption of oxygen, and to the higher degree of oxidation of the metal.

1911 Decompoſition. 5. The ſulphate of iron is converted into the red ſulphate by means of nitric acid. It is decompoſed by the alkaline earths and the alkalies, which precipitate it in the form of oxide. The pure fixed alkalies and lime ſeparate an oxide of a deep green colour, which, being expoſed to the air, is converted into the red oxide. Ammonia affords a precipitate of a deeper green colour. The ſulphurets and hydroſulphurets precipitate from the ſolution of green ſulphate of iron, a black ſulphurated or hydroſulphurated oxide. Moſt of the ſalts decompoſe the ſulphate of iron. When equal parts of nitrate of potaſh and ſulphate of iron are diſtilled together in a retort, a weak nitric acid at firſt paſſes over, then a nitrous acid, and at laſt a very ſmall quantity of ſulphurous acid. The muriate of ſoda is decompoſed by the ſulphate of iron, in conſequence of the diſengagement of ſulphuric acid, which ſeparates the muriatic acid from its baſe. Sulphate of ſoda, combined with the oxide of iron in the ſtate of a vitreous maſs, remains in the retort. The hyperoxymuriate of potaſh converts the green ſulphate of iron into the red. This ſalt is alſo decompoſed by the alkaline phoſphates, borates, and carbonates.

Red ſulphate of iron.—In the detail which has been 1912 Preparation. given of the properties of the green ſulphate of iron, it appears, that it has a ſtrong affinity for oxygen. The oxide of the green ſulphate contains 27 parts of oxygen; but by abſorbing another portion of oxygen, it is converted into the red oxide, which contains 48 parts of oxygen. This ſalt may be obtained by the direct combination of the red oxide of iron with concentrated ſulphuric acid, with the aſſiſtance of heat. The ſalt remains in the ſolution from which the green ſulphate of iron has been cryſtallized. This ſolution has been called the *mother water of vitriol*. The red ſulphate of iron is very different in its properties from the green ſulphate. It does not afford cryſtals; it is diſtinguiſhed by its red colour, and it depoſits the oxide of iron, when brought in contact with the air, or by 1913 Properties. the action of heat. It deliqueſces in the air, and at laſt becomes liquid. It is more ſoluble in water than the green ſulphate; and alſo ſoluble in alcohol, by which it may be ſeparated from the green ſulphate, which is not affected by the alcohol. When iron filings are added to a ſolution of red ſulphate of iron, part of the oxide is ſeparated, another part gives up a portion of its oxygen to the iron, and is converted into the green ſulphate. The ſame effect is produced, as M. Prouſt, by whom this ſubject has been greatly elucidated, obſerves, by means of other metals, as mercury, zinc, and tin. The two ſulphates of iron are diſtinguiſhed by other properties. The infuſion of nut-galls produces no change in the green ſulphate of iron, but gives a fine black precipitate with the red ſulphate.

1914 Action of pruſſiate of potaſh. Pruſſiate of potaſh occaſions no change of colour on the green ſulphate of iron, but produces a deep blue precipitate with the red ſulphate, from which it appears that there are two pruſſiates of iron, correſponding to the two oxides. The white pruſſiate contains the green oxide with the ſmaller proportion of oxygen; the blue pruſſiate, the red oxide with the greater proportion. Another characteriſtic property is, that the green ſulphate of iron abſorbs nitrous gas in conſiderable quantity, and aſſumes a yellowiſh colour; but no ſuch abſorption is effected by the red ſulphate.

2. Sulphite of Iron.

1915 Preparation. 1. Sulphurous acid is decompoſed by iron, and the portion of ſulphur which is ſeparated, remains in combination with the ſalt as it is formed. When liquid ſulphurous acid is added to iron filings, it aſſumes a deep yellow colour; ſome hydrogen gas is evolved, with a production of heat, and the yellow colour ſoon changes to a greeniſh ſhade. Sulphuric or muriatic acid, added to this ſolution produces an efferveſcence, but without any precipitation. It is neceſſary to add the acid in conſiderable quantity to obtain a precipitate of ſulphur in white powder. Fuming nitrous acid ſeparates the ſulphur of a yellow colour, and in the form of a ductile maſs. From theſe facts it appears, that the firſt portion of acids acts only on the ſimple ſulphite of iron; but when a greater quantity is added, the ſulphurated ſulphite is decompoſed, and the ſulphur is depoſited.

1916 Properties. 2. The ſolution of iron in ſulphurous acid expoſed to the air, depoſits a reddiſh-yellow powder, and affords cryſtals which are ſurrounded with this reddiſh powder. By adding water to this maſs, it diſſolves the cryſtallized part, and leaves the red powder, which being diſſolved in muriatic acid, gives up its iron, and depoſits ſulphur, which is ſtill mixed with a little iron. 1917 Sulphurated ſulphite. This precipitate diſſolved in water, affords a ſulphurated ſulphite of iron, with a ſmaller quantity of ſulphur than the firſt ſolution. Expoſed to the air after the firſt precipitate is formed, the ſurface is ſoon covered with a red pellicle. A red powder is depoſited, and afterwards cryſtals of ſulphite of iron.

1918 Properties. 3. The ſulphurated ſulphite of iron remains permanent by expoſure to the air. Its ſimple ſulphite abſorbs oxygen. The ſulphurated ſulphite depoſits ſulphur by the action of the acids. The ſulphite gives out ſulphurous acid. The ſulphurated ſulphite is ſoluble in alcohol; the ſulphite is inſoluble.

4. The red ſulphate of iron with the greater proportion of oxygen, does not produce the ſame effect on ſulphurous acid, by converting it into ſulphuric acid, and thus to form a ſulphate of iron, as the oxide of mangane ſe, becauſe iron has a ſtronger affinity for oxygen 1919 Strong affinity of iron for oxygen. than ſulphurous acid. Thus we have ſeen, in conſequence of the ſame affinity of iron for oxygen, that it decompoſes ſulphuric acid, and converts part of it into ſulphurous acid, and that it even decompoſes ſulphurous acid, by ſeparating its ſulphur, which combines with the oxide as it is formed, and conſtitutes the ſulphurated ſulphite of iron. Neither of theſe ſulphites of iron give a black colour with the infuſion of nut galls, nor a blue colour with the pruſſiate of potaſh, from which it is inferred that the iron is in its minimum ſtate of oxidation, or in that of a green ſulphate of iron.

3. Nitrate of Iron.

1920 Preparation. Nitric acid acts with great violence on iron; a great quantity of nitrous gas is diſengaged, eſpecially when the acid is a little diluted with water. When diluted 1921 Properties. acid has been employed, the ſolution is of a yellowiſh green colour, and when it is expoſed to the air, it aſſumes a pale colour, in conſequence of the nitrous gas which it holds in ſolution, combining with oxygen, and being converted into nitric acid. When it is expoſed to the air, or concentrated by evaporation, a precipitate of the red oxide of iron is formed, becauſe it combines with another portion of oxygen, and is converted from the green to the red oxide. By means of the alkalies, the green oxide is precipitated from this ſolution.

1922 Preparation. *Red nitrate of iron.*—This is the ſalt formed with nitric acid and the red oxide of iron. It is prepared by expoſing the green nitrate of iron to the air, which abſorbing oxygen, is converted into the red nitrate.

If iron be diſſolved in concentrated nitric acid, the iron is converted into the red oxide, and this combining with the undecompoſed acid, alſo forms the red nitrate of iron. 1923 Properties. The ſolution of this ſalt, which is of a brown colour, does not cryſtallize; when it is evaporated, it aſſumes the form of jelly, or depoſits a red powder. When this ſalt is heated, the acid is driven off, and the red oxide remains behind. 1924 Action of nut galls, &c. The red nitrate of iron gives a black colour with the infuſion of galls, and a blue precipitate with pruſſiate of potaſh, from which it appears, that the iron is in its higheſt degree of oxidation. This has been fully demonſtrated by an experiment made by Vauquelin. Concentrated nitric acid was kept for ſome months on black oxide of iron, without any apparent change. The nitric acid, however, loſt its acidity, and acquired a neutral taſte. The liquid had aſſumed a brown colour, and large cryſtals, tranſparent and white, with a ſlight tinge of violet by looking through them, were formed. The cryſtals were in ſquare priſms, terminated by two ſided-ridges. This ſalt was extremely deliqueſcent, and had a pungent inky taſte. The ſolution in water becomes red, as is alſo the precipitate by means of ammonia and potaſh. Pruſſiate of potaſh gives a fine blue precipitate.

4. Muriate of Iron.

1925 Action of muriatic acid in the ſtate of gas. 1. When iron filings are expoſed to muriatic acid gas they ſoon become black, and are converted into the ſtate of red oxide. This is owing to the decompoſition of the water which the gas holds in ſolution. The bulk of the gas is increaſed by the addition of hydrogen gas, from this decompoſition of water. When the whole of the muriatic acid is abſorbed by the iron in the ſtate of oxide; hydrogen gas only remains in the veſſel in which the proceſs has been conducted. When a little water is added, it aſſumes a green colour, having combined with the muriate of iron in the liquid ſtate.

1926 In the liquid ſtate. 2. Liquid muriatic acid acts upon iron in proportion to its degree of concentration, and the action is the more violent as it is leſs concentrated. An efferveſcence takes place, with the diſengagement of hydrogen gas. As the iron is oxidated by the decompoſition of the water, it is diſſolved in the acid. This ſolution is of a pale yellowiſh colour, and of a ſtrong ſtyptic taſte. When it is evaporated to the conſiſtence of ſyrup, it forms on cooling, a viſcid maſs, in which are found needle-ſhaped, deliqueſcent cryſtals. When this ſolution is expoſed to the air, or ſtrongly heated, it aſſumes a brown colour, and depoſits oxide of iron.

Red muriate of iron.—When the red oxide of iron is treated with muriatic acid, the acid diſſolves the iron, and forms a ſolution of a deep brown colour. During the ſolution, oxymuriatic acid is formed and given out, which is owing to the combination of a portion of the oxygen of the oxide with the muriatic acid. The oxide thus deprived of a portion of its oxygen, combines with the muriatic acid, and forms red muriate of iron. When this ſolution is evaporated to dryneſs, it affords a yellow coloured maſs, which is deliqueſcent in the air. This ſalt does not abſorb nitrous gas, and it is converted into muriate of iron by the action of ſulphurated hydrogen gas. When it is precipitated by the alkalies, the oxide is not farther changed by expoſure to the air. The infuſion of nut galls gives a black colour, and the pruſſiate of potaſh a blue.

5. Hyperoxymuriate of Iron.

This ſalt was formed by Mr Chenevix, by directing a ſtream of oxymuriatic acid gas into water, having red oxide of iron diffuſed in it; but its properties have not been aſcertained.

6. Fluate of Iron.

Fluoric acid has a very powerful action on iron, which is owing to the evolution of hydrogen gas, and the decompoſition of water. The iron is oxidated, and diſſolves in the acid, forming a fluate of iron. The ſolution has a ſtyptic, metallic taſte, does not afford cryſtals by evaporation, but aſſumes a gelatinous form. Evaporated to dryneſs it becomes hard and ſolid, and when ſtrongly heated, the acid is driven off, and there remains behind the red oxide of iron, ſo that this ſalt is the red fluate of iron. The red oxide of iron is alſo ſoluble in fluoric acid, and communicates to it, according to Scheele, an aluminous taſte. The fluate of iron is decompoſed by ſulphuric acid, and is precipitated by the alkalies and the earths.

7. Borate of Iron.

Boracic acid promotes the oxidation of iron by water very ſlowly. The borate of iron may be obtained by precipitating the ſulphate of iron by means of the borate of ſoda, or borax. The borate of ſoda is precipitated in the form of a whitiſh powder. It is inſoluble in water, but its other properties have not been aſcertained.

8. Phoſphate of Iron.

1927 Preparation. Phoſphoric acid combines very ſlowly with iron, but after the oxidation of the metal has taken place, it forms with its oxide an inſoluble ſalt. The phoſphate of iron may be prepared by adding a ſolution of an alkaline phoſphate to a ſolution of ſulphate or nitrate of iron. The alkali leaves the phoſphoric acid, and combines with the ſulphuric or nitric; while the phoſphoric acid combines with the iron, and forms a phoſphate of iron, which is in the ſtate of white precipitate. Phoſphoric acid combines with both oxides of iron, and conſtitutes either a green or a red phoſphate. The red phoſphate of iron may be obtained by precipitating the red muriate of iron in ſolution, by means of phoſphate of potaſh or ſoda; and when this latter ſalt is treated with pure fixed alkalies, a browniſh red powder is precipitated, which is the red phoſphate of iron with exceſs of baſe. It is nearly inſoluble in acids and in water, but is ſoluble in the ſerum of blood and the white of an egg, communicating to them a brown colour. 1928 Colours the blood. This ſalt exiſts in the blood of animals, and to it the red colour of the blood is owing.

9. Carbonate of Iron.

Carbonic acid combines readily with the oxide of iron. This is the caſe when iron ruſts in the air, for in proportion as the oxidation of the iron is effected, it combines with the carbonic acid of the atmoſphere, and forms a carbonate of iron. This acid diſſolved in water, when brought in contact with iron, acts upon it ſlowly; and there is diſengaged, but without effervеſcence, a perceptible odour of hydrogen gas, and the water acquires in the courſe of a few hours, an aſtringent taſte. When this ſolution is expoſed to the air, as Bergman obſerved, it becomes covered with an irideſcent pellicle, and is decompoſed by lime and the alkalies. But the alkaline carbonates have no ſuch effect. This ſolution of the carbonate of iron converts the ſyrup of violets to a green colour. When it is evaporated, it depoſits the ſalt in the form of a reddiſh ochre. It is this carbonate of iron which exiſts 1929 Ruſt. in mineral waters, to which, for this reaſon, the name of *chalybeate* has been given to waters. Ruſt is a carbonate of iron, mixed with the oxide. Fourcroy found by diſtilling it, that it yielded carbonic acid gas, and a little water, and there remained black oxide of iron; and diſtilled with muriate of ammonia, it afforded carbonate of ammonia. The component parts of this carbonate, according to Bergman, are

Acid	24
Oxide	76
	100

10. Arſeniate of Iron.

1930 Preparation. 1. When iron is digeſted with arſenic acid, it is diſſolved, and towards the end of the proceſs the ſolution aſſumes the form of a jelly. But if it be conducted in a cloſe veſſel, no coagulation takes place. By expoſing it to the open air for ſome hours, the ſurface becomes ſo ſolid, that the veſſel may be inverted without any part of it dropping out. The ſolution which has not been expoſed to the air, affords a precipitate with potaſh, of a greeniſh-gray colour, from which there is diſengaged by heat, arſenious acid, and there remains behind a red oxide of iron. One part of iron filings diſtilled with four of concrete arſenic acid, ſwell up and inflame; the metallic acid is ſublimed, and brown ſpots appear on the ſides of the retort. From this experiment it appears, that the iron has carried off the oxygen from the acid.

2. Arſenic acid does not precipitate iron from its ſolutions, but the arſeniates or arſenites form a very ſoluble precipitate, which becomes yellow or red in contact with the air. This precipitate, which is fuſible at a high temperature, exhales the odour of arſenic when it is melted, is converted into black ſcoriæ when it is treated with charcoal, gives out a conſiderable quantity of arſenic, and is reduced to the ſtate of black oxide of iron.

1931 Green arſeniate. 3. Arſenic acid combines with both the oxides of iron. The green arſeniate of iron may be obtained by adding a ſolution of arſeniate of ammonia to a ſolution of ſulphite of iron. The arſeniate precipitates in the form of powder which is inſoluble in water. The component parts of this ſalt, according to Chenevix, are,

Acid	38
Oxide	43
Water	19
	100

Red Arſeniate of Iron.—This ſalt is prepared, either by boiling arſeniate of iron in nitric acid, or by adding arſeniate of ammonia to a ſolution of red ſulphate of iron. It is compoſed of

Acid	42.4
Oxide	37.2
Water	20.4
	100.0

Both theſe ſalts have been found native.

11. Tungſtate of Iron.

Tungſtic acid has no great effect on iron in the cold. Iron immerſed in a ſolution of this acid in muriatic acid, communicates to it a beautiful blue colour, which is owing to the decompoſition of the tungſtic acid, and to its reduction to the metallic ſtate by means of the iron. Tungſtic acid precipitates from the ſolution of iron in ſulphuric acid, tungſtate of iron. Tungſtate of iron exiſts native under the name of wolfram.

12. Molybdate of Iron.

The alkaline molybdates which are ſoluble, precipitate iron from its ſolution in acids, of a brown colour.

13. Chromate of Iron.

If chromic acid, combined with an alkali, be added to a ſolution of the red ſulphate of iron, a precipitate is immediately formed, of a brown colour; but if an alkaline chromate be added to the green ſulphate of iron, the precipitate is green, becauſe the chromic acid is deprived of a portion of its oxygen, and is converted to the ſtate of green oxide *.

14. Columbate of Iron.

The columbate of iron is found native, and from the only ſpecimen which has yet been diſcovered, Mr Hatchet extracted a new metal, which has been deſcribed under the name of columbium. It is of a dark-browniſh gray colour, has a vitreous luſtre, and a lamellated ſtructure. According to Mr Hatchet, it is compoſed of

Columbic acid,	77.5
Oxide of iron,	21.0
	98.5

15. Acetate of Iron.

1932 Preparation. 1. Acetic acid diſſolves iron with effervеſcence, with the evolution of hydrogen gas. The liquid aſſumes a reddiſh-brown colour, and by evaporation becomes a gelatinous maſs, in which are found long brown cryſtals. This ſalt has a ſweetiſh ſtyptic taſte. It is decompoſed by heat, and is deliqueſcent in the air. When it is heated till it no longer gives out the odour of vinegar, it lets fall a yellowiſh oxide, which is eaſily reduced, and is attracted by the magnet. The alkalies ſeparate the iron nearly in the ſtate of black oxide. This ſolution affords a black precipitate with the infuſion of nut-galls, and a blue with the alkaline pruſſiates.

---

* *Fourcroy, Connaiſs. Chim.* vi. p. 217.

2. The ſolution of this ſalt is prepared in the large way with old iron and vinegar obtained from grain, or molaſſes. 1933 In the large way. They are expoſed to the air in large veſſels, and as the fermentation of the liquid goes on, it is converted into acetic acid, the iron is oxidated, and diſſolved by the acid. This ſolution is employed in dyeing and calico-printing.

Green acetate of iron.—This ſalt has been formed by diſſolving ſulphuret of iron in acetic acid. It affords cryſtals by evaporation, in the form of priſms, and of a green colour. The taſte is ſtyptic and ſweetiſh. It gives a white precipitate with the alkaline pruſſiates, and no change is effected by the infuſion of galls. When the ſolution of this ſalt is expoſed to the air, it very readily abſorbs oxygen, and is converted into red acetate of iron *.

16. Oxalate of Iron.

1934 Preparation. Oxalic acid produces a violent action on iron, with the evolution of hydrogen gas. This ſolution has a very ſtyptic taſte, and forms by evaporation priſmatic cryſtals of a greeniſh yellow colour. When this ſolution is expoſed to the air, or when it is heated, it aſſumes a red colour, which is owing to the abſorption of oxygen, and its converſion into red oxalate. 1935 Compoſition. The oxalate of iron is compoſed of

Acid,	55
Oxide,	45
	100

Red oxalate of iron.—Oxalic acid precipitates the red oxide of iron from its ſolution in ſulphuric acid, and forms an oxalate of iron of a fine red colour. The red oxalate of iron does not cryſtallize, and has little ſolubility in water. This has been propoſed to be employed as a pigment. None of the acids diſſolve the oxides of iron more readily than oxalic acid, and eſpecially the gallate of iron. On this account it anſwers well for removing ſpots of ink, for which purpoſe alſo the acidulous oxalate of potaſh, or ſalt of ſorrel, is alſo employed.

17. Tartrate of Iron.

1. Tartaric acid diſſolves iron with effervescence, and the evolution of hydrogen gas. The ſolution becomes of a red colour, and aſſumes the form of a gelatinous maſs, but does not cryſtallize. This is the red tartrate of iron.

2. But when tartaric acid is added to the ſolution of ſulphate of iron, and heat applied, a precipitate is formed, which is not very ſoluble, but affords lamellated cryſtals. This is the compound of tartaric acid with the green oxide of iron, for it does not form a precipitate with the alkaline pruſſiates, without the addition of nitric acid.

18. Tartrate of Potaſh and Iron.

This triple ſalt, which was formerly called *chalybeated tartar*, and *tartariſed tincture of Mars*, is prepared by forming into a paſte with water, ſix parts of iron filings with 16 of tartar in powder. The mixture is left at reſt for 24 hours; and being diluted with 192 parts of water, is boiled for two hours, when cryſtals are depoſited of tartrate of potaſh and iron.

19. Citrate of Iron.

Citric acid acts upon iron with effervescence, occaſioned by the emiſſion of hydrogen gas. The ſolution becomes of a brown colour; it depoſits, by ſpontaneous evaporation, ſmall cryſtals of citrate of iron. By evaporating with heat, it becomes black as ink, and ductile while it is hot, but falls to powder, and becomes very black when it is cold. This ſalt has a very aſtringent taſte, and is very ſoluble in water. It is compoſed of

Acid,	69.62
Oxide,	30.38
	100.00

The cryſtals which were obtained by ſpontaneous evaporation, were probably the green citrate; and the black maſs by the action of heat, is probably converted into the red citrate of iron.

20. Malate of Iron.

Malic acid gives a brown ſolution by its action on iron, but it does not cryſtallize.

21. Gallate of Iron.

It has frequently been mentioned, in deſcribing the 1936 Gallic acid gives a black colour only with the red oxide. ſalts of iron, that the infuſion of nut-galls, or gallic acid, produces no precipitate or change of colour, when it is added to ſalts of iron in ſolution, of which the black or green oxide conſtitutes the baſe; but when the acid is added to a ſolution of a ſalt of iron, having the red oxide for its baſe, a black precipitate is immediately formed. From this it appears, that the black precipitate can only be obtained from the red oxide of iron, or it is the gallate of iron in the higheſt degree of oxidation. 1937 Ink. Writing ink is a compound of the ſolution of gallate of iron and the tanning principle. The important qualities of good ink are, that it ſhall be durable, and have a black colour. On this ſubject Profeſſor Robiſon obſerves, in his Notes on Dr Black's Lectures, that "the great art in ink-making is to have a ſuperabundance of aſtringent matter to counteract the diſpoſition of the iron to a farther calcination, which renders the ink brown. It would be a great improvement in the manufacture of writing paper, if ſome aſtringent matter could be introduced. A little ardent ſpirits effectually prevents the ſpoiling of ink by keeping, but makes it ſink and ſpread.

A good Proportion for Writing-Ink.

Raſped logwood, 10 ounces;
Beſt gall-nuts in coarſe powder, 3 ounces;
Gum arabic in powder, 2 ounces;
Green vitriol, 1 ounce;
Rain water, 2 quarts;
Cloves in coarſe powder, 1 drachm.

Boil the water with the logwood and gum to one half; ſtrain the hot decoction into a glazed veſſel; add the galls and cloves; mix and cover it up. When nearly cold, add the green vitriol, and ſtir it repeatedly. After ſome days, decant or ſtrain the ink into a bottle, to be kept cloſe corked in a dark place *.

---

* *Jour. Roy. Inſt.* i. p. 308.

* *Black's Lect.* v. ii. p. 481.

1938 Reaſon of the pale colour. Ink is ſometimes of a very pale colour when firſt uſed, but becomes black by expoſure to the air. This is owing to the abſorption of oxygen. The green vitriol or ſulphate of iron, which is employed in making ink, has not its baſe fully ſaturated with oxygen, or is not in the ſtate of red oxide. It is the converſion of the green into the red oxide, which takes place when it is expoſed to the air. The uſe of gum in the compoſition of ink is to prevent the precipitation of the black particles, and alſo, it is ſuppoſed, to act as a varniſh, to defend it from the air, which might give it a brown colour by farther oxidation.

22. Benzoate of Iron.

Benzoic acid readily diſſolves the oxide of iron, and forms with it yellowiſh cryſtals, which are ſweet to the taſte, effloreſce in the air, and are ſoluble in water and in alcohol. Gallic acid produces a black precipitate, and the pruſſiates give a blue. It is decompoſed by the alkalies, and by the carbonates of lime and barytes. The acid is driven off by heat *.

23. Succinate of Iron.

Succinic acid combines with the oxide of iron; and the ſolution by evaporation, affords ſmall radiated cryſtals, which are tranſparent and of a brown colour. This ſalt is inſoluble in water. It may be formed by adding an alkaline ſuccinate to the ſolutions of iron in acids.

24. Suberate of Iron.

Suberic acid decompoſes the ſulphate of iron, and produces a deep yellow colour †.

25. Mellate of Iron.

Mellitic acid produces a copious precipitate of an Iſabella-yellow colour, in the ſolution of iron in nitric acid. This precipitate is readily diſſolved in muriatic acid ‡.

26. Lactate of Iron.

Lactic acid combines with iron, and forms with it a ſalt which does not cryſtallize. The ſolution is of a brown colour.

27. Pruſſiate of Iron.

1. Pruſſic acid combines with both the oxides of iron. When the pruſſiate of potaſh is added to a ſolution of the green ſulphate or muriate of iron, a white precipitate is obtained. This ſhews, as has been already obſerved, that the baſe of theſe ſalts, is in its loweſt degree of oxidation. It is in the ſtate of green or black oxide. But if the pruſſiate of potaſh be poured into a ſolution of the red ſulphate of iron, a fine blue precipitate is formed, which is Pruſſian blue, or a pruſſiate of iron in the ſtate of red oxide.

1939 Pruſſian blue. 2. When the white precipitate of iron is expoſed to the air, it gradually abſorbs oxygen, and is converted into the blue pruſſiate, or Pruſſian blue. On the other hand, the blue pruſſiate may be converted into the white, by preſerving it in a cloſe veſſel, with plates of iron or tin. The metallic ſubſtance deprives the iron of part of its oxygen, and makes it paſs to the ſtate of green oxide; in which ſtate, combined with pruſſic acid, it is colourleſs. Sulphurated hydrogen gas produces a ſimilar effect, by depriving the iron of its oxygen. The nitric and oxymuriatic acids convert the white pruſſiate into blue, by giving up their oxygen, which combines with the iron, and forms the red oxide.

II. Action of the Alkalies, &c. on Iron.

1940 Alkalies. 1. Iron, in the metallic ſtate, has a very feeble action on the alkalies and earths. The alkalies, in their pure and concentrated ſtate, promote the decompoſition of water by means of iron. Hydrogen gas is diſengaged, and the metal is converted into the ſtate of black oxide, or *martial ethiops;* but there ſeems to be no perceptible ſolution of the oxide of iron, which is thus formed in the liquid alkalies.

1941 Earths. 2. The brown oxides of iron readily combine with the earths ſuſpended in water. This combination has been long employed on account of its properties of aſſuming a great degree of ſolidity and hardneſs, as a cement, and eſpecially as a cement or mortar to be employed under water. Hence volcanic productions, as *pouzzolana earths*, which contain a conſiderable proportion of oxide of iron, are often employed for this purpoſe. The oxide of iron combines alſo with the earths by means of fuſion, and communicates to them various ſhades of colour, according to the degree of oxidation, and the proportion of oxide employed. In this ſtate it is uſed in the fabrication of enamels and coloured glaſs.

1942 Sulphates. 3. The alkaline ſulphates are decompoſed by iron at a high temperature. The iron deprives the ſulphuric acid of its oxygen, and reduces it to the ſtate of ſulphur. Fourcroy heated for an hour in a covered crucible, one part of ſulphate of potaſh, with two of iron filings. He obtained a kind of granulated ſcoria, which had ſwelled up, and was of a deep green on the ſurface. It was extremely hard, and exhibited in ſome of the internal cavities, ſhining ſix-ſided plates of black oxide of iron. It had a hot, acrid taſte. When reduced to powder, it exhaled the fetid odour of ſulphurated hydrogen gas. It was not deliqueſcent in the air; and diluted with 10 parts of water, it was of a deep green colour. This was a ſolution of hydroſulphuret of potaſh, holding a ſmall quantity of iron in ſolution. Sulphur was precipitated by the addition of acids, with the evolution of ſulphurated hydrogen gas.

1943 Nitrates. 4. The nitrates are alſo decompoſed by means of iron heated to redneſs. Two or three parts of nitre, with one of clean iron filings, well triturated together, and projected into a red-hot crucible, give out at each projection a great number of vivid ſparks. After the detonation, a half fuſed maſs remains, of a reddiſh yellow colour, which, by waſhing with water, affords pure potaſh, and there remains an oxide of iron in its higheſt degree of oxidation. Steel alſo detonates with nitre, and gives out a very brilliant red flame. Theſe mixtures are employed in artificial fireworks.

1944 Muriates. 5. Some of the muriates are alſo decompoſed by iron. The experiment of Scheele in which the muriate of ſoda was decompoſed by means of iron, has already been mentioned. The muriate of ammonia is readily decompoſed by iron with the aſſiſtance of heat. Hydrogen and ammoniacal gaſes are diſengaged. A preparation formerly known by the name of *martial*

---

* *Ann. de Chim.* xi. p. 316.

† *Ibid.* xxiii. p. 48.

‡ *Klaproth, Eſſays* ii. p. 102. *Tranſl.*

ammoniacal flowers, was made with 16 parts of muriate of ammonia and one of iron filings. This mixture is ſublimed in two earthen veſſels, the one being inverted over the other. A ſmall quantity of the muriate of ammonia only is decompoſed, and the ſalt aſſumes a yellowiſh colour, with a ſmall portion of muriate of iron. The muriate of ammonia is alſo decompoſed by triturating the red oxide of iron with this ſalt. Ammonia is diſengaged, and the oxide combines with the acid.

6. Hyperoxymuriate of potaſh produces a violent detonation with iron. Two parts of this ſalt with one of iron filings, detonate ſtrongly, and with a vivid red flame, by percuſſion, or even by ſudden preſſure, or by being brought in contact with a burning body.

7. There is no action between the fluates, borates, phoſphates, or the carbonates, and iron, in the cold.

III. Alloys.

1945 Arſenic. 1. Iron combines with arſenic by fuſion, forming a brittle alloy of a white colour, analogous to the native compound of arſenic and iron, known by the name of *miſpickel*. It is more fuſible than iron, and is therefore employed, on account of its luſtre and fine poliſh, for different purpoſes to which iron is not applicable.

1946 Tungſten. 2. The alloys of iron with tungſten, molybdena, chromium, columbium, titanium, and uranium, are ſcarcely known. With titanium iron affords an alloy of a gray colour, which is extremely infuſible.

1947 Cobalt. 3. The alloy of iron and cobalt poſſeſſes ſome of the properties of ſteel. It is extremely hard, its texture is fine-grained, and it is attracted by the magnet.

1948 Nickel. 4. Iron combines with nickel, and the affinity between theſe metals is ſo ſtrong, that it is extremely difficult to deprive nickel entirely of iron.

1949 Manganeſe. 5. Manganeſe is frequently found in combination with iron, to which it communicates a white colour, and renders it brittle.

1950 Biſmuth. 6. Biſmuth forms a brittle alloy with iron. It is attracted by the magnet, even when the proportion of biſmuth amounts to three-fourths of the whole. Twenty parts of iron and one of biſmuth, were broken by a weight of 151lb. but four parts of iron and three of biſmuth only ſupported 35lb. Theſe were the experiments of Muſchenbroeck. Gellert has obſerved that the alloy of iron and biſmuth has an inferior ſpecific gravity to the mean.

1951 Antimony. 7. Iron combines readily with antimony by fuſion. An alloy of equal parts of theſe metals is not attracted by the magnet, has no ductility, and ſcarcely any malleability. This alloy was formerly called *martial regulus*. It is brittle and hard, and has a leſs ſpecific gravity than the mean. Iron has a ſtronger affinity for ſulphur than for antimony, for when the ſulphuret of antimony is heated with iron, it is decompoſed, and the iron combines with the ſulphur.

1952 Mercury. 8. Iron, it has been long ſuppoſed, has no action on mercury; but by triturating together the amalgam of zinc and mercury with iron filings, and by adding to the mixture a ſolution of iron in muriatic acid, and afterwards by kneading this mixture and heating it, Mr Aikin obtained an amalgam of iron and mercury, having the metallic luſtre *.

1953 Zinc. 9. Zinc forms an alloy with iron, but combines with it in very ſmall proportion. It has been obſerved that zinc may be applied to the ſurface of iron by fuſion, ſo as to defend it from the action of the air, and thus to prevent it from ruſting.

1954 Tin. 10. Iron combines with difficulty with tin. Bergman made a number of experiments on the alloy of iron and tin. He put a quantity of tin into a crucible, and covered it with iron filings. The crucible was then filled with charcoal, and cloſely covered. He expoſed the apparatus to the heat of a forge for half an hour, and he always obtained two diſtinct alloys, correſponding to the weight of the metals which he had employed.

The one was iron combined with a ſmall quantity of tin, and the other tin united to a ſmall portion of iron. Tin alloyed with $\frac{1}{22}$ of iron was very malleable, might be cut with a knife, had loſt a little of its luſtre, and was a little harder. With the fuſible phoſphates it gave a brown glaſs, which was leſs fuſible; and by the addition of nitric acid, it became black, and there was ſeparated an inſoluble powder. Iron combined with half its weight of tin, exhibits ſome of the properties of the latter. It is ſlightly malleable, cannot be cut with a knife, unites with difficulty with mercury and with the phoſphates, and in fuſion with the latter, gives out brilliant ſparks, which do not appear from the iron or tin alone. This inflammation is ſtill more brilliant when the quantity of tin is increaſed to $\frac{11}{100}$.

1955 Tinplate. Tin combines with iron, and adheres ſtrongly to its ſurface, forming a thin covering. This is one of the moſt uſeful combinations of tin, for it renders the iron fit for a great many valuable purpoſes, for which, otherwiſe, on account of its ſtrong tendency to oxidation or ruſting, it would be totally inapplicable. This is well known by the name of *tinplate*, or *white iron*. 1956 Proceſs of tinning. The proceſs of tinning iron is the following: The plates of iron being reduced to the proper thickneſs, are cleaned by means of a weak acid. For this purpoſe the ſurface is firſt cleaned with ſand, to remove any ruſt that may have formed. They are then immerſed in water acidulated with a ſmall quantity of ſulphuric acid, in which they are kept for 24 hours, and occaſionally agitated. They are then well rubbed with cloths, that the ſurface may be perfectly clean. The tin is fuſed in a pot, the ſurface of which is covered with an oily or reſinous matter, to prevent its oxidation. The plates of iron are then immerſed in the melted tin, and are either moved about in the liquid metal, or are dipped ſeveral different times. They are then taken out, and rubbed with ſaw-duſt or bran, to remove the impurities from the ſurface.

It is ſaid by ſome chemical writers, that the tin not only covers the ſurface, but penetrates the iron completely, ſo as to give the whole a white colour. This ſeems to be quite a miſtake, which may be very eaſily proved by the teſt of experiment. If the ſurface of a piece of tin-plate be ſcraped with a knife, the metallic particles which are at firſt ſeparated, are not attracted by the magnet. As the proceſs is continued, ſome of the particles are magnetic, which ſhews that they are particles of iron, ſcraped off, after the coating of tin is ſeparated, and this coating may be ſo completely removed, that the whole of the particles are attracted by the magnet. This perhaps it may be ſaid, would take

---

* *Phil. Mag.* xiii. 406.

take place, even although the iron were alloyed with a certain proportion of tin; but when the coating of tin is entirely removed, and the iron is moiſtened, it is ſoon covered with ruſt, in the ſame way as if it never had been combined with a particle of tin.

1957 Lead. 11. Guyton has ſhewn, that an alloy may be formed of iron and lead, which it was formerly ſuppoſed could not be effected. By melting together equal parts of lead and filings of iron, he obtained two ſeparate metallic buttons, of which the lead occupied the lower part of the crucible, and the iron the upper part. When theſe were ſubjected to the teſt of experiment, it appeared that the lead contained a ſmall proportion of iron, and the iron a ſmall proportion of lead *.

The uſes of iron are extremely numerous and important, but they are ſo well known, that it is altogether unneceſſary to enumerate them.

Sect. XIX. *Of Copper and its Combinations.*

1958 Hiſtory. 1. Copper ſeems to have been known in the remoteſt periods of antiquity. It is among the firſt metals which was employed by the early nations of the world; and indeed this might have been expected, as it is not one of the ſcarce metals, is eaſily extracted from its ores, and not difficult to work. The Egyptians applied it to a great variety of uſes, as it appears, from the earlieſt period of their hiſtory. The Greeks were acquainted with the mode of working copper, and employed it in many of the arts. It was the baſis of the celebrated Corinthian metal. The Romans knew the uſes of this metal, and it is generally ſuppoſed that of it they fabricated the greateſt number of their utenſils. The alloys which they made with copper, after the example of the Egyptians and Greeks, were very numerous, and applied to a great variety of uſes.

1959 Ores. 2. Copper exiſts in conſiderable abundance in nature; it is found native, alloyed with other metals, combined with ſulphur, in the ſtate of oxide, and in that of ſalt. It is not unfrequently met with in the native ſtate, ſometimes cryſtallized in an arboreſcent form, and ſometimes in more regular figures. Copper exiſts native, alloyed with gold and ſilver. The moſt abundant ores of copper are the ſulphurets, and of theſe there is a conſiderable variety, exhibiting various colours, and various forms of cryſtals. In the ſtate of oxide, it has been found in Peru, of a greeniſh colour, mixed with white ſand. In the ſtate of ſalt, copper is combined with the ſulphuric and carbonic acids, forming native ſulphates and carbonates of copper. The latter preſent many varieties, but may chiefly be referred to the blue and green carbonates.

1960 Analyſis. 3. The extraction of the ores of copper is to be conducted according to the nature of the combination in which they exiſt. The following proceſs is recommended for the treatment of the ſulphurets of copper. The ore is firſt reduced to powder, and then boiled with five parts of concentrated ſulphuric acid. The ſolution is evaporated to dryneſs, and the reſiduum well waſhed with warm water, to remove all ſoluble matters. The ſolution being ſufficiently diluted, a plate of copper is immerſed in it, which precipitates the ſilver, and afterwards a plate of iron to precipitate the copper. It is boiled with the plate of iron, till no farther precipitate takes place. The copper which is thus obtained, is dried with a gentle heat, ſo that it may not undergo oxidation. If it is ſuppoſed that the copper is mixed with iron, the whole may be diſſolved in nitric acid, and the proceſs is again repeated by introducing the plate of iron. In this way it is eaſy to diſcover the quantity of copper in the ſulphurets of this metal.

1961 Properties. 4. Copper is a very brilliant metal, of a fine red colour, different from every other metallic ſubſtance. The ſpecific gravity of copper is 8.584. When it is hammered, it acquires a greater denſity. It poſſeſſes a conſiderable degree of hardneſs, and ſome elaſticity. It is extremely malleable, and may be reduced to leaves ſo fine that they may be carried about by the wind. It has alſo a conſiderable degree of ductility, intermediate, according to Guyton, between tin and lead. The tenacity of copper is alſo very great. A wire .078 of an inch in diameter, will ſupport a weight without breaking equal to more than 300lbs. avoirdupois. Copper has a peculiarly aſtringent and diſagreeable taſte. It is extremely deleterious, when taken internally, to the animal economy, and indeed may be conſidered as a poiſon. It is diſtinguiſhed by a peculiarly diſagreeable odour, which it communicates to the hands by the ſlighteſt friction.

1962 Action of heat. 5. Copper does not melt till the temperature is elevated to a red heat, which is about 27° Wedgwood, or by eſtimation 1450° Fahrenheit. When it is rapidly cooled after fuſion, it aſſumes a granulated and porous texture, but if it be cooled ſlowly, it affords cryſtals in quadrangular pyramids, or in octahedrons, which proceed from the cube, its primitive form. When the temperature is raiſed beyond what is neceſſary for its fuſion, it is ſublimed in the form of viſible fumes.

1963 Oxidation. 6. When copper is expoſed to the air, eſpecially if it be humid, it is ſoon deprived of its luſtre. It tarniſhes, becomes of a dull brown colour, which gradually deepens, till it is converted into that of the antique bronze, and at laſt is covered with a ſhining green cruſt, which is well known under the name of *verdigris*. This proceſs is the oxidation of the metal by the abſorption of oxygen from the atmoſphere; and it is promoted and accelerated, either by being moiſtened with water, or by the water which exiſts in the atmoſphere. As this oxide is formed the carbonic acid of the atmoſphere combines with it, ſo that it is to be conſidered as a mixture of oxide and carbonate of copper.

7. But when copper is ſubjected to a ſtrong heat, the oxidation proceeds more rapidly. If a plate of copper be made red-hot in the open air, it loſes its brilliancy, becomes of a deep brown colour, and the external layer, which is of this colour, may be detached from the metal. This is the brown oxide of copper. This oxide may be obtained by immerſing a plate of red-hot copper into cold water. The ſcales which are formed on the ſurface fall off by the ſudden contraction of the heated copper. This may be repeated till the whole is converted into this oxide. The copper in this ſtate is in the higheſt degree of oxidation. Sometimes it aſſumes a black, and ſometimes a green colour, which, according to Prouſt, are owing to the combination of carbonic acid with the oxide. This oxide of copper may alſo be obtained by diſſolving

---

* *Annal. de Chim.* xliii. 48.

1964 Black oxide.

diſſolving copper in nitric or ſulphuric acid, and then by precipitating with an alkali, which precipitate is to be dried, to ſeparate the water. The component parts of this oxide are,

Oxygen	25
Copper	75
	100

1965 Yellow.

But copper combines with a ſmaller proportion of oxygen, forming an oxide of an orange colour. If the black oxide of copper be mixed with leſs than an equal proportion of metallic copper in fine powder, triturated in a mortar, and introduced into a cloſe veſſel with muriatic acid, the whole of the copper is diſſolved with the emiſſion of heat, and the oxide is precipitated of an orange colour, by means of potaſh. This is the oxide of copper with the ſmaller proportion of oyxgen. The component parts of this oxide according to Mr Chenevix, are

Oxygen	11.5
Copper	88.5
	100.0 *

This oxide changes colour the moment it is expoſed to the air, by the abſorption of oxygen, for which it has a very ſtrong affinity.

8. There is no action between azote, hydrogen, or carbone, and copper.

1966 Phoſphuret.

9. Phoſphorus readily combines with copper, and forms with it a phoſphuret, which is prepared by fuſing equal parts of copper and phoſphoric glaſs, with $\frac{1}{8}$ of the whole of charcoal in powder. Or, it may be formed by projecting phoſphorus on red-hot copper in a crucible. The phoſphuret of copper is of a whitiſh gray colour, with a metallic luſtre, and of a cloſe texture. It is much more fuſible than copper; it melts by the action of the blow-pipe; the phoſphorus burns with deflagration on the ſurface, and the copper remains behind in the ſtate of black ſcoria. Expoſed to the air, it loſes it brilliancy, blackens, and is converted into a kind of effloreſcence, which is phoſphate of copper. It is compoſed of 20 parts of phoſphorus, and 80 of copper.

1967 Sulphuret.

10. Copper combines with ſulphur by different proceſſes. If ſulphur in powder and filings of copper are mixed together, and formed into a paſte with a little water, when they are expoſed to the air, the maſs ſwells up, becomes hot, and is converted into a brown matter, which effloreſces ſlowly in the air, and is converted into ſulphate of copper. This ſulphuret may be alſo formed by heating together in a crucible, equal parts of ſulphur and copper filings. A deep coloured maſs is thus obtained, which is brittle, and more fuſible than copper. This ſubſtance, which is employed in dyeing, is prepared by ſtratifying in a crucible plates of copper and ſulphur. When the whole is melted, it is afterwards reduced to powder, and was formerly known by the name of *æs veneris*.

1968 Singular experiment.

1969 Of difficult explanation.

A ſingular and ſplendid experiment was firſt made by the ſociety of Dutch chemiſts at Amſterdam, in the formation of ſulphuret of copper. If three parts of flowers of ſulphur, by weight, and eight parts of copper filings, be mixed together, introduced into a glaſs matraſs, and then placed upon red-hot coals, the mixture melts, and afterwards, with a kind of exploſion, becomes almoſt inſtantaneouſly red hot. If it be then removed from the fire, it continues red-hot for ſome time, and is converted into a ſulphuret of copper. The ſingular part of this experiment is, that it ſucceeds equally well without the acceſs of oxygen; or even it may be performed, when the mixture is under water. It ſeems, therefore, at firſt ſight, to be a caſe of combuſtion, or apparent combuſtion, without oxygen. Various opinions have been entertained concerning the nature of this proceſs, and different theories have been propoſed to account for the phenomena, which are ſeemingly irreconcileable with the preſent theory of combuſtion. Indeed it was at firſt held up as an objection to the Lavoiſierean theory. It has been explained by ſome, by ſuppoſing that a ſmall quantity of air may have remained within the apparatus, or mixed with the materials; or that the quantity of air neceſſary might be ſupplied from the moiſture, from which the materials and the apparatus may not have been ſufficiently freed. But this affords no ſatisfactory explanation, for the quantity of air or water which could remain when the experiment has been carefully performed, is not ſufficient to furniſh the neceſſary portion of air for the ſupport of ſuch a vivid combuſtion. Fourcroy conſiders it as a caſe of ſimple phoſphoreſcence, a change or ſudden increaſe of capacity for caloric, or as merely the ſeparation of light, or the converſion of caloric into light; and in ſupport of this opinion he ſtates, that the compound is always ſulphuret of copper, which would not have been the caſe, had real combuſtion been effected, for then it would have been a ſulphate of copper. But it is explained by others according to the principles of the theory of combuſtion, which has been given by Gren, and which we have already detailed, in treating of heat. According to this theory, the light exiſts in combination with the combuſtible, which in this caſe is the copper. When heat is applied to the mixture, the ſulphur melts, and therefore combines with a great quantity of caloric; but, when the ſulphur combines with the copper, it returns to the ſolid ſtate, and therefore gives out a quantity of caloric. The light from the metal at the ſame time combines with the caloric, and both appear in the form of fire. It is at the inſtant of combination that the maſs becomes red-hot, in conſequence of the ſudden extrication of heat and light from the two ſubſtances which form the compound.

1970 Copper pyrites.

Copper combined with ſulphur, is one of the moſt common ores of this metal. According to the experiments of Prouſt, the natural production, known by the name of copper pyrites, is a ſulphuret of copper, combined with an additional portion of ſulphur. It is diſtinguiſhed by its brittleneſs, metallic luſtre, and yellow colour.

1971 Affinities.

11. The order of the affinities of copper and its oxide, is according to Bergman, the following:

Copper.	Oxide of Copper.
Gold,	Oxalic acid,
Silver,	Tartaric,
Arſenic,	Muriatic,
Iron,	Sulphuric,
Mangaueſe,	Saclactic,
Zinc,	Nitric,

---

* Phil. Tranſ. 1801, p. 235.

Copper.	Oxide of Copper.
Antimony,	Arſenic,
Platina,	Phoſphoric,
Tin,	Succinic,
Lead,	Fluoric,
Nickel,	Citric,
Biſmuth,	Lactic,
Cobalt,	Acetic,
Mercury,	Boracic,
Sulphur,	Pruſſic,
Phoſphorus.	Carbonic.

I. Salts of Copper.

1. Sulphate of Copper.

1972 Preparation. 1. Sulphuric acid has no action on copper in the cold, but when it is concentrated, and at a boiling temperature, it is decompoſed by the copper, with the diſengagement of ſulphurous acid gas. By evaporating the liquid, and by ſlow cooling, cryſtals of a fine blue colour are obtained. This ſalt, which is a ſulphate of copper with exceſs of acid, reddens vegetable blues, 1973 Properties. has a ſtrong ſtyptic, metallic taſte, and is at the ſame time extremely acrid and cauſtic. Its ſpecific gravity is 2.1943. It is ſoluble in 4 parts of cold, and in 2 of boiling water. It effloreſces ſlightly in the air, loſes its water of cryſtallization when it is heated, and is converted into a bluiſh white powder. By increaſing the heat the acid is driven off and the oxide remains behind. 1974 Compoſition. The component parts of this ſalt are, according to Prouſt,

Acid	33
Oxide	32
Water	35
	100

1975 Native. 2. This ſalt is generally found in great abundance in nature, and is obtained either by evaporating the water which holds it in ſolution, or by expoſing the ſulphuret of copper to air and moiſture, by which it is converted into ſulphate of copper. This ſalt is known in commerce by the names of *blue vitriol*, *blue copperas*, and *vitriol of copper*.

3. None of the acids have any action on the ſulphate of copper. It is decompoſed by the alkalies and earths, and precipitated in the form of a bluiſh-gray oxide, which becomes green when expoſed to the air, by abſorbing carbonic acid from the atmoſphere. Ammonia decompoſes and precipitates the ſulphate of copper, and, with an exceſs of alkali, diſſolves the oxide, which aſſumes a rich, brilliant blue colour. It is alſo partially de- 1976 Sympathetic ink. compoſed by muriate of ammonia. Equal parts of this ſalt and ſulphate of copper in a heated ſolution, appear of a yellow colour, but when the ſolution cools, it is converted into a green. This ſolution has been employed as a ſympathetic ink. Paper moiſtened with it, appears of a yellow colour when it is heated, but, in the cold, the colour entirely diſappears.

4. When a ſmall quantity of cauſtic potaſh is added to a ſolution of ſulphate of copper, a greeniſh-coloured precipitate is formed, which is diffuſed in the ſolution. This is a ſulphate of copper with exceſs of baſe, and, according to Prouſt, is compoſed of

1977 Compoſition of.

Acid,	18
Oxide,	68
Water,	14
	100

Copper is reduced to the metallic ſtate from its ſolutions in acids, by ſeveral metallic ſubſtances, as iron, zinc, tin. If a plate of iron be introduced into a ſolution of copper in an acid, the iron is in a ſhort time covered with metallic copper. It is in this way that copper is obtained from its natural ſolutions in water.

2. Sulphite of Copper.

1978 Preparation. Sulphurous acid has no action whatever on copper; but the oxide of copper readily combines with this acid. Or, the ſulphite of copper may be formed by adding a ſolution of ſulphite of ſoda, to a ſolution of ſulphate of copper. An orange-yellow precipitate is formed, and ſmall cryſtals of a greeniſh white are depoſited. Theſe become deeper coloured by expoſure to the air. Both the yellow precipitate and the greeniſh white ſalt have been proved by experiment to be ſulphites of copper. The firſt contains a greater proportion of copper, and therefore has an exceſs of baſe, to which its colour and inſolubility are owing. The ſecond is a ſaturated ſulphite, which is ſoluble and cryſtallizes. When theſe ſalts are heated by the blow-pipe, they melt, blacken, aſſume a grayiſh colour, and are at laſt reduced to the metallic ſtate. By the addition of nitric acid they are converted into ſulphate of copper. By the ſulphuric acid the ſulphurous acid is driven off, and there remains behind a browniſh-coloured matter in the ſtate of powder, which is the oxide of copper mixed with a portion of that metal in the metallic ſtate.

3. Nitrate of Copper.

1979 Preparation. 1. Nitric acid is decompoſed by copper with great rapidity. Nitrous gas is given out in great abundance, the metal is oxidated, and diſſolved in the acid. The ſolution, which is at firſt of a pale blue, aſſumes a deep colour, and by ſlow evaporation yields cryſtals in the form of long parallelopipeds. This ſalt has an acrid ſtyptic taſte, is extremely cauſtic, and corrodes the ſkin. It is deliqueſcent, and very ſoluble in wa- 1980 Properties. ter. This ſalt expoſed to a heat, even under 100°, melts; by increaſing the heat, the water of cryſtallization is driven off; it detonates ſlightly on red-hot coals, and when mixed with phoſphorus, by percuſſion.

1981 Violent action on tin. 2. If a quantity of this dried ſalt, reduced to powder, be ſpread on a ſheet of tinfoil, it remains without any action; but if it be moiſtened a little with water, and wrapped up, a violent action takes place. The ſalt is decompoſed, and nitrous gas is diſengaged with a great degree of heat. The tinfoil is burſt to pieces, and ſometimes it is even inflamed. In this proceſs, the nitric acid of the nitrate of copper is decompoſed, in conſequence of the ſtrong affinity of the tin for the oxygen of the acid. The tin is oxidated, nitrous gas is given out, and the copper is partly reduced to the metallic ſtate.

1982 Decompoſition. 3. The alkalies and earths precipitate the ſolution of of nitrate of copper in the form of a bluiſh white oxide, which becomes green by expoſure to the air. When it is precipitated by means of potaſh, if the potaſh predominate, a bulky precipitate is formed, of a fine blue colour. This precipitate is compoſed of the oxide of copper and water, from which Prouſt, who particularly examined it, has denominated it *hydrate of copper*. Lime thrown into this ſolution, has the property of giving it a deeper ſhade of blue. It is by this proceſs that the blue pigment known in commerce by the name of *verditer*, and which is employed for painting paper, is prepared.

4. If nitrate of copper be diſtilled in a retort, the ſalt becomes thick, and forms a green cruſt on the retort. It is then in the ſtate of nitrate with exceſs of baſe, or *ſubnitrate*, which is inſoluble in water.

1983 Compoſition. 5. The component parts of this ſalt are, according to Prouſt,

Acid,	16
Oxide,	67
Water,	17
	100

4. Muriate of Copper.

1. Concentrated muriatic acid, with the aid of heat, acts on copper and diſſolves it. It produces a ſlight effervеſcence, with the evolution of hydrogen gas. 1984 Preparation. The ſolution is of a fine green colour, by which it is diſtinguiſhed from the ſulphate and nitrate of copper. This ſalt may be formed by the direct combination of the green oxide of copper with muriatic acid, a little diluted with water. By evaporation and ſlow cooling, cryſtals may be obtained in the form of long ſmall needles, or rectangular parallelopipeds, which are of a fine graſs green colour. 1985 Properties. This ſalt is extremely acrid and cauſtic; it melts with a moderate heat; it is deliqueſcent in the air, and is ſoon converted into a thick liquid like oil. This ſalt fuſes at a moderate heat, and becomes of a uniform maſs by cooling. It is not decompoſed by ſulphuric or nitric acids. The alkalies precipitate a bluiſh white oxide, which becomes green in the air; the copper is precipitated by zinc and iron. 1986 Compoſition. The component parts of this ſalt, according to Prouſt, are,

Acid,	24
Black oxide,	40
Water,	36
	100

This ſalt is therefore the muriate of copper with the oxide in the higheſt degree of oxidation.

1987 Submuriate. 2. This ſalt, according to the experiments of Prouſt, may be diſtilled to dryneſs without any change; but by increaſing the heat, a part of its acid is driven off in the ſtate of oxymuriatic acid, and the copper remains behind in its loweſt ſtate of oxidation, and forms a muriate of copper of a white colour. This muriate may alſo be obtained by diſſolving copper in nitro-muriatic acid. A greeniſh powder appears, which is a muriate of copper with exceſs of baſe. The component parts of this ſalt are,

1988 Compoſition.

Acid	12.5
Oxide	79.0
Water	8.5
	100.0

1989 With the orange oxide. 3. Muriatic acid alſo forms a ſalt with the oxide of copper in its loweſt degree of oxidation. Prouſt obtained this ſalt by mixing ſalts of copper with muriate of tin, which latter deprived the copper of a portion of its oxygen, and afforded a ſalt of a white colour. It may be formed alſo by introducing a plate of copper into a bottle filled with muriatic acid. This ſalt cryſtallizes in tetrahedrons. It may be precipitated in the ſtate of white powder; by diluting the ſolution with water, and by repeated waſhings, the orange oxide of copper is obtained. When it is expoſed to the air, it ſoon combines with oxygen, and is converted into muriate of copper with the oxide in its maximum ſtate of oxidation. This ſalt is ſoluble in ammonia, and forms with it a colourleſs ſolution, which, after being for ſome time expoſed to the air, aſſumes a fine blue colour by the abſorption of oxygen.

5. Hyperoxymuriate of Copper.

The oxide of copper diffuſed in water, is diſſolved, when a ſtream of oxymuriatic acid gas is directed through it. But the properties of this ſalt were not examined by Mr Chenevix, who formed it.

6. Fluate of Copper.

Fluoric acid readily oxidates and diſſolves copper; but the properties of this ſalt are little known. It forms a gelatinous ſolution, and affords by evaporation cubical cryſtals.

7. Borate of Copper.

This ſalt is moſt readily formed by adding a ſolution of an alkaline borate to the ſolution of nitrate or ſulphate of copper. A greeniſh precipitate is formed, which has very little ſolubility in water.

8. Phoſphate of Copper.

1990 Preparation. Phoſphoric acid is not decompoſed by copper; but when it remains for ſome time in contact with the metal, it promotes the oxidation, and there is thus formed a phoſphate of copper, which has little ſolubility. Or it may be obtained by pouring an alkaline phoſphate into a ſolution of ſulphate or nitrate of copper. The phoſphate of copper is formed, which is almoſt inſoluble. When it is heated with charcoal in a crucible it affords a gray phoſphuret of copper, which has ſome brilliancy. 1991 Compoſition. The component parts of phoſphate of copper, as they have been aſcertained by Mr Chenevix, are,

Acid,	35.0
Oxide,	61.5
Water,	3.5
	100.0

The above oxide is compoſed of 49.5 brown oxide, and 12 of water.

9. Carbonate of Copper.

1992 Preparation. Carbonic acid has no action on copper, either in the gaſeous or liquid ſtate; but it is very readily abſorbed by the blue or green oxides of this metal. It may be formed by adding an alkaline carbonate to any of the ſolutions of copper in the other acids. To prepare this ſalt of the moſt brilliant and uniform colour, it ſhould be precipitated with boiling water, waſhed carefully, and the veſſel which contains it placed in the ſun. This carbonate of copper is found native, and is known by the name of *malachite*. It contains the ſame proportions as the artificial carbonate. Its component

1993 Compoſition. parts are,

Acid	25.0
Brown oxide	69.5
Water	5.5
	100.0

10. Arſeniate of Copper.

This ſalt may be formed by adding a ſolution of an alkaline arſeniate to nitrate of copper; or, by digeſting arſenic acid on copper. A green ſolution is obtained, and the arſeniate of copper is precipitated in the form of a bluiſh-white powder. The arſenite of potaſh added to a ſolution of ſulphate of copper forms a precipitate of a very rich green, which was propoſed by Scheele as a paint, becauſe it is unaltered by the air, and hence it obtained the name of *Scheele's green*. It is the arſenite of copper. This ſalt may be formed by the following proceſs: 1994 Scheele's green.

Diſſolve a quantity of potaſh in water, and add white oxide of arſenic, till the potaſh is ſaturated. Filter the liquor, and add gradually a ſolution of ſulphate of copper while it is hot, ſtirring the mixture during the addition. It is then left at reſt for ſome time, after which the arſenite of copper precipitates in the form of a beautiful green powder. The precipitate is to be repeatedly waſhed with water, and dried. Several varieties of the arſeniates of copper have been deſcribed, and analyzed by the Count de Bournon and Mr Chenevix, and an account of them publiſhed in the Philoſophical Tranſactions for 1801.

11. Tungſtate of Copper.

Tungſtic acid combines with oxide of copper, or forms a precipitate when added to a ſolution of ſulphate of copper.

12. Molybdate of Copper.

Molybdic acid added to a ſolution of nitrate of copper, produces a green precipitate.

13. Chromate of Copper.

This is formed by adding chromic acid to a ſolution of nitrate of copper. A red precipitate is obtained.

14. Acetate of Copper.

1995 Preparation. Copper is readily oxidated and diſſolved in acetic acid. The ſolution is aided by heat, and gradually aſſumes a green colour. The oxide of copper, which is thus formed, is the verdegris of commerce. It is uſually prepared by expoſing plates of copper to the action of vinegar. The ſurface of the plates is covered with this bluiſh green powder, which being diſſolved in acetic acid affords a ſolution of a fine greeniſh blue colour. This ſolution by evaporation and cooling gives cryſtals of a deep blue colour, and in the form of quadrangular, truncated pyramids. The ſpecific gravity is 1.779. This ſalt has a ſtrong diſagreeable taſte, and 1996 Properties. is poiſonous. It effloreſces in the air, and is very ſoluble in water. It is decompoſed by all the alkalies; and by means of heat, or by diſtillation, it is decompoſed, and gives out acetic acid. This ſalt, according to the analyſis of Prouſt, is compoſed of

Acid and water	61
Oxide	39
	100

15. Oxalate of Copper.

Oxalic acid readily acts upon copper, and forms with it needle-ſhaped cryſtals of a green colour. It readily combines with the oxide of copper, and is then in the ſtate of a bluiſh green powder, which is little ſoluble in water. Oxalic acid precipitates the ſulphate, nitrate, and muriate of copper, in the form of a bluiſh gray powder.

16. Tartrate of Copper.

Tartaric acid diſſolves copper, when expoſed to the air, and at laſt converts it into an oxide. It combines readily with the oxides of copper, and forms with them a ſalt of little ſolubility, and of a green colour. When this acid is added to the ſolution of ſulphate or muriate of copper, it forms a tartrate of copper, which appears after ſome time in irregular greeniſh cryſtals.

17. Tartrate of Potaſh and Copper.

This triple ſalt may be prepared by boiling together oxide of copper and tartar in water. By evaporating the ſolution blue cryſtals are obtained, which have a ſweetiſh taſte. If the ſame ſolution be evaporated to dryneſs, a bluiſh green powder remains behind, which is employed as a paint by the name of *Brunſwick green*. 1997 Brunſwick green.

18. Citrate of Copper.

Citric acid diſſolves the oxide of copper at the boiling temperature. The ſolution affords by evaporation, greeniſh coloured cryſtals.

19. Benzoate of Copper.

Benzoic acid readily diſſolves the oxide of copper. The ſolution yields ſmall cryſtals of a deep green colour, which have little ſolubility in water. It is decompoſed by the alkalies, the carbonates of lime, and barytes, and the acid is driven off by heat.

20. Succinate of Copper.

When ſuccinic acid is long digeſted with copper, it diſſolves a ſmall portion, and the ſolution affords green cryſtals.

21. Suberate of Copper.

When ſuberic acid is added to a ſolution of nitrate of copper, it produces a green colour; but there is no precipitate.

22. Mellate of Copper.

When mellitic acid is added to a ſolution of acetate of copper it affords a precipitate, and the colour of verdigris, but it produces no change on muriate of copper.

23. Lactate of Copper.

Lactic acid, after digeſtion with copper, firſt aſſumes a blue colour, then changes to a green, and is afterwards converted into a dark brown. The ſolution does not yield cryſtals.

24. Pruſſiate of Copper.

1998 Preparation. The pruſſiates of potaſh precipitate the ſalts of copper of different colours. The pruſſiates obtained from ſulphate, nitrate, and muriate of copper, Mr Hatchet obſerves, are very beautiful; but the fineſt and deepeſt colour he obtained from the muriate. He has propoſed the pruſſiate of copper as a paint; and on trial with oil and water, it has been found to anſwer the purpoſe. The method which he recommends for the preparation of this pigment, is to take green muriate of copper with 10 parts of diſtilled or rain water, and to add pruſſiate of lime, which he thinks is preferable to pruſſiate of potaſh, until the whole is precipitated. The pruſſiate of copper is then to be well waſhed with cold water, and to be dried without heat *.

II. Action of Alkalies, &c. on Copper.

1999 Fixed alkalies. 1. The fixed alkalies in ſolution in water, digeſted with copper filings, and allowed to cool, promote the oxidation of the metal. The liquid aſſumes a ſlight blue colour, as well as the copper, but the action of the air is neceſſary for this proceſs. It ſcarcely ſucceeds in in cloſe veſſels.

2000 Ammonia. Liquid ammonia, treated in the ſame way, becomes of a brilliant blue colour, but it diſſolves only a very ſmall quantity of the oxide. By the ſlow evaporation of this ſolution, the greateſt part of the ammonia is ſeparated in the form of gas; a very ſmall quantity only remains combined with the oxide of copper. This ſolution, it has been ſaid, yields tranſparent cryſtals of a fine blue colour. The dried maſs aſſumes a green colour when it is expoſed to the air, as the ammonia is diſſipated, and the oxide abſorbs carbonic acid. The green oxide of copper is inſtantly converted to a blue. This action is promoted by heat, and when the heat is increaſed, azotic gas is diſengaged; the hydrogen of the ammonia combines with part of the oxygen of the oxide, and forms water; the oxide becomes of a brown colour, and the metal is at laſt revived.

2001 Glaſs coloured. 2. There is no action between the earths and copper, excepting by fuſion. With the vitrifiable earths and the oxides of this metal, a glaſs is formed, which is moſt commonly of a fine green colour, with different ſhades of brown or red, according to the degree of oxidation. The oxides of copper are frequently employed to colour glaſs, porcelain and pottery.

2002 Sulphates. 3. Copper ſeems to have but a feeble action on moſt of the ſalts. The ſulphates are not decompoſed by this metal, even with the aſſiſtance of heat. When copper is boiled with the ſolution of alum, it is oxidated and partially diſſolved, by the exceſs of ſulphuric acid which this ſalt contains. The ſulphate of copper thus formed, ſeems to combine in the ſtate of triple ſalt with the ſulphate of alumina and potaſh. It has been obſerved that alumina precipitated from alum, the ſolution of which has been kept for ſome time in copper veſſels, is ſlightly tinged with a blue colour. The nitrates, eſpecially the nitrate of potaſh, when fuſed together, give out ſparks, but without inflammation or detonation. A brown oxide of copper is thus formed, mixed with potaſh. When it is waſhed with water, the alkali is diſſolved, and there remains the pure oxide of copper, which is often prepared in this way for the fabrication of enamels. 2003 Nitrates.

2004 Muriates. Muriate of ammonia is decompoſed by copper with the aſſiſtance of heat. Hydrogen gas and ammoniacal gas are diſengaged, and there remains behind a muriate of copper. The ſolution of muriate of ammonia alſo acts upon copper, and becomes of a blue colour, when it is kept in veſſels of this metal. When muriate of ammonia is ſublimed with about $\frac{1}{60}$ of its weight of green oxide of copper, a ſmall quantity of the muriate of ammonia is decompoſed, and the muriate of copper which is formed, combines with the undecompoſed ſalt. This was formerly called *cupreous flowers of ſal ammoniac*, or *ens veneris*. If a quantity of lime water, with about $\frac{1}{16}$ of its weight of muriate of ammonia, be kept in a copper veſſel for 10 or 12 hours, the liquid aſſumes a fine blue colour. This was formerly called *celeſtial water*. In this proceſs a ſmall quantity of ammonia is diſengaged by the lime, and it diſſolves ſome portion of the copper, which communicates a blue colour to the whole ſolution. This compound may alſo be formed, by adding a ſmall quantity of copper filings to a mixture of the ſolution of muriate of ammonia and lime water.

4. The phoſphates, fluates, borates, and carbonates, have no other action on copper than by means of the water in which they are diſſolved. This action is greatly promoted by expoſure to the air.

III. Alloys.

1. Copper readily combines with almoſt all other metals, by means of fuſion; and many of the alloys which are thus formed, are of great importance in the arts.

2005 Arſenic. 2. When copper is combined with arſenic, by melting them together in a cloſe crucible, and covering the ſurface with muriate of ſoda, to prevent oxidation, a white brittle alloy is formed, which has been called *white tombac*. With a certain proportion of zinc and tin, this alloy is employed in the fabrication of various utenſils.

3. The alloys of copper with tungſten, molybdena, chromium, columbium, titanium, and uranium, are either altogether unknown, or have not been examined.

2006 Cobalt. 4. Little is known of the alloy of copper and cobalt. It is ſaid that it reſembles cobalt itſelf in texture and brittleneſs.

2007 Nickel. 5. Copper forms with nickel a white hard alloy, which has no ductility, and which is ſoon altered by expoſure to the air.

2008 Manganeſe. 6. Copper unites with manganeſe, and gives an alloy of a red colour, which is very malleable.

7. Equal

---

* Jour. Roy. Inſt. i. 307.

2009 Biſmuth. 7. Equal parts of copper and biſmuth, melted together, form a brittle alloy of a pale red colour. With one-eighth of biſmuth, the alloy is extremely brittle, of a very pale red colour, and exhibiting in its texture nearly cubical fragments. The ſpecific gravity of this alloy is exactly the mean of that of the two metals; and, as the proportion of biſmuth is increaſed, the tenacity of the alloy is diminiſhed.

2010 Antimony. 8. Copper combines readily with antimony by fuſion. Equal parts of the two metals conſtitute an alloy of a beautiful violet colour, and of a greater ſpecific gravity than the mean. This alloy is remarkable for its lamellated and fibrous texture. The alchemiſts gave it the name of *regulus of Venus*. A compound formed of equal parts of martial regulus and regulus of Venus, according to an alchemical preſcription, the ſurface of which exhibits the appearance of meſhes or cavities, was called *Vulcan's net*, becauſe it ſeemed to envelope iron and copper, which were denominated *Mars* and *Venus*.

2011 Mercury. 9. Copper enters into combination with mercury with ſome difficulty. This alloy may be formed by triturating very thin plates of copper which have been rubbed with vinegar or common ſalt, with mercury; or, by triturating copper filings with the ſolution of mercury in nitric acid. It is alſo formed by other proceſſes; but whatever be the proceſs, this amalgam is of a reddiſh colour, and ſufficiently ſoft to receive the moſt delicate impreſſions when it is a little heated. It becomes hard by expoſure to the air. It is decompoſed by heat, and the mercury is ſeparated.

2012 Zinc. 10. The compound of copper and zinc conſtitutes one of the moſt important and uſeful alloys, of all the combinations of the metals. Muſchenbroeck has given a particular deſcription of ſeveral of theſe alloys. Equal parts of copper and zinc afforded a metal of a fine golden yellow, whoſe ſpecific gravity was 8.047; one part of copper and half a part of zinc, formed a compound of a pale golden colour; one part of copper and three-fourths of zinc, compoſed an alloy of a golden colour, which yielded to the file; one part of copper and one-fourth of zinc, gave a compound of a finer colour than that of braſs. According to the proportions of the metals which are employed, the alloys have received different names. The uſual proceſs for combining them, is either by fuſing copper with a mixture of calamine, or native carbonate of zinc and charcoal, or by ſtratifying plates of copper with the ſame mixture, and expoſing them to heat.

2013 Braſs. The well-known compound, diſtinguiſhed by the name of *braſs*, is an alloy of copper and zinc. The proportion of the zinc is about one-fourth of the copper. This alloy is of a fine yellow colour, leſs liable to tarniſh, and more fuſible than the copper. The denſity of this alloy is one-tenth more than the mean. It is malleable, and poſſeſſes conſiderable ductility. A compound applied to a great variety of ornamental purpoſes, and known by the names of *Prince Rupert's metal*, *prince's metal* or *pinchbeck*, is an alloy of zinc and copper in the proportion of three parts of the former to four of the latter. This alloy is leſs malleable than braſs; but has a fine golden colour, which is pretty permanent, and little affected by expoſure to the air. 2014 Pinchbeck.

The compound of zinc and copper, called braſs, it is ſuppoſed, was well known to the ancients. An ore of zinc was employed in the fabrication of it, although it does not appear that they were at all acquainted with zinc as a diſtinct metal. "It is probable," Profeſſor Beckmann obſerves, after Pliny, "that ore containing zinc, acquired the name of *cadmia*, becauſe it firſt produced braſs." "Ipſe lapis è quo fit æs, cadmia vocata." "When it was afterwards remarked, that calamine gave to copper a yellow colour, the ſame name was conferred on it alſo. It appears, however, that it was ſeldom found by the ancients, and we muſt conſider cadmia in general as ſignifying ore that contains zinc. Gold-coloured copper or braſs was long preferred to pure or common copper, and thought to be more beautiful the nearer it approached to the beſt *aurichalcum* (c). Braſs, therefore, was ſuppoſed to be a more valuable kind of copper; and on this account Pliny ſays that cadmia was neceſſary for procuring copper, that is, *braſs*. Copper as well as braſs was for a great length of time called *æs*, and it was not till a late period, that mineralogiſts, in order to diſtinguiſh them, gave the name of *cuprum* to the former. Pliny ſays, that it was good when a large quantity of cadmia had been added to it, becauſe it not only rendered the colour more beautiful, but increaſed the weight (D) *.

2015 Braſs analyzed. To diſcover the proportions of the two metals in this alloy, Vauquelin diſſolved a quantity of braſs in nitric acid. When the ſolution is completed, he precipitates the two metals by means of potaſh, which is added in large quantity, to diſſolve the whole of the oxide of zinc; and as the oxide of copper is not ſoluble by this alkali, it remains in the form of black powder, which is ſeparated, waſhed, and dried. A fiftieth part of the weight of this precipitate is deducted for the oxygen with which it is combined; the remainder gives the weight of copper in the alloy. What is deficient of the whole weight of the alloy, is the weight of the zinc †.

11. Copper

* *Hiſt. of Invent.* v. iii. 74.

* *Fourcroy Connaiſs. Chim.* vi. 159.

(c) According to Biſhop Watſon, the *aurichalcum*, or *orichalcum* of the ancients is to be conſidered as the ſame with our braſs. *Mancheſt. Tranſ.* ii 47.

(D) Mr Beckmann farther adds, "at firſt it was called *æs cyprium*; but in courſe of time only *cyprium*, from which at length formed *cuprum*. It cannot, however, be aſcertained at what periods theſe appellations were common. The epithet *cupreus* occurs in manuſcripts of Pliny and Palladius, but we cannot ſay whether later tranſcribers may not have changed *cyprius* into *cupreus*, with which they were perhaps better acquainted. The oldeſt writer who uſes the word cuprum, is Spartian, who ſays in the life of Caracalla, *cancelli ex ære, vel cupro*; but may not the laſt word have been added to the text as a gloſs? Pliny, book xxxvi. 26. ſays, *addito cypreo et nitro*, which Iſidore, xvi. 15. p. 393, expreſſes by the words *adjecto cupro et nitro*. *Hiſt. of Invent.* iii. 75.

2016 Tin. 11. Copper combines very readily with tin. This is a very important alloy in the arts. It is with this alloy that *bronze*, metals for caſting ſtatues and cannons, bell-metal, and metallic mirrors, are formed. Tin diminiſhes the ductility of copper, and increaſes its tenacity, hardneſs, and ſonorous quality. According to Muſchenbroeck, copper acquires the greateſt ſolidity with the addition of one part of tin to five or ſix of this metal. By increaſing the quantity of tin, the alloy becomes hard and brittle.

2017 For cannons. To form the alloy employed for cannons, 12 parts of tin are united to 100 of copper. In fuſing the two metals for this alloy, it is neceſſary to ſtir or agitate the mixture, otherwiſe they remain uncombined. Bronze, or the metal which is uſed for ſtatues, is not different from that of which cannons are made, excepting in the proportion of tin being either more or leſs, to vary the colour.

2018 Bell metal. The component parts of bell-metal are uſually 75 of copper and 25 of tin, or three of copper and one of tin. A ſmall quantity of other metals is ſometimes detected by analyſis, in fragments of bells that have been examined, ſuch as zinc, antimony, biſmuth, and even ſilver. But theſe metals are not conſidered as eſſential to the alloy. Bell-metal is of a grayiſh white colour, of a cloſe grain, and ſo hard as to be ſcarcely touched with the file. It is alſo elaſtic and ſonorous. The ſpecific gravity is conſiderably more than the mean, and it is more fuſible than copper. A mixture of three parts of tin and one of copper, fuſed with a little arſenious acid, and black flux, gives an alloy of the colour of ſteel, very hard, and ſuſceptible of a fine poliſh, which is employed in the fabrication of mirrors for teleſcopes. But other proportions, with the addition of other metals, are employed by different opticians. Biſmuth, antimony, and ſilver, are added, to increaſe the reflecting property of the mirror.

2019 Tinning copper. Copper veſſels which are employed for the purpoſes of domeſtic economy, are apt to be corroded or oxidated by the ſubſtances which are boiled or preſerved in them. To defend them from the action of theſe ſubſtances, and to prevent the terrible accidents which would otherwiſe happen to thoſe who employ any of theſe matters as food, the inſide of ſuch veſſels is covered with a thin coating of tin. This is performed by the following proceſs. The ſurface to be covered with tin, is ſcraped very clean with an iron inſtrument, or it is ſcoured with wine lees, or weak nitric acid and ſand. The tin is then applied in two ways; in the firſt way, the tin is in a ſtate of fuſion, and the ſurface is covered with ſome reſinous or oily matter, to prevent oxidation, in the ſame way as in tinning iron. The ſurface to be tinned is firſt immerſed in a ſolution of muriate of ammonia, and dried, and then dipped into the melted tin. Another method is, to heat the copper veſſel on charcoal, and then to apply to the inſide of it a quantity of tin, which is then melted; a little muriate of ammonia being thrown in at the ſame time in powder. The ſurface is then rubbed with tow. The muriate of ammonia is employed, both to clean the ſurface of the copper, and alſo to prevent the tin from being oxidated. The coating of tin which can be applied to copper is extremely thin; and it cannot by any means be increaſed, to bear a heat greater than that which melts tin. Bayen in his reſearches concerning tin, found, that a veſſel nine inches in diameter, and three lines in depth, acquired, by having its ſurface covered with tin, only 21 grains of additional weight.

In uſing veſſels thus tinned, care ſhould be taken not to allow acid ſubſtances to remain for any length of time in contact with them, becauſe the tin would be corroded, and part of the copper afterwards diſſolved, which would inevitably act as a poiſon. Pure tin ought only to be employed, at leaſt without any mixture of lead.

2020 Lead. 12. Copper combines very readily with lead by fuſion. With an exceſs of lead, the alloy is of a gray colour, is ductile, but brittle when it is hot, on account of the great difference of fuſibility of the lead and copper. This alloy is employed in the fabrication of printing types for large letters. According to Savary, the proportion for this purpoſe is 100 parts of lead and 20 or 25 of copper.

2021 Iron. 13. Copper combines with iron, but with much greater difficulty than with the other metals. As the proportion of iron is increaſed, the alloy becomes of a darker gray, loſes its ductility, and is more infuſible. The alloy of copper with iron has been ſuppoſed to conſtitute that variety called *hot ſhort iron*, which poſſeſſes greater tenacity than other kinds of iron, and on account of ſome peculiar properties is more applicable to a variety of purpoſes.

2022 Uſes. Next to iron, copper is of the greateſt importance, and moſt extenſive utility, of all the metals. In the metallic ſtate it is employed for a great variety of inſtruments and utenſils; ſome of its oxides and ſalts are much uſed in painting, dyeing, and enamelling; and the alloys, with other metals, eſpecially with zinc and tin, are applied to many valuable purpoſes in the arts, and in domeſtic economy. But the uſes of copper in its different ſtates, and in its various combinations, are ſo familiar and well known, that it muſt appear quite unneceſſary to enumerate them.

SECT. XX. *Of SILVER.*

2023 History. 1. Silver has been reckoned among the noble or perfect metals, and has been known from the earlieſt ages of the world. Its ſcarcity, beauty, and utility, have always rendered it an object of reſearch among mankind, ſo that the nature and properties of this metal have been long ſtudied and minutely inveſtigated. In the midſt of the rage for the tranſmutation of metals which for centuries fired the imaginations of the alchemiſts, ſilver occupied a great ſhare of their attention and labour, with the hope of diſcovering the means of converting the baſer and more abundant metals into this, which is more highly valued on account of its ſcarcity and durability. When the dawn of ſcience commenced, and its light had diſſipated the follies and extravagancies of theſe purſuits, the earlier chemiſts were much employed in examining the properties and combinations of ſilver; nor has it been overlooked or neglected by the moderns.

2024 Ores. 2. Silver which is neither in ſuch abundance nor ſo univerſally diffuſed as many other metals, exiſts in nature in five different ſtates; in the native ſtate; in that of alloy with other metals, eſpecially with antimony; in that of ſulphuret, ſulphurated oxide, muriate, and carbonate. 1. Native ſilver, which is characterized by its ductility and ſpecific gravity, is frequently tarniſhed on the ſurface, of a gray or blackiſh colour, and appears under a great variety of forms. In this ſtate it is not perfectly pure. It is uſually alloyed with a little gold or copper. 2. The alloy of ſilver and antimony which is the moſt frequent, is diſtinguiſhed by its brittleneſs and lamellated ſtructure from native ſilver, which it reſembles in luſtre and colour. It cryſtallizes in priſms which are ſix-ſided and pretty regular. 3. The ſulphuret of ſilver which is known to mineralogiſts by the name of *vitreous ſilver ore*, is of a dark gray colour, and has ſome metallic luſtre. It is uſually cryſtallized in the form of cubes, octahedrons with angular facets, or ſometimes in the form of the dodecahedron. 4. The ſulphurated oxide of ſilver and antimony. In this ore of ſilver the ſulphur is combined with the metal in the ſtate of oxide; in the former, in the metallic ſtate. This ore is called *red ſilver ore.* It is of a deep red colour, ſometimes tranſparent, and ſometimes nearly opake, frequently having the luſtre of ſteel on the ſurface. The primitive form of its cryſtals is the rhomboidal dodecahedron. 5. The muriate of ſilver which has been long known to mineralogiſts by the name of *corneous ſilver*, is found in irregular maſſes of a grayiſh colour, frequently opake, but ſometimes ſemitranſparent. It is ſoft and very fuſible.

2025 Analyſis. 3. The analyſis of ſilver ore varies according to its nature and combinations. Native ſilver, after being broken down and waſhed, is rubbed with liquid mercury, which by ſtrong trituration diſſolves, and combines with the ſilver. This amalgam is ſubjected to preſſure, to ſeparate the exceſs of mercury. It is then diſtilled, and afterwards heated in a crucible, to volatilize the mercury, and the ſilver remains pure. When ſilver is combined with antimony and ſulphur, the ore is to be ſtrongly roaſted, to ſeparate the antimony or ſulphur. It is then melted with a proper quantity of alkaline flux. The ſulphurated oxide of ſilver and antimony may be treated in the ſame way.

2026 Silver purified by cupellation. But by theſe proceſſes the ſilver is not in a ſtate of perfect purity. To obtain it pure, by the ſeparation of other metals, as copper or iron, it is ſubjected to the proceſs called *cupellation*. This depends on the peculiar property of lead, when it is oxidated and afterwards vitrified, of combining with the metals, and leaving the ſilver in a ſtate of purity. A ſmall flat cup made of the powder of burnt bones, which has received the name of *cupel*, is employed for this purpoſe. The ſilver to be purified is included in a plate of lead, uſually double the weight of the ſilver. The cupel is introduced under a *muffle* in the middle of the furnace. The uſe of the muffle is to increaſe the heat, by allowing the metal to be ſurrounded on all ſides with coals, and at the ſame time preventing the admixture of any part of the fuel with the fuſed matter. The heat is then to be applied ſufficiently great, that every part of the metal may be in fuſion, but not ſuch as to ſublime the lead too rapidly. As the proceſs advances, the lead is oxidated and vitrified, and having combined with all the other metals except the ſilver, ſinks into the porous cupel, and leaves the ſilver pure. The lead which is now in the ſtate of litharge, is extracted from the cupel, and applied to the uſual purpoſes.

2027 Properties. 4. Silver is of a fine white colour, and great brilliancy. The ſpecific gravity is 10.474, and according to ſome, when it is hammered, 10.535, and ſometimes nearly 11. The hardneſs of ſilver is intermediate between iron and gold. The elaſticity of ſilver is conſiderable, and it is one of the moſt ſonorous of the metals. It poſſeſſes very great ductility and malleability. It may be beaten out into leaves $\frac{1}{160000}$ of an inch thick, and a grain of ſilver may be ſo extended as to be formed into a hemiſpherical veſſel of ſufficient capacity to hold an ounce of water, or to be drawn out into a wire 400 feet in length. The tenacity of ſilver is very great. A wire .078 of an inch in diameter, will ſupport a weight of 187 lbs. avoirdupois.

2028 Action of heat. 5. Silver is a good conductor of caloric. Its expanſive power is leſs than that of lead and tin, and greater than that of iron. When it is expoſed to a white heat, it melts. The temperature neceſſary to bring it to fuſion has been calculated at the 1000° of Fahrenheit, but according to Kirwan, it requires a higher temperature than 28° Wedgwood to melt it, although at that temperature it continues in a ſtate of fuſion. When it is cooled ſlowly after fuſion, it exhibits ſome marks of cryſtallization. It aſſumes the form of four-ſided pyramids, or of octahedrons. If the heat be increaſed after the ſilver is melted, it boils, and may be reduced to vapour. The ſurface of melted ſilver is ſo extremely brilliant, that it ſeems to throw out ſparks, which is called *coruſcation* by the workmen.

2029 Electricity, &c. 8. Silver is a good conductor of electricity. It has no perceptible taſte or ſmell.

2030 Of air. 9. Silver is not altered by expoſure to the air, although it is ſoon tarniſhed, which is owing, as Prouſt aſcertained, to a thin covering of ſulphuret of ſilver, which is formed by ſulphureous vapours to which it is expoſed; but when it is ſubjected to a ſtrong heat for a long time, in an open veſſel, it combines with the oxygen of the atmoſphere, and is converted into an oxide. 2031 Oxidation. In the experiments of Macquer, the oxidation of ſilver was effected by expoſing it for 20 times ſucceſſively in a crucible, to the ſtrong heat of a porcelain furnace. At laſt perceptible traces of oxidation were obſerved, and a vitreous matter of an olive colour was obtained. In other experiments ſilver being acted on by the heat of a burning glaſs, was covered with a white powder, which was afterwards converted into a cruſt of a green colour. Van Marum paſſed electric ſhocks through ſilver wire, which was inſtantly reduced to a kind of powder, with a greeniſh white flame, and the oxide which was formed was diſſipated in vapour. The oxide of ſilver, which is formed by theſe proceſſes, is of a greeniſh or yellow colour. It is compoſed of about ten parts of oxygen, and 90 of ſilver. The oxide of ſilver is very eaſily reduced, for the affinity of oxygen for this metal is very feeble. It is decompoſed by the application of heat, and even when it is expoſed to the light. By heating it in cloſe veſſels, pure oxygen gas is obtained, and the metal is converted to the metallic ſtate, by melting it in a crucible.

7. Azote, hydrogen, or carbone, have no action whatever on ſilver.

2032 Phoſphuret. 8. Silver combines with phoſphorus, forming a phoſphuret. One part of ſilver in filings with two of phoſphoric

phoſphoric glaſs, and half a part of charcoal, expoſed to heat in a crucible, yielded a phoſphuret of ſilver which had acquired one-fourth of its primitive weight of ſilver. This phoſphuret is of a white colour, brittle, of a granulated texture, and may be cut with a knife. By throwing pieces of phoſphorus on ſilver red hot in a crucible, the metal is inſtantly melted, and the phoſphuret which is formed remains at the bottom. At the moment when the ſurface becomes ſolid, a quantity of phoſphorus is thrown out with a kind of exploſion, and the ſurface of the metal then exhibits a mamellated appearance. Pelletier, who firſt made this experiment, concludes from it, that ſilver is ſuſceptible of retaining a greater proportion of phoſphorus in combination with it, when it is in fuſion than in the ſolid ſtate, and that the ſeparation of the phoſphorus is owing to the ſudden contraction of the ſilver. A hundred parts of ſilver in fuſion retain 25 of phoſphorus, but only 15 when it becomes ſolid. Phoſphorus has the property of reducing the oxides of ſilver, and of precipitating them from this ſolution in acids, in the metallic form.

2033 Sulphuret. 9. Sulphur combines readily with ſilver, both in the dry and humid way. By ſtratifying in a crucible plates of ſilver alternately with ſulphur, and melting them rapidly, a deep violet-coloured maſs is obtained, which is more fuſible than ſilver, brittle, cryſtallized, and has a metallic luſtre. It may be cut with a knife, and has a good deal of reſemblance to vitreous ore of ſilver. When this ſulphuret of ſilver is expoſed to heat for a conſiderable time, the ſulphur is gradually diſſipated, and the ſilver remains pure and ductile. Silver combines very readily with ſulphur, when it is long expoſed to thoſe matters which gradually depoſit this ſubſtance. This effect is immediately produced, when ſilver is brought into contact with ſulphurated hydrogen gas, or when it is immerſed in water impregnated with this gas, as in natural ſulphureous waters. It is owing to the ſame cauſe that a ſilver ſpoon is tarniſhed by a boiled egg, and particularly if the egg has begun to ſpoil. Sulphurated hydrogen gas which is exhaled by the egg, is decompoſed, the ſulphur combines with the ſilver, and forms a thin layer of ſulphuret of ſilver, which is of a dark or violet colour. The ſame thing happens, when ſilver is expoſed in places that are much frequented, as in churches and theatres.

2034 Affinities. 10. Silver forms alloys with moſt of the metals, and ſalts with the acids. The order of the affinities of ſilver and its oxide, as they have been arranged by Bergman, is the following.

Silver.	Oxide of Silver.
Lead,	Muriatic acid,
Copper,	Oxalic,
Mercury,	Sulphuric,
Biſmuth,	Saclactic,
Tin,	Phoſphoric,
Gold,	Sulphurous,
Antimony,	Nitric,
Iron,	Arſenic,
Manganeſe,	Fluoric,
Zinc,	Tartaric,
Arſenic,	Citric,
Nickel,	Lactic,
Platina,	Acetic,
Sulphur,	Succinic,
Phoſphorus.	Pruſſic,
	Carbonic.

I. Salts of Silver.

1. Sulphate of Silver.

2035 Preparation. 1. Sulphuric acid has no action on ſilver in the cold, but three or four parts of the concentrated acid, boiled with one part of ſilver in filings or ſmall pieces, produce an efferveſcence, with the evolution of ſulphurous acid gas. A white powder is formed, which is entirely ſoluble in water acidulated with ſulphuric acid. With exceſs of acid, a ſolution of ſulphate of ſilver is obtained, which is colourleſs, very acrid and cauſtic. 2036 Properties. By evaporation it affords cryſtals, which are white and brilliant, and in the form of fine priſms or needles. When the ſolution is more concentrated, a depoſition is formed as it cools, and then it cryſtallizes in large white, brilliant plates, which ſeem to be compoſed of compreſſed four-ſided priſms.

2. This ſalt is not very ſoluble in water. When expoſed to heat, it melts and ſwells up; at a higher temperature it blackens, gives out ſulphurous acid, and oxygen gas, and is then reduced to the metallic ſtate. It is ſlowly decompoſed by the action of light. It is decompoſed by phoſphorus, and vapour of ſulphur in the cold, and by charcoal at a red heat. It is not altered by the action of the acids, excepting the muriatic. All the alkalies and the alkaline earths precipitate the oxide of ſilver from its ſolution in ſulphuric acid, of a dark gray or brown colour, and eſpecially in contact with light. Lime cauſes a precipitate of a greeniſh-gray colour. Ammonia rediſſolves the precipitate. 2037 Decompoſition. Sulphate of ſilver is decompoſed by the muriates, phoſphates, and fluates. The carbonates give a white inſoluble precipitate of carbonate of ſilver. The alkaline ſulphurets, ſulphurated hydrogen gas, and water impregnated with this gas, decompoſe the ſulphate of ſilver, and form in its ſolution a black precipitate of ſulphuret of ſilver; for the oxide is reduced by the hydrogen, while the ſilver combines with the ſulphur.

2. Sulphite of Silver.

2038 Preparation. Sulphurous acid combines readily with the oxide of ſilver. It aſſumes the form of ſmall ſhining grains, of a pearly-white colour. It is not altered by expoſure to light. Sulphurous acid precipitates the ſolution of ſilver in nitric acid, in form of a white powder of ſulphite of ſilver. The ſame ſalt is obtained by adding a ſolution of ſulphite of ammonia to a ſolution of nitrate of ſilver. An exceſs of this ſulphite rediſſolves the precipitate, and forms a triple ſalt. This ſulphite of ammonia and ſilver expoſed to the ſun's rays, is ſoon covered with a pellicle of ſilver, and the liquid contains ſulphate of ammonia. Sulphurous acid, aided by the affinity of ammonia, deprives the oxide of ſilver of its oxygen, and is converted into ſulphuric acid, which combines with the ammonia, and forms a ſulphate. Sulphite of ſilver is decompoſed by muriate of ammonia, and the precipitate, which is formed, aſſumes a black colour, and is partly reduced. 2039 Decompoſition. When ſulphite of ſilver is expoſed to the action of the blow-pipe, it gives out ſulphurous acid, melts into a yellow maſs, and leaves behind a metallic button of pure ſilver. This ſalt has an acrid metallic taſte; it is ſoluble in the cauſtic alkalies, and forms with them a triple ſalt.

3. Nitrate of Silver.

2040 Preparation. 1. Silver diſſolves nitric acid with effervescence, in conſequence of the evolution of nitrous gas. If the ſolution be made in a tall conical veſſel, the nitrous gas, which is diſengaged from the bottom, is diſſolved in the acid, and communicates a green colour to the lower part of the liquid. If the green colour is permanent, or paſſes to a blue, the metal is contaminated with copper; but if it be mixed with gold, a purple coloured powder is depoſited at the bottom of the veſſel.

Nitric acid diſſolves more than $\frac{1}{2}$ of its weight of ſilver. This ſolution is nearly colourleſs, very heavy, and extremely cauſtic. It colours the ſkin, firſt of a reddiſh purple, and then of a deep black. It produces the the ſame effect on the nails, the hair, and all animal ſubſtances. It is employed to dye the hair of a black colour, but this ſhould be done with great caution. When it is diluted with water, ſo as to deprive it of its cauſticity, it has an aſtringent bitter taſte. By evaporating the ſolution till a pellicle is juſt formed on the ſurface, and by ſlow cooling, it cryſtallizes in tranſparent, brilliant plates, ſometimes of a metallic luſtre, when the liquid has been expoſed to the ſun during 2041 Properties. the cryſtallization. Theſe cryſtals are not very regular. They are ſometimes ſix-ſided, ſometimes ſquare, and ſometimes triangular; but they ſeem to be compoſed of very fine ſmall priſms. The taſte is ſo extremely bitter, that it has been denominated *the gall of the metals*. It is not deliqueſcent in the air. When expoſed to the light of the ſun, it gradually blackens, and the ſilver is reduced. When it is heated in a crucible, it readily melts into a brown liquid, which ſwells up, as it is deprived of its water of cryſtallization; and in this ſtate of fuſion, if it be allowed to cool, it 2042 Lunar cauſtic. aſſumes the form of a deep gray, or black maſs. When the nitrate of ſilver is thus fuſed, and caſt into ſmall cylindrical moulds, the cylinders thus formed, which exhibit a radiated fracture, are well known in ſurgery by the names of *lunar cauſtic*, or *lapis infernalis*. This is generally prepared by evaporating the ſolution of nitrate of ſilver to dryneſs, without previous cryſtallization.

2043 Action of heat. 3. When nitrate of ſilver is heated in a retort, it firſt gives out nitrous gas, then very pure oxygen gas, which is afterwards mixed with azotic gas. The ſilver is reduced at the bottom of the veſſels. When a plate or cryſtal of nitrate of ſilver, well dried, is put upon burning coals, it produces a brilliant detonation; the ſilver is reduced, and adheres to the ſurface of the charcoal.

2044 Decompoſition. 4. The nitrate of ſilver is very ſoluble in water, and 2045 By hydrogen. in this ſtate it may be reduced by hydrogen gas and phoſphorus. By expoſing paper or ſilk moiſtened with a ſolution of nitrate of ſilver to hydrogen gas, the paper or ſilk is coated with metallic ſilver, in conſequence of the reduction of the ſalt by the hydrogen, which has a ſtronger affinity for the oxygen than the ſilver. 2046 And phoſphorus. The ſame effect takes place, if a cylinder of phoſphorus be immerſed in a ſolution of nitrate of ſilver. The phoſphorus combines with the oxygen of the oxide, and the ſilver is depoſited on the ſurface of the phoſphorus in the metallic ſtate. The phoſphorus may be ſeparated from the ſilver by melting it in boiling water. Theſe experiments were made by Sage and Bouillon in France, and Mrs Fulham in England.

5. A mixture of this ſalt and phoſphorus ſtruck 2047 Detonation. ſmartly with a hammer, produces a violent detonation. Nine grains of nitrate of ſilver and three of ſulphur produce no detonation, but only an inflammation of the ſulphur, when they are ſtruck with a cold hammer; but with a hot hammer, a detonation takes place, with the reduction of the ſilver.

6. Nitrate of ſilver is decompoſed by ſulphuric acid, and forms a precipitate of ſulphate of ſilver, in the ſtate of white powder. It is alſo decompoſed by ſulphurous acid. Muriatic acid produces a copious white precipitate which is very inſoluble, and is depoſited in the form of thick heavy flakes of muriate of ſilver.

7. Nitrate of ſilver is decompoſed by all the alkaline and earthy matters. A white precipitate is at firſt formed, which afterwards paſſes to an olive green; but the carbonates of the alkalies give a white precipitate which remains unaltered. Ammonia occaſions a ſparing precipitate, which is re-diſſolved by an exceſs of alkali, when there is formed a triple ſalt. But a very peculiar action takes place between ammonia and the oxide of ſilver, by which both the one and the other are decompoſed with a violent detonation. This is the celebrated *fulminating ſilver*, which was diſcovered by Berthollet in 1788. It is prepared by the following proceſs.

2048 Fulminating ſilver. A ſolution of pure ſilver in nitric acid is precipitated by lime water. The precipitate is placed on gray paper, which abſorbs the whole of the water and the nitrate of lime. Pure cauſtic ammonia is then added, which produces an effect ſomewhat ſimilar to the ſlaking of lime. The ammonia diſſolves only part of this precipitate. It is left at reſt for 10 or 12 hours, when there is formed on the ſurface a ſhining pellicle, which is rediſſolved with a new portion of ammonia, but which does not appear, if a ſufficient quantity of ammonia has been added at the firſt. The liquid is then ſeparated, and the black precipitate found at the bottom, is put in ſmall quantities on ſeparate papers. This powder is *fulminating ſilver*, which, even while it is moiſt, explodes with great violence, when it is ſtruck with a hard body. When it is dry, it is ſufficient to touch, or rub it ſlightly, to produce an exploſion. If the liquid decanted off this precipitate be heated in a glaſs retort, it effervesces, gives out oxygen gas, and there are ſoon formed ſmall, brilliant, opaque cryſtals, which have a metallic luſtre, and which fulminate with the ſlighteſt touch, though covered with liquid, and break with violence the veſſels containing them. In this action the moſt obvious circumſtance is the tendency of the compound to decompoſition. The oxygen of the oxide combines with the hydrogen of the ammonia, and forms water, while the azote of the ammonia eſcapes in the form of gas, and the ſilver remains behind in the metallic ſtate. The violence of the exploſion is owing to the ſudden expanſion of the azotic gas. The ſhining pellicle which appears on the ſurface, is part of the ſilver, from

from which the ammonia has been ſeparated by the action of the air; and to have the full effect, another portion of ammonia is neceſſary to diſſolve it. Carbonate of ammonia diſſolves the oxide of ſilver precipitated by lime, with efferveſcence, and the evolution of carbonic acid; but there remains enough of this acid to form a triple ſalt, which when dried, is in the form of a yellow powder, but has no fulminating property. The preparation of this dangerous powder frequently fails. A mixture of copper, the abſorption of carbonic acid by the oxide of ſilver, precipitated by means of lime, and left too long expoſed to the air, and ammonia containing a little of this acid, either diminiſh or deſtroy its fulminating property.

2049 Action of ſalts.

7. Many of the ſalts decompoſe the nitrate of ſilver. All the ſulphates produce a precipitate of ſulphate of ſilver in the form of powder. The ſame effect is produced by the other ſalts, and the effect is ſimilar to that which takes place with the acids of which they are compoſed.

2050 Of metals.

8. Moſt metallic ſubſtances have a ſtronger affinity for oxygen than ſilver has; it is therefore precipitated from its ſolution in nitric acid, either partially or entirely deprived of its oxygen, and in the metallic ſtate. (2051 Mercury.) In the precipitation which takes place by means of mercury, the ſilver is reduced in an arboreſcent form, which has long retained the name of *arbor Dianæ*. (2052 *Arbor dianæ*, or ſilver tree.) Different proceſſes have been recommended to effect this decompoſition. One part of ſilver, according to Lemery, is diſſolved in diluted nitric acid. The ſolution is then to be farther diluted with 20 parts of diſtilled water, and then to add two parts of mercury. It is ſaid, that it requires, by this proceſs, about 40 days for the formation of the metallic tree. Homberg gives a ſhorter proceſs, which ſucceeds ſufficiently well. It conſiſts in making an amalgam in the cold of four parts of ſilver-leaf and two of mercury. This amalgam is then to be diſſolved in a ſufficient quantity of nitric acid, and the ſolution to be diluted with 32 times the weight of the metals of water. By introducing into part of this liquid a ſmall ball of ſoft amalgam of ſilver, the formation of the tree immediately takes place. It may be formed alſo by putting a ſoft amalgam of ſilver into ſix parts of a ſolution of nitrate of ſilver, and four of a ſolution of nitrate of mercury. In theſe proceſſes one part of the mercury of the amalgam attracted by that of the ſolution, and carrying off the oxygen of the ſilver, precipitates the latter in the metallic ſtate. The precipitation of the ſilver is ſtill favoured by the affinity between it and the portion of undiſſolved mercury, and alſo part of the ſilver of the amalgam. All theſe attractions conſpire to effect the ſeparation of the ſilver, when it is depoſited in priſmatic needles, which arrange themſelves in an arboreſcent form.

2053 Copper.

9. Silver is precipitated from its ſolution in nitric acid, by means of copper. When a plate of copper is immerſed in this ſolution, diluted with its weight of diſtilled water, the ſilver is immediately ſeparated in whitiſh gray-coloured flakes. If this precipitate is ſcraped off, and well waſhed with water, afterwards fuſed in a crucible, and ſubjected to the proceſs of cupellation with lead, pure ſilver may be obtained.

4. Muriate of Silver.

2054 Preparation.

Muriatic acid has no action whatever on ſilver; but by adding muriatic acid to a ſolution of ſilver in ſulphuric or nitric acid, the moment it comes in contact with theſe ſolutions, it decompoſes them, carries off the oxide of the ſilver, and forms with it a white inſoluble ſalt, which is precipitated in a kind of coagulated ſtate. The muriates alſo produce a ſimilar precipitate, and hence it is that the nitrate of ſilver is employed as a re-agent, and a moſt delicate teſt of muriates or muriatic acid in mineral waters. The muriate of ſilver, which is called *corneous ſilver* or *horny ſilver*, is extremely inſoluble in water. Expoſed to the light, it becomes brown, violet, and black. By heating it gently in a matraſs, it melts like tallow, and when it becomes ſolid by cooling, it aſſumes the form of a ſemitranſparent gray ſubſtance, ſimilar to ſome kinds of horn, from which it derived its name of *luna cornea*, or horn ſilver. If it be fuſed on a ſtone, it is converted into a kind of friable matter, cryſtallized in beautiful, brilliant, and as it were metallic needles. When it is ſtrongly heated in a crucible, it filters through it, and is loſt in the fire. (2055 Compoſition.) The component parts of this ſalt are, according to Prouſt,

Acid	18
Oxide	82
	100

This ſalt is not decompoſed by any of the acids, or by the pure alkalies. It is decompoſed by the alkaline carbonates. The muriate of ſilver is very ſoluble in cauſtic liquid ammonia. This ſolution, which is tranſparent and colourleſs, undergoes a remarkable change when it is expoſed to the air. As the ammonia evaporates in the air, there is formed on the ſurface a pellicle which aſſumes a brilliant, bluiſh, or irideſcent colour. This pellicle, which gradually increaſes in thickneſs, deepens in colour, and at laſt becomes of a dirty gray or black, by the contact of light. The ſubſtance thus ſeparated is the muriate of ammonia, containing a ſmall proportion of the metal reduced.

5. Hyperoxymuriate of Silver.

This ſalt may be prepared by paſſing oxymuriatic acid gas through water having the oxide of ſilver diffuſed in it. It is ſoluble in two parts of warm water, and cryſtallizes in cooling in the form of ſmall rhomboids. It is decompoſed by muriatic acid, and by nitric and acetic acids. The muriate of ſilver remains behind. Expoſed to a moderate heat, it melts, oxygen gas is given out, and the ſalt is reduced to the muriate of ſilver. With one-half its weight of ſulphur, it produces violent detonation, by ſlight percuſſion. It gives out a white vivid flaſh.

6. Fluate of Silver.

Fluoric acid diſſolves the oxide of ſilver, and forms with it an inſoluble ſalt. It is decompoſed by ſulphuric acid.

7. Borate of Silver.

Boracic acid combines with the oxide of ſilver, by adding

adding a ſoluble borate to the ſolution of nitrate of ſilver. The whole of the ſilver is precipitated in the form of a white, heavy, inſoluble powder.

8. Phoſphate of Silver.

Phoſphoric acid diſſolves the oxide of ſilver, and precipitates it from its ſolution in nitric acid. The precipitate is a white, heavy powder; with conſiderable heat it melts into a kind of greeniſh enamel. It is not ſoluble in water without an exceſs of acid. When it is heated in a retort with charcoal, it gives out a little phoſphorus, and is reduced, in great part, to phoſphuret of ſilver.

9. Carbonate of Silver.

Carbonic acid combines readily with the oxide of ſilver. It may be prepared by adding an alkaline carbonate to ſulphate or nitrate of ſilver. The carbonate of ſilver is precipitated in the form of a white powder. This ſalt, which blackens by the action of light, readily gives out its carbonic acid by heat.

10. Arſeniate of Silver.

Arſenic acid diſſolved in water, and heated with ſilver, has no action upon it; but when the water is evaporated, and the heat is increaſed to produce vitrification, arſenic is ſublimed, and there remains a white vitreous matter, which contains the ſilver oxidated, and is covered with a deep yellow-coloured glaſs. By heating water on this glaſs reduced to powder, the ſolution becomes of a brown red colour; the arſenic acid is diſſolved, and carries with it a little oxide of ſilver, which is precipitated by adding muriatic acid. The brown inſoluble powder is fuſed at a high temperature, and becomes ſemitranſparent. By continuing the heat in a crucible, the ſilver is reduced. Arſenic acid gives a brown precipitate in the ſolution of nitrate of ſilver.

11. Tungſtate of Silver.

Tungſtic acid does not ſeem to have any action on ſilver; but when added to a ſolution of nitrate of ſilver, it occaſions a precipitate in the form of white powder, but its properties have not been examined.

12. Molybdate of Silver.

2056 Molybdate. Molybdic acid produces a white, flaky precipitate in a ſolution of nitrate of ſilver. Nothing is known of the properties of this ſalt.

13. Chromate of Silver.

2057 Chromate. By adding chromate of potaſh to a ſolution of ſilver in nitric acid, a precipitate is formed, of a moſt beautiful crimſon red, which the action of light changes to purple. This precipitate, which is the chromate of ſilver, is in the ſtate of powder. When heated by the action of the blow-pipe, it becomes black, and is reduced in part to the metallic ſtate. Reduced to powder in this ſtate, it is ſtill of a purple colour; but when it is heated with the blue flame of a candle directed by the blow-pipe, it becomes green, and the ſilver is ſeparated in globules. The chromic acid decompoſed by the hydrogen of the blue flame, paſſes to the ſtate of green oxide, and the oxide of ſilver is reduced.

14. Acetate of Silver.

2058 Acetate. Acetic acid diſſolves the oxide of ſilver. The acetate of ſilver may be prepared, by adding acetate of potaſh to a ſolution of nitrate of ſilver. The ſolution affords, on cooling, ſmall priſmatic cryſtals. This ſalt is very ſoluble in water, and has an acrid metallic taſte. When heated, it ſwells up, and is decompoſed. The acid is driven off, and the oxide remains behind.

15. Oxalate of Silver.

2059 Oxalate. Oxalic acid diſſolves a ſmall portion of the oxide of ſilver, which is precipitated from nitric acid, by means of potaſh; or, by adding oxalic acid to a ſolution of nitrate of ſilver. A white, thick, inſoluble precipitate is formed, which is oxalate of ſilver. This ſalt is ſoon changed by the action of light. When expoſed to the rays of the ſun, it becomes black; and when it is heated in a ſpoon, it undergoes a kind of detonation.

16. Tartrate of Silver.

2060 Tartrate. Tartaric acid combines with the oxide of ſilver, and forms with it a tartrate of ſilver, which becomes black by expoſure to the air. This acid has no action on ſilver itſelf, nor does it produce a precipitate in the ſolution of nitrate of ſilver.

17. Tartrate of Potaſh and Silver.

When tartar is added to a ſolution of nitrate of ſilver, there is formed according to Thenard, a triple ſalt, which conſiſts of tartaric acid, oxide of ſilver, and potaſh.

It is decompoſed by the alkalies and alkaline carbonates, and by the ſulphates, and muriates *.

18. Citrate of Silver.

2061 Citrate. Citric acid diſſolves the oxide of ſilver, and forms with it an inſoluble ſalt, which becomes black by being expoſed to the ſun. It has a harſh, ſtrong, metallic taſte. It affords by diſtillation, concentrated acid, and leaves behind the ſilver reduced in an arboreſcent form, mixed with a little charcoal, at the bottom of the retort. This ſalt is decompoſed by nitric acid. Its component parts are,

Acid,	36
Oxide of ſulphur,	64
	100

19. Malate of Silver.

2062 Malate. Malic acid added to a ſolution of nitrate of ſilver, produces a precipitate, the nature of which is unknown.

20. Benzoate of Silver.

2063 Benzoate. Benzoic acid combines with the oxide of ſilver, and forms with it a ſalt which is ſoluble in water, is not deliqueſcent in the air, but becomes brown by expoſure to the ſun's rays, and is decompoſed by heat; the acid being driven off, and the oxide reduced to the metallic ſtate.

21. Succinate of Silver.

2064 Succinate. Succinic acid has no action on ſilver, but it combines with

---

* Ann. de Chim. xxxviii. p. 36.

with its oxide. The ſuccinate of ſilver cryſtallizes in thin, oblong priſms, which are arranged in a radiated form.

22. Saccolate of Silver.

2065 Saccolate. Saclactic acid poured into a ſolution of nitrate of ſilver produces a white precipitate, the nature of which has not been examined.

II. Action of Alkalies, &c. upon Silver.

2066 Action of ammonia on ſilver. 1. The pure alkalies have no effect on ſilver. Its oxide is ſoluble in ammonia; but if this ſolution be long expoſed to the light, the ammonia is decompoſed, azotic gas is diſengaged, water is formed by the combination of the hydrogen of the ammonia and the oxygen of the oxide, which is reduced to the metallic ſtate.

2. Silver forms no compound with the earths; but in the ſtate of oxide it combines with ſome of them, by vitrification, and in this ſtate it colours glaſs and enamels of a yellow, olive green, or browniſh ſhade. For this purpoſe the oxide of ſilver is employed in the arts.

3. None of the ſalts have any action on ſilver. It is not ſenſibly oxidated by the nitrates or hyperoxymuriates. The metals which are more eaſily oxidated, and with which ſilver is frequently contaminated, are acted on by theſe ſaline matters, and in this way it has been obſerved, ſilver may be refined or purified by means of nitre.

III. Alloys.

1. There are few metallic ſubſtances with which ſilver does not enter into combination, and form alloys. Few of theſe, however, are applied to uſeful purpoſes. Arſenic combines with ſilver, and forms an alloy, which is externally of a yellow colour, but internally of a dark gray. It is brittle; and, when it is expoſed to heat, the arſenic is ſublimed, and the ſilver remains behind in a ſtate of purity.

2067 Cobalt. 2. Cobalt is with difficulty alloyed with ſilver. When they are melted together in a crucible, they ſeparate from each other, according to their ſpecific gravities, and each having a ſmall proportion of the other.

2068 Biſmuth. 3. Biſmuth combines with ſilver very readily by fuſion. The alloy is brittle, lamellated, and of an intermediate colour between biſmuth and antimony. The ſpecific gravity is greater than the mean. The two metals cannot be ſeparated, but with difficulty. When this alloy is expoſed to ſtrong heat in the open air, the biſmuth is oxidated, and vitrified at the ſame time that it is partially ſublimed, ſo that it might be employed in place of lead for the cupellation of ſilver; and in ſome caſes biſmuth is preferred, on account of its more rapid oxidation.

2069 Antimony. 4. The alloy of antimony and ſilver is eaſily effected by fuſion. It is heavier than the mean of the two metals. This alloy is brittle, and has not been applied to any uſe.

2070 Mercury. 5. Silver has a ſtrong affinity for mercury. An amalgam may be formed of theſe two metals, by ſaturating ſilver leaf, or fine filings of ſilver, with mercury; or by adding to ſilver, while it is red-hot, heated mercury. The conſiſtence of this amalgam varies according to the proportion of the two metals. In general it is white and ſoft, and the ſpecific gravity is greater than the mean. It ſinks to the bottom of liquid mercury. Expoſed to a moderate heat for ſome time, it ſhoots out into a kind of vegetation, like the tree of Diana; and, if after fuſion, it is allowed to cool ſlowly, it cryſtallizes in the form of ſmall leaves, or in ſquare priſms, terminated by four-ſided pyramids. When it remains long expoſed to the air, it becomes harder, and of a more ſolid conſiſtence. This amalgam is much employed in gilding.

2071 Zinc. 6. Silver combines readily with zinc, by means of fuſion, and forms with it a brittle alloy, which has not been applied to any uſe.

2072 Tin. 7. Silver combines eaſily with tin, and forms an alloy which is extremely brittle. The ſilver is entirely deprived of its ductility. This alloy, however, inſtead of being uſeful, is conſidered as one of the moſt troubleſome in the working of ſilver, on account of the hardneſs and brittleneſs which it communicates, and it is found almoſt impoſſible to ſeparate them entirely.

2073 Lead. 8. Lead, it has been already obſerved, readily combines with ſilver by means of fuſion. It is employed for the purification of lead in the proceſs of cupellation. This alloy is very fuſible, reſembles lead in colour, and is leſs ſonorous, but not leſs ductile than ſilver. The ſpecific gravity is greater than the mean.

2074 Iron. 9. An alloy of ſilver and iron in equal proportions has nearly the colour of ſilver. It is harder, has ſome ductility, and is attracted by the magnet. Steel is ſoldered with ſilver. Guyton fuſed together ſilver and iron, and obtained two buttons, which were placed by the ſide of each other, and ſtrongly adhering, but ſufficiently diſtinct. Each of the metals was found to be alloyed with a ſmall proportion of the other. The ſilver renders the iron hard and compact, and the iron communicates to the ſilver properties which ſeem to render it applicable to many important uſes.

2075 Copper. 10. Silver combines readily with copper, and forms with it one of the moſt uſeful alloys. This alloy gives hardneſs to the ſilver, and the colour of the latter is not diminiſhed, unleſs the quantity of copper is conſiderable. Theſe properties render it extremely uſeful in the fabrication of various utenſils, and eſpecially of money. The denſity of the alloy is leſs than the mean of the two metals. If 137 parts of ſilver be alloyed with 7 of copper, the mean ſpecific gravity is 10.301, but it is only 10.175, which ſhews an increaſe of bulk of $\frac{1}{81}$ part. This is the alloy of the ſilver coin of France *. The ſtandard ſilver, which is employed in the Britiſh ſilver coin, is compoſed of 11 parts of ſilver and one of copper.

2076 Uſes. The uſes of ſilver are as important and extenſive as any of the metals, except iron, and eſpecially when it is alloyed with copper; as it is applied as the medium of commerce by all civilized nations, and for various inſtruments and utenſils, moſt of which are ſo familiar as to require no particular enumeration.

Sect. XXI. *Of* Gold *and its Combinations*.

2077 Hiſtory. 1. Gold is ſpoken of in the earlieſt hiſtories of the world. The peculiar properties of this metal, its ſcarcity, durability, and beauty, have rendered it always an object of purſuit, and have raiſed it high in the eſtimation

---

* *Jour. ds Mines,* n° 30.

tion of mankind. The alchemiſts regarded gold as the pureſt, the ſimpleſt, the moſt perfect, and very juſtly the moſt indeſtructible of all the metals with which they were acquainted. Hence it was eſteemed the nobleſt and moſt perfect of what they conſidered as perfect metals, and dignified with the pompous name of *king of the metals*. It was the object of all their labours and reſearches, to diſcover the means of tranſmuting the baſer and more abundant metals into this precious metal.

2078 Univerſally diffuſed, but in ſmall quantities.

2. Gold is ſuppoſed to be, next to iron, the moſt univerſally diffuſed of all the metals; but, at the ſame time it is found in ſuch ſmall quantities, that it is one of the ſcarceſt. It is moſt commonly found in the ſtate of ſmall grains, mixed with the ſand or with the ſoil, almoſt in every part of the world. Gold is alſo found imbedded in ſtones, eſpecially quartz, either in grains, or cryſtals, which are octahedrons; and it is probably from theſe that the grains found in the ſoil or in the ſand of the beds of rivers, have been derived. Gold is, however, more abundant in the tropical regions of the earth, where it forms an article of commerce, under the name of *gold duſt*. In this ſtate it is found in the rivers of Africa, and exported to Europe. But although gold is always found in the metallic ſtate, it is not abſolutely pure. It is generally alloyed with copper or ſilver, and ſometimes with iron and mercury.

2079 Extraction from its ores.

3. To ſeparate gold from the metals with which it is alloyed, the proceſs recommended by Bergman may be employed. It is firſt diſſolved in nitro-muriatic acid; the ſilver is depoſited ſpontaneouſly in the form of muriate of ſilver, which is inſoluble; the gold is precipitated in fine powder by the ſulphate of iron; the quantity of iron may be aſcertained by pruſſiate of potaſh; and the copper is ſeparated by means of iron. Each of theſe proceſſes is performed on different portions of native gold, ſo that the quantity of gold, and the different metals with which it is alloyed, may be determined. In the large way, the extraction of gold is a very ſimple proceſs. The auriferous ſand of rivers is firſt waſhed, to carry off all extraneous matters. It is triturated in a veſſel with water, with 10 or 12 times its weight of mercury. The water is poured off, and carries with it the earthy matters. The amalgam is preſſed in ſkins, to ſeparate the exceſs of mercury, and the ſolid portion which remains is expoſed to heat in ſtoneware retorts, to drive off the mercury, and the gold remains behind. To ſeparate the gold from other metals, it is ſubjected to the proceſs of cupellation, which has been already deſcribed in treating of the purification of ſilver.

2080 Properties.

4. Gold is of a reddiſh yellow colour. It poſſeſſes conſiderable luſtre, although other metals have this property in a ſuperior degree. Gold, next to platina, is the heavieſt body in nature, having a ſpecific gravity of 19.3 and 19.4. It is not very hard, but is extremely ductile and malleable. It may be beaten out into leaves ſo thin as to equal $\frac{1}{282000}$ part of an inch. The method of extending gold, which is followed by the gold beaters, is by hammering a number of thin rolled plates between ſkins or animal membranes. A ſingle grain of gold may be beaten out in this way, ſo as to cover 56¾ ſquare inches. The coating of gold, which covers wire, is ſtill thinner. By computation it is found, from the diameter and length of the wire, and the quantity of gold employed, that it is only $\frac{1}{12}$ of the thickneſs of gold leaf. The tenacity of gold alſo is very conſiderable. A gold wire .078 of an inch in diameter will ſupport a weight equal to more than 150lbs. avoirdupois, without breaking. Gold has no perceptible taſte or ſmell.

2081 Action of heat.

5. Gold melts, according to Guyton, at the temperature of 32° Wedgwood. It has been obſerved, that gold, in the ſtate of filings or grains, melts with more difficulty than in larger maſſes; and that the ſmall fragments, even after they are fuſed, remain in ſeparate globules. To make them run into one maſs, a little nitre or borax is thrown into the crucible. It has alſo been obſerved, that gold, which has only been ſubjected to the degree of heat neceſſary for its fuſion, is brittle after cooling. To preſerve its ductility, therefore, the temperature muſt be raiſed much higher. It is brittle alſo, when it is too ſuddenly cooled after fuſion. By increaſing the temperature while the gold is in fuſion, it ſeems to become convex on the ſurface, and when it cools, it ſinks, which is aſcribed to the expanſion and contraction of the metal. When it is ſlowly cooled, it cryſtallizes in the form of quadrangular pyramids, or regular octahedrons. If the heat be continued while it is in perfect fuſion, it ſeems to be agitated, and to undergo a kind of ebullition. This was obſerved by Homberg and Macquer, by the action of the burning glaſs, or when a ſmall globule of gold was acted on by the blow-pipe. According to Macquer, it roſe in vapour to the height of five or ſix inches, and attached itſelf to the ſurface of a ſilver plate, which it gilded completely.

2082 Of air.

6. Gold is the moſt indeſtructible, and the leaſt altered of all the metals, by expoſure to the air. It preſerves its luſtre, its brilliancy, and colour, for any length of time.

2083 Oxidation.

7. The ſtrongeſt heat of a furnace, which has been applied to gold in fuſion, has been found incapable of producing the ſmalleſt change, or the leaſt tendency to oxidation; but, by the action of Tſchirnhauſen's powerful burning glaſs, Homberg having placed ſome gold in the focus, found that it roſe in vapour; and that it was covered with a violet-coloured vitreous oxide. This change was at firſt aſcribed to foreign bodies, particularly to the charcoal on which the gold was placed during the experiment. But Macquer repeated the ſame experiments with a more powerful glaſs, and obtained the ſame reſult. The vitrification after ſome time gradually extended, the gold diminiſhed, and the ſupport was impregnated with a purple coloured matter.

2084 By electricity.

The effect of electricity on gold leaf, placed between two cards, was obſerved by Camus in 1773. The gold was converted into a violet coloured powder, which adhered to the paper. This ſeeming oxidation was regarded by ſome as merely a minute mechanical diviſion of the gold; but this objection has been removed by the experiments of Van Marum on the combuſtibility of gold by means of the powerful electrical machine at Haerlem. A ſtrong electrical ſhock was paſſed through a golden wire ſuſpended in the air. It kindled, burned with a perceptible green flame, and was reduced to fine powder which was diſſipated in the air. It was ſuppoſed by this philoſopher, that the inflammation of gold might be effected

effected without the exceſs of oxygen gas, as he found it to take place in hydrogen gas and other elaſtic fluids, which are incapable of ſupporting combuſtion. But the force of this objection is removed by recollecting, that all gaſes hold in ſolution a quantity of water, and that water is very readily decompoſed by electricity.

2085 By lightning. A ſimilar oxidation has been obſerved to take place on the gilding in the inſide of houſes, or on the furniture, which has been ſtruck with lightning. The purple oxide of gold thus obtained, contains about five or ſix parts in the hundred of oxygen. Gold combines with a greater proportion of oxygen, forming a different oxide of a yellow colour, but this oxide is incapable of combining with any farther portion of oxygen. It remains, therefore, unchanged in the air, and retains for a long time its brilliant rich colour. This oxide, however, is decompoſed by the action of heat; the oxygen is driven off, and the gold remains behind in the metallic ſtate.

2086 Yellow oxide. When gold is diſſolved in nitro-muriatic acid, or in a mixture of equal parts of nitric and muriatic acids, an efferveſcence takes place, and the ſolution becomes of a yellow colour. In this proceſs the nitric acid is decompoſed, its oxygen combines with the gold, and the oxide, as it is formed, is diſſolved in the muriatic acid. By adding lime water, a precipitate is formed, which is the yellow oxide of gold, conſiſting of eight or ten parts of oxygen in the 100.

8. There is no action between gold and azote, hydrogen, carbone or ſulphur. The oxides of gold, indeed, are readily decompoſed by hydrogen.

2087 Phoſphuret. 9. Phoſphorus, according to the experiments of Pelletier, combines with gold, by heating together in a crucible a mixture of one part of gold in filings, with two parts of phoſphoric glaſs, and one-eighth part of charcoal. Great part of the phoſphorus is ſeparated from the acid, and driven off, but there remains a ſmall quantity united with the gold, forming a phoſphuret of gold. This phoſphuret is whiter and more brittle than the gold, and has ſome appearance of cryſtallization. It may be formed alſo by adding phoſphorus to gold in a red heat in a crucible. It becomes pale coloured, granulated, brittle, and a little more fuſible. This phoſphuret contains $\frac{1}{24}$ part of phoſphorus. It is decompoſed by being kept ſome time in fuſion; the phoſphorus is driven off in the ſtate of vapour, and inflamed.

2088 Affinities. 10. The order of the affinities of gold and its oxides, as they have been arranged by Bergman, is the following:

GOLD.	OXIDE of GOLD.
Mercury,	Muriatic acid,
Copper,	Nitric,
Silver,	Sulphuric,
Lead,	Arſenic,
Biſmuth,	Fluoric,
Tin,	Tartaric,
Antimony,	Phoſphoric,
Iron,	Pruſſic.
Platina,	
Zinc,	
Nickel,	
Arſenic,	
Cobalt,	
Manganeſe.	

II. Salts of Gold.

1. Nitrate of Gold.

2089 Preparation. When concentrated nitric acid is ſeveral times ſucceſſively poured upon gold, boiled and diſtilled to dryneſs, the gold is diſſolved, and the ſolution aſſumes a yellow colour. This effect was firſt obſerved by Brandt, in ſeparating gold and ſilver, by means of this acid. But it appears from the obſervation of Deyeux on the ſolubility of gold in nitric acid, that the ſolution is more readily effected in proportion to the quantity of gas, or nitrous gas, which the acid contains. According to the experiments and obſervations of Fourcroy, gold leaf is diſſolved in nitric acid, impregnated with nitrous oxide, and that it is owing to the nitrous oxide that the gold is oxidated, this oxide being more eaſily decompoſed than nitric acid. Thus it happens that the acid is deprived of its colour as it acts on the gold, and the ſolution is more rapidly effected in the cold than with heat, becauſe the nitrous gas is diſengaged by heat. The acid which at firſt had been deprived of its colour, by the oxidation of the gold, as this oxide is diſſolved, aſſumes an orange-yellow colour, holding in ſolution the nitrate of gold with exceſs of acid. 2090 Decompoſed by heat and the alkalies. The nitrate of gold cannot be obtained in cryſtals. It is decompoſed by heat, or by expoſure to the light of the ſun. When this ſolution is filtered, it leaves on the paper a violet-coloured trace, which is the oxide of gold. The nitrate of gold is alſo decompoſed by the alkalies, or by introducing a plate of tin or ſilver into the ſolution, and the purple oxide is precipitated in the form of powder. It is alſo decompoſed by muriatic acid, which, at the inſtant of combination, converts the orange colour to a pure yellow.

2. Muriate of Gold.

2091 Preparation. 1. Muriatic acid has no action whatever on gold, or on its purple oxide, but gold is immediately oxidated and diſſolved by oxymuriatic acid; or if nitric acid be added to muriatic acid, the ſolution of gold is immediately effected. It is on account of this property that nitro-muriatic acid was diſtinguiſhed by the name of *aqua regia*, becauſe it diſſolved gold, which was ſtiled by the alchemiſts, the *king of the metals*. The nature of this action is obvious. Gold is oxidated with great difficulty. This is effected by oxymuriatic acid, which readily parts with its oxygen, or by the addition of nitric to the muriatic acid, the former of which is decompoſed, giving up its oxygen to the gold, which being oxidated, is diſſolved in the muriatic acid, forming a muriate of gold. 2092 Properties. This ſolution of the muriate of gold is of a deep yellow colour, extremely acrid and cauſtic, has a very aſtringent, metallic taſte, and ſtains the ſkin of a deep purple colour, which becomes darker by expoſure to the air and the light. It continues permanent till the epidermis is renewed. It produces a ſimilar effect on all vegetable and animal matters, and on marble and ſiliceous ſtones. By evaporating this ſolution, nitric acid is diſengaged, and cryſtals are obtained, in the form of truncated octahedrons, or ſmall quadrangular priſms, of a topaz colour. Theſe cryſtals are eaſily procured by evaporating the ſolution to one-half, and adding a little alcohol. They aſſume a red colour by the action of ſtrong

ſtrong light. They attract moiſture from the air, and ſpontaneouſly become liquid. By gradually heating in a retort this ſolution of gold in nitro-muriatic acid, there paſſes over nitric acid, muriatic acid, which carries with it a portion of gold, and even reddiſh-yellow cryſtals of muriate of gold. To the nitro-muriatic liquid, which is of a high colour, and which riſes during the diſtillation, the alchemiſts gave the name of *red lion*. By evaporating the ſolution to dryneſs, a dry muriate of gold is obtained, which may be reduced by a ſtrong heat, previouſly giving out oxygen gas, and leaving the gold behind in the metallic ſtate.

2093 Decompoſition. 2. The muriate of gold is very ſoluble in water. 2094 By hydrogen. It is decompoſed by hydrogen gas. If a piece of ſilk be moiſtened with a ſolution of muriate of gold, the ſalt is decompoſed, and the gold, reduced to the metallic ſtate, attaches itſelf to the ſilk. 2095 Phoſphorus. Muriate of gold is alſo decompoſed by phoſphorus. If a ſtick of phoſphorus be introduced into a ſaturated ſolution of muriate of gold, the ſalt is decompoſed, and the gold being reduced to the metallic ſtate, forms a cylindrical covering to the phoſphorus, which may be ſeparated by diſſolving the latter in hot water. A ſimilar effect is produced by burning ſulphur, by ſulphurated and phoſphorated hydrogen gaſes, and by ſulphurous acid. 2096 Sulphurous acid. If a ſolution of muriate of gold be cautiouſly added to ſulphurous acid, a fine pellicle of gold appears on the ſurface, which is inſtantly precipitated in the form of ſmall grains. Theſe curious and intereſting experiments were made by Mrs Fulham. It is eaſy to ſee the nature of the proceſs. All the ſubſtances which have been enumerated, have a ſtronger affinity for oxygen than gold, ſo that the oxide of gold in combination with the acid is decompoſed; the oxygen combining with the hydrogen, for inſtance, and forming water, or with the phoſphorus or ſulphur, and forming ſulphuric or phoſphoric acid. The reduction of muriate of gold, Mrs Fulham has obſerved, does not take place except in the liquid ſtate, and ſhe ſuppoſes that the decompoſition of water is neceſſary to produce this effect. But the liquid ſtate of the ſalt, it is ſuppoſed by others, is only neceſſary, to expoſe it to the action of combuſtibles in a ſtate of minute diviſion, and that otherwiſe this theory does not account for the phenomena.

2097 Soluble in ether. 3. The muriate of gold is ſoluble in ether. It forms with it a ſolution of a golden-yellow colour, which floats on the top of the fluid. By adding ether to a ſolution of gold, and agitating the mixture, as ſoon as it is left at reſt, the two liquids ſeparate, the ether riſes to the top, and aſſumes a yellow colour, while the nitro-muriatic acid remains below and becomes white. By this proceſs a tincture of gold, or what was formerly called *potable gold*, was prepared. The ſolution of gold in ether is not permanent. It is ſoon reduced to the metallic ſtate, and is ſometimes found cryſtallized on the ſurface.

2098 Action of alkalies. 4. The muriate of gold is decompoſed by all the alkalies and earths, and is reduced to the ſtate of yellow oxide. This decompoſition is effected ſlowly by the fixed alkalies, and if the alkali be added in ſufficient quantity, the precipitate is re-diſſolved, and the liquid aſſumes a reddiſh colour. It is owing to this ſolution of the oxide of gold by theſe alkalies, that the precipitation is ſlow and difficult. Triple ſalts are formed, the nature of which is unknown. The oxide of gold thus precipitated, becomes of a purple colour by expoſure to the light; by the action of heat it gives out oxygen gas, and the gold is revived.

2099 Fulminating gold. The moſt ſingular precipitate from the muriate of gold, is that by means of ammonia, which forms the compound called *fulminating gold*. It is prepared by the following proceſs. To a ſolution of gold in nitro-muriatic acid, and diluted with three or four times its weight of diſtilled water, gradually add pure ammonia, as long as any precipitate is formed. No exceſs of alkali muſt be added, becauſe the precipitate is re-diſſolved. It is then waſhed and dried in the air on paper, and afterwards put into a phial, which ſhould be covered only with a bit of cloth or paper, as the powder is apt to explode with the ſlighteſt friction.

2100. Another proceſs. Fulminating powder may alſo be obtained, by diſſolving gold in a ſolution of two parts of nitrate of ammonia, and one of muriatic acid. The oxygen of the nitric acid combines with the gold, and forms an oxide, which is diſſolved in a portion of the muriatic acid; nitrous gas is diſengaged, and there remain in the liquid, muriate of gold, and muriate of ammonia. By precipitating this ſolution by means of a fixed alkali, fulminating gold is obtained. The alkali combines with the muriatic acid of the gold and ammonia, and the oxide of gold uniting with the ammonia, forms the fulminating gold. The precipitate is waſhed and dried as in the former proceſs. Baſil Valentine, who firſt deſcribed this ſingular preparation, had obſerved that it produced detonation equally by means of heat, by friction, and percuſſion. When a ſmall quantity of fulminating powder is expoſed to heat, it produces a violent detonation; or, if it be rubbed with a hard body, a ſimilar effect takes place. It explodes alſo, by being ſmartly ſtruck with a hammer. Theſe aſtoniſhing effects long excited the attention of philoſophers, but received no ſatisfactory explanation, till the nature of the compoſition of this ſubſtance was diſcovered by modern chemiſts. It was examined by Scheele and Bergman; and at laſt the theory of its violent action was fully developed by Berthollet. This compound conſiſts of the oxide of gold and ammonia, and as the oxide performs the part of an acid, it is ſometimes denominated *aurate of ammonia*. 2101 Theory. During the exploſion which takes place, whether by the application of heat, or by friction or percuſſion, the hydrogen of the ammonia combines with the oxygen of the oxide of gold, and forms water. This water being ſuddenly raiſed to the ſtate of vapour, and the azote, the other component part of ammonia, being at the ſame time ſuddenly converted into gas, produce the exploſion. The gold is reduced to the metallic ſtate.

2102 May be decompoſed without exploſion. This ſubſtance may be deprived of its fulminating property, by being expoſed for ſome time to a very gentle heat. It is then converted into a blackiſh brown powder. A ſimilar effect is produced, by ſubjecting it for a long time to the temperature of boiling water. Its fulminating property is at leaſt greatly diminiſhed by the latter proceſs. It appears too, that the contact of air promotes this action; for when it was heated in an iron globe, in an experiment which

which Birch performed before the Royal Society of London, or in a ſphere of ſtrong copper, in an experiment by Bergman, no detonation took place. Berthollet applied a gentle heat to a quantity of fulminating gold, in copper tubes; and he obtained ammoniacal gas, and the gold was reduced to the ſtate of purple oxide. By theſe experiments it appears, that this ſubſtance is decompoſed without detonation, when the ſudden dilatation of the gaſes which are diſengaged is reſiſted by ſtrong veſſels, or when the heat is ſo moderate as to ſeparate the ammonia without decompoſition.

2103 Action of metals.

5. The muriate of gold is decompoſed by almoſt all metallic ſubſtances. Some metals decompoſe it completely, and reduce it to the metallic ſtate, while others deprive it of a portion of oxygen, and reduce it to the ſtate of purple oxide. Biſmuth, zinc, iron, copper, and mercury, reduce the gold to the metallic ſtate. Lead, ſilver, and tin, occaſion a precipitate in the form of purple oxide. The moſt ſingular of all theſe precipitates, and which has long occupied the attention of chemiſts, is that which is produced by means of tin. This is called the *purple precipitate*, or *powder of Caſſius*. It was at firſt particularly deſcribed by Caſſius, from whom it derived its name; but it was known long before, even ſo early as the time of Baſil Valentine, by whom it is mentioned. If a plate of tin be immerſed in a ſolution of muriate of gold, the ſurface of the metal is ſoon covered with a deep-coloured violet or purple powder, which is gradually diffuſed through the whole liquid. This is uſually prepared by adding to a ſolution of gold in nitro-muriatic acid, a ſolution of muriate of tin recently prepared. The theory of this proceſs is the following. The gold in ſolution is in the ſtate of yellow oxide. It is deprived of part of its oxygen, and reduced to the ſtate of purple oxide by the tin. The purple oxide is no longer ſoluble in the acid, and is therefore precipitated. The ſame effect is produced when a ſalt of tin is added, provided this ſalt be not fully ſaturated with oxygen, for in that caſe no precipitate is obtained. This is the reaſon, as Pelletier has ſhewn, that muriate of tin, after it has been for ſome time expoſed to the air, loſes the property of producing the purple precipitate, becauſe it has abſorbed oxygen from the atmoſphere, and is not ſuſceptible of combining with a greater quantity. For the ſame reaſon no precipitate is obtained by the oxymuriate of tin, or the *ſmoking liquor of Libavius*, or the red ſulphate of iron, becauſe both theſe ſalts have their baſes fully ſaturated with oxygen. Other metallic ſolutions have alſo the property of decompoſing and precipitating the muriate of gold. The nitrate of ſilver produces a reddiſh precipitate, which is a mixture of white muriate of ſilver and purple oxide of gold. The nitrate of lead depoſits a dark coloured ſubſtance, compoſed of muriate of lead and oxide of gold.

2104 Purple powder of Caſſius.

2105 Metallic acids.

6. The metallic acids have no effect whatever on gold. Vauquelin found that chromic acid, mixed with muriatic acid, gave it the property of diſſolving gold. This is owing to the chromic acid giving up part of its oxygen, which appears to be the caſe, from its paſſing from its natural colour which is orange, to the ſtate of green oxide.

II. Action of Alkalies, &c. upon Gold.

2106 Alkalies.

1. None of the alkalies have any action upon gold, or on its purple oxide, but the yellow oxide precipitated from its ſolution by means of the fixed alkalies, and digeſted for ſome time with ammonia, is readily converted into fulminating gold.

2107 Earths.

2. The earths have no action on gold in the metallic ſtate; but in the ſtate of purple or yellow oxide, it combines with the earths which are vitrified by means of the alkalies, and forms with them enamels, which are of a violet or purple colour, or glaſs of a golden-yellow colour. It is on account of the latter property that the yellow oxide is employed in the fabrication of artificial topazes. It has been obſerved that glaſs coloured by means of gold, and which contains a conſiderable proportion of oxide of lead or of manganeſe, has a remarkable property of changing to a permanent purple or ruby-red colour, when it is ſlightly heated, and long before fuſion. This is ſuppoſed to be owing to ſome change in the ſtate of the oxidation of the different metals.

2108 Salts.

3. The moſt powerful ſalts, as the nitrates, the hyperoxymuriates, have no action on pure gold. It has, however, been obſerved, that borax diminiſhes its colour, and that nitre which is employed in its purification, renders it more brilliant.

III. Alloys of Gold.

2109 With arſenic.

1. Gold is ſuſceptible of combination with moſt metallic ſubſtances, which produce a very particular change on its properties. The alloy with arſenic is brittle, hard, of a granulated texture, and of a very pale colour. According to Mr Hatchett's experiments, arſenic readily combines with gold raiſed to a common red heat, when the former is in the ſtate of vapour, and particularly when the combination is made in cloſe veſſels.

2110 Tungſten, &c.

2. The alloys of gold with tungſten, molybdena, chromium, titanium, and uranium, have not been examined.

2111 Cobalt.

3. The combination of gold and cobalt is not perceptibly different from pure cobalt. This alloy reduced to a fine powder, and heated in contact with air, gives, after its oxidation, and by ſtrong heat, a deep blue glaſs. In Mr Hatchett's experiments, one part of cobalt and 14 of gold form a brittle alloy of a dull yellow colour. With $\frac{1}{65}$ of cobalt the alloy was brittle, but became ductile with $\frac{1}{130}$ part.

2112 Nickel.

4. Gold forms with nickel a white and brittle alloy. In Mr Hatchett's experiments $\frac{1}{28}$ of nickel rendered the alloy brittle. It was ſcarcely, if at all, brittle with $\frac{1}{65}$ part, and with $\frac{1}{130}$ of nickel it was completely ductile. One part of nickel and 16 of gold give an alloy of the colour of braſs.

5. Mr Hatchett formed an alloy of gold with manganeſe. It was of a pale yellowiſh-gray colour, had ſomething of the luſtre of poliſhed ſteel, and ſome ductility, although it was very hard. It contained about one-ninth of manganeſe. Acids produced no effect, nor was it altered by expoſure to the air *.

2113 Biſmuth.

6. Biſmuth fuſed with gold, yields an alloy which is brittle in proportion to the quantity of biſmuth employed. The ſpecific gravity of this alloy is greater than

---

* *Phil. Tranſ.* 1803.

than the mean. In Mr Hatchett's experiments, this alloy was brittle, when the proportion of biſmuth amounted only to $\frac{1}{1920}$ part.

2114 Antimony. 7. Antimony combines with gold, and renders it hard and brittle. Equal parts of theſe metals form an alloy not much different in appearance from gold itſelf. This compound was frequently employed by the alchemiſts in their reſearches. Antimony was called the *royal bath*. They pretended that the quantity of gold was increaſed when it was ſeparated from the alloy, after having been fuſed with this metal. But it appears that this increaſe of weight was owing to part of the antimony, which was not ſeparated from the gold. The ſulphuret of antimony was formerly much employed for the purification of gold, to ſeparate by means of the ſulphur, the metals which were combined with it; and from this property of acting on all the metals then known, excepting gold, the ſulphuret of antimony was called by the alchemiſts, *the wolf of the metals*.

2115 Mercury. 8. Gold unites very readily with mercury. If gold be brought into contact with this metal, it is inſtantly covered with it; and if gold leaf be triturated with mercury, it totally diſappears, and is diſſolved in the mercury; ſo that even in the cold, mercury combines with the whole quantity of gold with which it can be alloyed. When the proportion of gold is increaſed, the amalgam becomes ſolid. When this operation is performed in the large way, the combination is promoted by means of moderate heat. This amalgam is of a yellowiſh white colour; it is fuſible at a moderate heat, and cryſtallizes in the form of quadrangular priſms. It is decompoſed by a ſtrong heat, and the mercury is diſſipated. This amalgam is much employed in gilding.

2116 Zinc. 9. Gold combines with zinc by means of fuſion. This alloy is paler than gold, has little malleability, and if the proportion of the zinc be conſiderable, is very brittle. An alloy conſiſting of equal parts of the two metals, is of a greater ſpecific gravity than the mean, is very hard, ſuſceptible of a fine poliſh, and is not much altered by the air. It has been recommended, on account of theſe properties, for the fabrication of the mirrors of teleſcopes.

2117 Tin. 10. Gold combines eaſily with tin by means of fuſion. This alloy, it is ſaid, is the dread of the workmen, becauſe it deprives gold of its ductility. They are even cautious in preſerving gold from the contact of the vapour of tin in fuſion, which renders the gold ſo brittle, that it may be reduced to powder in a mortar. It is extremely difficult to purify gold after it has been alloyed with tin, for it does not paſs into the cupel with lead or with biſmuth. Nitre, borax, and even the hyperoxymuriate of mercury, which are often employed with this view, do not always ſucceed. The moſt ſucceſsful method is by treating the alloy with ſulphuret of antimony, or with muriatic acid, which diſſolves the tin when it is in conſiderable proportion. But in the experiments of Mr Hatchett and Mr Bingley, it appears that the univerſal opinion which has hitherto prevailed, of tin being ſo injurious to the ductility of gold, is to a certain extent, erroneous; and it appears probable, that the ductility of gold being deſtroyed, as was ſuppoſed, even by the fumes of tin, ought to have been aſcribed to other metals, as biſmuth, lead, antimony, or zinc, with which the tin was contaminated.

2118 Lead. 11. Lead very readily combines with gold by fuſion; this alloy deprives the gold of its ductility, and diminiſhes the colour. So ſmall a proportion as $\frac{1}{1920}$ part of lead deſtroys the ductility of gold. This alloy, it has been already ſtated, is made for the purpoſe of purifying gold from other metals, in conſequence of the eaſy oxidation and vitrification of the lead.

2119 Iron. 12 Gold is eaſily alloyed with iron, and forms with it a hard brittle maſs. Some of theſe alloys are ſo hard, that Dr Lewis found them fit for cutting inſtruments. Equal parts of iron and gold form an alloy of a gray colour. Four parts of iron and one of gold afford an alloy nearly of the colour of ſilver, and the ſpecific gravity of this alloy has been aſcertained to be leſs than the mean. One part of iron alloyed with 12 of gold, according to Mr Hatchett, was of a pale-yellowiſh gray colour, and was ſo ductile that it might be rolled and cut. When gold is fuſed, it adheres readily to iron; and hence it has been propoſed to ſolder ſmall pieces of ſteel with gold, which ſeems to be preferable to copper.

2120 Copper. 13. Gold readily combines with copper by fuſion. This is one of the moſt important alloys, on account of the hardneſs which copper communicates to gold, without diminiſhing its colour. This alloy, according to Muſchenbroeck, poſſeſſes the greateſt hardneſs, without ſenſibly diminiſhing its ductility, when the proportions are one part of copper and ſeven of gold. This alloy is more fuſible than gold, and on that account it is employed as a ſolder for that metal. The gold coin of moſt countries conſiſts of this alloy. The proportions in the gold coin of Britain and France are 11 parts of gold to one of copper. According to Briſſon, the ſpecific gravity of this alloy is greater than the mean. It is 17.486, but it ought to be 17.153. But, according to Mr Hatchett's experiments, there is no mutual penetration in the alloy of theſe metals, and therefore no increaſe of denſity. On the contrary, ſome degree of expanſion was obſerved. Four hundred and forty-two grains of gold of ſpecific gravity 19.172, were alloyed with 38 grains of copper of ſpecific gravity 8.875. The ſpecific gravity of the alloy was found to be 17.157. The bulk of the alloyed maſs amounted to 27.98, while the natural bulk of the two metals before combination was 27.32, which ſhews an increaſe of expanſion of the alloyed maſs equal to $\frac{66}{100}$. Mr Hatchett obſerves that Briſſon's experiment was probably made on part of a large bar or ingot, in which it generally happens, that the two metals are very unequally diffuſed, and this inequality, which is greater according to the quantity of the metal, is found to vary with the form, nature, and poſition of the mould, and therefore to produce variations in the ſpecific gravity *.

2121 Silver. 14. Silver forms an alloy with gold. Homberg found, that equal parts of theſe metals fuſed together in a crucible, formed an alloy which contained $\frac{1}{7}$ of its weight of ſilver. One part of ſilver and two of gold, according to Muſchenbroeck, give to the alloy the greateſt degree of hardneſs. One-twentieth part of ſilver changes the colour of gold very ſenſibly. This alloy is employed for ſoldering gold, being more fuſible than this metal.

---

* *Phil. Trans.* 1803, p. 112.

15. Mr

15. Mr Hatchett obſerves, that the obvious inference to be deduced from his experiments is, that only two metals are proper for the alloy of gold coin. Theſe are, ſilver and copper. All other metals either conſiderably alter the colour, or diminiſh the ductility of gold. According to the ſame philoſopher, the ductility of gold is diminiſhed by different metallic ſubſtances, nearly in the following decreaſing order:

Biſmuth, } Theſe are nearly equal in effect.
Lead, }
Antimony, }
Arſenic,
Zinc,
Cobalt,
Manganeſe,
Nickel,
Tin,
Iron,
Platina (E),
Copper,
Silver *.

* *Phil. Tranſ.* 1803, 95. 2122

Uſes. The uſes of gold, many of which have been already detailed, in deſcribing its properties and combinations, are too familiar to require particular enumeration (F).

SECT.

(E) Mr Hatchett ſuppoſes that the platina not being quite pure, the place he has aſſigned to it is perhaps not preciſely that which it ought to occupy.

(F) The metals which were earlieſt known, were long diſtinguiſhed by particular names and characters, of which the following account is taken from the elaborate reſearches of Profeſſor Beckmann. The following table exhibits their names and characters.

Metals.	Names.	Characters.
Gold,	Sun,	☉
Silver,	Moon,	☽
Mercury,	Mercury,	☿
Copper,	Venus,	♀
Iron,	Mars,	♂
Tin,	Jupiter,	♃
Lead,	Saturn,	♄

It cannot be doubted, Profeſſor Beckmann obſerves, that theſe names were firſt given to the heavenly bodies; and the metals which were then known, amounting to the ſame number, were ſuppoſed to have ſome affinity or relationſhip to the planets, and with them to the gods, and were accordingly named after them. "To each god was aſſigned a metal, the origin and uſe of which was under his particular providence and government; and to each metal were aſcribed the powers and properties of the planet and divinity of the like name; from which aroſe, in the courſe of time, many of the ridiculous conceits of the alchemiſts.

"The oldeſt trace of the diviſion of the metals among the gods is to be found, as far as I know, in the religious worſhip of the Perſians. Origen, in his refutation of Celſus, who aſſerted that the ſeven heavens of the Chriſtians, as well as the ladder which Jacob ſaw in his dream, had been borrowed from the myſteries of Mithras, ſays, 'Among the Perſians the revolutions of the heavenly bodies were repreſented by ſeven ſtairs, which conducted to the ſame number of gates. The firſt gate was of lead; the ſecond of tin; the third of copper; the fourth of iron; the fifth of a mixed metal; the ſixth of ſilver, and the ſeventh of gold. The leaden gate had the ſlow tedious motion of Saturn; the tin gate the luſtre and gentleneſs of Venus; the third was dedicated to Jupiter; the fourth to Mercury, on account of his ſtrength and fitneſs for trade; the fifth to Mars; the ſixth to the Moon, and the laſt to the Sun.' 'Celſus de quibuſdam Perſarum myſteriis ſermonem facit. Harum rerum, inquit, aliquod reperitur in Perſarum doctrina Mithraciſque eorum myſteriis veſtigium. In illis enim duæ cæleſtes converſiones, alia ſtellarum fixarum, errantium alia, et animæ per eas tranſitus quodam ſymbolo repræſentantur, quod hujuſmodi eſt. Scala altas portas habens, in ſumma autem octava porta. Prima portarum plumbea, altera ſtannea, tertia ex ære, quarta ferrea, quinta ex ære mixto, ſexta argentea, ſeptima ex auro. Κλιμαξ ὑψιπυλος, επι δ'αυτη πυλη ογδοη. Ἡ πρωτη των πυλων μολιβδου, η δευτερα κασσιτερου, ἡ τριτη χαλκου, ἡ τεταρτη σιδηρου, ἡ πεμπτη καραστου νομισματος, ἡ ἑκτη αργυρου, χρυσου δ' ἡ ἑβδομη. Primum aſſignant Saturno tarditatem illius ſideris plumbo indicantes: alteram Veneri, quam referunt, ut ipſi quidem putant, ſtanni ſplendor et mollities; tertiam Jovi, aheneam illam quidem et ſolidam: quartam Mercurio, quia Mercurius et ferrum, uterque operum omnium tolerantes, ad mercaturam utiles, laborum patientiſſimi. Marti quintam, inæqualem illam et variam propter mixturam. Sextam, quæ argentea eſt, lunæ; ſeptimam auream ſoli tribuunt, quia ſolis et lunæ colores hæc duo metalla referunt.' *Contra Celſum*, lib. vi. 22. p. 161. Here then is an evident trace of metallurgic aſtronomy, as Borrichius calls it, or of the aſtronomical or mythological nomination of metals, though it differs from that uſed at preſent. According to this arrangement, tin belonged to Jupiter, copper to Venus, iron to Mars, and the mixed metal to Mercury. The conjecture of Borrichius, that the tranſcribers of Origen have, either through ignorance or deſign, tranſpoſed the names of the gods, is highly probable: for if we reflect that in this nomination men, at firſt, differed as much as in the nomination of the planets, and that the names given them were only confirmed in the courſe of time, of which I ſhall ſoon produce proofs, it muſt be allowed that the cauſes aſſigned by Origen for his nomination do not well agree

with

SECT. XXII. *Of PLATINA and its Combinations.*

2123 History.

Platina in moſt of its properties is equal to gold, but in others, it is ſuperior. It was firſt clearly aſcertained to be a diſtinct metal, by Scheffer, a Swediſh chemiſt, in the year 1752. It had been indeed taken notice of at an earlier period. A quantity of it was brought from Jamaica in 1741, by Mr Wood. It is particularly mentioned by Antonio de Ulloa, a Spaniſh mathematician, in the account of his voyage to Peru with the French academicians, to meaſure a degree of the meridian, which was publiſhed in 1748. After this period numerous experiments were made upon this new ſubſtance, all of which tended to prove that it is a different metal from any formerly known.

Scheffer

---

with the preſent reading, and that they appear much juſter when the names are diſpoſed in the ſame manner as that in which we now uſe them. Borrichius arranges the words in the following manner: Secundam portam faciunt Jovis, comparantes ei ſtanni ſplendorem et mollitiem; tertiam Veneris æratam et ſolidam; quartam Martis, eſt enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter miſturam inæqualem ac variam, et quia negotiator eſt; ſextam Lunæ argenteam; ſeptimam Solis auream. *Ol. Borrichius de ortu et progreſſu chemiæ.* Hafniæ 1668, 4to. p. 29.

" This aſtrological nomination of metals appears to have been conveyed to the Brachmans in India; for we are informed that a Brachman ſent to Apollonius ſeven rings, diſtinguiſhed by the names of the ſeven ſtars or planets, one of which he was to wear daily on his finger, according to the day of the week. This can be no otherwiſe explained than by ſuppoſing that he was to wear the gold ring on Sunday; the ſilver one on Monday; the iron one on Tueſday, and ſo of the reſt. Alluſion to this nomination of the metals after the gods occurs here and there in the ancients. Dydimus, in his Explanation of the Iliad, calls the planet Mars the iron ſtar. Thoſe who dream of having had any thing to do with Mars are by Artemidorus threatened with a chirurgical operation, for this reaſon, he adds, becauſe Mars ſignifies iron. Heraclides ſays alſo in his allegories, that Mars was very properly conſidered as iron; and we are told by Pindar that gold is dedicated to the ſun.

" Plato likewiſe, who ſtudied in Egypt, ſeems to have admitted this nomination and meaning of the metals. We are at leaſt aſſured ſo by Marſilius Ficinus; but I have been able to find no proof of it, except where he ſays of the iſland Atlantis, that the exterior walls were covered with copper and the interior with tin, and that the walls of the citadel were of gold. It is not improbable that Plato adopted this Perſian or Egyptian repreſentation, as he aſſigned the planets to the demons; but perhaps it was firſt introduced into his ſyſtem only by his diſciples. They ſeem, however, to have varied from the nomination uſed at preſent; as they dedicated to Venus copper, or braſs, the principal component part of which is indeed copper; to Mercury tin, and to Jupiter electrum. The laſt-mentioned metal was a mixture of gold and ſilver; and on this account was probably conſidered to be a diſtinct metal, becauſe in the early periods mankind were unacquainted with the art of ſeparating theſe noble metals.

" The characters by which the planets and metals are generally expreſſed when one does not chooſe to write their names, afford a ſtriking example how readily the mind may be induced to ſuppoſe a connection between things which in reality have no affinity or relation to each other. Antiquaries and aſtrologers, according to whoſe opinion the planets were firſt diſtinguiſhed by theſe characters, conſider them as the attributes of the deities of the ſame name. The circle in the earlieſt periods among the Egyptians was the ſymbol of divinity and perfection; and ſeems with great propriety to have been choſen by them as the character of the ſun, eſpecially as, when ſurrounded by ſmall ſtrokes projecting from its circumference, it may form ſome repreſentation of the emiſſion of rays. The ſemicircle is, in like manner, the image of the moon, the only one of the heavenly bodies that appears under that form to the naked eye. The character ♄ is ſuppoſed to repreſent the ſcythe of Saturn; ♃ the thunderbolts of Jupiter; ♂ the lance of Mars, together with his ſhield; ♀ the looking-glaſs of Venus; and ☿ the caduceus or wand of Mercury.

" The expreſſion by characters adopted among the chemiſts agrees with this mythological ſignification only in the character aſſigned to gold.—Gold, according to the chemiſts, was the moſt perfect of metals, to which all others ſeemed to be inferior in different degrees. Silver approached neareſt to it; but was diſtinguiſhed only by a ſemicircle, which, for the more perſpicuity, was drawn double, and thence had a greater reſemblance to the moſt remarkable appearance of the moon; the name of which this metal had already obtained. All the other metals, as they ſeemed to have a greater or leſs affinity to gold or ſilver, were diſtinguiſhed by characters compoſed of the characters aſſigned to theſe precious metals. In the character ☿ the adepts diſcover gold with a ſilver colour. The croſs placed at the bottom, which among the Egyptian hieroglyphics had a myſterious ſignification, expreſſes, in their opinion, ſomething I know not what, without which quickſilver would be ſilver or gold. This ſomething is combined alſo with copper, the poſſible change of which into gold is expreſſed by the character ♀. The character ♂ declares the like honourable affinity alſo; though the ſemicircle is applied in a more concealed manner; for, according to the propereſt mode of writing, the point is wanting at top, or the upright line ought only to touch the horizontal, and not to interſect it. Philoſophical gold is concealed in ſteel; and on this account it produces ſuch valuable medicines. Of tin one half is ſilver, and the other conſiſts of the ſomething unknown: for this reaſon the croſs with the half moon appears in ♃. In lead this ſomething is predominant, and a ſimilitude is obſerved in it to ſilver. Hence in its character ♄ the croſs ſtands at the top, and the ſilver character is only ſuſpended on the right hand behind it.

" The mythological ſignification of theſe characters cannot be older than the Grecian mythology; but the chemical

Scheffer gave it the name of *white gold*, becauſe it reſembled this metal in many of its properties. In the year 1754, Dr Lewis publiſhed an account of a very full and elaborate ſet of experiments on platina, in the Philoſophical Tranſactions. The properties of this new metal were ſtill farther inveſtigated by Margraaf in 1757 and by Macquer and Beaumè in 1758. It became afterwards the ſubject of reſearch with many other philoſophical chemiſts. Among theſe may be mentioned Buffon, Bergman, Sickingen, and more lately Guyton, Lavoiſier, and Pelletier. It was at laſt denominated *platina*, ſignifying *little ſilver*, from the Spaniſh word *plata*, *ſilver*.

2124 Where found. 2. Platina has only been found among the gold ores of South America, and eſpecially in the mine of Santa Fe near Carthagena, and in the diſtrict of Choco in Peru. It is found in the form of ſmall grains or ſcales, of a white or grayiſh colour, intermediate between that of ſilver and iron. Theſe grains are mixed with ſeveral other ſubſtances, as particles of gold, a black ferruginous ſand, and ſome particles of mercury. Some of theſe grains extend under the hammer, others which ſeem to be hollow, containing particles of iron and a whitiſh powder, break to pieces. To theſe grains of iron is aſcribed the magnetic property which platina ſeems to poſſeſs (G).

2125 Purification. 3. To obtain platina in a ſtate of purity, it is firſt ſeparated from the ſubſtances with which it is contaminated. Mercury is driven off by expoſing it to a red heat, and the particles of iron are ſeparated by the magnet. The grains of platina are then heated with muriatic acid, which diſſolves the remaining part of the iron. By this proceſs, Bergman has obſerved, that the platina diminiſhes in weight about 0.05. The platina is now only alloyed with gold, which is to be ſeparated by diſſolving both in nitro-muriatic acid, and by precipitating the gold by means of the green ſulphate of iron. But even after theſe proceſſes, the platina is not in a ſtate of abſolute purity, as will appear afterwards (H).

2126 Properties. 4. This metal is of a white colour, but leſs bright than ſilver, and it poſſeſſes nothing of the brilliancy of either ſilver or gold. Platina is the denſeſt body, and therefore the heavieſt yet known. Its ſpecific gravity, when it is hammered, is 23; or, according to Chabaneau, 24. According to Guyton, it comes next to iron and manganeſe in hardneſs. It poſſeſſes very conſiderable malleability, for it may be hammered

---

mical may be traced to a much earlier period. Some, who conſider them as remains of the Egyptian hieroglyphics, pretend that they may be diſcovered on the table of Iſis, and employ them as a proof of the high antiquity, if not of the art of making gold, at leaſt of chemiſtry. We are told alſo that they correſpond with many other characters which the adepts have left us as emblems of their wiſdom.

" If we are deſirous of deciding without prejudice reſpecting both theſe explanations, it will be found neceſſary to make ourſelves acquainted with the oldeſt form of the characters, which, in all probability, like thoſe uſed in writing, were ſubjected to many changes before they acquired that form which they have at preſent. I can, however, mention only three learned men, Saumaiſe, Du Cange, and Huet, who took the trouble to collect theſe characters. As I am afraid that my readers might be diſguſted were I here to inſert them, I ſhall give a ſhort abſtract of the concluſion which they form from them; but I muſt firſt obſerve that the oldeſt manuſcripts differ very much in their repreſentation of theſe characters, either becauſe they were not fully eſtabliſhed at the periods when they were written, or becauſe many ſuppoſed adepts endeavoured to render their information more enigmatical by wilfully confounding the characters; and it is probable alſo that many miſtakes may have been committed by tranſcribers.

" The character of Mars, according to the oldeſt mode of repreſenting it, is evidently an abbreviation of the word Θουρος, under which the Greek mathematicians underſtood that deity; or, in other words, the firſt letter Θ, with the laſt letter ς placed above it. The character of Jupiter was originally the initial letter of Ζευς; and in the oldeſt manuſcripts of the mathematical and aſtrological works of Julius Firmicus the capital Z only is uſed, to which the laſt letter ς was afterwards added at the bottom, to render the abbreviation more diſtinct. The ſuppoſed looking-glaſs of Venus is nothing elſe than the initial letter, diſtorted a little, of the word Φωσφορος, which was the name of that goddeſs. The imaginary ſcythe of Saturn has been gradually formed from the two firſt letters of his name Κρονος, which tranſcribers, for the ſake of diſpatch, made always more convenient for uſe, but at the ſame time leſs perceptible. To diſcover in the pretended caduceus of Mercury the initial letter of his Greek name Στιλβων, one needs only look at the abbreviations in the oldeſt manuſcripts, where they will find that Σ was once written as C; they will remark alſo that tranſcribers, to diſtinguiſh this abbreviation from the reſt ſtill more, placed the C thus ◡, and added under it the next letter τ. If thoſe to whom this deduction appears improbable will only take the trouble to look at other Greek abbreviations, they will find many that differ ſtill farther from the original letters they expreſs than the preſent character ☿ from the C and τ united. It is poſſible alſo that later tranſcribers, to whom the origin of this abbreviation was not known, may have endeavoured to give it a greater reſemblance to the caduceus of Mercury. In ſhort, it cannot be denied that many other aſtronomical characters are real ſymbols, or a kind of proper hieroglyphics, that repreſent certain attributes or circumſtances, like the characters of Aries, Leo, and others quoted by Saumaiſe. *Hiſt. of Invent.* iii. 53.

(G) Collet-Deſcoſtils obſerves, that among the metallic ſubſtances which are uſually found accompanying platina, there are two kinds of ferruginous ſand; of which one is attracted by the magnet, and ſoluble in acids. This contains titanium. The other has no magnetic property, and is only partially ſoluble in acids. This laſt contains a conſiderable proportion of chromic acid. *Ann. de Chim.* xlviii. 154.

(H) A new metal, or ſeveral new metals, have been diſcovered in platina, by ſome late experiments. Theſe will be mentioned in a future ſection.

mered out, although with difficulty, into very thin plates; and it is ſo ductile, that it may be drawn out into wire $\frac{1}{1940}$ of an inch in diameter. The tenacity of platina is very conſiderable. A wire of .078 of an inch in diameter will ſupport a weight without breaking, equal to more than 274 lbs. avoirdupois.

2127 Fuſing point unknown.

5. Platina is the moſt infuſible of all the metals. The temperature at which it enters into fuſion is unknown. But ſmall particles of platina have been fuſed by means of the blow-pipe, or by directing a ſtream of oxygen gas on red-hot charcoal. Guyton alſo ſucceeded in fuſing it by means of a flux, compoſed of eight parts of pounded glaſs, one of calcined borax, and one-half part of charcoal in powder. When platina has been expoſed to a white heat, it may be welded by hammering, like iron.

2128 Oxidation.

6. As platina is infuſible in the ſtrongeſt furnace heat, ſo it remains otherwiſe unchanged (1). It does not appear to undergo, like moſt other metals, any degree of oxidation; but if platina be diſſolved in 16 times its weight of nitro-muriatic acid, by boiling

2129 Yellow oxide.

the ſolution becomes at firſt of a yellow, and then changes to a brown colour. This ſolution is precipitated by means of lime, and the precipitate is in the form of a yellowiſh powder, which is the oxide of platina. The proportion of oxygen in this oxide is ſuppoſed not to exceed .07. But according to the experiments of Mr Chenevix, it is compoſed of

Platina,	87
Oxygen,	13
	100

2130 Green oxide.

The ſame chemiſt alſo found, that in the reduction of this oxide of platina, it became of a green colour, and remained for ſome time in that ſtate. Ammonia aſſumes a green colour when it holds oxide of platina in ſolution. This Mr Chenevix conſiders as a ſecond oxide of platina, and it contains

Platina,	93
Oxygen,	7
	100

* Phil. Tranſ. 1803. 314.

Platina has alſo been oxidated by means of electricity. In Van Marum's experiments, a wire of this metal through which electric ſparks were ſent, burnt with a white flame, and was diſſipated in the form of fine powder or duſt.

7. Azote, hydrogen, and carbone, have no action whatever on platina.

2131 Phoſphuret.

8. Phoſphuret of platina was formed by Pelletier by mixing together equal parts of platina and phoſphoric glaſs, with one-eighth of charcoal. This mixture being expoſed to the temperature of 32° of Wedgwood for an hour, yielded a ſmall button of phoſphuret of platina, of a ſilvery white colour, part of which had aſſumed the form of cubic cryſtals. It was ſo hard as to ſtrike fire with ſteel, and was not attracted by the magnet. It was covered with a dark coloured glaſs, which afterwards became green, bluiſh, and white. By expoſing this phoſphuret to a ſtrong heat, the phoſphorus is ſeparated, and burns on the ſurface, and the metal remains behind very pure and malleable. Pelletier has propoſed this proceſs for the purification of platina from other metals.

2132 Sulphuret.

9. Sulphur has been found in combination with native platina. When native platina is expoſed to the action of the blow-pipe on charcoal, it exhales the penetrating odour of ſulphur, accompanied with a vapour which does not render gold white, and which requires a higher temperature to ſublime it than mercury *.

* Ann. de Chim. xxxviii. 149.

I. Salts of Platina.

1. Sulphate of Platina.

By adding ſulphuric acid to a ſolution of platina in muriatic acid, Mr Chenevix obtained an inſoluble ſalt, which he found to be compoſed of

Oxide of platina,	54.5
Acid and water,	45.5
	100.0

2. Sulphate of Platina and Potaſh.

This triple ſalt is formed by adding a ſolution of potaſh to ſulphate of platina. The component parts of this ſalt are, ſulphuric acid, oxide of platina, and potaſh; but the proportions have not been aſcertained by Bergman, who examined it.

3. Sulphate of Platina and Ammonia.

This triple ſalt is formed in the ſame way as the former, by adding ammonia to the ſulphate of platina.

4. Nitrate of Platina.

Nitric acid has no action on platina, but it diſſolves the yellow oxide. Mr Chenevix precipitated the oxide of platina from its ſolution in nitro-muriatic acid by means of lime, and although it was added in exceſs, a great portion of platina remained in the liquor. The precipitate was rediſſolved in nitric acid, and evaporated to dryneſs. The reſult was, a ſubnitrate of platina, which conſiſted of

Yellow oxide	89
Nitric acid and water	11
	100

5. Nitrate of Platina and Potaſh.

When potaſh is added to a ſolution of nitrate of platina, cryſtals are depoſited forming a triple ſalt, and compoſed of nitric acid, oxide of platina and potaſh.

6. Nitrate of Platina and Ammonia.

This triple ſalt is formed by adding ammonia to a ſolution of nitrate of platina.

7. Muriate

---

(1) Guyton propoſes to conſtruct a pyrometer of platina. See *Ann. de Chim.* xlvi. 276.

7. Muriate of Platina.

2133 Preparation. Muriatic acid has no action on platina, but the muriate of platina may be obtained by diſſolving the metal in nitro-muriatic acid. Boiled in 16 parts of a mixture conſiſting of one part of nitric acid and three parts of muriatic acid, it is gradually diſſolved with efferveſcence. It may be alſo diſſolved in oxymuriatic acid. The ſolution of platina in muriatic acid is of a reddiſh or deep brown colour. It is extremely acrid and cauſtic, corrodes and burns animal matters, and leaves a dark brown ſpot on the ſkin. When the ſolution is concentrated, it depoſits on cooling, ſmall irregular cryſtals, nearly in the ſtate of powder, and of a browniſh-yellow colour. 2134 Properties. When theſe cryſtals are waſhed and dried, they are found to be leſs ſoluble by boiling in water, than even the ſulphate of lime. The ſolution is of a yellow colour. The muriate of platina has a harſh, aſtringent taſte; it is decompoſed by heat; the acid is driven off, and the oxide remains. It is alſo decompoſed by concentrated ſulphuric acid. Potaſh produces in this ſolution, ſmall reddiſh cryſtals, frequently in the form of octahedrons, conſtituting the triple ſalt already deſcribed. The ſame triple ſalt is formed by the ſulphate of potaſh. Ammonia, or the muriate of ammonia, alſo forms a triple ſalt, by being added to the ſolution of muriate of platina. Soda in ſufficient quantity occaſions a precipitate of the yellow oxide of platina, and a triple ſalt alſo is formed. Mr Chenevix found that the inſoluble muriate of platina is compoſed of

2135 Compoſition.

Oxide of platina	70
Acid and water	30
	100

8. Muriate of Platina and Soda.

Till the experiments of Collet-Deſcoſtils, little was known of this triple ſalt. It may be obtained by adding to a ſolution of platina a ſalt with baſe of ſoda. By concentration and cooling it cryſtallizes in the form of long priſms, and ſometimes in that of triangular tables, of a yellow or red colour. It is very ſoluble in water, and alſo in alcohol. It is decompoſed by muriate of ammonia, and by a ſolution of ſoda; but an exceſs of this ſalt re-diſſolves the precipitate. It may be reduced by the action of the blowpipe on charcoal. This cryſtallized triple ſalt, if it has no exceſs of acid, changes from a red colour to a green by expoſure to the air. If in this ſtate it be diſſolved in water, and oxymuriate of lime be added to it, a deep blue precipitate is formed, which being waſhed and collected, is ſoluble in muriatic acid, and communicates to it a beautiful blue colour. The addition of alcohol deprives the ſolution of its colour, but the oxymuriate of lime reſtores it *.

9. Muriate of Platina and Potaſh.

This ſalt is formed by adding potaſh to a ſolution of muriate of platina. Small cryſtals of a red colour in the form of octahedrons, are precipitated, which are a triple ſalt conſiſting of muriatic acid, oxide of platina and potaſh.

10. Muriate of Platina and Ammonia.

1. A ſimilar triple ſalt is formed by adding ammonia to the ſolution of muriate of platina. The triple ſalt is precipitated in the form of cryſtalline grains, of a reddiſh-yellow colour, which are ſoluble in water. By evaporating the ſolution of theſe triple ſalts to dryneſs, and by expoſing it to a ſtrong heat, the platina is reduced. This fact with regard to the fuſibility of platina by means of potaſh or ammonia, was obſerved by Bergman, and it is by this proceſs that platina is purified and wrought.

2. When this ſalt is precipitated by means of potaſh, a fulminating platina is obtained. This, according to Fourcroy and Vauquelin by whom it was prepared, is a compound of oxide of platina and ammonia. When it is expoſed to ſudden heat, it decrepitates and is agitated with a rapid motion, but when the heat is gradually applied, it detonates violently *.

11. Oxalate of Platina.

Oxalic acid combines with the oxide of platina, and affords by evaporation cryſtals which are of a yellow colour.

12. Benzoate of Platina.

Benzoic acid, according to Trommſdorf, diſſolves a ſmall quantity of the oxide of platina. When this ſolution is evaporated, it cryſtallizes. This ſalt undergoes no change by expoſure to the air, and is not very ſoluble in water. The acid is driven off by heat, and the oxide of platina remains behind.

II. Alloys.

1. Platina combines with many of the metals, and forms with them alloys, ſome of which are of conſiderable importance in the working of this metal.

2136 Combines with arſenic. Platina forms an alloy with arſenic, which is brittle and very fuſible. It is in this ſtate of alloy that platina is ſuſceptible of being formed into different utenſils and inſtruments for which it is peculiarly fitted. It is firſt fuſed with this metal, and then caſt into moulds, at firſt in the form of ſquare plates. It is then expoſed to a red-heat, and hammered into bars. By the heating and hammering, the arſenic is driven off, and the metal is purified and becomes infuſible, but retains its ductility, ſo that it may be wrought like iron.

2. The alloys of tungſten, molybdena, chromium, columbium, titanium, uranium, and manganeſe, are unknown; nor have the alloys of cobalt and nickel with this metal been examined.

2137 Biſmuth. 3. Platina combines with biſmuth by means of fuſion. This alloy is fuſible and hard in proportion to the quantity of biſmuth. It is altered by expoſure to the air; it becomes yellow, purple, and black.

2138 Antimony. 4. Platina readily combines with antimony, and forms a very brittle alloy. The antimony may be ſeparated by means of heat, but not completely. Some part remains, which diminiſhes the weight and ductility of the platina.

2139 Mercury. 5. It has been found extremely difficult to combine platina and mercury. Guyton had obſerved that the adheſive force of platina and mercury is greater than

---

* Ann. de Chim. xlviii. p. 165.

* Annal. de Chim. xlix. p. 179.

that of metals which do not combine with it, and that it is not inferior even to thoſe which readily form alloys; from which he conjectured that the alloy of platina and mercury might be effected by the following proceſs. He placed a very thin plate of pure platina at the bottom of a matraſs containing a quantity of mercury. The matraſs was put upon a ſand bath, and heat applied, till the mercury boiled and the matraſs became red-hot. When the platina was taken out, it was found to have acquired additional weight, and to have become very brittle. But this combination is different from the other combinations of mercury with the metals, for the platina did not loſe its ſolid form. Mr Chenevix, in the courſe of experiments and reſearches reſpecting a ſuppoſed new metal called palladium, ſucceeded in forming an amalgam with platina and mercury. He heated purified platina in the form of fine powder, with ten times its weight of mercury, and rubbed them together for a long time. The reſult was an amalgam of platina, which being expoſed to a violent heat, loſt all the mercury it contained, and the original weight of the platina remained.

2140 Zinc. 6. Platina readily combines with zinc, and forms with it a fuſible alloy, of a bluiſh colour, brittle, and hard. By heating, the zinc is ſublimed, and burns on the ſurface.

2141 Tin. 7. Platina alloys readily with tin. This alloy is one of the moſt fuſible. It is hard and brittle, when the two metals are in equal proportions; but tin in the proportion of 12 parts to one of platina, affords a very ductile alloy, which becomes yellow by expoſure to the air. From this it appears that platina diminiſhes the ductility of tin.

2142 Lead. 8. Platina readily combines with lead, by means of fuſion. An alloy of equal parts of theſe metals is of a purpliſh colour, granulated in its fracture, brittle, and eaſily altered by expoſure to the air. The cupellation of platina by means of lead has been an object of conſiderable importance with chemiſts, in the view of being able to purify it in the ſame way as gold and ſilver; but on account of the infuſibility and refractory nature of platina, the attempts that have been made have rarely ſucceeded.

2143 Iron. 9. Dr Lewis failed in his attempt to combine platina with iron, but he obtained an alloy by fuſing together platina and caſt iron. This alloy was extremely hard, and poſſeſſed ſome degree of ductility. Platina, as it is found native, is frequently alloyed with iron.

2144 Copper. 10. Platina combines with copper by means of fuſion, and gives it hardneſs. When the proportion of copper is three or four times greater than that of platina, the alloy is ductile, ſuſceptible of a fine poliſh, and is not altered by expoſure to the air. This alloy has been employed in the fabrication of mirrors for teleſcopes.

2145 Silver. 11. Platina readily combines with ſilver by fuſion, although a very ſtrong heat is required. The platina greatly increaſes the hardneſs of ſilver, but diminiſhes its whiteneſs. When this alloy is kept in fuſion for ſome time, the two metals are ſeparated. During this fuſion, Dr Lewis obſerved the ſilver forced towards the ſides of the crucible with a kind of exploſion.

2146 Gold. 12. Gold combines readily with platina, but it requires a very powerful heat for the fuſion of theſe two metals. Platina diminiſhes the colour of gold, unleſs it be in very ſmall quantity. When the proportion of platina is above $\frac{1}{17}$, the colour of the gold begins to be altered. There is no perceptible change in the ſpecific gravity or the ductility of gold from this alloy.

Platina, on account of its peculiar properties, its infuſibility, denſity, and indeſtructibility, could it be obtained in ſufficient quantity, and at a moderate price, would undoubtedly prove one of the moſt uſeful, and moſt important of the metals yet known. The importance and utility of platina, on account of its ſcarcity, have been hitherto limited to chemical purpoſes; and for different chemical inſtruments and utenſils, it has been found peculiarly appropriate, as there are few chemical agents whoſe effects it cannot reſiſt. There is indeed little doubt but it might be employed with equal advantage in the conſtruction of inſtruments and utenſils, in various arts and manufactures.

SECT. XXIII. *Of PALLADIUM, a ſuppoſed new Metal, and of IRIDIUM and OSMIUM, two new Metals obtained from crude PLATINA.*

2147 Palladium announced. 1. In the month of April 1803, the diſcovery of a new metal, to which the name of *Palladium* was given, was announced in London. It was ſaid to poſſeſs the following properties: "1. It diſſolves in pure nitric acid, and makes a dark-red ſolution. 2. Green ſulphate of iron throws it down in the ſtate of a regulus from the ſolution. 3. If you evaporate the ſolution, you get a red calx, which diſſolves in muriatic or other acids. 4. It is thrown down by quickſilver, and by all the metals, but gold, platina, and ſilver. 2148 Properties. 5. Its ſpecific gravity, by hammering, is only 11.3; but by flatting as much as 11.8. 6. In a common fire the face of it tarniſhes a little, and turns blue; but becomes bright again, like other noble metals, on being ſtronger heated. 7. The greateſt heat of a blackſmith's fire would hardly melt it. 8. But if you touch it, while hot, with a ſmall bit of ſulphur, it runs as eaſily as zinc." Nothing was ſaid of the hiſtory of the diſcovery; but from the unuſual manner in which it was announced, Mr Chenevix, 2149 Mr Chenevix's ſuſpicions and experiments. conceiving it to be an impoſition, procured a ſpecimen, which being ſubjected to various teſts, he found could not be referred to any of the known metals. He afterwards purchaſed the whole quantity which was offered to ſale. The ſubſtance had been wrought by art, had been rolled out in flatting mills, and was offered for ſale in thin laminæ. The largeſt, about three inches in length, and half an inch in breadth, weighing about 25 grains, were ſold at a guinea. When this ſubſtance was poliſhed, it could ſcarcely be diſtinguiſhed from platina. It was flexible, but not very elaſtic. The ſpecific gravity of ſome pieces was 10.972, while others were only 11.482.

The effects of galvanic electricity upon palladium were the ſame as upon gold and ſilver. Expoſed to the blow-pipe, the ſide removed from the immediate action of the flame, became blue. Expoſed in an open veſſel to a greater degree of heat than the fuſing temperature of gold, no appearance of fuſion or oxidation was obſerved. When the heat was increaſed, a melted button was obtained, which had loſt a little of its weight, but was increaſed in ſpecific gravity. The addition of ſulphur renders it more fuſible, and extremely

tremely brittle. There ſeems to be no action between charcoal and palladium. Mr Chenevix found that this ſubſtance formed alloys with gold, platina, ſilver, copper, lead, and ſome other metals. The alloy with lead was the hardeſt of all, but extremely brittle, and its ſpecific gravity was 12. He alſo ſubjected this ſubſtance to other experiments, with alkalies, ſome of the earths, ſeveral of the acids, and ſome of the ſalts; and from the whole he concludes that it would be difficult to ſay of what metal, or of what combination of metals, palladium conſiſts.

2150 Is an alloy. 2. Mr Chenevix ſtill proſecuted his experiments, and he concluded at laſt, that this ſuppoſed new metal is an alloy of platina and mercury. It muſt however, be obſerved, that he did not arrive at this diſcovery by analyzing palladium, for he failed in every attempt with that view. It was by combining platina and mercury in certain proportions, that he compoſed a ſubſtance which he conſidered as exactly ſimilar in all its properties to palladium. The proceſs by which he ſucceeded in forming palladium, or a ſubſtance exactly ſimilar, was by diſſolving 100 grains of platina in nitro-muriatic acid, and then adding 200 grains of red oxide of mercury. This being inſufficient to ſaturate the exceſs of acid, more was added till it ceaſed to be diſſolved. A quantity of green ſulphate of iron was then poured into a long-necked matraſs, to which the mixed ſolution of platina and mercury was added, and the whole placed upon a ſand bath. In leſs than half an hour, a precipitate formed, and the inſide of the matraſs was lined with a thin metallic coat. The liquor was paſſed through a filter, and the precipitate, after being digeſted with muriatic acid, was well waſhed and dried. The whole quantity collected amounted to 276 grains, which were compoſed of 92 of platina, and 184 of mercury. It was in the form of a fine powder, with a metallic luſtre. It was put into a charcoal crucible, and fuſed into a button. The ſpecific gravity was 11.2. It was entirely ſoluble in nitric acid, eaſily fuſed by ſulphur, and precipitated by green ſulphate of iron; thus exhibiting all the properties of palladium, which Mr Chenevix concludes, is compoſed of two parts of mercury, and one of platina.

2151 Specific gravity remarkable. 3. One of the moſt ſingular circumſtances with regard to this alloy, if ſuch it can be called, is its ſpecific gravity, which is not only far below the mean of the ſpecific gravity of the two metals, but conſiderably inferior to either of its elements. The ſpecific gravity of platina is 22, according to ſome greater, and that of mercury is nearly 14, and yet the ſpecific gravity of the compound is only 10.972, little more than the half by calculation. But although we have no reaſon to doubt the accuracy and preciſion of Mr Chenevix's experiments, and although we are little diſpoſed to place any confidence in the aſſertion of the unknown diſcoverer of this ſubſtance, from the extraordinary circumſtances under which it has been announced, yet we do not conſider the reſult of theſe experiments fully ſatisfactory, in proving palladium to be an alloy of platina and mercury (k). Every attempt which Mr Chenevix made to analyze this ſuppoſed new metal, failed. It is true, he was equally unſucceſsful in decompoſing the alloy of platina and mercury which he had formed, and which reſembled palladium in moſt of its properties which were compared. 2152 His experiments not fully ſatisfactory. The attempts which have been made to repeat the experiments of Mr Chenevix, have not ſucceeded. No other chemiſt has yet been able to form the compound of platina and mercury, which poſſeſſes the properties of palladium *. Till, therefore, Mr Chenevix ſhall have extended his reſearches concerning this alloy, or till it ſhall have been examined by ſome other chemiſt, we muſt remain in ſuſpenſe with regard to its nature.

2153 Iridium. 4. Two other metals have been juſt announced. They were diſcovered in crude platina by Mr Tennant, in analyzing the black powder which remains after diſſolving platina. To the firſt of theſe metals Mr Tennant has given the name of *iridium*, from the various colours it aſſumes in ſolution. It poſſeſſes the following properties. It is ſoluble in all the acids, but leſs ſoluble in muriatic acid, with which it forms octahedral cryſtals. The ſolution with much oxygen is deep red; with a ſmaller proportion, green or deep blue. It is partially precipitated by the alkalies, and by all the metals except gold and platina. Infuſion of galls and pruſſiate of potaſh deprive this ſolution of its colour, but without any precipitate; thus affording an eaſy teſt of its preſence. The oxide, therefore, loſes its oxygen by water alone. When combined with gold or ſilver, it cannot be ſeparated by the uſual proceſs of refining theſe metals. The ſame ſubſtance was examined by Deſ-coſtils and Vauquelin, and the properties which they aſcribe to this metal are the following. 1. It reddens the precipitates of platina made by muriate of ammonia. 2. It is ſoluble in muriatic acid. 3. It is precipitated by the infuſion of galls and pruſſiate of potaſh.

2154 Oſmium. 5. The other new metal is obtained by heating the black powder with pure alkali in a ſilver crucible. The oxide of this metal combines with the alkali, and may be expelled by an acid, and obtained by diſtillation, being very volatile. It does not redden vegetable blues, but ſtains the ſkin of a deep red or black. The oxide in ſolution with water has no colour; but by combining with alkali or lime, becomes yellow. With the infuſion of nut-galls it gives a very vivid blue colour. It is precipitated by all the metals excepting gold and platina. An amalgam may be formed with mercury, by agitating it with the aqueous ſolution of this oxide. When this amalgam is heated, the mercury is driven off, and the pure metal remains behind in the ſtate of black powder. To this metal Mr Tennant has given the name of *oſmium*, on account of the ſtrong ſmell of the oxide †.

Such is the account of theſe metals which we have received. Should a fuller detail reach us in time, we ſhall

* *Phil. Tranſ.* 1803, p. 290.

† *Nichol. Jour.* viii. p. 118, & 220.

(k) Fourcroy and Vauquelin have thrown out a conjecture that palladium is probably an alloy of platina and a new metal diſcovered in crude platina by Collet-Deſcoſtils and Mr Tennant. *Ann. de Chim.* xlviii. 185.

ſhall not fail to lay it before our readers, either in an appendix to this treatiſe, or under the names of the metals themſelves, in the order of the alphabet, in the courſe of the work.

Chap. XV. Of the ATMOSPHERE.

The atmoſphere is that inviſible elaſtic fluid which ſurrounds the earth. Its phyſical properties, ſuch as denſity, elaſticity, and preſſure, have been long known; but its compoſition and conſtituent parts muſt be ranked among the diſcoveries of modern chemiſtry. In the preſent chapter, we propoſe only to take a ſhort view of the nature, conſtitution, and changes of the atmoſphere, reſerving the full diſcuſſion of the latter to meteorology, to which it properly belongs.

Sect. I. *Of the Component Parts of the Atmosphere.*

2155 Is a compound

2156 of oxygen and azotic gaſes.

1. The air of the atmoſphere was conſidered by the ancients as one of the four elements of which all bodies are compoſed. The ſame opinion was held by all philoſophers, previous to the diſcoveries of modern chemiſtry. It was univerſally admitted to be a ſimple homogeneous ſubſtance, till by the diſcovery of oxygen gas by Dr Prieſtley, and that of azotic gas by Scheele, it was fully demonſtrated that theſe two ſubſtances are the chief ingredients in atmoſpheric air.

2157 Phyſical properties.

2. This compound poſſeſſes all the phyſical properties of the different kinds of air which we have hitherto examined. It is inviſible, elaſtic, and may be indefinitely expanded and compreſſed. The ſpecific gravity of atmoſpheric air is 0.0012, or it is 816 times lighter than water. A hundred cubic inches weigh 31 grains troy; but in conſequence of the elaſticity of the air, the abſolute weight and the denſity muſt vary with the temperature and preſſure. The eſtimation which we have here given, is taken at the ordinary temperature of the atmoſphere, between 50° and 60°, and when the barometer, which indicates the preſſure, ſtands at 30 inches. The denſity muſt vary by diminiſhing, according to the height above the ſurface of the earth. The experiments of naturaliſts, whoſe attention has been particularly directed to this ſubject, have ſhewn that the diminution of denſity is in the ratio of the compreſſion, and therefore, that the increaſe of denſity is in geometrical progreſſion, while the heights increaſe in arithmetical progreſſion.

2158 Method of eſtimating the proportions.

3. After the diſcovery of the compoſition of atmoſpheric air, it became an object with philoſophers to determine the proportions of its component parts. It was obſerved by Prieſtley and Scheele, and other philoſophers who were occupied in the proſecution of their diſcoveries, that a certain portion of a given quantity of atmoſpheric air only was abſorbed during the proceſſes of combuſtion and reſpiration. It was obſerved too, that certain ſubſtances combined with the portion of atmoſpheric air which diſappeared during theſe proceſſes, and that the ſame quantity of atmoſpheric air, ſuffered no farther diminution, whatever length of time it was expoſed to the action of theſe ſubſtances. The portion of the air abſorbed is the oxygen gas, and on this principle is founded the conſtruction of thoſe inſtruments which have been denominated *eudiometers*, becauſe they are employed to meaſure the purity of a given portion of air, by aſcertaining the quantity of oxygen gas which it contains. Different eudiometers have been propoſed for this purpoſe, but all depending on the ſame principle, namely the abſtraction of oxygen gas from a given quantity of air. The reader will probably recollect the effects which take place by mixing together nitrous gas and the air of the atmoſphere, or oxygen gas. When theſe gaſes come into contact, red fumes are produced; the bulk of atmoſpheric air is partially, and that of oxygen gas almoſt entirely diminiſhed. This is owing to the combination of the nitrous gas with the oxygen gas, forming nitric acid, which, if the experiment be made over water, is abſorbed; thus diminiſhing the bulk of the air by the quantity of oxygen gas abſtracted. This is the principle of the firſt eudiometer, which was propoſed by Dr Prieſtley; but it has been found that the reſults and experiments with this kind of eudiometer are far from being uniform and conſtant. It is ſubject to variation from the difference of purity of the nitrous gas employed, the water over which the experiment is made, and even the form and conſtruction of the apparatus. The variations in the reſults of different experiments by different philoſophers, are from 22. to 30. of oxygen gas in 100 parts of atmoſpheric air.

Scheele propoſed a different eudiometer. A mixture of iron filings and ſulphur formed into a paſte with water, abſorbs the whole of the oxygen gas of any given portion of atmoſpheric air. The diminution of bulk of a portion of air, expoſed to the action of this ſubſtance, therefore, indicates the proportion of oxygen gas which it contains; but this abſorption goes on ſlowly, and is therefore an objection to this mode of aſcertaining the proportions of atmoſpheric air. This objection has been removed by an improvement of this eudiometer, in which hydrogenated ſulphuret of potaſh or lime is ſubſtituted for the iron filings and ſulphur. This is prepared by boiling together ſulphur and lime water, or a ſolution of potaſh in water. By the uſe of this ſulphuret, the abſorption takes place in a few minutes. A given portion of air is agitated in a bottle with this ſulphuret, taking care to exclude the external air with a ground ſtopper. The diminution of the bulk of this quantity of atmoſpheric air ſhews the proportion of oxygen gas which it contained.

Volta propoſed to explode a given portion of atmoſpheric air with hydrogen gas, by means of the electric ſpark. The hydrogen and oxygen combine together and form water; and the diminution of the bulk of the airs employed is in proportion to the quantity of water formed. But to this method of aſcertaining the quantity of oxygen gas in a given portion of atmoſpheric air, it has been objected, that the proportion of hydrogen gas requires to be accurately adjuſted; for if it exceed, the ſuperabundant quantity increaſes the bulk of the remaining air; and, if the proportion be too ſmall, the oxygen and azote will form nitric acid by the action of electricity, and thus the reſiduary quantity of air will be too much diminiſhed.

When phoſphorus is expoſed to the air, it abſorbs the oxygen readily, and is converted into phoſphorous acid. This, which was firſt propoſed by Achard, has been improved by Berthollet, for the purpoſes of a eudiometer.

diometer. A given portion of air is expoſed to the action of phoſphorus, in a veſſel over water; when the abſorption has ceaſed, the remaining air is meaſured, the diminution of which indicates the quantity of oxygen gas which it contained.

Mr Davy has propoſed the green ſulphate or muriate of iron diſſolved in water, impregnated with nitrous gas. This ſolution is prepared by tranſmitting nitrous gas through green muriate or ſulphate of iron diſſolved to ſaturation in water. All the apparatus neceſſary is a ſmall graduated tube, having its capacity divided into 100 parts, and greateſt at the open end, and a veſſel for containing the fluid. The tube is filled with the air to be examined, and then introduced into the the ſolution. To promote the abſorption, it is gently moved from a perpendicular to a horizontal poſition. In a few minutes the experiment is completed, and the whole of the oxygen condenſed by the nitrous gas in the ſolution, in the form of nitric acid. But in this proceſs it is neceſſary to obſerve the period at which the diminution ſtops, for after this the volume of reſidual gas is increaſed by the decompoſition of the nitric acid, by means of the green oxide of iron*.

From a number of comparative experiments made by Mr Davy, with different eudiometers, and from other experiments on air in different places, and collected under different circumſtances, it appears, that the component parts of atmoſpheric air are always nearly the ſame. Theſe proportions are from .21 to .22 of oxygen gas, and from .78 to .79 of azotic gas. The conſtituent parts, therefore, of atmoſpheric air by bulk may be taken at

2159 Compoſition.

Oxygen gas	22
Azotic	78
	100

But in eſtimating the proportions of given bulks of atmoſpheric air, it is neceſſary, as we have already hinted, to take into account the denſity and temperature, otherwiſe very great anomalies muſt happen.

2160 Water.

4. It is univerſally admitted, that water exiſts in the atmoſphere; but philoſophers are greatly divided with regard to the quantity of water, and the ſtate in which it exiſts in the air. To aſcertain the quantity of water, inſtruments called *hygrometers*, or *meaſurers of moiſture*, have been contrived; the quantity of which is indicated by certain changes which take place by its abſorption; but none of theſe inſtruments that have yet been invented are ſuſceptible of great accuracy, and perhaps to this is owing the very different reſults in eſtimating the quantity of water in the atmoſphere. There is alſo a very great difference of opinion whether this water exiſts in the atmoſphere in the ſtate of water, or whether it has been converted into vapour. According to the firſt opinion, the water is held in ſolution by the air, and the quantity increaſes as the temperature of the air is increaſed. But according to others, the water of the atmoſphere is in the ſtate of vapour. According to the experiments of naturaliſts, the quantity of water in the atmoſphere varies in different climates, and at different ſeaſons of the year from $\frac{1}{60}$ to $\frac{1}{300}$ part of the weight of the atmoſphere.

2161 In the ſtate of vapour.

5. When lime-water, or an alkaline ſolution is expoſed to the air, it is ſoon covered with a cruſt or pellicle. This is owing to the abſorption of carbonic acid, and the converſion of the alkali or lime to the ſtate of carbonate. This ſhews that carbonic acid gas exiſts in the atmoſphere. This gas has been found not only on the ſurface of the earth, where the denſity of the atmoſphere is greateſt, but alſo on the tops of ſome of the higheſt mountains. The quantity of carbonic acid gas in the atmoſphere is ſuppoſed to vary from .01 to .005 part.

2162 Carbonic acid gas.

Sect. II. *Of the* Constitution *of the* Atmosphere.

2163 Different opinions.

1. The component parts of the atmoſphere are, azotic gas, oxygen gas, water, and carbonic acid gas. Here a queſtion has ariſen among philoſophers, whether theſe parts are chemically combined, or merely form a mechanical mixture. According to one ſet of philoſophers, the oxygen and azotic gaſes of the atmoſphere are in chemical union, becauſe their proportions are always found to be uniform and conſtant, which it is ſuppoſed could not be the caſe from the inequality of the cauſes acting in diminiſhing the quantity of oxygen gas, by the different proceſſes of combuſtion and reſpiration, which are going on in the ſurface of the earth, if the component parts of the air were not in chemical combination. The air of the atmoſphere too, it is ſaid, poſſeſſes properties very different from the artificial mixture of its component parts. The proceſſes of combuſtion and reſpiration continue for a greater length of time in the latter, becauſe it parts with a greater proportion of its oxygen, and for the ſame reaſon it is more diminiſhed by nitrous gas. According to others, the air of the atmoſphere is merely a mechanical mixture. This opinion is ſupported by Mr Dalton, in ſome ingenious ſpeculations on the conſtitution of mixed gaſes, and particularly of the atmoſphere. The principle on which Mr Dalton's hypotheſis is founded is, that the particles of homogeneous elaſtic fluids only mutually act upon each other, and that the particles of an elaſtic fluid of one kind are neither attracted nor repelled by the particles of an elaſtic fluid of a different kind, when they are mixed together. According to this hypotheſis, therefore, the particles of the oxygen gas of the atmoſphere mutually act on each other, or are only attracted and repelled by thoſe of their own kind*.

2164 In chemical union.

2165 Mechanical mixture.

2. A difference of opinion alſo prevails, whether the vapour of water, as it exiſts in the atmoſphere, be merely a mechanical mixture, or chemically combined. The former opinion is alſo ſupported by Mr Dalton, upon the principle that all gaſes mixed with vapour, expand in a proportional degree to the elaſticity of the vapour in that temperature.

Sect. III. *Of the* Changes *of the* Atmosphere.

2166 Temperature.

1. The changes which are produced in the atmoſphere by heat and cold, are too obvious to eſcape obſervation; but it was not till the invention of the thermometer that theſe changes could be obſerved and marked with any degree of accuracy; and even after the invention and improvement of this inſtrument, it was long before any ſcientific application was made of the

---

* *Jour. Roy. Inſt.* i. p. 45.

* See *Manch. Mem.* vol. v.

the changes of the temperature which it indicated. The variable temperature of the ſame day, the great difference between midnight and midday, and the ſtill greater difference between the heat of ſummer and the cold of winter, ſeem to hold out a number of inſulated facts, without reſemblance or connexion, and incapable of being arranged under any general law. But more comprehenſive views, and more extended obſervations, have not only ſhewn the poſſibility of eſtabliſhing a general principle, but have enabled philoſophers to arrange and claſſify phenomena which were otherwiſe ſeemingly unconnected.

2167 The ſun the ſource of heat.

2. The great ſource of heat is the ſun. This is fully demonſtrated by the increaſe of temperature being in proportion to the duration and greater or leſs obliquity of the ſun's rays. It has been imagined that the earth is heated by central fires: but this opinion ſeems to be fully diſproved by obſerving that the temperature depends invariably on the abſence or preſence of the ſun; that this temperature is diminiſhed, at leaſt to a certain extent, by going deeper into the earth; and that the cold is greateſt in places moſt diſtant from the ſun's rays; ſo that the temperature which is moſt uniform within the tropics, diminiſhes, other things being equal, in proportion to the diſtance from the equator towards the poles.

2168 Fixed points of temperature important.

3. In conſidering the difference of temperature which is obſerved in different places, it became an object with philoſophers to diſcover ſome fixed points from which the whole amount of the changes for any given period could be aſcertained. This was firſt thought of by Mayer, who propoſed the method uſed by aſtronomers, of finding the mean of certain large periods, as for years and months; and he made the diſcovery by which the mean annual temperature of two latitudes being known, the mean annual temperature for every other degree of latitude may be alſo found. The application of this rule has been greatly improved and extended by Mr Kirwan, and upon this principle he conſtructed tables which exhibit the mean annual temperature for all degrees of latitude from the equator to the poles.

2169 Annual temperature.

Theſe tables were conſtructed by finding from obſervation the temperature of what he calls a ſtandard ſituation, that is, a place leſs liable to be affected by adventitious cauſes, but where the cauſe of temperature, or the communication of heat from the ſource, was moſt uniform and conſtant; and having diſcovered this ſtandard ſituation, to compare the temperature of every other ſituation with it. The land, Mr Kirwan thought, owing to the operation of cauſes which occaſion variations leſs eaſily appreciable, would not afford reſults ſufficiently uniform. This ſituation, he then concluded, was to be ſought for on the water, and that part of the ocean which he choſe, was the immenſe tract of water which includes that part of the Atlantic lying between the 80° of north latitude, and the 45° of ſouth latitude, extending weſtward as far as the gulf ſtream, and to within a few leagues of the coaſt of America; and all that part of the Pacific ocean reaching from the 45° north latitude to the 40° ſouth latitude, and from the 20° to the 275° of longitude eaſt from London. This includes the greater part of the ſurface of the globe. But for the method of conſtructing theſe tables, and for the tables themſelves, we refer our readers to the article METEOROLOGY, where they will be inſerted.

The difference of temperature, it may be obſerved, within 10° of the equator and within the ſame diſtance from the poles, is very ſmall, and the variation of temrature for different years within the ſame ſpace, is alſo found to be very little; but as the diſtance increaſes from the equator towards the poles, the difference of temperature is greater. In latitudes under 35°, it ſcarcely ever freezes, excepting in very elevated ſituations, and it ſcarcely ever hails in latitudes higher than 60°. In places near the ſea, between the latitudes of 35° and 60°, it generally thaws when the ſun's altitude is 40°, and ſeldom begins to freeze till the meridian altitude be below 40°.

2170 Monthly.

4. Mr Kirwan has alſo conſtructed tables to mark the mean monthly temperature. In every latitude the mean temperature of the month of April approaches nearly to the mean annual heat of that latitude. And from this analogy he proceeded, ſuppoſing that the temperature is always regulated by the direct action of the ſolar rays, unconnected with other circumſtances which occaſion conſiderable variations. Taking all theſe into the account, and endeavouring to reduce them to ſtrict calculation, he found it impracticable; and therefore he conſtructed his tables, partly from principle, and partly from the beſt obſervations he could procure from ſea journals, and ſimilar ſources of information. The mean monthly temperature in theſe tables alſo refers to the ſtandard ocean.

2171 Coldeſt ſeaſon.

The coldeſt weather prevails about the middle of January in all climates, and the warmeſt in July; but if it depended immediately on the ſun's heat, the greateſt heat ſhould prevail in the latter end of June, and the greateſt cold in the latter end of December.

2172 Warmeſt.

But as the earth requires a conſiderable time to abſorb heat, ſo alſo it is ſome time before what has been abſorbed is given out. All theſe obſervations and calculations refer to the ſurface of the ocean, which is leſs ſubject to variation from cauſes, the influence of which could not be aſcertained with preciſion.

2173 The earth heats the atmoſphere.

6. But as the earth is the chief ſource of heat in the atmoſphere that ſurrounds it, the temperature muſt decreaſe with the elevation above the earth, and in the higheſt regions of the atmoſphere, where the air is perfectly free from clouds, the greateſt cold muſt prevail. Hence, in conſequence of this elevation above the level of the ocean, the higheſt mountains, even under the equator, are covered with perpetual ſnow. Mr Bouguer found the cold on the top of Pinchinca in South America, immediately under the line, to vary from 7° to 9° below the freezing point every morning before ſunriſe, and hence at a certain height which varies in almoſt every latitude, it conſtantly freezes at night in every ſeaſon; although in ſome latitudes, in the warmer climates, it thaws next day. This height he calls the lower term of congelation, and he places it at the height of 15,577 feet between the tropics. In latitude 28° he thinks it ſhould commence in ſummer at the height of 13,440 feet above the level of the ſea. But at ſtill greater heights it never freezes at all, becauſe the vapours do not aſcend ſo high. This height Mr Bouguer denominates the *upper term of congelation*; and immediately under the

the equator he fixes it at 28000 feet. As the weather is not ſubject to great variations under the equator, the height of both theſe terms is nearly conſtant, but in other latitudes this height is variable, both in ſummer and winter, in proportion to the degree of heat which prevails; and as there is a mean annual temperature peculiar to each latitude, ſo is there a mean height for each of theſe terms peculiar to each latitude. By taking the differences between the mean temperatures of every latitude, and the point of congelation, it will appear that whatever proportion the difference under the equator bears to the height of either of theſe terms, the ſame proportion will the difference peculiar to every other latitude bear to their height.

2174 Land and water different in temperature.

7. But there is not the ſame uniformity or capacity in air, land, and water, for receiving and returning heat. Hence ariſe very conſiderable deviations in the temperature of places, as they are more or leſs connected with theſe bodies. Air, when it is perfectly tranſparent, receives very little heat from the rays of the ſun as they paſs through it. Air which is over ſeas or large tracts of water, is generally many degrees warmer in winter, and colder in ſummer, than air which is incumbent on land, becauſe the land receives the heat much more readily than the water; in general the air participates of the temperature of thoſe ſubſtances with which it is in contact. Land, if dry, receives heat rapidly, but tranſmits or conducts it to great depths very ſlowly; but water receives it more ſlowly, and diffuſes it more rapidly. From experiments made by Dr Hales, it appears that the earth is much heated during the ſummer, but that this heat deſcends very ſlowly, great part of it being communicated to the air; that during winter, the earth gives out to the air the heat it had received during the ſummer, and that wet ſummers muſt be ſucceeded by cold winters, becauſe the heat is carried off by the greater proportion of evaporation during the wet ſeaſon. At the depth of 80 or 90 feet below the ſurface of the earth, the temperature is found to vary very little, and it generally approaches to the mean annual heat. The temperature of the cave at the obſervatory of Paris, which is 90 feet below the pavement, is about 53.5°. The greateſt variation which has been obſerved, does not exceed half a degree, and this only happens in very cold years. Hence, too, the temperature of ſprings is almoſt uniformly the ſame throughout the year, and correſponds with the mean annual temperature of the climate.

2175 Temperature varies according to the height of places.

8. There is not only a conſiderable difference in the temperature of land and water; but this variation alſo holds with regard to the land itſelf, according as it is elevated above the ſurface, and according to the nature of the ſurface, whether it is covered with vegetables, or only exhibits bare rocks, or ſterile ſand. A conſiderable deviation alſo is obſerved to take place, in proportion to the diſtance from the ocean. All theſe cauſes, however, are greatly modified by the relative ſituation of places with regard to ſeas and oceans, mountainous regions, and extenſive tracts of level country covered with thick foreſts, or improved by cultivation. Theſe cauſes too are modified by particular winds, which produce conſiderable deviations, as they proceed from the ocean, from low, flat countries, or elevated regions.

2176 Preſſure.

9. Another remarkable change to which the atmoſphere is ſubject, is the difference of its weight or preſſure. The air, like all other matter, is influenced by the law of gravitation, by which it preſſes with a certain force on the ſurface of the earth. It has been found that the meaſure of this force is nearly equal to 15lb. on every ſquare inch. The variations which take place in the atmoſphere are meaſured by the barometer. The mercury in the barometrical tube is ſupported by a column of air of an equal baſe, and ſince this column of air and the mercury in the tube mutually balance each other, it follows that they are of the ſame weight, and therefore the barometer may be employed as a meaſurer of the weight or preſſure of the air.

1177 The ſame at the level of the ſea.

10. The firſt general fact with regard to the weight of the atmoſphere is, that in all places at the level of the ſea, the barometer ſtands nearly at the ſame point, and the mean height is about 30 inches. But as the elevation is increaſed, the barometer ſinks, becauſe then there is a ſhorter column of air to ſupport it, which is therefore lighter. In no place does the weight of the air continue always the ſame. It is ſubject to daily variations, which are greater or ſmaller according to the latitude of the place, or the influence of particular cauſes. In all places within the tropics, the variations of the barometer have been obſerved to be ſmalleſt, and in elevated ſituations the variations are conſiderably ſmaller than on the level of the ſea. The deviations of the mercury from its mean annual altitude are more frequent and extenſive in the neighbourhood of the poles than in that of the equator, and they are greater and more frequent without the tropics in winter than in ſummer.

2178 Cauſes.

11. The cauſes which have been propoſed to account for theſe variations, are changes of temperature, velocity of winds, and the agency of vapours. The air is ſubject to the action of heat, by which it is rarefied or condenſed, according to the increaſe or diminutions of temperature. Denſe air is heavier than that which is rarer; but if the maſſes of air remain the ſame, the weights muſt be the ſame, and conſequently the heights to which they elevate the mercury will be alſo equal. If, therefore, a change of temperature occaſion a variation of the barometer, it muſt be by increaſing or diminiſhing the maſs of the atmoſphere. But it appears from obſervation, that a variation of the maſs of the atmoſphere is not a neceſſary conſequence of a change of temperature, for the mercury is often at the ſame height at different ſeaſons, and at different places at the ſame time, when the difference of temperature is very great. But even when the mercury changes with the temperature, this variation is often directly contrary to what it ought to be. The barometer has ſometimes riſen with an increaſe of temperature, inſtead of falling by the rarefaction of the air. The changes of temperature are very inconſiderable in the higher regions of the atmoſphere, ſo that it would appear that the barometer can be little affected by changes of temperature. Mr Kirwan has endeavoured to ſhow, that the influence of winds, or a greater or ſmaller quantity of vapours exiſting in the atmoſphere,

can have little effect in elevating or depreſſing the barometer. According to Mr Kirwan, the variations of the barometer, or the difference of preſſure of the air of the atmoſphere, can only be accounted for from an accumulation of air over thoſe places in which the mercury exceeds its mean height, and from the diminution or ſubtraction of the natural quantity of air, over thoſe regions in which the mercury falls below its mean height.

2179 Winds.

12. The winds conſtitute another remarkable change in the atmoſphere. The winds in general are ſubject to great irregularity; but in ſome parts of the world they are pretty regular and uniform. Between the 30° of N. Lat. and the 30° of S. Lat. the wind, when it is not counteracted by local cauſes, continues to blow conſtantly from the ſame points. On the north ſide of the equator, that is, from the equator to the 30° of N. Lat. it blows from the north-eaſt, and from the equator to the 30° S. Lat. it blows from the ſouth-eaſt. This is called the *trade-wind.* Immediately under the equator the wind is obſerved to be pretty nearly from the eaſt; that is, about the place where the two currents meet, the one from the north eaſt, and the other from the ſouth-eaſt; but receding from the equator, the direction of it deviates more and more from the eaſterly point, till it reaches the intermediate point beween north and ſouth, and then conſtitutes the north-eaſt trade-wind on the north ſide, and the ſouth-eaſt trade-wind on the ſouth ſide of the equator. Were the cauſes which produce this conſtancy and uniformity of the trade-winds uninfluenced by others, theſe winds would prevail without variation within the limits or near the boundaries of the torrid zone: but they are greatly counteracted, and ſubject to great variations, from the unequal influence of land and water, in rarefying or condenſing the air.

2180 Trade-winds.

13. As the air of the atmoſphere is a fluid body, and therefore ſubject to all the laws of fluids, if any part be removed, the remainder ruſhes in to reſtore the equilibrium, and hence an agitation or wind is produced, as air is capable of indefinite dilatation and compreſſion. The denſer air being heavier, muſt ſink, and the rarefied air aſcends, when air of unequal denſities is mixed together. The greateſt degree of mean temperature is within the torrid zone, in conſequence of the ſun's rays being more perpendicular, and acting with greater force on the earth's ſurface. The air therefore round the equator undergoes the greateſt degree of rarefaction, and this extends to the north and ſouth, in proportion to its diſtance from the equator, or rather its diſtance from the ſun's place. Thus, when the ſun is perpendicular to the equator, or middle part of the torrid zone, the air in that place being moſt rarefied, becomes lighter, aſcends, and its place is filled with the colder air from the north and ſouth. And thus, as long as the ſun's influence continues to rarefy the air, would a north and ſouth wind blow to that quarter where the rarefied air, being rendered lighter, had aſcended. But as the earth has a diurnal motion on its axis from weſt to eaſt; thoſe parts of the earth's ſurface to the weſtward are firſt heated, and conſequently the incumbent air is firſt rarefied. The denſer air from the eaſt muſt therefore ruſh in to reſtore the equilibrium. Thus, there is produced an eaſterly wind. But there is another current of air from the north and ſouth: the two currents coming from the north-eaſt trade-wind on the north ſide of the equator, and the ſouth-eaſt trade-wind on the ſouth ſide. Such are the cauſes which are generally ſuppoſed to produce the regular trade winds.

2181 Deviations.

14. Theſe winds are regular and uniform in open oceans, ſuch as the Pacific or Atlantic, but they are ſubject to conſiderable variation from the unequal rarefaction of the air over land and water. Thus, iſlands ſituated within the very courſe of the trade-winds have regular land and ſea breezes, which are often directly contrary to the trade-wind. In conſequence of the air incumbent on the land being more rarefied during the day, the wind blows from the ſea, conſtituting the ſea breeze; but the air over the ſea being warmer during the night, the wind blows from the land, from which it is called the *land wind.* To a ſimilar cauſe is owing another remarkable deviation from the uniformity of the trade winds, which is obſerved in the great Indian ocean. Here the winds called *monſoons* blow from one quarter during ſix months of the year, and from an oppoſite direction during the remaining ſix months. While the ſun is in the northern tropic, the air over the extenſive Indian continent is greatly rarefied; and, in conſequence of this rarefaction, the denſer air from the ocean ruſhes in to reſtore the equilibrium, and hence the current of the air or wind continues during this period of the year, conſtituting the ſouth-eaſt monſoon. But when the ſun paſſes the equator to the ſouthward, the air over the ſouthern hemiſphere is more influenced by his rays, and therefore more rarefied. The denſer air then ruſhes in from the north, and thus produces the north-weſt monſoon, which blows during our winter, when the ſun is in the ſouthern tropic.

2182 Monſoons.

2183 Part of the air ſuppoſed to be abſtracted.

15. But even a ſuperficial obſervation will ſhew, that the phenomena of the winds cannot be ſatisfactorily accounted for, merely upon the general principle of the unequal rarefaction of the air over land and water. Thus, ſudden changes of wind often happen in particular places, which are extremely limited, and altogether unconnected with the difference of denſity of the air over land and water. The hurricane has ſwept the land, whoſe effects have not been felt on the neighbouring ocean, and the ſtorm frequently agitates the ocean without reaching the land. Theſe and other phenomena of the winds, equally inexplicable, have been aſcribed by naturaliſts to the abſtraction or ſudden deſtruction of a certain quantity of the air of the atmoſphere in particular places. But for the full diſcuſſion of this ſubject and the other phenomena of the atmoſphere, we muſt refer our readers to METEOROLOGY.

CHAP. XVI. OF WATERS.

1. We have already treated of the component parts of water, of the diſcovery of its compoſition, and of its moſt remarkable properties; and eſpecially thoſe which it exhibits by a change of conſtitution, as in the ſolid ſtate or that of ice, in the liquid ſtate, and in the ſtate of vapour. In theſe views water was conſidered as perfectly pure; but this is rarely or never the caſe, as it is found in nature. Rain water, which is the pureſt, is not entirely free from impregnation, even when collected

2184 Water not found pure.

lected before it falls to the earth. It is ſlightly contaminated with certain ſubſtances, which it held in ſolution, as it exiſted in the clouds, or with which it combined in its paſſage through the atmoſphere. But waters as they flow on the ſurface of the earth, or are carried through the ſtrata under the ſurface, muſt diſſolve thoſe ſoluble ſubſtances with which they come in contact. It is the object of our preſent inveſtigation to examine the waters as they are found in nature, and the ſubſtances with which they are impregnated.

2. The properties of pure water are almoſt obvious to the ſenſes, ſo that few ſubſtances, at leaſt in any quantity, can be diſſolved in water, without being eaſily recognized. Thus, the ſaline, nauſeous taſte of ſea-water, the fetid odour, or the aſtringent taſte of mineral ſprings, muſt readily be diſtinguiſhed by theſe ſtriking qualities. But although it is probable that the remarkable diverſity of waters, from their obvious properties, could not fail to be early obſerved by mankind, it is only by chemical inveſtigation that the nature of the ſubſtances to which they owe theſe properties, can be aſcertained; and indeed we are indebted to the diſcoveries and improvements of modern chemiſtry for the knowledge which we poſſeſs of the nature and proportion of the ingredients which enter into the compoſition, either of ſea water or mineral ſprings.

2185 Can only be examined by chemical agents.

This ſubject has been particularly inveſtigated by Bergman, Weſtrumb, Black, Fourcroy, Klaproth, and Kirwan. In the three following ſections we propoſe to treat, 1. Of ſea-water; 2. Of mineral waters; 3. Of the method of analyzing them.

SECT. I. *Of Sea-water.*

2186 Properties.

1. The ſaline taſte of ſea-water, we have already obſerved, could not fail to make it be diſtinguiſhed from pure water; and this taſte, it is well known, is chiefly derived from common ſalt which it holds in ſolution. Sea-water is alſo diſtinguiſhed by a nauſeous bitter taſte, which is aſcribed to the animal and vegetable matters which are floating in it. This taſte has been conſidered as in ſome meaſure foreign to it; for it is only found in the water on the ſurface of the ocean or near the ſhores. Sea-water taken up at conſiderable depths, contains only ſaline matters. The ſpecific gravity of ſea-water varies from 1.0269 to 1.0285. Its greater denſity is owing to the ſalts which are diſſolved in it; and to this impregnation alſo it is owing, that it is not frozen till the temperature is reduced nearly to 28°.

2187 Salts.

2. The ſalts which are chiefly found in ſea water, are muriate of ſoda, or common ſalt, muriate of magneſia, ſulphate of magneſia, ſulphate of lime and ſoda. The quantity of ſaline ingredients in the waters of the ocean varies from $\frac{1}{24}$ to $\frac{1}{31}$ part. Mr Kirwan makes the average quantity about $\frac{1}{28}$ of its whole weight. The quantity of ſaline contents of water, taken up by Lord Mulgrave at the back of Yarmouth ſands, in latitude 53°, amounted nearly to $\frac{1}{32}$; while Bergman found the water taken up in the latitude of the Canaries to contain about $\frac{1}{24}$ of its weight of ſaline matter. Theſe quantities, however, vary, even in the ſame latitude, during rainy and dry ſeaſons, near the land, or the mouths of great rivers. The difference of latitude does not ſeem to make any conſiderable difference in the proportion of ſaline matter. In latitude 80° north, 60 fathoms under ice, ſea water taken up by Lord Mulgrave, yielded about $\frac{1}{28}$; in latitude 74° nearly the ſame; and in latitude 60°, $\frac{1}{29}$. Pages obtained four per cent. from water taken up in latitude 81°, and the ſame quantity of ſaline matter from water taken up in latitudes 45° and 39° north. In ſouthern latitudes, the proportion was ſtill greater; he found it to contain the following proportions:

2188 Proportion varies.

2189 In ſouthern latitudes.

Lat. 49° 50′ S.	4.1660 per cent. of ſaline matter.
46° 00′	4.5
40° 30′	4
28° 54′	4
20° 00′	3.9
1° 16′	3.5

In the Mediterranean the proportion is ſaid to be ſtill greater; but the Euxine and Caſpian ſeas are found to be leſs ſalt than the ocean. This alſo is the caſe with the Baltic. If the ſaline matters of the waters of the ocean did not conſiſt of different kinds, the proportion of ſalts which it contains might be aſcertained by the ſpecific gravity. In the following table the ſpecific gravity of ſea water taken up in different latitudes has been determined by Mr Bladh. The temperatures are reduced by Mr Kirwan to 62° of Fahrenheit; and the longitude is reckoned by Bladh from Teneriffe.

2190 Specific gravity in different latitudes.

Lat.	Long.	Sp. Gr. at 62°
N.	E.	
59° 39′	8° 48′	1,0272
57° 18′	18° 48′	1,0269
	W.	
57° 1′	1° 22′	1,0272
54° 00′	4° 45′	1,0271
44° 32′	2° 04′	1,0276
	E.	
44° 07′	1° 00′	1,0276
40° 41′	0° 30′	1,0276
34° 40′	1° 18′	1,0280
29° 50′	0° 00′	1,0281
	W.	
24° 00′	2° 32′	1,0284
18° 28′	3° 24′	1,0281
16° 36′	3° 37′	1,0277
14° 56′	3° 46′	1,0275
10° 30′	3° 49′	1,0272
5° 50′	3° 28′	1,0274
2° 20′	3° 26′	1,0271
1° 25′	3° 30′	1,0273
S.		
0° 16′	3° 40′	1.0277
5° 10′	6° 00′	1,0277
10° 00′	6° 05′	1,0285
14° 40′	7° 00′	1,0284
20° 06′	5° 30′	1,0285
25° 45′	2° 22′	1,0281
	E.	
30° 25′	7° 12′	1,0279
37° 37′	68° 13′	1,0276

From this table it appears that the proportion of ſaline matter is greateſt near the tropics; and the ſmaller quantity near the equator is aſcribed to the great quantity of rain that uſually falls on that part of the globe.

2191 In the Baltic. 3. The experiments of Mr Wilcke ſhow that the proportion of ſaline matter in the Baltic is leſs than that of the ocean; and that it is ſalter during the prevalence of a weſterly wind, by which the water is driven from the ocean, than during an eaſterly wind. The following is the ſpecific gravity of the waters of the Baltic, taken during the prevalence of different winds, and reduced by Mr Kirwan to the temperature of 62°.

Wind.	Specific gravity.
Eaſt,	1.0039
Weſt,	1.0067
Weſt, a ſtorm,	1.0118
North-weſt,	1.0098

From this it appears, that the proportion of ſaline matters in the Baltic is increaſed by the influx of water from the ocean, and is conſiderably influenced during a ſtorm, when the wind blows from that quarter.

4. Dr Watſon has eſtimated the quantity of ſalt in water of different ſpecific gravities. It is alſo reduced to the temperature of 62° by Mr Kirwan, as in the following table.

Salt.	Specific gravity.
$\frac{1}{24}$	1.0283
$\frac{1}{25}$	1.0275
$\frac{1}{26}$	1.0270
$\frac{1}{27}$	1.0267
$\frac{1}{28}$	1.0250
$\frac{1}{30}$	1.0233
$\frac{1}{39}$	1.0185
$\frac{1}{44}$	1.0033
$\frac{1}{56}$	1.0105
$\frac{1}{108}$	1.0040
$\frac{1}{162}$	1.0023

Theſe experiments were made with ſolutions of common ſalt, which was not perfectly pure, and therefore it is allowed that they may correſpond pretty nearly with the proportions of ſaline matter in ſea-water of the ſame ſpecific gravities.

2192 Proportions. 5. The proportions of the different ſalts in an analyſis by Bergman, are the following.

Muriate of ſoda	30.911
Muriate of magneſia	6.222
Sulphate of lime	1.000
	38.133

In 1000 parts of water taken up near Dieppe, Lavoiſier found the following ſalts.

Muriate of ſoda	1375
——— of lime and magneſia	256
——— of magneſia	156
Lime	87
Sulphate of ſoda and magneſia	84
	1958

SECT. II. *Of* MINERAL WATERS.

2193 Characters. 1. The name of *mineral waters* has been given to thoſe waters which are diſtinguiſhed by the ſmell, taſte, or colour, from pure water; the obvious properties of which are, tranſparency and inſipidity. Theſe peculiarities of taſte, ſmell, and other properties, are owing to the impregnation of certain mineral ſubſtances which they have acquired in their paſſage through the ſoil or ſtrata of the earth. The effects which ſuch waters produce on the animal economy, early attracted the attention of mankind, and led to their application as remedies in the cure of diſeaſes. It was long indeed before any other diſtinction of mineral waters was made, except what was indicated by their ſenſible qualities, and their effects on the human conſtitution. 2194 Claſſes. From theſe properties mineral waters have been divided into four claſſes: 1. Acidulous or gaſeous waters; 2. Saline waters; 3. Sulphureous or hepatic waters; and 4. Chalybeate waters.

2195 Acidulous. 1. Acidulous waters are diſtinguiſhed by their penetrating acid taſte, the facility with which they boil; by ſparkling when they are poured into a glaſs; and by the emiſſion of bubbles of air, by agitation. The acid with which they are impregnated is generally the carbonic. Theſe waters redden the tincture of turnſole, and precipitate lime-water.

2196 Saline. 2. The ſecond claſs, or the ſaline waters, are ſufficiently characterized by their taſte, which varies according to the nature of the ſalt with which they are impregnated.

2197 Sulphureous. 3. The ſulphureous or hepatic waters are at once recognized by their fetid odour, and by blackening ſome metallic ſubſtances, as lead and ſilver. Some of theſe waters are impregnated with ſulphurated hydrogen gas, while in others it is combined with lime, or with an alkali.

2198 Chalybeate. 4. The fourth claſs, or the chalybeate waters, are diſtinguiſhed by an aſtringent taſte. With the pruſſiate of lime they give a blue colour, or a black with the infuſion of nut galls. This property is owing to a portion of iron which is held in ſolution, either by carbonic or ſulphuric acid. Sometimes carbonic acid is in exceſs, and then the water has a penetrating ſlightly acid taſte.

2199 Subſtances found in mineral waters. 2. The ſubſtances which have been found in mineral waters, as they have been enumerated by Mr Kirwan, belong either to the claſs of gaſeous bodies, acids, alkalies, earths, or ſalts.

2200 Gaſes. 3. Oxygen gas was firſt diſcovered in waters by Scheele. It is generally in ſmall proportion, and does not exiſt in waters with ſulphurated hydrogen gas, or iron, becauſe it is incompatible with theſe ſubſtances. Azotic gas has been found in the waters of Buxton, Harrowgate, and Lemington Priors. Common air was firſt diſcovered in mineral waters by Mr Boyle; the quantity ſcarcely exceeds $\frac{1}{28}$ of the bulk of the water. Fixed air or carbonic acid was firſt diſcovered in Pyrmont waters by Dr Brownrig. The proportions are very variable; but there are few mineral waters which are entirely free from it. A hundred cubic inches of moſt waters, contain from 6 to 40 of carbonic acid gas. A hundred cubic inches of Pyrmont waters contain, according to Bergman, 95 of fixed air; according

ing to Dr Higgins, 160, and according to Weſtrumb, 187 cubic inches. Sulphurated hydrogen gas is the principal ingredient in ſulphureous or hepatic water. Carbonated hydrogen gas is ſaid to have been detected in ſome mineral waters in Italy.

2201 Acids. 4. The next claſs of ſubſtances found in mineral waters, are the acids. Sulphuric acid has never been found, except in combination with other ſubſtances, forming ſalts in mineral waters. With ſome of theſe ſalts it exiſts in exceſs. Sulphurous acid has been detected in many of the hot mineral ſprings in Italy, in the vicinity of volcanoes. Muriatic acid has only been found in mineral waters, in combination with other ſubſtances. Nitric acid is ſaid alſo to exiſt in mineral waters in Hungary, in a combined ſtate. Boracic acid has been found in a ſeparate ſtate, in ſome lakes in Italy.

2202 Alkalies. 5. The alkalies are rarely found uncombined in mineral waters. In the ſtate of carbonate they are frequent. Soda only was detected in the hot mineral ſprings of Iceland, by Dr Black.

2203 Earths. 6. Few of the earths, except in combination, have been found in mineral waters. Lime, it is ſaid, exiſts uncombined in ſome waters; but Bergman obſerves that it muſt be in hot, and not in cold mineral waters. Dr Black detected ſilica in the waters of Geyſer and Rykum in Iceland. It has been found in thoſe of Carlſbad by Klaproth, and it has not unfrequently been obſerved by others in different mineral waters.

2204 Salts. 7. The ſalts which have been found in mineral waters, are ſulphates, nitrates, muriates, and carbonates.

Sulphates.—Sulphate of ſoda is frequently found in the waters of ſprings and lakes. Sulphate of ammonia has been found in mineral waters, in the neighbourhood of volcanoes. Sulphate of lime is one of the moſt common ſubſtances in moſt ſprings. Sulphate of magneſia or Epſom ſalt, is not unuſual in many mineral ſprings. Sulphate of alumina is rarely found in mineral waters; it is more commonly found in the ſtate of triple ſalt or alum. Sulphate of iron is frequent in the ſprings and lakes of volcanic countries. It has alſo been found in other places. Sulphate of copper has only been detected in the waters which iſſue from copper mines.

Nitrates.—Nitrate of potaſh or nitre, is rarely found in mineral waters. It has, however, been detected in ſeveral ſprings in Hungary; ſome traces of it have been obſerved in wells in Berlin, and in ſome ſalt ſprings in Germany. Nitrate of lime has been detected in ſprings in the ſandy deſerts of Arabia. Nitrate of magneſia is ſaid alſo to have been found in mineral waters.

Muriates.—Muriate of potaſh is but rarely found in mineral waters. It has been detected in the ſprings of Uleaburg in Sweden. Muriate of ſoda or common ſalt exiſts in almoſt all waters, as well as in the ocean. Muriate of ammonia is not very frequent in waters; it has been detected, however, in ſome mineral lakes in Italy, and alſo in Siberia. Muriate of barytes is very rare, but according to Bergman, it has been found in ſome mineral waters. Muriate of lime is very generally found in mineral ſprings. Muriate of magneſia is very common in mineral waters. Muriate of alumina has been detected in ſome mineral waters by Dr Withering. Muriate of mangane ſe was found by Bergman in ſome mineral waters in Sweden, and it has lately been diſcovered, in ſmall proportion, in the waters of Lemington Priors, by Mr Lambe.

Carbonates.—Carbonate of potaſh, it is ſaid, has been found in ſome mineral waters. Carbonate of ſoda exiſts very frequently in the waters of many ſprings and lakes. Carbonate of ammonia has been found in the waters of Rathbone place in London, by Mr Cavendiſh, and in ſome waters in France. Carbonate of lime is commonly found in almoſt all waters, and it is held in ſolution by an exceſs of carbonic acid. Carbonate of magneſia very frequently exiſts in mineral waters. When it is fully ſaturated with carbonic acid, it is ſoluble in water, without any exceſs of acid. Carbonate of alumina is ſaid to have been found in the waters of Avor in Anjou, in France. Carbonate of iron is frequently found in mineral waters. It is to this that chabybeate waters owe their diſtinguiſhing properties.

8. *Borax*, or the ſubborate of ſoda, is found in ſome lakes in Thibet and Perſia.

2205 Hydroſulphurets. 9. *Sulphurated alkali* and *ſulphurated lime*, or the hydro-ſulphurets of ſoda and of lime, have been found in mineral waters. It is to theſe ſubſtances that hepatic or ſulphureous waters owe their diſtinctive properties.

2206 Bitumen. 10. Bituminous ſubſtances have alſo been diſcovered in ſome mineral waters. Sometimes they have been found combined with an alkali. Waters alſo ſometimes contain vegetable and animal matters, but theſe are not, properly ſpeaking, to be conſidered as ingredients in theſe waters.

SECT. III. *Of the* ANALYSIS *of* MINERAL WATERS.

2207 Phyſical properties. In the analyſis of mineral waters, the firſt thing to be attended to is to aſcertain the temperature and ſituation of the ſprings from which they are obtained. The ſenſible properties are then to be examined, ſuch as colour, tranſparency, ſmell and taſte. Of the phyſical properties of mineral waters, one of the moſt important and the firſt to be aſcertained, is the ſpecific gravity. By this means although not with perfect accuracy, the quantity of ſaline ingredients may be known. But it is only by means of chemical operations that the nature of the ſubſtances with which mineral waters are impregnated, can be determined; and by obtaining theſe ſubſtances in a ſeparate ſtate, or forming new combinations, that their quantity or proportions can be accurately aſcertained. In the analyſis of mineral waters, therefore, after diſcovering their phyſical properties, the object of the chemiſt is firſt to detect the nature of the ſubſtances, and then the quantity or proportion of theſe ſubſtances which they contain. In both theſe we ſhall follow the method pointed out by Mr Kirwan, in his Eſſay on the analyſis of mineral waters.

I. Of the Method of Diſcovering the Subſtances in Mineral Waters.

1. The nature of the component parts of mineral waters is diſcovered by the addition of certain ſubſtances which produce changes of different kinds. The ſub-

2208 Teſts.

ſtances employed for this purpoſe are known in chemiſtry by the name of *teſts* or re-agents, becauſe they act upon the ſubſtances with which the waters are impregnated, by decompoſing them, and forming new combinations.

2209 Gaſeous bodies.

2. Gaſeous ſubſtances are eaſily detected, either by their eſcaping in the form of bubbles when the water is expoſed to the air, or, if they are more permanently held in ſolution, by boiling a quantity of the water in a retort, and receiving the gas over water or mercury. The nature of the gas, thus collected, may then be examined by the uſual teſts for gaſes.

2210 Carbonic acid.

3. Carbonic acid is detected by the infuſion of litmus, not, however, when the acid is ſaturated with any baſe, unleſs the acid be in exceſs. Saturated lime water may alſo be employed as a teſt for carbonic acid. One cubic inch of carbonic acid gas in 7000 grains of water, may be diſcovered by this teſt. Theſe effects are not produced by carbonic acid, after the water has been boiled.

2211 Mineral acids.

4. The infuſion of litmus, or paper tinged with it, is alſo employed as a teſt for mineral acids exiſting in waters. A red colour is produced, either when the acid is uncombined, or united with a baſe in exceſs. In this caſe the redneſs is permanent, and is not deſtroyed by boiling.

2212 Sulphurated.

5. Sulphurated hydrogen gas reddens the infuſion of litmus, and blackens ſilver or lead, or the ſolutions of theſe ſalts. It is alſo eaſily recognized by its peculiar odour.

2213 And carbonated hydrogen gas.

6. Carbonated hydrogen gas burns with common air without exploſion; is not abſorbed by lime-water, and has no peculiar ſmell.

2214 Fixed alkalies.

7. The fixed alkalies produce a reddiſh brown colour with the infuſion of turmeric. The ſame change takes place with the alkaline and earthy carbonates. The infuſion of Brazil wood aſſumes a blue colour. Paper tinged blue with litmus, and reddened with vinegar, may be alſo employed as a teſt for alkalies; and by all the alkaline and earthy carbonates, the original blue colour is reſtored. The muriate of magneſia is precipitated only by the fixed alkalies. Potaſh forms with nitric acid a priſmatic ſalt; with acetic acid a ſalt which does not deliqueſce, and with ſulphuric acid, a ſalt which effloreſces. Ammonia, when in conſiderable quantity, is detected by the ſmell. If the proportion be ſmall, it may be diſcovered by diſtilling part of the water with a gentle heat.

2215 Carbonates.

8. The carbonates of the earths and the metals are precipitated by expoſure to the air, or by boiling and evaporation. Carbonates of lime, of alumina, and of iron, are precipitated by boiling for a quarter of an hour. Carbonate of magneſia is only partially precipitated by the ſame proceſs.

2216 Iron.

9. Iron, either in the ſtate of carbonate, or combined with ſome other acid, is detected by tincture of galls, which produces a black or purple colour. A very minute portion of iron is detected by this teſt. Three grains of cryſtallized ſulphate of iron diſſolved in five pints of water, ſtrike a purple colour in five minutes, with a ſingle drop of this tincture. With this teſt the colour aſſumes different ſhades, according to the nature of the other ſubſtances which are in combination. If the water contains a carbonate of an alkali or an earthy ſalt, the colour is violet; it is dark purple with other alkaline ſalts; with ſulphate of lime it is firſt whitiſh, and afterwards black; and with ſulphurated hydrogen gas, the colour is purpliſh red. The latter, Mr Kirwan ſuſpects, is occaſioned by manganeſe. Iron diſſolved in carbonate of ammonia, is at firſt whitened, and afterwards blackened by tincture of galls. In the cauſtic fixed alkalies the precipitate is at firſt crimſon red, but afterwards becomes black. Pruſſian alkali is a ſenſible teſt of iron; the precipitate is blue: but if an alkali exiſts in the water, it prevents a ſmall portion of iron from ſtriking a blue colour with this teſt, until it be ſaturated with an acid.

2217 Sulphuric acid.

10. Sulphuric acid is detected by muriate, nitrate, or acetate of barytes; nitrate or acetate of lead, nitrate of mercury, nitrate, muriate, or acetate of ſtrontites, and nitrate, muriate, or acetate of lime.

2218 Muriatic.

11. Muriatic acid is readily detected by nitrate of ſilver. It forms a white precipitate, or a cloud in the water. If there are any carbonates of alkalies or earths in the water, they muſt be previouſly ſaturated with nitric acid. Sulphuric acid, or the ſulphates, muſt be precipitated by nitrate or acetate of barytes. Acetate and ſulphate of ſilver may be alſo employed for the ſame purpoſe.

2219 Boracic.

12. Boracic acid when it is uncombined, is detected by acetate of lead; but the alkaline and earthy carbonates muſt be previouſly ſaturated with acetic acid. The ſulphates muſt be decompoſed by means of acetate of ſtrontites, and the muriates by acetate of ſilver.

2220 Lime.

13. Lime is readily detected with oxalic acid; but if the water contains any mineral acid, it muſt be previouſly ſaturated with an alkali. Barytes, if any exiſts in the water, muſt be precipitated by ſulphuric acid. Magneſia is precipitated very ſlowly with oxalic acid, by which it is readily diſtinguiſhed from lime.

2221 Barytes.

14. Barytes is detected by diluted ſulphuric acid, with which it inſtantly forms an inſoluble white precipitate.

2222 Magneſia and alumina.

15. Magneſia and alumina are both precipitated by means of pure ammonia and lime water; but it is neceſſary that carbonic acid, if any exiſts in the water, be previouſly ſeparated by means of a fixed alkali, and by boiling. If lime-water is employed, the ſulphuric acid muſt be firſt precipitated with nitrate of barytes. If the two earths are precipitated together, the alumina may be ſeparated from the magneſia, by boiling them with pure potaſh, which combines with the alumina.

2223 Silica.

16. Siliceous earth may be diſcovered by evaporating a large quantity of water nearly to dryneſs, and then by rediſſolving the precipitate in nitric or ſulphuric acid, and afterwards evaporating to dryneſs. The dry maſs rediſſolved in water and filtered, leaves the ſilica on the filter.

2224 Sulphates.

17. Mr Kirwan gives the following directions for diſcovering the ſulphates.

Sulphate of ſoda is detected by ſeparating ammonia by gentle diſtillation, and then by evaporating to one-half, and afterwards by adding lime-water, while any precipitate is formed. By this means all the other ſulphates are precipitated. By farther evaporation, and the addition of a few drops of alcohol and oxalic acid, the whole of the lime is ſeparated. To the filtered reſiduum add a ſtrong ſolution of nitrate of lime; and if the alkaline ſulphates exiſt in the quantity of eight grains

grains in 1000 of the liquid, a precipitate will appear. To aſcertain whether the baſe of this alkaline ſalt be potaſh or ſoda, add to an equal quantity of the water acetate of barytes; filter the ſolution, and evaporate to dryneſs. Add alcohol to ſeparate the other ſalts. This ſolution filtered and evaporated to dryneſs gives an acetate of potaſh or ſoda; if the former, it deliqueſces, but if it be the latter, it effloreſces by expoſure to the air.

2225 Sulphate of lime. 18. Sulphate of lime is depoſited by evaporation to a few ounces, if it be contained in the proportion of four grains to 1000. It affords a precipitate with muriate of barytes, oxalic acid, or alcohol; the latter of the ſpecific gravity of 0.848 produces a cloud inſtantaneouſly, in a ſolution of one grain of the ſalt in 1000 of water.

2226 Alum. 19. The teſt for alum is carbonate of lime. With this, alum forms a precipitate. If the water contain muriate of barytes, it muſt be precipitated with diluted ſulphuric acid. A ſulphate of any of the metals may be precipitated by means of an alkaline pruſſiate.

2227 Sulphate of magneſia. 20. The hydroſulphuret of ſtrontites affords a good teſt for ſulphate of magneſia, and it does not give an immediate precipitate with any other ſalt; but the water ſhould be free from any exceſs of acid.

2228 Of iron. 21. Sulphate of iron is detected by expoſing it in an open veſſel to the air for a few days; or it may be precipitated from the water by means of alcohol.

2229 Muriate of potaſh and ſoda. 22. To detect the muriate of potaſh and of ſoda, it is neceſſary, firſt, to ſeparate the ſulphates, if any exiſt, in the mineral water, which is done by means of alcohol and nitrate of barytes. The earthy nitrates and muriates are decompoſed by diluted ſulphuric acid, and the nitric and muriatic acids are expelled by heat. The ſalts formed with ſulphuric acid may be ſeparated by alcohol and barytic water, ſo that nothing can now remain but alkaline nitrates and muriates. The laſt is decompoſed by acetate of ſilver, and if a precipitate is thus formed, the water contains muriate of ſoda or of potaſh. To ſeparate theſe from potaſh or ſoda, evaporate to dryneſs, and treat the dry maſs with ſtrong alcohol for 24 hours in a temperature of 60°. The acetates are thus diſſolved and depoſited by evaporation. The acetate of potaſh is known by its deliqueſcence, and the acetate of ſoda effloreſces.

2230 Of ammonia. 23. Muriate of ammonia is to be detected by firſt ſeparating the ſulphates by the acetate of barytes, and then evaporating the ſolution to dryneſs. The maſs can only conſiſt of acetates and alkaline muriates. Diſſolve the dry maſs in alcohol, and let it remain for 24 hours in the temperature of 60°. All the ſalts are diſſolved, except the alkaline muriates. The reſiduum diſtilled with quicklime will give out ammonia, which will precipitate the ſolutions of iron, alum or lead, previouſly introduced into the receiver.

2231 Of barytes. 24. Muriate of barytes is diſcovered by ſulphuric acid. This is the only barytic ſalt yet found in mineral waters.

2232 Of lime. 25. To detect muriate of lime, firſt ſeparate the ſulphate of lime by evaporation, to a few ounces; add alcohol, and afterwards nitrate of barytes. Evaporate the filtered ſolution to dryneſs, treat the maſs with alcohol; evaporate the ſolution to dryneſs, and re-diſſolve the reſiduum in water. If a precipitate be formed, by adding nitrate of ſilver, oxalic or ſulphuric acid, the ſolution then may contain muriate of lime; if to a portion of the ſolution, carbonate of lime be added, alumina is precipitated, if the muriate of alumina exiſt in the water, but not muriate or nitrate of magneſia. Pure ammonia will precipitate magneſia from its combination with the nitric or muriatic acid. And if none of theſe earths appear, the muriatic acid detected in the water muſt be united to lime.

2233 Of magneſia. 26. Muriate of magneſia is diſcovered by decompoſing the ſulphates by means of nitrate of barytes. Filter the ſolution, evaporate to dryneſs, and diſſolve the reſiduum in alcohol. Evaporate this ſolution to dryneſs, and diſſolve the reſiduum in water. The nitrates of lime and magneſia, and the muriates of lime, magneſia and alumina, can only exiſt in the ſolution. Carbonate of lime precipitates alumina; pure ammonia precipitates magneſia. Muriatic acid is detected by nitrate of ſilver. To aſcertain whether the muriatic acid be united to magneſia, treat another portion of the ſolution with ſulphuric acid and alcohol. If no alumina has been found, and no precipitate now appears, magneſia is the only earth retained in the ſolution.

2234 Of alumina and iron. 27. To detect the muriates of alumina and iron, the alkaline carbonates, if they exiſt in the water, ſhould be ſaturated with nitric acid, and the ſulphates decompoſed with nitrate of barytes. By adding carbonate of lime to a portion of the water filtered and purified, the muriates of alumina and iron will be precipitated. Muriate of manganeſe is alſo ſeparated by carbonate of lime.

2235 Nitrate of potaſh and ſoda. 28. To diſcover the nitrates of potaſh and of ſoda, precipitate the ſulphates with acetate of barytes, and the muriates with acetate of ſilver. Evaporate to dryneſs, and diſſolve the reſiduum in alcohol. The alkaline nitrates, and a portion of acetate of lime remain undiſſolved. Filter off the undiſſolved nitrates, waſh them with alcohol, and rediſſolve them in water. Carbonate of magneſia decompoſes nitrate of lime. To ſeparate the nitrate of magneſia thus formed, evaporate to dryneſs, add alcohol to the dried maſs; the nitrate of magneſia is diſſolved, but the alkaline nitrates remain untouched.

2236 Of lime. 29. To detect nitrate of lime, evaporate the water conſiderably to ſeparate the ſulphate of lime which it may contain, and add alcohol to ſeparate the other ſulphates. The ſulphates being filtered off, and the alcohol expelled by heat, oxalic acid added to the ſolution, will produce a precipitate, if there be any lime in it. Decompoſe the muriates with acetate of ſilver; filter the ſolution, and evaporate it to dryneſs; diſſolve the dry maſs in alcohol; evaporate this to dryneſs, and rediſſolve it in water. If nitrate of lime exiſt in the ſolution, ſulphuric acid will diſcover it.

2237 Of magneſia. 30. To diſcover nitrate of magneſia, the ſulphates and muriates are firſt to be ſeparated; the ſolution being filtered, and evaporated to dryneſs, the reſiduum is to be diſſolved in alcohol. Evaporate this ſolution to dryneſs, and diſſolve the reſiduum in water. Add to the ſolution pure potaſh, which precipitates the earthy acetates and the nitrate of magneſia. Filter the ſolution, evaporate to dryneſs, and treat the reſiduum with alcohol, which diſſolves the alkaline acetates,

tates, and leaves the nitrate of potaſh untouched; by which proceſs it muſt appear, that nitrate of magneſia previouſly exiſted in the water.

2238 Bitumen. 31. Alkalies combined with bitumen are ſometimes found in mineral waters. Theſe mineral ſoaps, or bituminated alkalies, as they are called by Mr Kirwan, form a coagulum with the acids. This coagulum is ſoluble in the alkalies.

2239 Extractive matter. 32. Extractive matter, which is ſometimes found in mineral waters, is diſcovered by means of nitrate of ſilver, with which it forms a brown precipitate, but the water containing it muſt be freed from ſulphuric and muriatic acids with nitrate of lead. Three grains of the precipitate, according to Weſtrumb, indicate one grain of extractive matter.

2240 Animal. 33. Animal extractive matter gives a very diſagreeable taſte and ſmell to water. It is ſoluble in alcohol.

2241 Incompatible ſalts. 34. The following is a liſt of ſalts which are incompatible with each other, or which cannot exiſt together in the ſame water.

1. Alkaline carbonates; and earthy or metallic ſulphates, muriates, or nitrates.
2. Sulphuric acid; and earthy nitrates, muriates, or carbonates.
3. Alkaline ſulphates; and earthy nitrates, or muriates.
4. Sulphate of ſoda; and muriate of potaſh.
5. Sulphate of potaſh; and nitrate of ſoda.
6. Sulphate of ammonia; and nitrate of potaſh, and muriate of potaſh.
7. Sulphate of magneſia; and nitrate or muriate of lime.
8. Alum; and nitrate of lime and of magneſia, or muriate of magneſia.
9. Nitrate of lime; and muriate of potaſh, muriate of ammonia, of barytes, or magneſia,
10. Nitrate of magneſia; and muriate of barytes, and of potaſh.
11. Muriate of magneſia; and nitrate of ſoda or lime *.

II. Of the Method of aſcertaining the Proportions of Subſtances in Mineral Waters.

2242 Phyſical properties firſt aſcertained. 1. In examining any mineral water, it has been already mentioned, that it is neceſſary, firſt to aſcertain the phyſical properties, and eſpecially the ſpecific gravity, from which the quantity of ſaline matter, as Mr Kirwan obſerves, may be eſtimated. The method he propoſes is the following. He ſubtracts 1000, the ſpecific gravity of pure water, from the ſpecific gravity of the mineral water to be examined, expreſſed in whole numbers, and multiplying the product by 1.4, which gives the weight of the ſalts freed from their water of cryſtallization. Thus, a ſolution of common ſalt, whoſe ſpecific gravity is 1.079. A thouſand ſubtracted from this leaves 79, which multiplied by 1.4 is equal to 110.6 which is the quantity of ſaline matter in 1000 parts of the ſolution of common ſalt.

2243 Gaſeous bodies. 2. After aſcertaining the phyſical properties, the firſt ſtep in the analyſis is to eſtimate the quantity of gaſeous bodies which the water contains. Theſe are, oxygen gas, azotic gas, atmoſpheric air, ſulphurated hydrogen gas, and ſulphurous acid. They are to be collected by heating a quantity of the water in a retort, and receiving the gas over water, or over mercury, if it is abſorbed by water. The nature of the gas will be aſcertained by the different teſts which have been already mentioned for detecting the gaſes, and the quantity of it may be aſcertained, by calculating the bulk, taking care to make the proper allowance for the difference of preſſure of the air and temperature. But for this ſee Mr Kirwan's method of calculation, in his Eſſay on the Analyſis of Min. Wat. p. 178.

2244 Carbonates. 3. To diſcover the carbonates which may exiſt in the water, is the next ſtep in the analyſis. There may be carbonate of lime, of magneſia, of alumina, or iron. If the water contains ſulphurated hydrogen, it muſt be ſeparated by expoſure to the air, or by means of litharge. Filter and boil a quantity of the water for half an hour. In this way it is deprived of the earthy or metallic carbonates, if the water contains no ſulphurated hydrogen. It is to be boiled for a quarter of an hour, expoſed to the air till it is cool, and filtered. Diſſolve the precipitate in diluted muriatic acid. The whole are ſoluble in this acid, excepting alumina and ſulphate of lime. Let the reſiduum be expoſed to a red heat; mark the weight, and boil it in carbonate of ſoda. Saturate the ſoda with muriatic acid, and boil the mixture for half an hour. Carbonate of lime and alumina are thus precipitated. Diſſolve the dried precipitate in acetic acid. The lime is diſſolved, but the alumina remains. The weight of the lime, after being dried, ſubtracted from the original weight, gives the proportion of ſulphate of lime. To ſeparate the iron, add ammonia to the muriatic ſolution, as long as a reddiſh precipitate is perceived. If magneſia be precipitated with the iron, expoſe the precipitate in the open air for ſome time, to a heat of about 200°; add acetic acid in ſmall quantities, to diſſolve the magneſia; the iron thus ſeparated, is to be re-diſſolved in muriatic acid, precipitated by an alkaline carbonate, and gently dried and weighed. The acetate of magneſia is next to be precipitated and eſtimated as above. The muriatic ſolution is thus freed from iron and part of the magneſia. Add ſulphuric acid as long as any precipitate appears; heat the ſolution ſlightly, and add alcohol. The ſulphate of lime is ſeparated and heated to redneſs. A hundred grains are $= 70$ of carbonate of lime. The magneſia is to be precipitated by carbonate of ſoda, dried and weighed. The whole of the carbonate of magneſia is not precipitated by boiling. Evaporate the boiled water nearly to dryneſs. The carbonate of magneſia and ſulphate of lime will be depoſited. Add a large quantity of boiling diſtilled water, which will diſſolve the ſulphate of lime, and other ſubſtances. The carbonate of magneſia remains behind, and may be collected, dried, and weighed. The carbonate of alumina and ſulphate of lime are to be eſtimated by weighing them, after they have been dried in a red heat.

2245 Sulphuric acid. 4. To aſcertain the proportion of ſulphuric acid, add barytic water to ſaturation, and weigh the precipitate after it has been expoſed to a red-heat. A hundred parts of the ſulphate of barytes contain 33 of real ſulphuric acid.

2246 Muriatic. To determine the quantity of muriatic acid, likewiſe add barytic water, till it is neutralized, then precipitate the barytes with ſulphuric acid. A hundred parts of barytes take up 31.8 of real

---

* *Analyſis of Min. Wat.* p. 34.—142.

2247 Boracic.

real muriatic acid. The proportion of boracic acid may be aſcertained by precipitating it with acetate of lead. The precipitate is to be digeſted in a heat of 200° for an hour with ſulphuric acid. Evaporate the ſolution to dryneſs, and add to the dried maſs 10 or 12 times its weight of alcohol. Diſtil and evaporate this ſolution; the boracic acid remains behind, which may be dried and weighed.

2248 Sulphate of ſoda.

5. The alkaline ſulphates are precipitated by means of nitrate of barytes. A hundred and ſeventy parts of ignited ſulphate of barytes indicate 100 of dried ſulphate of ſoda; and 136.86 of ſulphate of barytes indicate 100 of dry ſulphate of potaſh.

2249 Of lime.

6. Sulphate of lime is moſt conveniently determined by evaporating to a few ounces, and adding a few drops of alcohol, which will precipitate the ſulphate of lime. It is then to be dried and weighed. The proportion of alum in a mineral water is aſcertained by evaporating to one-half, and precipitating by means of carbonate of lime. Acetic acid added to the precipitate, combines with the exceſs of lime which may have been added. The alumina thus freed from the carbonate of lime, is to be heated to incandeſcence for half an hour. Twelve parts denote 100 cryſtallized alum, or nearly 49 of the dried ſalt.

2250 Of magneſia.

7. If no other ſulphate exiſts in the water, ſulphate of magneſia may be eſtimated by precipitating the acid with barytic ſalt. A hundred grains of ſulphate of barytes indicate 52.11 of ſulphate of magneſia. But if the water contains ſulphate of lime, without any other ſulphate, it may be decompoſed by means of carbonate of magneſia. The lime thus obtained being weighed, ſhews the quantity of ſulphate of lime. By adding barytes, the whole of the ſulphuric acid is precipitated, and thus the quantity of this acid may be eſtimated. Then by ſubtracting the quantity of ſulphuric acid belonging to the ſulphate of lime, the remaining portion indicates what was combined with the magneſia. If the water is found to contain ſulphate of ſoda, none of the earthy nitrates or muriates can exiſt along with it. If, therefore, no other earthy ſulphate has been detected, the magneſia is to be precipitated by means of ſoda, and is then to be dried and weighed; 36.68 parts indicate 100 of dried ſulphate of magneſia. If ſulphate of lime accompany theſe two ſulphates, the precipitate conſiſts both of lime and magneſia. It is then to be diſſolved in ſulphuric acid and evaporated to dryneſs. By adding twice its weight of cold water, the ſulphate of magneſia is diſſolved; the ſulphate of lime is inſoluble. Evaporate the ſulphate of magneſia to dryneſs, expoſe it to a heat of 400°, and weigh it. If the water contain alum inſtead of ſulphate of lime, the ſame proceſs may be followed. But the precipitate being dried, muſt firſt be treated with acetic acid to diſſolve the magneſia, but the alumina remains untouched. Sulphate of iron is ſeparated by expoſing the water to the air for ſome days, and then adding alumina. The iron is precipitated in the ſtate of oxide, and the ſulphate of alumina, being inſoluble, is precipitated at the ſame time. Theſe ſalts being previouſly ſeparated, the proportion of ſulphate of magneſia may be eſtimated in the way which has been already deſcribed.

2251 Of iron.

8. The proportion of ſulphate of iron may be eſtimated by the following proceſs. Let the weight of a precipitate formed with pruſſiate of potaſh in a ſolution of a known weight of ſulphate of iron in water, be previouſly aſcertained. Then with the ſame pruſſiate precipitate the ſulphate of iron in the water. But if muriate of iron has been detected in the water; evaporate to dryneſs, and add to the reſiduum alcohol, in which the muriate, but not the ſulphate, is ſoluble.

2252 Muriate of potaſh and ſoda.

9. Muriate of potaſh or of ſoda, unaccompanied with other ſalts, may be eſtimated by precipitating by means of nitrate of ſilver. 217.65 grains of muriate of ſilver denote 100 of muriate of potaſh; and 235 grains of muriate of ſilver denote 100 of muriate of ſoda. If the water contains any of the alkaline carbonates, they muſt be previouſly ſeparated by ſaturating with ſulphuric acid. The muriatic acid is then to be precipitated by ſulphate of ſilver. Muriate of ammonia is decompoſed by means of barytic water; the ammonia is expelled by boiling, the barytes is precipitated by ſulphuric acid, and the muriatic acid is ſaturated with ſoda. The ſulphate of barytes denotes the quantity of muriate of ammonia.

2253 Of lime, &c.

10. If the common ſalt be accompanied with muriate of lime, of magneſia, of alumina, or of iron, theſe may be precipitated with barytic water, and each earth waſhed, but not dried, re-diſſolved in muriatic acid. If only one of theſe ſalts be found, ſaturate the exceſs of acid with a known quantity of an earth of the ſame kind, and evaporate to dryneſs. Then deduct from the weight that of the muriate formed by the earth added: thus 50 grains of lime denote 100 of muriate of lime heated to redneſs; 31 grains of magneſia indicate 100 of muriate of magneſia; and 21.8 grains of alumina indicate 100 of muriate of alumina. The barytes is precipitated by ſulphuric acid; and the muriatic acid is driven off by heat. The muriate of ſoda may then be eſtimated by evaporation; but the proportion of muriate of ſoda, which the known quantity of muriatic acid ſeparated from the earths denotes, muſt be deducted.

If ſulphates and muriates are found accompanying each other, the former may be precipitated by alcohol, or by evaporating the whole to dryneſs. The earthy muriates may then be diſſolved in alcohol. Sulphate of lime, accompanying alkaline and earthy muriates, is decompoſed by muriate of barytes, and the precipitate of ſulphate of barytes indicates the proportion of ſulphate of line.

If muriates of ſoda, magneſia, and alumina, accompany the ſulphates of lime and magneſia, the water to be examined is to be divided into two equal portions. To precipitate the whole of the lime and alumina, add to the one portion carbonate of magneſia. The proportion of lime in ſulphate of lime is then to be aſcertained; and, by precipitating the ſulphuric acid by means of muriate of barytes, the quantity contained in the ſulphates of magneſia and of lime is aſcertained. The proportion of ſulphate of magneſia is determined by deducting this laſt portion. The whole of the magneſia and alumina is precipitated from the ſecond portion of water by lime water. The quantity of theſe earths indicates the proportion of muriate of magneſia and alumina, deducting that portion of magneſia which was diſcovered in the ſtate of ſulphate in the firſt portion of water. The ſulphuric acid is then precipitated by barytic water, and the lime by carbonic acid; the common ſalt is obtained by evaporating the water to dryneſs.

2254 Nitrate of potaſh. 11. Nitre may exiſt in water with all ſulphates and muriates which are not incompatible with each other. After ſufficient evaporation, the ſulphates are to be precipitated by acetate of barytes, and the muriates by acetate of ſilver. Filter and evaporate to dryneſs; and add to the reſiduum alcohol, which diſſolves the acetates. The nitrate of potaſh, which remains undiſſolved, may then be eſtimated. If ſoda be found in the water, it muſt be previouſly ſaturated with ſulphuric acid.

If nitre be accompanied with common ſalt, nitrate of lime, muriate of lime, muriate of magneſia, evaporate to dryneſs, and add alcohol, which diſſolves the earthy ſalts. Re-diſſolve the dry reſiduum in water, from which the nitre and common ſalt may be ſeparated by acetate of ſilver. Evaporate the ſpirituous ſolution to dryneſs, and re-diſſolve the reſiduum in water. The weight of muriate of magneſia is aſcertained by precipitating by means of nitrate of ſilver. The weight of the nitrate of lime is determined by precipitating by means of ſulphuric acid: 35 grains denote 100 of dry nitrate of lime. *

Chap. XVII. Of MINERALS.

In following out the arrangement which we have laid down at the beginning of this treatiſe, we ſhould now enter upon the conſideration of mineral ſubſtances. To preſerve the chemical inveſtigation of the different departments of nature unbroken, we propoſed to employ this chapter in a general view of the characters of mineral bodies, of their compoſition and methods of analyſis; but as this article has been unavoidably extended to ſo great a length, we ſhall reſerve the whole to the article Mineralogy, where they will be fully detailed.

Chap. XVIII. Of VEGETABLES.

2255 Diviſion of natural bodies. 1. Natural bodies may be properly divided into organized and inorganized, each of which exhibit characters ſufficiently diſcriminative. The ſubſtances included under the 17 preceding chapters, belong to the latter claſs. Organized ſubſtances are vegetables and animals, which are to be treated of in this and the following chapters. The diſtinction between theſe two claſſes of bodies, although in ſome caſes it is leſs obvious, in general is eaſily recognized. The moſt perfect forms of inorganized matter afford no marks of reſemblance to the varied and complicated ſtructure of a plant or an animal. In the mode of formation, or the growth and increaſe of the individuals of theſe two claſſes, there is the moſt ſtriking diverſity, which exhibits plain and certain characters of diſtinction. In the one claſs the growth or increaſe takes place by the mere aggregation of the particles of matter already prepared, and according to the laws of affinity between the the particles; and no new properties exiſt in the aggregate, which did not exiſt in the minuteſt particle of which it is compoſed. The other claſs of bodies, comprehending vegetables and animals, exhibits a very different proceſs. The ſubſtances which enter into their compoſition are received into tubes or veſſels, are conveyed by them to every individual part of the vegetable or animal, are ſubjected to peculiar changes, and aſſume new forms, poſſeſſing properties and qualities which could not be previouſly detected in the ſimple elements, by any chemical or mechanical operation. This is indeed the eſſential characteriſtic of vegetables and animals. The particles which compoſe a cryſtal, formed by the evaporation of water, were held in ſolution by the water, and invariably and uniformly arranged according to certain laws; but the almoſt infinite variety of ſubſtances which compoſe vegetables and animals, are not to be found in the materials which are neceſſary to promote their growth and health; neither in the water, the earth, the air, the heat nor the light, all which contribute their ſhare to the ſame end. Theſe undergo new changes, and enter into new combinations, none of which exiſted in the ſimple elements, and none of which can be effected by any mechanical or chemical proceſs. Indeed the laws which regulate vegetable and animal operations, ſeem to be totally different from the eſtabliſhed laws of chemical action. Hence from obſerving this difference of action, the exiſtence and influence of a different principle have been inferred in animals and vegetables. This has been called the *vital principle*, or the principle of life, becauſe by its influence the varied and complicated phenomena of animals and vegetables are exhibited, which cannot be accounted for on mechanical or chemical principles. It is by the influence of this principle that the animal or vegetable ſeems to poſſeſs the remarkable power of reſiſting or counteracting to a certain degree the effects of chemical or mechanical agents which may prove injurious to its exiſtence; the power of regulating and ſelecting what is beneficial and neceſſary, of ſupplying what is deficient, and of curtailing what is redundant. Organized ſubſtances admit of a natural diviſion into vegetables and animals. The bodies included under each of theſe diviſions have ſome points of reſemblance; but in general are ſufficiently characterized and diſtinguiſhed from each other, by their form, ſtructure, power of motion, component parts and peculiarities of habits. The firſt of theſe diviſions, namely vegetables, forms the ſubject of the preſent chapter.

2. A vegetable is compoſed of a root, ſtem, leaves, flowers, fruits, and ſeeds; and when all theſe different parts are fully developed, the vegetable is ſaid to be *perfect*. When any are deficient, or at leaſt leſs obvious, the vegetable is ſaid to be *imperfect*. 2256 Structure of plants.

The root is that part of the plant which is concealed in the earth, and which ſerves to convey nouriſhment to the whole plant. 2257 Root. The ſtem, which commences at the termination of the root, ſupports all the other parts of the plant. When the ſtem is large and ſolid, as in trees, it is denominated the *trunk*, which is divided into the wood and the bark. The bark conſtitutes the outermoſt part of the tree, and covers the whole of the plant from the extremity of the roots to the termination of the branches. 2258 Bark. The bark is compoſed of three parts, namely the epidermis, the parenchyma, and cortical layers. The epidermis, which is a thin tranſparent membrane, forming the external covering of the bark, is compoſed of fibres croſſing each other. When the epidermis is removed, it is reproduced.

---

* See *Anal. Min. Waters*, 175—258.

The parenchyma, which is immediately below the epidermis, is of a dark-green colour, compoſed of fibres croſſing each other in all directions, and is ſucculent and tender. The cortical layers which conſtitute the interior part of the bark, are compoſed of thin membranes, and increaſe in number with the age of the plant.

2259 Wood. The wood immediately under the bark, is compoſed of concentric layers, which increaſe with the age of the plant, and may be ſeparated into thinner layers which are compoſed of longitudinal fibres. The wood next the bark, which is ſofter and whiter, is called the *alburnum*. The interior part of the trunk is browner and harder, and is denominated the *perfect wood*.

2260 Pith. In the middle of the ſtem is the pith, which is a ſoft, ſpongy ſubſtance, compoſed of cells or *utriculi* as they are called. In old wood this part entirely diſappears, and its place is occupied by the perfect wood. The leaves are compoſed of fibres arranged in the form of net-work, which proceed from the ſtem, and footſtalks by which they are attached to the branches. Theſe fibres form two layers in each leaf, which are deſtined to perform different functions. The leaves are covered with the epidermis, which is common to the whole of the plant. Each ſurface of a leaf has a great number of pores and glands, which abſorb or emit elaſtic fluids. 2261 Flowers and fruits. Flowers are compoſed of different parts. The *calyx* or cup is formed by the extenſion of the epidermis; the *corolla* is a continuation of the bark, and the ſtamina and piſtilla, the internal parts of fructification, are compoſed of the woody fibres and pith of the plant. Fruits are uſually compoſed of a pulpy, parenchymatous ſubſtance, containing a great number of *utriculi* or veſicles, and traverſed by numerous veſſels. Seeds are conſtituted of the ſame utricular texture, in the veſicles of which is depoſited a pulverulent or mucous ſubſtance. Theſe cells have a communication with the plant by means of veſſels, and by theſe is conveyed the neceſſary nouriſhment during germination.

2262 Veſſels. Plants contain different orders of veſſels, which are diſtinguiſhed from each other by their courſe, ſituation, and uſes. Lymphatic veſſels ſerve for the circulation of the ſap. They are chiefly ſituated in the woody part of the plant. The peculiar veſſels, which generally contain thick or coloured fluids, are placed immediately under the bark; they are ſmaller in number than the ſap veſſels, and have their interſtices filled up with utriculi or cells, with which they form a communication. Some of theſe proper veſſels are ſituated between the epidermis and the bark, which are readily detected in the ſpring. Some are ſituated in the interior part of the bark, forming oval rings, and filled with the peculiar juices of the plant. Another ſet of proper veſſels is placed in the alburnum, nearer the center of the ſtock or trunk, and ſometimes in the perfect wood. The utriculi or cells conſtitute another ſet of veſſels, which ſeem to reſemble a flexible tube, ſlightly interrupted with ligatures at nearly equal diſtances, but ſtill preſerving a free communication through its whole length. They vary in form, colour, and magnitude in different vegetables, and exiſt in the roots, the bark, leaves, and flowers. The tracheæ or ſpiral veſſels, which are readily detected in ſucculent plants, appear in the form of fine threads, and may be drawn out to a conſiderable length without breaking. Theſe veſſels are very numerous in all plants, eſpecially under the bark, where they form a kind of ring, and are diſpoſed in diſtinct bundles, in trees, ſhrubs, and ſtalks of herbaceous plants.

After theſe preliminary obſervations on the characters of organized ſubſtances, and the general ſtructure of plants, we now proceed to give a ſhort view of the functions, decompoſition, and component parts of vegetables. Theſe ſhall form the ſubject of the three following ſections.

Sect. I. *Of the Functions of Vegetables.*

I. Of Germination.

2263 Temperature. 1. When the perfect ſeeds of a vegetable are placed in certain circumſtances, they produce plants exactly ſimilar to thoſe from which they originated. The requiſite circumſtances for the germination of ſeeds are, heat, air, and moiſture. It is well known that no vegetation goes on when the temperature of the air is at the freezing point, and very little till it riſes a conſiderable number of degrees above it. The ſeeds of different plants, it is obſerved, require different degrees of heat for their germination, and hence, the various ſeaſons and climates in which different plants and ſeeds are found to vegetate.

2264 Air. But whatever the temperature may be, no ſeeds germinate, unleſs they are expoſed to the action of the air. It is found that it is the oxygen of the air which is neceſſary for the production of this change; for when it is entirely excluded, no change takes place, and when it is in greater quantity, vegetation is more rapid and more vigorous.

2265 Moiſture. Moiſture is alſo neceſſary for the vegetation of ſeeds. But although water be neceſſary for this purpoſe, it muſt be applied in moderate quantity, for, except the ſeeds of aquatic plants, which are poſſeſſed of peculiar habits, moſt ſeeds are deprived of their vegetative power, and entirely decompoſed, when they are kept in water. Hence it is that many ſeeds do not vegetate in ſtiff clay ſoils, which retain too much water, nor in ſandy ſoils, which allow the whole of the water to filter through them. Many ſeeds, although they are expoſed to the favourable action of theſe agents, do not vegetate when they are expoſed to the action of light. It is on this account, and alſo no doubt, for the proper application of moiſture, that ſeeds are covered with the ſoil, by which means germination is found to be greatly promoted.

2266 Parts of ſeeds. 4. A ſeed is compoſed of three principal parts, which have been denominated the cotyledons or lobes, the radicle, and plumula. The greateſt number of ſeeds have two cotyledons. Some, however, as many of the farinaceous ſeeds, and ſeeds of graſſes, have only one. Other ſeeds have three, and ſome ſix. Hence plants have been diſtinguiſhed into *mono-cotyledinous*, *di cotyledinous*, and *poly-cotyledinous*.

2267 Root formed. 5. The firſt change which takes place on a ſeed placed in circumſtances favourable for germination, is the increaſe of ſize by the abſorption of moiſture. The radicle is then formed, which ſtretches downwards into the earth. The plumula ſhoots upwards, and expands into leaves and branches. The peculiar function of the root is to convey nouriſhment from the earth for the ſuture growth of the plant; but from what ſource is the nouriſhment derived for the formation of the root itſelf?

2268
Oxygen abſorbed.

6. The very firſt change which takes place within the ſeed is the combination of the oxygen of the air which is abſorbed, with the carbone which exiſts in the lobes of the ſeed, and the formation of carbonic acid, which is given out in the ſtate of gas. The farinaceous matter of the ſeed being deprived of part of its carbone, is converted into a ſaccharine ſubſtance, which is deſtined for the nouriſhment of the embryo plant, till its parts are ſo far evolved, and its ſtructure ſo completed, as to derive nouriſhment from the earth.

2269
Carbonic acid gas emitted.

7. The firſt chemical change, therefore, which is obſerved in the germination of ſeeds, is the abſorption of oxygen, the emiſſion of carbonic acid gas, and the converſion of the farinaceous matter into a ſaccharine ſubſtance. This is the proceſs of germination, as it has been deſcribed by chemical phyſiologiſts. But if oxygen gas be entirely excluded, no change takes place; no part of the proceſs of germination goes on; or even if it has proceeded ſo far as that the plumula ſhall have appeared above the ſurface in the form of ſeminal leaves; if theſe leaves are removed before others have been unfolded, the plant dies. The ſeminal leaves are the lobes which have been puſhed out of the earth along with the plumula, ſo that if they are deſtroyed, the plant is cut off from the neceſſary ſource of nouriſhment for the evolution of its parts, and the formation of roots and leaves, which are deſtined to perform the different functions of vegetation.

II. Of the Food of Plants.

2270
Suppoſed to be water.

2271
Not pure.

1. But air, heat, and moiſture, are not only neceſſary for the formation of the different parts of the plant; their action muſt be continued, and are abſolutely requiſite for its future health and growth. It could not long eſcape obſervation, that plants ceaſe to vegetate when they are entirely deprived of water. Hence it became the opinion of the earlier phyſiologiſts, that water conſtituted the chief, or the only food of plants; but it has been proved by experiments in analyzing plants which grew in pure water, that they received no increaſe of one of the neceſſary principles in their conſtitution, farther than what previouſly exiſted in the ſeeds or roots from which they ſpring. In a ſeries of experiments inſtituted by Haſſenfratz, on the roots of hyacinths, the ſeeds of kidney beans and other ſeeds, he found that the quantity of carbonaceous matter in the full-formed plant, was even leſs than what previouſly exiſted in the bulb or ſeed.

2272
Is the ſolvent of the food.

2. But although pure water ſeems not to contribute to the growth of plants, yet it is neceſſary as a ſolvent for thoſe ſubſtances which are conſidered as the proper food of vegetables. But when water is impregnated with certain ſaline and earthy, but eſpecially with carbonaceous matter, it is then found to be moſt proper for promoting the growth and increaſe of vegetables. We have obſerved plants growing in a ſoil which was frequently moiſtened with the water from a dung-hill, advance with a more rapid and vigorous growth, and attain to a larger ſize, than ſimilar plants in the ſame ſoil, which received only the uſual ſupply of rain and dew from the clouds. It has been found by experiment, that this water holds in ſolution a conſiderable portion of carbone. It is not improbable that it alſo contains ſome of thoſe ſaline matters which have been detected by analyſis in plants in the greateſt health and luxuriance. The waſte of the ſoil muſt be repaired with frequent additions of manure, which may be conſidered as neceſſary ſupplies of food or nouriſhment.

2273
Peculiar ſtructure of the root.

3. But whatever may be the food of plants, it is taken up by the roots in the ſtate of ſolution in water, and conveyed by the veſſels to every part of the vegetable. For this purpoſe it would appear that there is a peculiarity of ſtructure in the extremities of the roots; for, if part of the fibre of a root be cut off, the plant ceaſes to vegetate till new fibres are formed, which are ſo conſtructed, as to be capable of abſorbing the neceſſary quantity of water.

2274
Sap.

4. This fluid, which is found in plants, is called the *ſap*. It is moſt abundant in the ſpring, as the ſeaſon of vegetation advances; and during that ſeaſon, when the plant is wounded, it flows out copiouſly, and it is then ſaid *to bleed*. This is particularly the caſe with ſome trees, ſuch as the birch and a ſpecies of maple; the ſap of which, by certain proceſſes, yields wine or ſugar. The ſap is contained in what is called the *lymphatic* or common veſſels of the plant.

2275
Is prepared in the plant.

2276
Sap of the elm.

2277
Experiments.

5. The fluids taken up by vegetables, it is probable, no ſooner enter the plant, than they undergo ſome change. Vauquelin has directed his attention to this ſubject, and has analyzed the ſap at different periods during the ſeaſon of vegetation. The ſap of the common elm (*ulmus campeſtris Lin.*) extracted from the tree early in the ſpring, was of a brown colour, had a ſweet, mucilaginous taſte, but ſcarcely reddened the tincture of turnſole. Ammonia produced in this fluid a copious yellow precipitate, ſoluble with efferveſcence in acid. Barytes and lime-water produced a ſimilar effect. Oxalic acid and nitrate of ſilver gave a white precipitate. Sulphuric acid, diluted with water, occaſioned a briſk efferveſcence, with the evolution of the odour of acetic acid from the mixture. Oxymuriatic acid deſtroyed the colour of the ſap, and formed in the liquid a yellow precipitate. Hydroſulphuret of potaſh and ſulphate of iron effected no change, but alcohol threw down a flaky precipitate. A quantity of this ſap being evaporated with a moderate heat, there was found on the ſurface a browniſh pellicle; a brown matter ſeparated in the form of flakes, and an earthy matter depoſited on the ſides of the veſſel, which was dry to the touch. After evaporation to a certain degree, and cooling, a yellow earth was depoſited, which diſſolved with efferveſcence in muriatic acid. When the ſolution was completed, the liquid was filtered, to ſeparate the inſoluble vegetable matters. The muriatic ſolution mixed with carbonate of potaſh, yielded carbonate of lime. The liquid which had depoſited the vegetable matter being evaporated with a gentle heat afforded a grayiſh extract, which ſtrongly attracted moiſture from the air, and had a very pungent, ſaline taſte. It efferveſced with the addition of concentrated ſulphuric acid, and gave out the odour of radical vinegar. Diſtilled with three parts of ſulphuric acid, it furniſhed very concentrated acetic acid, and there remained in the retort ſulphate of potaſh with exceſs of acid.

6. From this analyſis it follows, that the extract of the

ſap of the elm is chiefly compoſed of acetate of potaſh. One thouſand and thirty nine parts of this ſap yielded nearly the following proportions.

2278 Compoſition.

Acetate of potaſh	9.240
Vegetable matter	1.060
Carbonate of lime	.796

The deficiency was made up of water and ſome volatile matter.

When the ſeaſon was farther advanced, the ſap of the ſame tree was again ſubjected to analyſis, and it was found that the quantity of acetate of potaſh and carbonate of lime had diminiſhed, but that the quantity of vegetable matter was nearly double. At a ſtill more advanced period of the ſeaſon, the experiment was repeated, the reſult of which was, that the increaſe of the vegetable matter, and the diminution of the acetate of potaſh and carbonate of lime were ſtill greater. It appeared too, that carbonic acid exiſted in exceſs in the ſap, and that the carbonate of lime was held in ſolution by it.

2279 Of the beech. 7. The ſame chemiſt analyzed the ſap of the beech, and it was found to be compoſed of water, acetate of lime with exceſs of acid, acetate of potaſh, gallic acid, tan, mucus, extractive matter, and acetate of alumina; but the proportions of theſe parts have not been mentioned. From this analyſis it appears, that the ſap of the beech is different from that of elm, in containing acetic acid uncombined, beſides gallic acid and tan, but at the ſame time having no carbonate of lime. When the ſap of the ſame plant was examined latter in the ſeaſon, the proportion of gallic acid and tan had increaſed. 2280 Of the hornbeam. Vanquelin alſo examined by analyſis, the ſap of the carpinus ſylveſtris or hornbeam, and the betula alba or birch *. The component parts of the ſap of the former were found to be, acetate of potaſh and lime, mucilage, ſugar, and extract, with water; and the latter were found to be water, acetates of lime, alumina and potaſh, ſugar, and vegetable extract. From theſe experiments it appears that the fluids which are taken up by plants, are immediately changed by certain proceſſes within the plant; for ſome of the ſubſtances which are component parts of the ſap of plants, are either not found in the liquids before they enter the plant, or exiſt in them in very ſmall quantity. Theſe changes, it appears too, from the ſame experiments, are conſiderably greater, at the later periods of the ſeaſon of vegetation. Some of the component parts are greatly increaſed, while others are much diminiſhed.

2281 Aſcends through the wood. 8. The ſap aſcends from the roots to the extremities of the branches, which has been proved by making inciſions in the trunk of a tree at different heights in the ſpring ſeaſon. The ſap is obſerved to flow, firſt, from the loweſt inciſion, and ſucceſſively to the higheſt. It is through the veſſels in the woody part of the tree, that the ſap aſcends, for no ſap flows from an inciſion unleſs it has penetrated the wood, and in ſome trees it is neceſſary to make the inciſion nearly to the center. It has been obſerved that coloured infuſions always paſs from that part of the wood called the alburnum.

2282 By the tracheæ. 9. The ſap of plants is conveyed through thoſe veſſels which were deſcribed under the name of *tracheæ* or ſpiral veſſels. Theſe were denominated tracheæ or air veſſels by the earlier phyſiologiſts, becauſe being found empty, when they were cut acroſs and examined, they were ſuppoſed to convey nothing but air.

2283 Cauſe of the aſcent. 9. As the ſap of vegetables moves with very conſiderable force, it has given riſe to much ſpeculation about the nature of that power, or the cauſe by which this is effected. Malpighi aſcribed the aſcenſion of the ſap to the dilatation and contraction of the air in the air-veſſels; while Grew ſuppoſed that it was owing to the lightneſs of the vapour, in which ſtate he conceived the ſap entered the plant, and was conveyed through it. By many others the aſcent of the ſap in vegetables has been aſcribed to the force of capillary attraction; but the nature of this action, as it is demonſtrated and explained by mechanical philoſophers, ſeems to be incompatible with the phenomena of the circulation of the ſap in vegetables, and has therefore been rejected as a hypotheſis equally unſatisfactory with thoſe which have been juſt mentioned. It has been aſcribed with more probability to the action of the veſſels themſelves. This is owing, in the language of phyſiologiſts, to the irritability of the veſſels, or a certain power by which they are enabled to contract, by the action or influence of certain ſubſtances. This is ſuppoſed to be the caſe with the ſap, and the action which takes place when it enters the roots, is owing to the irritability of the veſſels. As the ſap is carried a certain length by the firſt contraction, it is carried ſtill farther by the ſecond; and thus by ſucceſſive contractions it is propelled through every part of the plant, while at the ſame time new additions continue to enter the extremities of the root.

III. Of the Functions of the Leaves.

1. Whatever be the nature of the proceſs, the ſap is carried to every part of the vegetable, and we have ſeen that it has no ſooner entered it than it undergoes certain changes, which become more conſiderable according to the length of time after its abſorption. 2284 Produce great changes on the ſap. But the greateſt changes which take place in the ſap of plants, are effected in the leaves. The leaves are to be conſidered among the eſſential organs of vegetables, 2285 Convert it into the peculiar juice. for in them the ſap is totally changed, and converted into the peculiar juice, or *ſuccus proprius* of the plant. As the functions of the leaves are of great importance in vegetation, it will be neceſſary to conſider the nature of their action.

2286 During the day. 2. During the day, the leaves of plants tranſpire a very conſiderable quantity of moiſture, the proportion of which, it appears from ſome experiments, was not much inferior to the quantity abſorbed. From ſimilar experiments it appears that the quantity evaporated was in proportion to the extent of ſurface of the leaves. The quantity has been obſerved to be greateſt too, during ſunſhine and warm weather. It is greatly interrupted during the night, and entirely checked by cold. When the quantity of moiſture tranſpired is diminiſhed, the moiſture imbibed is alſo found to be leſs in proportion. This indeed might have been expected, for when the tranſpiration of a plant ceaſes, this being an eſſential function of vegetation, the whole proceſs muſt be interrupted. In experiments made on this tranſpired matter, by evaporating to dryneſs a quantity which had been collected, a ſmall portion of carbonate of lime was obtained; from the reſiduum,

---

* *Ann. de Chim.* xxxi. 20.

a ſtill ſmaller proportion of ſulphate of lime, with a little gummy and reſinous matter. It has been found that the tranſpiration of moiſture takes place chiefly on the upper ſurfaces of the leaves, and this ſeems to be performed by a particular ſet of organs.

2287 Oxygen gas given out.

2288 Carbonic acid gas abſorbed.

3. During the day, and eſpecially during bright ſunſhine, oxygen gas is given out by the leaves of plants. The quantity of oxygen gas emitted by leaves, as appears from the experiments of naturaliſts, depends on the quantity of carbonic acid gas which is abſorbed by the plant; for it has been aſcertained that vegetables grow rapidly and vigorouſly when they are expoſed to this gas; nay, it is found eſſentially neceſſary to their health and growth. If the water with which plants are ſupplied be deprived of the whole of its air by boiling, no oxygen gas is emitted, and water which is impregnated with the greateſt proportion of carbonic acid gas, gives out the greateſt quantity of oxygen gas.

2289 Action of light.

4. This proceſs goes on only during the day, and it is more vigorous during bright ſunſhine; from which it is natural to conclude, that light performs ſome neceſſary part in it. It is well known that plants which grow in the dark do not acquire a green colour; and it is found that theſe plants contain a ſmaller proportion of carbone than ſimilar plants, in the ſame circumſtances, expoſed to the light. From this it may appear what is the nature of the proceſs when carbonic acid gas is abſorbed by plants, and oxygen gas emitted. It is the decompoſition of the former, which is effected; the carbone being retained in the plant, and the oxygen given out; but light being a neceſſary agent in this decompoſition, the proceſs muſt be interrupted when it is excluded.

2290 Parenchyma of the leaf gives out the oxygen gas.

5. This decompoſition takes place in the parenchymatous ſubſtance of the leaf, and the quantity emitted, it appears, is in proportion to the thickneſs of this ſubſtance. The green colour of plants, it has already been mentioned, depends on the action of light. Plants which vegetate in the dark, have not only a ſmaller proportion of carbone, but alſo continue of a white colour; but in a ſhort time after they are expoſed to the light, the green colour is reſtored.

2291 Vegetables the great ſource of oxygen.

6. Thus it appears, that it is one part of the functions of leaves of plants to exhale a conſiderable proportion of the moiſture taken in by the roots; to abſorb carbonic acid gas; to decompoſe this gas, by which its carbone is retained in the plant, and the oxygen is given out. Thus too, it appears, that vegetables are one of the great ſources of ſupply of oxygen gas, which is eſſentially neceſſary in the numerous proceſſes of combuſtion, and the reſpiration of animals, which are conſtantly going on on the ſurface of the earth; and thus the waſte of this vital fluid is repaired, and the balance preſerved between its deſtruction and ſupply.

2292 Function of leaves during the night.

7. The leaves of plants perform a very different function during the night. Inſtead of emitting moiſture and oxygen gas, and abſorbing carbonic acid gas, which takes place during the day, the proceſs is reverſed. Carbonic acid gas is emitted, and moiſture and oxygen gas are abſorbed. The abſorption of moiſture ſeems to be chiefly performed by the under ſurface of the leaves, at leaſt in many plants. It has been found by experiment, that plants, which have been made to grow in oxygen gas give out a greater quantity of carbonic acid gas, than when they grow in common air. From this circumſtance it has been ſuppoſed, that the carbonic acid gas, emitted by plants during the night, is owing to the combination of the oxygen abſorbed, with the carbone of the ſap; for it is at the ſame time that oxygen is abſorbed. It has alſo been aſcribed to the decompoſition of the water.

2293 Peculiar juice.

8. By theſe different proceſſes which are carried on in the leaves of plants, by the abſtraction of ſome of its principles, and by entering into minute combinations with others, the ſap undergoes very great changes. It is there converted into the peculiar juice of the plant, from which are derived, by other proceſſes, the different ſubſtances which are produced in the different parts of plants, the nature of which will be afterwards examined. The leaves of plants have been compared to the lungs and ſtomach of animals. How far this analogy is juſt, it is not neceſſary to inquire; but there can be no doubt that the leaves are eſſential organs in the economy of vegetables. In the very firſt ſtep in the proceſs of vegetation, during the germination of ſeeds, the moiſture abſorbed by the roots is carried to the ſeminal leaves, and there undergoes certain changes, before it is fit for the formation of the ſtem and other leaves of the plant; for, if theſe leaves are removed, vegetation is entirely interrupted, and the plant dies. Even when plants have made farther progreſs, and are in full vigour, if they are entirely ſtripped of their leaves, the powers of vegetation ceaſe, till theſe neceſſary organs are reſtored, and new leaves are formed. The progreſs of vegetation is alſo ſtopped when the ſurface of leaves is varniſhed over, ſo that the abſorption and emiſſion of the neceſſary fluids are interrupted.

2294 Sap flows from the roots to the leaves.

9. The ſap of plants, it has been already obſerved, flows from the roots towards the branches and leaves of the plant. In the leaves it undergoes peculiar changes, in conſequence of part being exhaled, and in conſequence of the abſorption of different principles which combine with it, and no doubt contribute by this combination to the changes which take place. The ſap, as we have already ſaid, is then converted into the *ſuccus proprius*, or peculiar juice. It is the ſap of the plant, which is ſo far prepared to be converted into the different parts of the plant, correſponding to its nature and properties; and, as the different parts, both of liquids and ſolids in plants, poſſeſs properties totally diſtinct from each other, and have derived theſe from the ſame nouriſhment, the proceſſes by which theſe different ſubſtances are produced in different plants, and even in the ſame plant, muſt undoubtedly be different.

2295 Peculiar juice from the leaves to the roots.

10. The peculiar juice of plants flows from the leaves towards the roots. If a ligature is faſtened round the ſtem of a plant, the place immediately above the ligature, that is, between it and the leaves, ſwells out by the accumulation of this juice. Or if a wound be made in the bark, the peculiar juice flows in greater abundance from that ſide of the wound next to the leaves, than from the other ſide.

2296 Properties of it.

11. The peculiar juice of plants has a greater conſiſtence than the other juices. It is readily recognized by ſome peculiarity of colour. In a great many plants it is milky, in ſome it is of a green colour, and in

others

others it is red. The component parts of the peculiar juice of plants are little known, but from ſome experiments which have been made on this ſubject, it appears that ſome part of the vegetable is ready formed. In the experiments of Chaptal on the peculiar juice of plants, he detected a ſubſtance which poſſeſſed the properties of the woody fibre. In ſimilar experiments on the ſeeds of plants, it was found that they contained a greater proportion of the woody fibre, from which it is inferred, that the peculiar juices of plants contain their nouriſhment ready prepared, and in that ſtate in which it is found in the ſeed. The peculiar juices of plants contain a greater proportion of theſe elements which conſtitute the different parts of plants, than what is found to exiſt in the ſap. Theſe are carbone, hydrogen, and oxygen.

2297 Plants have different periods of duration.

12. Many plants ceaſe to vegetate as ſoon as they have perfected their ſeeds, which is accompliſhed by ſome in one ſeaſon, by others in two, and hence ſuch plants have been called *annuals* and *biennials*. Other plants, however, continue to yield ſeeds and fruit for many ſucceſſive ſeaſons, and to live for a great length of time. What is the cauſe of this remarkable diverſity among the vegetable tribes,—why the humble annual ſprings up, flowers, and forms perfect ſeeds within the ſhort period of a few months, while the ſtately oak rears its lofty head, and continues to be the pride and glory of the foreſt for hundreds of years, it would be difficult to ſay. At preſent, however, it is not our province to enter into the ſpeculation.

SECT. II. *Of the DECOMPOSITION of VEGETABLES.*

1. As ſoon as plants have ceaſed to vegetate, they undergo a new ſet of changes. The whole plant is broken down; the elements of which it is compoſed enter into new combinations, and new ſubſtances make their appearance, which did not previouſly exiſt in the plant. This decompoſition is owing, partly to the affinities between the component parts of the vegetable themſelves, and partly to the affinities which exiſt between ſome of the elementary principles of the plant, and the heat, air, and moiſture, without which no decompoſition takes place. While the plant continued to exhibit the phenomena of vegetation, that is, while it continued to live, it poſſeſſed a power of reſiſting this chemical action between the elements of which it is compoſed, and alſo to a certain extent the action of external agents. During this decompoſition of vegetables, air, heat, and moiſture, are neceſſary. Gaſeous bodies are generally given out, and new compounds are formed. Some plants, and ſome parts of the ſame plant, have a greater tendency to undergo this decompoſition than others, becauſe they either poſſeſs a greater proportion of the ſubſtances which promote the decompoſition, or a greater proportion of the ſubſtances of which the new compounds are formed.

2298 Fermentation.

2. The changes or ſpontaneous decompoſitions of vegetables, as they are almoſt always accompanied with an inteſtine motion, have received the name of *fermentation*. The nature of theſe changes is very different, both with regard to the gaſeous bodies which are abſorbed or emitted, and the nature of the products which are obtained after the proceſs is finiſhed. Hence, fermentations have been uſually diſtinguiſhed into three kinds; namely the *vinous*, ſo called, becauſe the product is wine, when certain ſubſtances are ſubjected to this proceſs, or beer, when other ſubſtances are employed; the *acetous* fermentation, becauſe during this part of the proceſs vinegar is produced; and the *putrid* or *putrefactive* fermentation, becauſe the ſubſtances are ſtill farther decompoſed, and run into the ſtate of putridity. But theſe different kinds of fermentation might perhaps be conſidered merely as different ſtages of the ſame proceſs; for unleſs it is checked at certain periods, it runs on through the different ſtages without interruption. According to ſome, theſe three ſpecies of fermentation do not include all the changes which have the characters of this proceſs to which vegetables are ſubject. To theſe it has been propoſed to add the ſaccharine fermentation, or that change which is induced on farinaceous ſeeds by heat and moiſture, which is the germination of ſeeds or the proceſs of malting; and the colouring fermentation, or that proceſs by which the colouring matter of vegetables, as indigo, is developed.

2299 Four kinds.

In the preſent ſection we propoſe to treat, 1. Of the vinous fermentation; 2. Of the acetous or acid fermentation; 3. The panary fermentation, or the formation of bread; and 4. Of the putrid fermentation.

I. Of the Vinous Fermentation.

2300 Hiſtory.

1. The vinous fermentation, otherwiſe denominated the ſpirituous, has been ſo called, becauſe the firſt product is wine, which by diſtillation yields ſpirits. Boerhaave was the firſt who directed his attention to trace the cauſes, and to obſerve the phenomena of fermentation. The ſame ſubject was afterwards proſecuted by other chemiſts, and much was written on the nature and manufacture of wine; but till the diſcoveries of modern chemiſtry, and eſpecially the important one of the compoſition of water, nothing was aſcertained with preciſion concerning the nature of fermentation, or the changes which take place on the fermenting ſubſtances. To the experiments and reſearches of Lavoiſier on the formation and decompoſition of alcohol, chemiſtry is indebted for ſome of the moſt important facts with regard to the proceſs of fermentation.

2301 Conditions.

2. Certain conditions are neceſſary to promote the vinous fermentation. The firſt indiſpenſable condition is the preſence of ſome ſaccharine matter. Experience has ſhewn that no vegetable ſubſtances are ſuſceptible of this fermentation, which do not contain ſugar. Thus, the ſweet juices of fruits are uſually employed in this proceſs; and particularly, for the production of wine, the juice of the grape.

But ſugar in a ſtate of purity, or uncombined with other ſubſtances, is not ſuſceptible of any change. A certain quantity of water, therefore, is neceſſary that the ſaccharine matter may be in the liquid ſtate. Water therefore, is one of the eſſential conditions of the vinous fermentation; and it ſeems neceſſary that the water ſhould neither be in too great quantity, nor deficient. In the latter caſe the fermentation is interrupted; in the former it is promoted too rapidly, and is apt to be converted into the next ſtage, the acetous or acid fermentation. When the conſiſtence is too great, water muſt be added, and when it is too fluid, the addition of ſugar becomes neceſſary.

The

The vinous fermentation ſcarcely commences, if the temperature be below 60°, but at the temperature of 70° the proceſs goes on briſkly.

But ſugar and water alone do not ferment, without the addition of ſome other ſubſtances. In the liquid expreſſed from grapes, which has received the name of *muſt*, there are, beſides ſugar, a portion of jelly, ſome glutinous matter, and tartar.

The contact of air has been conſidered as one of the requiſites of the vinous fermentation; but this is not neceſſary, on account of the fermenting liquid deriving any addition from the atmoſphere, for the proceſs goes on equally well, when it is excluded, provided the gaſeous bodies which are formed are permitted to eſcape.

A large maſs is alſo favourable for promoting the vinous fermentation. A ſmall quantity of ſaccharine matter ſcarcely at all undergoes this change, while it runs ſpeedily to the acid fermentation.

2302 Phenomena of fermentation. 3. When the ſubſtances which are ſuſceptible of this fermentation, are placed in proper circumſtances, the proceſs commences in a few hours, or a few days, according to the temperatuie and the quantity of liquid employed. The liquid is then agitated with an inteſtine motion; it becomes thick and muddy; the temperature increaſes, and carbonic acid gas is diſengaged. The liquid is increaſed in bulk, and the ſurface is covered with a voluminous, frothy matter, which is owing to the carbonic acid gas adhering for ſome time to the viſcid matters in the liquid. The quantity of carbonic acid gas diſengaged during this proceſs is very conſiderable. It begins to be evolved at the commencement of the fermentation, and continues till its termination. At the end of a few days, or a longer or ſhorter time, according to the temperature and other circumſtances, the fermentation ceaſes. The liquid becomes tranſparent, the matters which occaſioned the muddineſs having precipitated to the bottom, and from having a ſweet taſte, it becomes ſharp and hot, and from having been viſcid and glutinous, it becomes more liquid and lighter. It is now converted into wine.

2303 Decompoſition of the ſugar. 4. Such are the phenomena of fermentation, from which, and from the nature of the product, very conſiderable changes muſt have taken place on the component parts. One change has been obſerved during this proceſs; namely, that the quantity of ſugar is always diminiſhing, and, at the end of the proceſs, is entirely decompoſed. The liquid is now more fluid, is ſpecifically lighter, and has obtained a vinous taſte; which new properties are aſcribed to the formation of alcohol which exiſts in all wine. It would appear, from the experiments of M. Lavoiſier, that it is the ſugar only which has ſuffered decompoſition. It is divided into two portions, one of which ſeparates, and is carried off in the form of carbonic acid gas, while the other, containing a great proportion of hydrogen, remains in the liquid, in the form of alcohol. Part of the alcohol is carried off, and the alcohol which remains in the liquid is combined with the acids of the wine and the colouring matter, from which it muſt be ſeparated by diſtillation. The tartaric acid, it has alſo been found, is partially decompoſed during the proceſs, and a portion of malic acid is formed. It appears from other experiments, that azotic gas is diſengaged during this proceſs, from which it is inferred, that ſome others of the conſtituents of the fermenting liquid have been decompoſed, ſince ſugar contains no azote.

2304 Component parts of wines. 5. There is great variety in the colour, flavour, and ſtrength of wines. Theſe differences depend on the nature of the ſoil and of the grapes, and very often on the manner in which it is manufactured. But the component parts of wine are generally ſome acid matter, alcohol, extractive matter, oil, and colouring matter. It is be enaſcertained by experiment, that all wines redden the tincture of turnſole. The acid which exiſts in greateſt abundance in wine, was found by Chaptal to be the malic acid; ſome portion of citric acid alſo has been detected. Some wines, as champaigne, contain a conſiderable portion of carbonic acid.

It is to a certain portion of alcohol contained in wines that they owe their ſtrength; and, when wines are ſubjected to the proceſs of diſtillation, the alcohol paſſes over, and the ſpirit which is thus obtained is known by the name of *brandy*.

2305 Extractive matter. The extractive matter found in wines has been obſerved to diminiſh in proportion to the age of the wines; as it ſeparates gradually from the liquid, and is precipitated to the bottom.

2306 Volatile oil. The flavour and odour of wines have been aſcribed to a ſmall quantity of volatile oil; but this quantity is ſo ſmall, that no means hitherto employed have ſucceeded to obtain it in a ſeparate ſtate. Wines are diſtinguiſhed by a peculiar colour, which is owing to the colouring matter originally derived from the huſk of the grape.

2307 From other ſubſtances. 6. The juices of other fruits alſo afford materials for fermentation, as that of cyder from apples, and perry from pears. Theſe are diſtinguiſhed from wines properly ſo called by containing a greater proportion of mucilaginous matter. The juice of the ſugar cane alſo affords a fermenting liquid, from which is obtained by diſtillation the ſpirit called *rum*.

2308 Beer. 7. Beer or malt liquors, as they are called in Britain, are fermented liquors obtained from farinaceous ſeeds. Different kinds of corn are employed for the purpoſe of making beer. In Britain, barley is the moſt common grain in the preparation of this liquid. It is firſt ſteeped in water, and afterwards thrown together in a heap for about 24 hours. During this period, in conſequence of the moiſture which has been abſorbed by the grain, the proceſs of germination commences, oxygen gas is abſorbed, carbonic acid gas is given out and heat is evolved, while the radicle is protruded. The proceſs having advanced thus far, is checked by ſlowly drying the grain. For this purpoſe it is ſpread out on a floor, and in this ſtate it is known by the name of malt. It is afterwards expoſed to heat, fully dried, and ground to a coarſe powder. An infuſion is then made with water about the temperature of 160°, which is drawn off; more water is added till the whole ſoluble part of the malt is extracted. This infuſion, which has a ſweet taſte, from having a portion of ſaccharine matter, is called *wort*. After being boiled with ſome bitter ſubſtances, as hops, it is allowed to ferment, and the proceſs of fermentation is in a great meaſure ſimilar to that which has been already deſcribed of the fermentation of wine. The temperature moſt proper for this fermentation is about 60°; the fermentation of wort is greatly promoted, and the quantity of the fermented liquor is more abundant with the addition of yeaſt.

2309 Fermentation goes on in cloſe veſſels. It has been found alſo, that the infuſion of malt ferments in cloſe veſſels, and equally well as when expoſed to the open air. During this fermentation carbonic acid gas is diſengaged, which is mixed with a portion of the wort. By the diſtillation of the liquid obtained after the fermentation has ceaſed, alcohol is obtained; the nature and properties of which have been already deſcribed in treating of that liquid under inflammable ſubſtances.

II. Of the Acetous Fermentation.

1. In treating of acetic acid, which is the product of this fermentation, we have already detailed the method propoſed by Boerhaave for the manufacture of vinegar, and we have alſo deſcribed the properties of that acid. All that is now neceſſary, therefore, is ſhortly to ſtate the general phenomena 2310 Phenomena. which are exhibited during this fermentation. When wine or beer, which is the product of the vinous fermentation, is expoſed to a temperature between 70° and 90°, it becomes gradually turbid, the temperature is increaſed; it is agitated with inteſtine motions, and flaky ſubſtances are ſeen floating through it in all directions. The inteſtine motions at laſt ſubſide, the liquid becomes tranſparent by the matters which rendered it turbid precipitating to the bottom of the veſſel. The liquid has now aſſumed different properties; it is converted into acetic acid or vinegar.

2311 Conditions. 2. The conditions neceſſary for the acetous fermentation are, a conſiderable elevation of temperature, and expoſure to the air of the atmoſphere. During this fermentation oxygen is abſorbed from the air, and unleſs this abſorption takes place, the fermentation does not go on. It is neceſſary that the ſubſtances to be ſubjected to this fermentation contain a certain proportion of extractive matter; for if they are entirely deprived of it, the proceſs does not go on. Weak wines or beer are more readily converted into vinegar than ſtrong wines; but when the proceſs of fermentation has commenced on the latter, the product is a ſtronger and better vinegar.

2312 Changes. 3. In examining the products of this fermentation it has been found that the malic acid and the alcohol which previouſly exiſted in the wine, have entirely diſappeared, ſo that by their decompoſition they have contributed to the formation of the vinegar. Some portion of the extractive matter alſo has been decompoſed. The acetic acid is formed alſo during the decompoſition of many vegetable ſubſtances, either by means of heat, or other chemical agents.

III. Of the Panary Fermentation, or of Bread.

2313 Nature of this fermentation. The fermentation which takes place in making bread is ſuppoſed to be peculiar; but the phenomena and product have not been ſufficiently examined to be able exactly to aſcertain its nature. The proceſs is extremely ſimple. Wheat flour, which is generally employed, is formed into a paſte with water, the proportions of which vary according to the age and quality of the flour. After ſome time it is agitated with an internal motion, ſimilar to the other fermentations, in conſequence of the action of the component parts upon each other, the formation of new compounds, and the evolution of gaſeous matter. Water is eſſentially requiſite in this fermentation. One of the changes which have taken place during the proceſs, is, that the gluten which conſtitutes a part of the flour, has diſappeared. It is entirely decompoſed. This matter has acquired a ſour diſagreeable taſte, and if it is made into bread, it is found unfit to be eaten.

2314 Leaven. A quantity of new paſte is then prepared, and a ſmall quantity of the old ſour paſte is added to it. This produces rapid fermentation. The ſour paſte thus added, to promote the fermentation, is called *leaven*, and the bread prepared by this proceſs has received the name of *leavened bread*; a diſtinction which has been known to mankind from the earlieſt ages of the world. It is frequently mentioned in Scripture, in the Jewiſh hiſtory. It requires ſome attention to be able to determine the exact quantity of leaven neceſſary for the proper fermentation of the paſte. When it is deficient in quantity, the proceſs of fermentation is interrupted, and the bread thus prepared is ſolid and heavy, and if too much leaven be uſed, it communicates to the bread a diſagreeable ſour taſte. When the fermentation ſucceeds, the paſte ſwells up, and is greatly enlarged in bulk, which is owing to the formation of a quantity of gas, which is confined within the maſs, by the viſcidity of the glutinous part of the flour.

Other ſubſtances are employed to promote the fermentation of paſte for the purpoſe of making bread; one of the moſt common is the matter which collects on the ſurface of fermenting liquids from farinaceous matters. This ſubſtance, which is called barm or yeaſt, is equally efficacious in producing fermentation, and is leſs apt to contaminate the bread with any diſagreeable taſte. 2315 Yeaſt. As it is collected on the ſurface of fermenting beer, it was examined by Weſtrumb, and was found to contain a great variety of ingredients. Beſides the water, which was in greateſt proportion, it conſiſted of gluten, ſugar, and mucilage, with a quantity of alcohol, and a ſmall portion of malic, acetic, and carbonic acids. 2316 Component parts. The eſſential parts of barm or yeaſt were found, by the ſame chemiſt, to be gluten mixed with a vegetable acid; and therefore yeaſt, which has been collected and put into bags ſtrongly preſſed and dried, by which means it is obvious many of the component parts muſt be ſeparated, has been found equally fit for fermentation.

2317 Baking of bread. 2. When the paſte has undergone the proper degree of fermentation, it is formed into loaves, and introduced into an oven, which has been previouſly heated. The ſame temperature is as nearly as poſſible employed for the baking of bread. This is regulated by throwing a little flour on the bottom of the oven. If it becomes black, without taking fire, the oven is ſuppoſed to have acquired a proper temperature. This is found to be about 448°.

2318 Changes. 3. If the fermentation has been properly conducted, the bread during the proceſs of baking enlarges in bulk, becomes light and porous, and is full of eyes or cavities, in conſequence of the extrication of the gas which was confined by the viſcid, glutinous matter, and now driven off by means of heat. It is alſo conſiderably

ſiderably lighter, in conſequence of the evaporation of moiſture; and it ſtill continues to loſe weight by being kept, if it be expoſed to the air. When it is firſt removed from the oven bread is diſtinguiſhed by a peculiar taſte and odour. Theſe are alſo carried off by the evaporation of the moiſture, unleſs it be prevented by excluding the air. The component parts of bread, ſo far as they have been inveſtigated, are quite different from thoſe of the flour, ſo that theſe have undergone a chemical change.

2319 Bread of rye and potatoes. 4. Loaf bread is uſually made of wheat flour, which is found moſt proper for this purpoſe, in conſequence of the great proportion of gluten which it contains. Rye is alſo frequently employed in making bread, but being deficient in the proportion of gluten, it is leſs proper for the purpoſe. Bread made of rye has not the lightneſs and porouſneſs of the wheaten loaf. Parmentier has deſcribed a proceſs for making bread from potatoes. The potatoes are boiled and reduced to a fine paſte; but before they can be converted into bread, it is neceſſary to add an equal weight of ſtarch obtained from the ſame root. In this way a white, well-raiſed bread, it is ſaid, is obtained.

2320 Colouring fermentation. To a fermentation ſomewhat ſimilar is aſcribed the production of the colouring matter of ſome vegetable ſubſtances, as for inſtance that of indigo; in this however, greater changes are effected. In this proceſs the indigo plants are put into water, which is ſoon agitated with an inteſtine motion. It is alſo accompanied with an increaſe of temperature, the production of a frothy matter on the ſurface, and the evolution of an elaſtic fluid, which is a mixture of carbonic acid and carbonated hydrogen gas. During this proceſs, the colouring matter of the plant is ſeparated and precipitated, from which Fourcroy propoſes to denominate this the *colouring* fermentation.

IV. Of the Putrid Fermentation of Vegetables.

2321 Nature. 1. The putrefactive proceſs is the laſt ſtage in the decompoſition of vegetable matters. In ſome the parts are completely ſeparated, and reſolved into their primary elements by the eſcape of thoſe ſubſtances by which they were mutually held together. In others, new compounds are formed, by a new ſet of attractions and combinations.

2322 Conditions. 2. Several conditions are neceſſary to promote putrefaction. The firſt requiſite is water, without which the proceſs does not go on. When vegetables are kept perfectly dry, they undergo no change. The contact of air is alſo neceſſary, and a moderate temperature. When the temperature is too high, the moiſture is carried off by evaporation, before the changes in which this proceſs conſiſts can be effected; but when the moiſture is not carried off, the higher the temperature, the more rapid is the putrefaction.

2323 Phenomena. 3. When vegetables are placed in proper circumſtances to favour this proceſs, the colour and conſiſtence are ſoon changed; the texture is deſtroyed, the fibres are ſeparated; the ſoft and liquid parts ſwell up and are covered with froth; elaſtic fluids are diſengaged, the temperature is increaſed, and ſometimes ſo high as to produce actual inflammation. The gaſes which are diſengaged, are, after the proceſs has fairly commenced, accompanied with a fetid odour. They are compoſed of a mixture of carbonated hydrogen, carbonic acid and azotic gaſes. After theſe phenomena have continued for ſome time, which is longer or ſhorter, according to the nature and conſiſtence of the vegetable matters, great part, it appears, has been diſſipated by evaporation. There remains a dark coloured ſubſtance containing the more fixed materials of the vegetable, as the earths combined with the acids and part of the carbone.

2324 Changes. 4. In obſerving the neceſſary conditions, the phenomena, and the products of the putrid fermentation of vegetables, the influence of the numerous attractions of the different materials which enter into their compoſition is manifeſt. Part of the hydrogen combines with the oxygen, and is carried off in the ſtate of water, part eſcapes in the ſtate of gas combined with a portion of carbone, and another portion of hydrogen unites with the azote of thoſe plants which contain it, and forms ammonia. A fourth part remains behind, and communicates odour and colour to the reſiduary maſs. The carbone combines partly with the diſengaged hydrogen, partly with the oxygen, forming carbonic acid, and part remains behind. The oxygen is divided between the hydrogen and carbone, forming compounds of which theſe elements are the baſe.

SECT. III. *Of the* COMPONENT *Parts of* VEGETABLES.

1. Having in the two former ſections given a ſhort view of the functions and ſpontaneous decompoſition of plants, we are now to conſider the nature and properties of thoſe ſubſtances which enter into their compoſition. 2325 Obtained by different proceſſes. Some of theſe ſubſtances are obtained from plants, while they continue to exhibit the phenomena of vegetation; ſuch are ſaccharine matters obtained from the ſap, which is extracted by wounding the bark and wood, without much ſeeming injury to the health and growth of the plant; and ſuch too are gummy and reſinous matters, which many plants throw off by ſpontaneous exudation; and which, ſo far from being injurious, is perhaps neceſſary in ſome degree to vegetation; but in general, the ſubſtances formed during the proceſs of vegetation, or which are conſtituent parts of vegetable matters, can only be obtained by the deſtruction of the vegetable itſelf. Theſe are procured by different proceſſes, which we ſhall ſhortly deſcribe, in treating of the nature and properties of each individual ſubſtance.

2326 Enumeration of ſubſtances. 2. The component parts of vegetables, ſo far as they have been examined, and ſufficiently characterized by diſtinct properties, may be enumerated under the following heads:

1. Gum,
2. Sugar,
3. Jelly,
4. Acids,
5. Starch,
6. Albumen,
7. Gluten,
8. Extractive matter,
9. Colouring ditto.
10. Bitter ditto,
11. Narcotic ditto.

12. Oils,
13. Wax,
14. Camphor,
15. Caoutchouc,
16. Reſins,
17. Gum-reſins,
18. Wood,
19. Tan,
20. Suber,
21. Alkalies,
22. Earths,
23. Metals.

I. Of Gum.

2327 Extraction and properties.

1. Gum exudes from many trees during the proceſs of vegetation, in the form of a viſcid, tranſparent, inſipid fluid. The finer kind of gum is obtained chiefly from the *mimoſa nilotica*, a plant which is very common in many parts of Africa. This gum is uſually diſtinguiſhed by the name of *gum arabic*. After it ſeparates from the tree, the watery part evaporates, and the gum remains behind. It has then ſome degree of hardneſs, and is ſo brittle that it may be reduced to fine powder. It retains its tranſparency, is generally of a yellow colour; but, when pure, it is entirely colourleſs. It has neither taſte nor ſmell. The ſpecific gravity is from 1.316 to 1.481.

2328 Action of air and heat.

2. Gum is not changed by expoſure to the air, but it is deprived of its colour by the action of the ſun's light. When it is expoſed to heat, it becomes ſoft, ſwells up, gives out air bubbles, blackens, and is reduced to charcoal. During this change it gives out very little flame, and is greatly enlarged in volume. It readily diſſolves in water. The ſolution is thick and adheſive, and well known as a paſte, under the name of *mucilage*. This ſolution is little diſpoſed to decompoſition. By evaporation the whole of the gum may be obtained unchanged.

2329 Of acids.

3. Gum is ſoluble in the vegetable acids without decompoſition. Sulphuric acid decompoſes it, and converts it into water, acetic acid, and charcoal. With the aſſiſtance of heat, muriatic acid produces a ſimilar effect. Oxymuriatic acid converts it into citric acid.

Gum is ſoluble in nitric acid with the aſſiſtance of heat. Nitrous gas is emitted during the ſolution, and, when it cools, ſaclactic acid is depoſited. Malic acid appears at the ſame time; and by continuing the heat, the gum is at laſt converted into oxalic acid. Four hundred and eighty grains of gum digeſted with ſix ounces of nitric acid, afforded Mr Cruickſhank 210 grains of oxalic acid, and ſix grains of oxalate of lime.

2330 Alcohol.

4. By pouring alcohol into a mucilaginous ſolution, the gum is precipitated, ſo that it is inſoluble in this liquid. It is alſo inſoluble in ether.

2331 Diſtillation.

5. Mr Cruickſhank diſtilled 480 grains of gum arabic by expoſing it to a red heat in a glaſs retort, and obtained the following products:

Acetic acid mixed with ſome oil	210 grs.
Carbonated hydrogen and carbonic acid gaſes	164
Charcoal	96
Lime and a little phoſphate of lime	10
	480

Thus the conſtituent parts of gum are, oxygen, hydrogen, carbone, azote, and lime.

2332 Conſtituents.

2333 Obtained from other plants.

6. Beſides gum arabic, the properties of which we have now deſcribed, there are different ſpecies of gum obtained from different plants, which, however, in their general properties reſemble gum arabic. In ſome indeed they ſeem to be different, but theſe differences have not been diſtinctly aſcertained. Gum tragacanth, the produce of the *aſtragalus tragacantha*, which is in the form of vermicular maſſes, is leſs tranſparent than gum arabic, leſs ſoluble in water, and more adheſive; but yields by diſtillation ſimilar products. Gum obtained from the cherry and plum tree, is of a browniſh colour, ſofter and more ſoluble in water, but ſeems otherwiſe to poſſeſs nearly the ſame properties as gum arabic.

2334 Mucilage exiſts in many plants.

7. Gum in the ſtate of mucilage exiſts in a great number of plants, and eſpecially in the roots and leaves. It ſeems to be moſt abundant in bulbous roots, as thoſe of the hyacinth, which contain ſuch a quantity that they may be advantageouſly employed in place of gum arabic. It is obtained alſo in conſiderable quantity from many of the lichens, and moſt of the fuci. Mucilage is found in greateſt proportion in young plants, but this proportion diminiſhes with the age of the plant. It is a principal conſtituent in the leaves and roots of eſculent vegetables.

2335 Uſes.

8. In the ſtate of mucilage, gum conſtitutes a nutritious aliment. On account of its adheſive properties, it is employed as a paſte, and by the callico-printers to mix with their colours to give them conſiſtency. It is well known as a component part of ink, to prevent the precipitation of its more inſoluble ingredients, and it forms a very valuable article in the Materia Medica.

II. Of Sugar.

2336 In all parts of plants.

1. Sugar exiſts in every part of plants. It is found in the roots, as thoſe of the carrot and beet root; in the ſtems, as in the birch, the maple, ſome palms, and eſpecially the ſugar-cane; in the leaves, as thoſe of the aſh; in the flowers, the fruits, and ſeeds.

2337 Sugar cane.

2. But the ſugar which now forms a very extenſive article of commerce, and may be conſidered as a neceſſary of life, is entirely obtained from the juice of the ſugar-cane, which is chiefly cultivated in the Eaſt and Weſt Indies, for the purpoſe of extracting the ſugar. When the plants have arrived at their full growth, which in the Weſt Indies is in the courſe of 12 or 14 months, they are cut down and bruiſed by means of machinery; the juice which is collected, is conveyed to iron boilers, where it is boiled, with the addition of a ſmall quantity of quicklime, and the impurities which riſe to the ſurface are ſcummed off. The boiling is continued till it acquires the conſiſtence of ſyrup, after which it is put into ſhallow veſſels, where it is allowed to cool and granulate. In general it is afterwards put into hogſheads, in which it is imported to Europe, the bottoms of which are perforated, that the molaſſes with which the ſugar is mixed, may be allowed to drain off. Sometimes it is put into conical earthen veſſels, open at both ends, the baſe of which is covered with moiſt clay, ſo that the water filters through the ſugar, and carries with it a greater quantity of the molaſſes and other impurities. The ſu-

2338 Manufacture.

gar thus treated, is called clayed ſugar. It is not different from the former, but in being ſomewhat purer. The addition of quicklime in the boiling is ſuppoſed to take up ſome vegetable acids which prevent the granulation of the ſugar.

2339 Raw. 3. In this ſtate the ſugar is known in commerce by the name of *raw* or *Muſcovado ſugar*. It is ſtill farther purified by diſſolving it in water, and boiling, when the impurities which riſe to the ſurface, are again removed; a quantity of lime is alſo added, and it is clarified with blood. When boiled down to a proper conſiſtency, it is put into unglazed earthen veſſels of a conical ſhape, and inverted, to allow the water from the moiſt clay with which the baſe of the cone is covered, to paſs through the ſugar, and carry off its impurities. It is ſtill farther purified by again diſſolving it in water, and ſubjecting it to a ſimilar proceſs. According to the number of proceſſes to which it has been ſubjected, it is called ſingle or double refined ſugar.

2340 Properties. 4. Sugar in this ſtate is of a white colour; it is well known for its ſweet taſte; it has no ſmell. It has ſome degree of tranſparency when it is cryſtallized. It is conſiderably hard; but it is brittle, and may be eaſily reduced to powder. It is phoſphoreſcent in the dark. When the ſolution of ſugar in water is concentrated, it cryſtallizes in the form of ſix-ſided priſms, terminated by two-ſided ſummits. The ſpecific gravity of ſugar is 1.4045.

2341 Action of heat. 5. When ſugar is expoſed to heat, it melts, ſwells up, becomes of a dark brown or black colour, emits air bubbles with a peculiar ſmell, which has been called *caromel*. If a red-heat be applied, it ſuddenly burſts into flames, with a kind of exploſion.

6. Neither oxygen nor azote have any action on ſugar. It is not altered by expoſure to the air. If the air be moiſt, it abſorbs a little water. There is no action between hydrogen and ſugar. It is very ſoluble in water; at ſo low a temperature as 48°, water diſſolves its own weight of ſugar. This power increaſes with the temperature of the water. When water is ſaturated with ſugar, it is called ſyrup, which by concentration and reſt affords cryſtals.

2342 Water.

2343 Acids. 7. Sugar is ſoluble in many of the acids. It is decompoſed by ſulphuric acid; when heat is applied, the acid itſelf is decompoſed, and converted into ſulphurous acid; and a great quantity of charcoal is depoſited.

Nitric acid acts on ſugar with conſiderable violence; an efferveſcence is produced, nitrous gas is emitted, and the ſugar is converted into oxalic and malic acids.

Muriatic acid gas is ſlowly abſorbed by ſugar, which becomes of a brown colour, and acquires a very ſtrong ſmell. Sugar is inſtantly diſſolved when it is thrown in the ſtate of powder into liquid oxymuriatic acid; it is converted into malic acid, while the oxymuriatic acid is deprived of its oxygen, and reduced to the ſtate of muriatic acid. Alcohol readily diſſolves ſugar. One part of ſugar is ſoluble in four of boiling alcohol. Sugar alſo combines with the oils, and by this means they may be mixed with water.

2344 Alkalies. 8. The fixed alkalies combine with ſugar, and deprive it of its ſweet taſte; but by adding ſulphuric acid, and precipitating the ſulphate which is formed by means of alcohol, the taſte is reſtored. Some of the earths, as lime, combine with ſugar, and form ſimilar compounds.

2345 Sulphurets, &c. 9. The ſulphurets, hydroſulphurets, and phoſphurets of the alkalies and ſome of the earths, decompoſe ſugar, and reduce it to a ſtate ſomewhat ſimilar to gum. Mr Cruickſhank diſſolved a quantity of ſugar in alcohol, and added to it phoſphuret of lime. After expoſing the mixture to the open air for ſome days, it was evaporated, and water was added. There was no evolution of gas, and the phoſphuret was found converted into a phoſphate. By filtering the liquid, and by evaporation, a tenacious ſubſtance, reſembling gum, remained behind.

10. By diſtilling ſugar in a retort, the firſt part of the product is water, nearly in a ſtate of purity. Acetic acid with a little oil next comes over, and afterward empyreumatic oil. A bulky carbonaceous matter, which ſometimes contains a little lime, remains behind. Mr Cruickſhank obtained by the diſtillation of 480 grains of pure ſugar, by means of a red-heat,

Acetic acid and oil,	270 grs.
Charcoal,	120
Carbonated hydrogen and carbonic acid gaſes,	90
	480

2346 Conſtituent parts. Sugar, therefore, is compoſed of oxygen, carbone, and hydrogen. The proportions of its conſtituent parts, according to Lavoiſier, are the following:

Oxygen,	64
Carbone,	28
Hydrogen,	8
	100

2347 Maple ſugar. 11. Sugar is alſo obtained from the juice of the maple tree in North America. The juice is extracted from the tree during the aſcent of the ſap in the ſpring ſeaſon. A ſingle tree, it is ſaid, yields from 20 to 30 gallons of ſap, from which are obtained five or ſix libs. of ſugar. It is manufactured in the ſame way as the juice of the ſugar-cane.

2348 Beet root. It has lately been propoſed to extract ſugar from the root of the beet; and the attempt has been made, even in the large way, by Achard of Berlin. The proceſs which he followed is to boil the roots, cut them into ſlices, and extract the juice by preſſure. The roots are again put into water for 12 hours, and again ſubjected to the preſs. The liquids thus obtained are filtered through flannel, boiled down to ⅔, and filtered a ſecond time. The remaining liquid is reduced by boiling to ⅓ of the original quantity, and again filtered. It it then evaporated to the conſiſtence of ſyrup. The cruſt which forms on the ſurface muſt be broken from time to time, and the ſpontaneous evaporation allowed to continue till the ſurface is covered with a viſcid pellicle, inſtead of the cryſtals which firſt form on it. The whole maſs is then introduced into woollen bags, and the mucilage is ſeparated by preſſure. This ſugar, which in many reſpects poſſeſſes the properties of common ſugar, is contaminated with ſome matter, which communicates a bitter nauſeous taſte. Many other plants alſo contain ſugar, either in the roots, the ſap, or the ſeeds. It exiſts in wheat, barley, beans, peaſe,

peaſe, and other leguminous ſeeds, eſpecially when they are young, in conſiderable quantity.

2349 Uſes. 12 The uſes of ſugar are ſo familiar, that it is ſcarcely neceſſary to enumerate them. In moſt countries where it can be obtained, it may be conſidered in ſome meaſure as a neceſſary of life. It contains a great proportion of nutritious matter. It is not changed by the action of the air, ſo that it may be preſerved for any length of time. It is employed to preſerve other vegetable matters from putrefaction, and ſometimes it is alſo advantageouſly applied to a ſimilar purpoſe, in the preſervation of animal ſubſtances.

III. Of Jelly.

2350 Preparation. 1. Jelly is a ſoft tremulous ſubſtance which is obtained from the juice of different fruits, eſpecially from currants and bramble berries. The juice is extracted by expreſſion, and when it is allowed to remain at reſt, it coagulates. It is ſtill mixed with a portion of aqueous liquid, but this being poured off, and the coagulated part waſhed with water, the jelly remains nearly pure.

2351 Properties. 2. It is ſometimes perfectly colourleſs, but frequently tinged with the colouring matter of the fruit. It is of a ſoft, tremulous conſiſtence, and has an agreeable, ſlightly acid taſte. It diſſolves readily in hot water, and again coagulates on cooling. In cold water it is nearly inſoluble. It is deprived of the property of coagulating by boiling, and then it is ſimilar to mucilaginous matter.

2352 Reſembles gum. 3. By coagulating the juices of the fruits which yield jelly, ſeparating the liquid parts by filtration, afterwards waſhing the coagulum with cold water, and by allowing the maſs to dry, it is found diminiſhed in bulk, and is tranſparent and brittle, having many of the properties of gum; ſo that it has been ſuppoſed that jelly is this latter ſubſtance in combination with ſome vegetable acid.

2353 Action of nitric acid. 4. Jelly is converted into oxalic acid by means of nitric acid. It combines readily with the alkalies; and when it is diſtilled, it yields a conſiderable portion of acetic acid mixed with oil, but no perceptible quantity of ammonia. Jelly is found in all the acid fruits, as in gooſeberries, oranges and lemons.

IV. Of Acids.

2354 Eaſily known. 1. The acids which exiſt in many vegetables are at once recognized by their taſte. Theſe acids were formerly denominated *eſſential ſalts of vegetables*, and it was ſuppoſed, that all eſſential ſalts were the ſame, and were compoſed of tartar, or vinegar. But Scheele's diſcovery of the citric, malic, and gallic acids, which poſſeſſing diſtinct properties from thoſe of tartaric and acetic acids, proved the contrary. Some vegetables contain only one acid, as oranges and lemons, which contain citric acid only. In other vegetables two acids are found, as in gooſeberries and currants, the malic, and citric acids; and ſometimes three, as the tartaric, citric, and malic acids, which exiſt together in the pulp of the tamarind. As the acids which exiſt in vegetables have been already deſcribed, with the method of preparing them, it is now only neceſſary to enumerate the vegetable acids, ſpecifying at the ſame time ſome of the plants from which they are obtained.

2355 Acetic. 2. Acetic acid has been diſcovered in the ſap of ſome trees, and in the acid juice of cicer arietinum. In the latter it is mixed with oxalic and malic acids. Acetic acid was detected by Scheele in the *ſambucus nigra* or elder.

2356 Oxalic. 3. Oxalic acid exiſts in combination with potaſh, in the leaves of the *oxalis acetoſella* or wood-ſorrel. In other ſpecies belonging to the ſame genus, and in ſome ſpecies of rumex, it is in the ſtate of acidulous oxalate of potaſh. Oxalate of lime has been found in the root of rhubarb.

2357 Tartaric. 4. The following vegetable ſubſtances contain tartaric acid; in which, however, it is combined with potaſh, in the ſtate of acidulous tartrate of potaſh. In this ſtate it is found in the pulp of the tamarind, the juice of grapes, of mulberries, of *rumex acetoſa* or ſorrel, of *rheum raponticum*, or rhubarb, and of *agave americana*. It is found alſo in the roots of *triticum repens*, or couch-graſs, and in *leontodon taraxacum*, or dandelion.

2358 Citric. 5. Citric acid is found in the juice of oranges and lemons, in the berries of two ſpecies of *vaccinium*, the *oxycoccos* or cranberry, and the *vitis idæa* or red whortleberry, the *prunus padus*, or bird-cherry, *ſolanum dulcamara*, bitter-ſweet, or nightſhade, *roſa canina*, or wild roſe.

2359 Malic. 6. Malic acid exiſts unmixed with other acids, in the apple, the barberry, plumb, ſloe, elder, rowan, or fruit of the mountain aſh.

In the gooſeberry, in the cherry, ſtrawberry, currants and ſome other fruits, malic and citric acids are found nearly in equal proportions.

Malic acid has been found mixed with tartaric acid in the *agave americana*, and in the pulp of tamarinds, along with citric acid. Vauquelin found it combined with lime, forming a malate of lime, in the *ſempervivum tectorum* or houſe-leek; in three ſpecies of *ſedum* or ſtone-crop, namely the *album*, *acre*, and *telephium*; in different ſpecies of *craſſula* and *meſembryanthemum*, and in *arum maculatum*.

2360 Gallic. 7. Gallic acid is found in a great number of plants, and in them it exiſts chiefly in the bark. The following are the relative proportions of the quantity of gallic acid in different plants, as they have been aſcertained by Mr Biggin.

Elm	7	Sallow	8
Oak cut in winter	8	Mountain aſh	8
Horſe-cheſnut	6	Poplar	8
Beech	7	Hazel	9
Willow boughs	8	Aſh	10
Elder	4	Spaniſh cheſnut	10
Plum-tree	8	Smooth oak	10
Willow trunk	9	Oak cut in ſpring	10
Sycamore	6	Huntingdon or Leiceſter willow	10
Birch	4		
Cherry-tree	8	Sumac	14[*]

2361 Benzoic. 8. Benzoic acid is found in benzoin, balſam of Tolu and Peru, liquid ſtyrax, cinnamon, and vanilla. Fourcroy and Vauquelin ſuſpect that it exiſts in the *anthoxanthum odoratum*, or ſweet-ſcented graſs, which communicates the aromatic flavour to hay.

[*] *Nichol. Jour.* iii. p. 394. 4to.

2362 Pruſſic. 9. Pruſſic acid has been found in the leaves of the lauroceraſus and peach, in bitter almonds, in the kernels of apricots; and it is ſuppoſed that it exiſts alſo in the kernels of peaches, of plums, and cherries. It is obtained from the kernels of apricots by diſtilling water off them with a moderate heat; and if lime be added to the concentrated infuſion of bitter almonds, a pruſſiate of lime is formed.

2363 Phoſphoric. 10. Phoſphoric acid has been found in different parts of plants; but it is generally combined with lime, forming a phoſphate of lime. This ſalt exiſts in the leaves of many trees, in the *aconitum napellus*, or monks-hood, and in all kinds of grain.

V. Of Starch.

2364 Preparation. 1. If a paſte be formed of wheat flour and water, and this be waſhed with additional quantities of water, till it is no longer turbid, but comes off pure and colourleſs, the maſs which remains becomes tenacious and ductile. This is called *gluten*, which will be afterwards deſcribed. If the water with which the paſte was waſhed be allowed to remain at reſt, it depoſits a white powder, which is diſtinguiſhed by the name of *fecula* or *ſtarch*.

2365 Properties. 2366 Action of heat. 2. Starch is of a fine white colour, and is uſually in the ſtate of concrete columnar maſſes. It has no perceptible ſmell, and ſcarcely any taſte. It is little altered by expoſure to the air; when it is expoſed to heat on a hot iron, it melts, ſwells up, becomes black, and burns with a bright flame. The charcoal which remains, contains a little potaſh. When it is diſtilled, it gives out water mixed with acetic acid, which is contaminated with oil. It gives out alſo carbonic acid and carbonated hydrogen gas.

3. Starch is not ſoluble in cold, but forms a thick paſte with boiling water, and when this paſte is allowed to cool, it becomes ſemitranſparent and gelatinous; it is brittle when dry, ſomewhat reſembling gum. If this paſte be expoſed to moiſt air, it is decompoſed, for it acquires an acid taſte.

2367 Of acids. 4. Sulphuric acid diſſolves ſtarch ſlowly; ſulphurous acid is diſengaged, and a great quantity of charcoal is formed.

Muriatic acid alſo diſſolves ſtarch, and the ſolution reſembles mucilage of gum arabic. When left at reſt a thick, oily, mucilaginous liquid appears above, and a tranſparent ſtraw-coloured fluid below. The odour of muriatic acid remains, but when water is added, it is deſtroyed, and a ſtrong peculiar ſmell is emitted.

Starch is alſo ſoluble in nitric acid, with the evolution of nitrous gas. The ſolution aſſumes a green colour, and when heat is applied, the ſtarch is converted into oxalic and malic acids. Some part of the ſtarch, however, is inſoluble in nitric acid, and when this is ſeparated by filtration, and waſhed with water, it has a thick oily appearance like tallow, is ſoluble in alcohol, and when diſtilled, yields acetic acid, and an oily matter ſimilar to tallow in odour and conſiſtence.

2368 Compoſition. 5. Starch is inſoluble in alcohol, but is ſoluble in the alkalies; in pure potaſh it ſwells up, becomes tranſparent and gelatinous, and is then ſuſceptible of ſolution in alcohol. The component parts of ſtarch, as appears by diſtilling it, and by the action of reagents, are oxygen, hydrogen, and carbone.

2369 Found in roots and ſeeds. 6. Starch exiſts in a great number of vegetable ſubſtances, but chiefly in the roots and ſeeds, and particularly thoſe which are employed as food.

2370 Potato. Starch, it is well known, may be obtained from the potato. If the potato be grated down and waſhed with water till it comes off pure and colourleſs, this water being left at reſt, depoſits a fine white powder, which aſſumes ſomething of a cryſtallized appearance, and is heavier than wheat ſtarch.

2371 Sago. Sago, which is well known, on account of its nutritious qualities, is obtained from the pith of different ſpecies of palms, which grow within the tropics. The ſtem is cut into pieces, which are ſplit into two; the pith is waſhed out with cold water, which being left at reſt, depoſits the ſtarch. The water is poured off, and before the remaining maſs is fully dried, it is forced through a perforated veſſel, and granulated, in which ſtate it is brought to Europe.

2372 Saloup. Saloup, which is chiefly compoſed of ſtarch, is prepared from the roots of different ſpecies of orchis. It is moſtly imported from Perſia.

2373 Caſſava. Caſſava, or caſſada, is a kind of bread chiefly compoſed of ſtarch, which is much uſed as an article of food in the Weſt Indies. It is prepared from the roots of the *jatropha manihot*. The roots are well waſhed, grated down, and put into bags, which are ſubjected to ſtrong preſſure. By this proceſs the whole of the juice is ſeparated. This juice, or ſomething at leaſt which it holds in ſolution, when taken internally, is a deadly poiſon to moſt animals. The matter remaining in the bag is dried and ſifted, and without any other addition, when it is ſpread thin on a hot ſtone, it forms a cake, which is the caſſada bread, found to be of a very nutritious quality, in conſequence of the great proportion of ſtarch which it contains.

2374 Lichen. Some ſpecies of the tribe of lichen contain a conſiderable proportion of ſtarch, as the lichen rangiferinus, or rein-deer lichen, which affords food to the rein-deer, and the lichen iſlandicus which is formed into bread by the Icelanders, and is found to be extremely nutritious. The latter has lately been recommended as a remedy in conſumption; but it probably poſſeſſes no other virtue in the cure of that fatal diſeaſe, than affording a great proportion of nutritious matter in ſmall bulk.

VI. Of Albumen.

1. The exiſtence of albumen in vegetable ſubſtances had begun to be doubted by chemiſts, till it was lately diſcovered, by Vauquelin, in the juice of the *carica papaya*, or *papaw-tree*, which grows in different countries within the torrid zone. The juice which exudes from this tree, was brought home in the liquid ſtate, mixed with an equal quantity of rum, and another portion of the juice was in the ſtate of extract. The firſt was of a reddiſh brown colour, was ſemitranſparent, and had the odour and taſte of boiled beef. The ſecond was of a yellowiſh white colour, ſemitranſparent, and of a ſweetiſh taſte; had no perceptible ſmell, but was of a firm conſiſtence, and in the form of ſmall irregular maſſes. When the dried portion was macerated in cold water, it was almoſt entirely diſſolved. When nitric acid was added, a copious white precipitate was formed. This was the albumen in the ſtate

ſtate of white flakes. When the extract of this juice was ſubjected to diſtillation, it yielded carbonate of ammonia, a thick fetid, reddiſh coloured oil, carbonic acid, and carbonated hydrogen gaſes, and there remained behind a light carbonaceous matter; which, being burnt, left a quantity of white aſhes, conſiſting almoſt entirely of phoſphate of lime.

2375 Reſembles animal albumen. 2. From other experiments to which this matter was ſubjected by the ſame chemiſt, from its ſolution in water, its coagulation by means of heat, its action with the acids, the alkalies, metallic ſolutions, the infuſion of nut-galls, and alcohol, he concludes, that it is preciſely of the ſame nature with animal albumen *.

VII. Of Gluten.

2376 Preparation. 1. When a paſte is formed with flour and water, and waſhed with more water till it paſſes off pure and colourleſs, a tenacious, ductile, ſoft, elaſtic maſs remains behind, which is gluten.

2377 Properties. 2. This ſubſtance is of a gray colour, extremely ductile and tenacious, and poſſeſſes conſiderable elaſticity. It has a peculiar ſmell, but no perceptible taſte. When it is ſuddenly dried, it increaſes much in volume, and when it is expoſed to heat, it cracks, ſwells, blackens, and burns like horn, exhaling a fetid odour. When it is diſtilled, it yields water impregnated with ammonia, and an empyreumatic oil; charcoal remains behind. When moiſt gluten is expoſed to the air, it gradually dries, becomes hard, brittle, ſlightly tranſparent, and of a browniſh colour, having ſome reſemblance to glue. When it is broken, it reſembles the fracture of glaſs. It is inſoluble in water, but retains a portion of it, which it abſorbs, and to which the elaſticity and tenacity are owing. It is deprived of theſe properties by boiling.

2378 Ferments. 3. When it is kept moiſt, it ferments with the evolution of hydrogen and carbonic acid gaſes. An offenſive putrid odour is given out at the ſame time. The gluten afterwards, if the proceſs be allowed to go on, exhales the ſmell, and acquires the taſte of cheeſe. In this ſtate it is found to contain ammonia and acetic acid.

2379 Action of acids. 4. Gluten is ſoluble in all the acids. It is precipitated from this ſolution by all the alkalies, and is then nearly in the ſtate of extractive matter, being deprived of its elaſticity. It is decompoſed by concentrated ſulphuric acid; hydrogen gas is emitted, and water, charcoal, and ammonia are formed. It is alſo decompoſed by nitric acid; azotic gas is emitted, and if the heat be continued, a portion of oxalic acid is formed. Yellow coloured oily flakes are precipitated. After gluten is fermented, it is ſoluble in acetic acid, and this ſolution may be employed as a varniſh.

2380 Of alcohol on fermented gluten. 5. Gluten is inſoluble in alcohol and in ether; but if fermented gluten be triturated with a little alcohol, and afterwards mixed with a quantity of the ſame liquid, part of it is diſſolved and forms a varniſh, which may be employed either for paper or wood, for cementing china, or for mixing with vegetable colours that are uſed as paints. Pieces of linen dipped in this varniſh, adhere ſtrongly to other bodies, and if lime be added to the ſolution, it conſtitutes a good lute.

2381 Of alkalies. 6. With the aſſiſtance of heat gluten is ſoluble in the alkalies; and when they are much concentrated, it is decompoſed, and formed into a kind of ſoap, conſiſting of oil and ammonia.

2382 Compoſition. 7. It appears from the diſtillation of gluten, and from its ſpontaneous decompoſition, that it conſiſts of oxygen, hydrogen, carbone, and azote. The vapour which is evolved during the fermentation of gluten, blackens ſilver, from which it is inferred that ſulphur is one of its conſtituent parts. From the properties and compoſition of gluten, the reſemblance between this ſubſtance and animal matter is ſufficiently obvious.

2383 In wheat. 8. Gluten exiſts in greateſt abundance in wheat flour, but it is found in a great number of plants, and in different parts of vegetables. 2384 Leaves. It exiſts in conſiderable proportion in the juice of the leaves of many plants, as thoſe of the cabbage, creſſes, &c. When this juice is procured by expreſſion, filtered through a cloth, and allowed to remain at reſt, it depoſits in the courſe of ſome days, a greeniſh powder, which has been called the green fecula of plants. This fecula is chiefly compoſed of gluten mixed with a reſinous matter, which gives it its colour, and a portion of woody fibre. If this juice be expoſed to the temperature of about 130°, the fecula coagulates in the form of large flakes. It dries when ſeparated from the water, and aſſumes the appearance of horn. When it is treated like gluten, it alſo acquires the ſmell and taſte of cheeſe.

2385 In ſeeds and fruits. Gluten has been found in acorns, cheſnuts, and horſe-cheſnuts, in barley, rye, peaſe, and beans; in apples and quinces; in the leaves of ſedum of different ſpecies, hemlock, borrage, ſaffron; in the petals of the roſe, in the berries of the elder, and in the grape. None was detected in the potato by Prouſt, although he found it in ſeveral other roots.

A ſubſtance which reſembles the fibrina of the blood, was found by Vauquelin in the juice of the papaw-tree. When this juice is mixed with water, part is diſſolved, and part remains inſoluble. The latter has a greaſy appearance, becomes ſoft in the air, viſcid, brown, and ſemitranſparent. It melted when thrown on burning coals, while drops of greaſe exuded. It was entirely conſumed, without leaving any reſiduum. But according to ſome, this ſubſtance is exactly ſimilar to gluten, and therefore, is not to be conſidered as one of the conſtituents of vegetable matter.

2386 Uſes. 9. Gluten is one of the moſt important of the component parts of vegetable ſubſtances. It is one of the chief ingredients in wheat, and to this it is owing that wheat flour is fit for being formed into bread.

VIII. Of Extractive Matter.

2387 Preparation. 1. The word *extract* was formerly employed to ſignify the inſpiſſated juices of vegetables, but of late it has been limited to a peculiar principle poſſeſſed of diſtinct properties. If ſaffron be infuſed in water for ſome time, and if the infuſion be filtered and evaporated to dryneſs, the reſiduum is that ſubſtance to which the name of extractive principle is given.

2388 Properties. 2. The following properties of extract were aſcertained by Vauquelin. 1. All extracts have an acid taſte. 2. If a few drops of ammonia be added to a ſolution of extract, a brown precipitate is formed, which conſiſts of lime, and part of the extract becomes inſoluble. 3. Sulphuric acid diſengages a penetrating acid vapour, which is found to be acetic acid. 4. When

quicklime

---

* *Annal. de Chim.* xliii. p. 270. and xlix. p. 304.

quicklime is added to a ſolution of extractive matter, ammonia is diſengaged. 5. A ſolution of ſulphate of alumina without exceſs of acid, being poured into a ſolution of extractive matter, and boiled, there is formed in the liquid a flaky precipitate which is compoſed of alumina and vegetable matter, and rendered inſoluble in water. 6. Almoſt all metallic ſolutions produce a ſimilar effect. With muriate of tin an inſoluble brown precipitate is formed, which is compoſed of the oxide of tin and vegetable matter. 7. Oxymuriatic acid poured into a ſolution of extractive matter, forms a copious, dark yellow precipitate. Muriatic acid remains in the ſolution. 8. If wool, cotton, or thread, be impregnated with alum, and boiled with a ſolution of extractive matter, theſe ſubſtances become charged with a great quantity of the extractive ſubſtance, they aſſume a fawn-brown tint, and the ſolution loſes a great deal of its colour. The ſame effect is produced by immerſing the ſubſtances to be dyed in a ſolution of muriate of tin. The effect is ſtill better, if oxymuriatic acid be employed inſtead of alum, or the ſolution of muriate of tin. 9. When extractive matter is diſtilled in an open fire, it yields an acid liquid, which contains a greater portion of ammonia than when it is diſtilled in the humid way with lime or alkali. 10. When extractive matter is diſſolved in water, and is left expoſed to the open air, it is completely decompoſed. The carbonates of potaſh, of ammonia, and of lime, and ſome other mineral ſalts which previouſly exiſted in the extractive matter, and are indeſtructible by putrid fermentation, remain behind.

2389 Exiſts in old plants. 3. It appears that extractive matter is found in greater proportion in old plants. It is found in different parts of the plant. It frequently forms one of the conſtituents of the ſap. It is this extractive matter which precipitates during the evaporation of the ſap, or when oxymuriatic acid is added to it.

2390 In the bark. Extractive matter has been found in the bark of many trees, and it is ſuppoſed that it exiſts in all barks which poſſeſs an aſtringent property. It has been found in the bark of the common willow, the Leiceſter willow, the oak, and the elm.

2391 Catechu. Extractive matter has been obtained from the infuſion of catechu, in which it is united with tan. If the powder of catechu be repeatedly waſhed with water, the liquid which paſſes off no longer precipitates gelatine. The reſiduum is extractive matter, of a reddiſh-brown colour, has no ſmell, but a ſlightly aſtringent taſte. The ſolution in water is at firſt yellowiſh-brown, but acquires a red colour by expoſure to the air. Many of the metallic ſalts form a precipitate with the ſolution of this matter. Linen boiled in it almoſt extracts the whole, and becomes of a light red brown colour. Extractive matter ſoftens when expoſed to heat; the colour becomes darker, but it does not melt. When it is diſtilled, it yields carbonic and carbonated hydrogen gaſes, acetic acid, and a ſmall portion of extractive matter unchanged. A light porous charcoal remains behind.

2392 Senna. The infuſion of the leaves of ſenna is of a brown colour, has a peculiar aromatic odour, and a bitter taſte. When the air of the atmoſphere or oxygen gas is made to paſs through this infuſion, a yellow coloured precipitate is formed. It is produced alſo by adding to the ſolution muriatic or oxymuriatic acid. In this ſtate the extractive matter has combined with oxygen, and has aſſumed a yellow colour, and being no longer ſoluble in water, it is precipitated. The taſte is ſlightly bitter. It is ſoluble in alcohol, but when water is added, it is thrown down. It is ſoluble alſo in alkalies, and forms with them a deep brown ſolution. When placed on burning coals, it gives out a denſe ſmoke, exhales an aromatic odour, and leaves behind a ſpongy maſs of charcoal.

2393 Peruvian bark. Extractive matter is obtained from the infuſion of Peruvian bark, which being united with oxygen, becomes of a fine red colour. It is obtained by boiling water on it, and by ſlow evaporation, and then diſſolving what remains in alcohol. By evaporating the alcohol, the peculiar extractive matter is depoſited. The matter thus obtained was of a brown colour, of a bitter taſte, ſoluble in hot water and alcohol, but inſoluble in cold water. It is of a black colour when dry, and brittle. It breaks with a poliſhed fracture. With the addition of lime-water it was precipitated in the form of a fine red powder, which combined with alkalies, but is inſoluble in water and alcohol.

IX. Of Colouring Matter.

2394 Exiſts in many plants. 1. Colouring matter is extracted from a number of plants for the purpoſes of dyeing, as from madder, carthamus, brazil wood, logwood, yellow weed or reſeda luteola, fuſtic or yellow-wood, anatto, and indigo.

2395 Madder. 2. The colouring matter of madder, or *rubia tinctorum*, is ſoluble in alcohol. By evaporation it leaves a reſiduum of a dark red colour. A violet precipitate is formed in this ſolution by a fixed alkali. Sulphuric acid produces a fawn-coloured precipitate, and ſulphate of potaſh, a beautiful red. Precipitates of different ſhades of colour are obtained with alum, nitre, chalk, acetate of lead, and muriate of tin.

2396 Carthamus. 3. Carthamus (tinctorius) contains two colouring matters, the one yellow and the other red. The firſt only is ſoluble in water, but the ſolution is turbid. It becomes tranſparent with the addition of acids; with alkalies it inclines to an orange colour; a fawn-coloured precipitate is formed, and then the ſolution becomes clear. Alum produces a dark yellow precipitate, but not very copious. A ſlight tincture is extracted from the flowers of this plant by means of alcohol, after the whole of the yellow matter has been diſſolved by water.

2397 Brazil wood. 4. Brazil wood, or *fernambouc*, is much employed in dyeing. A recent decoction of this wood gives a red precipitate inclining to fawn colour with ſulphuric acid. The liquid in which the ſolution was made remains tranſparent and of a yellow colour. With the firſt addition of nitric acid the tincture firſt paſſes to a yellow colour; but with a greater quantity, becomes of a dark orange yellow and tranſparent, after having depoſited a matter ſimilar in colour to the former, but more copious. The ſame changes take place with the muriatic acid as with the ſulphuric.

2398 Logwood. 5. Logwood or *Campeachy wood* yields its colouring matter to water and to alcohol, but more copiouſly to the latter. The tincture of logwood, or the ſolution in alcohol is of a beautiful red colour, inclining to violet or purple. Theſe different ſhades are more obvious in the decoction in water. When the aqueous ſolution is left to itſelf, it firſt becomes yellow, and then changes to black. The addition of acids produces a yellow colour; alkalies deepen the colour and reſtore the purple or violet. Sulphuric, nitric, and muriatic acids throw down a light precipitate which ſeparates ſlowly. Sulphate of iron communicates a bluiſh colour ſomewhat reſembling ink. A copious precipitate of a ſimilar colour is formed at the ſame time.

2399 Yellow weed.

6. Yellow weed, or dyers weed (*reſeda luteola* Lin.) in ſolution in water yields a yellow colour inclining to brown. When it is diluted with a greater quantity of water, the yellow colour which was more or leſs bright changes a little to green. The colour becomes paler with the addition of acids. It becomes deeper by the action of alkalies.

2400 Fuſtic.

7, Fuſtic, or yellow wood, (*morus tinctoria*, Lin.) contains a great proportion of colouring matter. A ſtrong decoction in water is of a dark reddiſh-yellow colour. When water is added to this ſolution the colour becomes orange-yellow. The liquid grows turbid with the addition of acids. Alkalies render it much deeper and nearly red.

2401 Anatto.

8. Anatto is in the form of a dry hard paſte, externally brown, and internally of a beautiful red colour. It is prepared from the ſeeds of the *bixa orellana* by reducing them to powder, mixing them with water, and allowing them to ferment. Anatto is more ſoluble in alcohol than in water. With the addition of an alkali the ſolution is promoted, and the colour inclines leſs to red.

Beſide theſe, a great variety of other vegetable ſubſtances give out their colouring matter to water or alcohol, and are employed in dyeing. To what has now been ſaid, however, we ſhall only add a ſhort account of one of the moſt important, namely indigo.

2402 Indigo.

9. Indigo is a colouring matter which is obtained from ſeveral plants, and has ſome reſemblance to fecula or ſtarch. The indigo of commerce is chiefly obtained from the *indigofera tinctoria*, a ſhrubby plant which is cultivated in the Eaſt and Weſt Indies, for the purpoſe of extracting the colouring matter.

2403 Preparation.

10. When the indigo plant has arrived at maturity, it is cut down, and conveyed to large wooden veſſels, where it is covered with water, and ſoon commences a fermentation. When the plant is cut down at the period of its maturity, it produces a more beautiful colour, but in ſmaller quantity. If it be too late, the quantity is ſtill diminiſhed, and the indigo is of a bad quality. The putrefactive proceſs ſoon commences, and ſucceeds beſt about the temperature of 80°. The water becomes turbid, and of a green colour. The ſmell of ammonia and carbonic acid gas are evolved. The fermenting proceſs is finiſhed in the period of from 6 to 24 hours, according to the temperature and ſtate of the plant. The liquid is then poured off into flat veſſels, in which it is conſtantly agitated till blue flakes appear. With the addition of a quantity of lime-water theſe flakes precipitate to the bottom. A yellowiſh liquid is poured off, and the blue precipitate is collected in linen bags, from which the water drains off. When the matter in the bag has acquired ſufficient conſiſtence, it is formed into ſmall cakes, which are ſlowly dried in the ſhade. This is the indigo of commerce.

2404 From other plants.

11. Indigo may be alſo extracted from the *nerium tinctorium*, or roſebay, a plant which grows in abundance in the Eaſt Indies, from the leaves of which Dr Roxborough extracted it, by the following proceſs. He digeſted the leaves in a copper veſſel with water, kept at the temperature of 160° till they aſſumed a yellowiſh colour. The liquid becomes of a deep green; it is then poured off, and with the addition of lime-water is agitated till the indigo is precipitated. To produce one pound of indigo, two or three hundred pounds weight of green leaves were found neceſſary; but this quantity varies according to the ſeaſon and ſtate of the weather in which they are collected.

2405 From woad.

12. The *iſatis tinctoria*, or woad, which is a Britiſh plant, alſo yields indigo, by treating it in the ſame way as the indigo plant.

2406 Hiſtory of indigo.

13. The hiſtory of indigo is curious. It was early known in India, but its value as a dye-ſtuff was not underſtood in Europe before the middle of the 16th century. But what is moſt ſingular, the uſe of this ſubſtance was either reſtricted or entirely prohibited in different countries, from ſome prejudice that its effects in dyeing were injurious. The uſe of it was prohibited in England from the time of Queen Elizabeth till the reign of Charles II. It was alſo prohibited in Saxony. It is deſcribed in the edict as a corroſive ſubſtance, and denominated *food for the devil!* In France during the adminiſtration of Colbert, the dyers were reſtricted to the uſe of a certain quantity. For ſome time after, indigo was generally employed as a dye ſtuff in Europe, and was chiefly cultivated in the Weſt Indies, and ſome parts of the American continent. This indigo was generally preferred in the market. What is now cultivated in the Eaſt Indies is found to be equal in quality.

2407 Properties.

14. Indigo is a light, friable ſubſtance, of a compact texture, and a deep blue colour. The ſhade varies from copper, violet, and blue tints. The lighteſt indigo is the beſt. It is always contaminated with extraneous matters. Bergman found in the pureſt indigo which he could procure, the following component parts.

2408 Compoſition.

Pure indigo	47
Gum	12
Reſin	6
Barytes	10.2
Lime	10.0
Silica	1.8
Oxide of iron	13.0
	100.0

Other earths have been found in indigo. In ſome ſpecimens Prouſt detected magneſia.

2409 Action of heat.

15. Pure indigo is a ſoft powder of a deep blue colour, which has neither taſte nor ſmell. When expoſed to heat, it emits a bluiſh-red ſmoke, and then burns away with a faint white flame. The earthy parts remain behind in the ſtate of aſhes. It undergoes no change by expoſure to the air. It is inſoluble in water, but if kept ſome time under it, a fetid odour is exhaled, owing to ſome change.

2410 Of acids.

16. Diluted ſulphuric acid poured upon indigo, diſſolves

ſolves only the earthy and mucilaginous matters; but if concentrated ſulphuric acid be added, in the proportion of eight parts of acid to one of indigo, the latter is diſſolved with the evolution of heat, in about 24 hours. The mixture is black and opaque; but if water be added, it becomes clear, and of a fine blue colour, producing various ſhades, according to the quantity of water. This ſolution of indigo in ſulphuric acid is called *liquid blue*, or according to Bancroft, ſulphate of indigo.

2411 Effects of different ſubſtances on liquid blue. Bergman made a great number of experiments on the effect of different ſubſtances on this ſolution, ſome of which we ſhall now mention, in which the colour was either changed, or entirely deſtroyed. When it was dropped into ſulphurous acid, the colour which was at firſt blue, became green, and was at laſt deſtroyed. In diluted tartaric acid the colour became gradually green, and was at laſt converted into a pale yellow. In acetic acid it became green, and was at laſt deſtroyed. In potaſh, carbonate of potaſh, ſoda, ammonia and its carbonate, the colour became green, and at laſt diſappeared. In ſulphate of ſoda the ſolution being diluted, after ſome time became green. It alſo became green in ſulphate of iron, and at laſt diſappeared. In the ſulphurets the colour was very ſoon deſtroyed. Black oxide of mangameſe produced the ſame effect. Theſe experiments have been mentioned, to ſhew that indigo is deprived either partially or totally of its colouring matter, by thoſe ſubſtances which have a ſtrong affinity for oxygen. From this it is inferred that indigo owes its colour to oxygen; and that it becomes green when it is deprived of it.

2412 Nitric acid. Concentrated nitric acid attacks indigo with ſuch violence, that it ſometimes inflames it. By diluting the acid, the action is greatly moderated. The ſolution becomes of a brown colour; cryſtals appear, which are ſuppoſed to be oxalic acid, and a brown viſcid ſubſtance remains behind.

Muriatic acid diſſolves indigo precipitated from ſulphuric acid, and forms a liquid of a dark-blue colour. The other acids, as the phoſphoric, acetic, and tartaric, exhibited ſimilar phenomena. They readily diſſolve indigo, which has been precipitated.

Oxymuriatic acid has little action on indigo in ſubſtance, but it deſtroys the colour of it in the ſtate of ſolution.

2413 Of alcohol. 17. Neither alcohol, ether, nor oils, have any action on indigo. Common indigo, when digeſted with alcohol and ether, communicates a yellow colour; but this, it is ſuppoſed, is owing to the ſolution of the reſinous ſubſtance.

2414 Alkalies. 18. The ſolution of the fixed alkalies readily diſſolves indigo, when it is precipitated from its ſolution. The colour of the ſolution is at firſt green, and is at laſt deſtroyed. Liquid ammonia and its carbonate produce a ſimilar effect, from which it appears, that indigo is decompoſed by the alkalies.

19. Lime water alſo diſſolves indigo precipitated from its ſolution. The colour is at firſt green, becomes gradually yellow; when expoſed to the air, the green returns, and at laſt diſappears.

2415 Compoſition. 20. Bergman ſubjected indigo to the proceſs of diſtillation; from 576 grains he obtained the following products:

Carbonic acid gas	19
Yellow acid liquid containing ammonia	173
Oil	53
Charcoal	331
	576

The component parts of indigo, therefore, appear to be oxygen, carbone, hydrogen, and azote.

X. Of Bitter Matter.

2416 In different ſubſtances. 1. A great number of vegetable ſubſtances are diſtinguiſhed by a very bitter taſte, ſuch as quaſſia, a ſubſtance uſed in medicine, gentian, hops, camomile. This taſte is aſcribed to a peculiar matter, called from this property *bitter matter*. It may be obtained by infuſing quaſſia for ſome time in water. This ſolution, which is of a yellow colour, has an extremely bitter taſte, but no ſmell. If the water be evaporated with a moderate heat to dryneſs, a browniſh yellow ſubſtance, which has ſome degree of tranſparency and ductility remains behind. After ſome time it becomes brittle.

2417 Properties. 2. When this ſubſtance, which has a very bitter taſte, and a browniſh yellow colour, is heated, it ſoftens, ſwells and blackens, then burns away without much flame, and leaves a ſmall quantity of aſhes. It is very ſoluble in water and alcohol. Nitrate of ſilver renders it turbid, and afterwards produces a yellow precipitate in the form of flakes. Acetate of lead produces a copious white precipitate.

XI. Of Narcotic Matter.

2418 Found in different plants. 1. A peculiar ſubſtance has been detected in opium, to which it is ſuppoſed the properties it poſſeſſes of producing ſleep, are owing. On account of this property this ſubſtance has received the name of *narcotic matter*. It is obtained from the milky juices of ſome plants, as thoſe of the poppy, lettuce, and ſome others. Opium, which is extracted from the poppy, is prepared by the following proceſs.

2419 Extraction of opium. The heads of the *papaver album* or white poppy, which is cultivated in India and different countries of the eaſt for this purpoſe, are wounded with a ſharp inſtrument; a milky juice flows out, which concretes, and is collected and formed into cakes.

2420 Properties. 2. In this ſtate opium is a tenacious ſubſtance, of a browniſh colour, has a peculiar ſmell, and a diſagreeable bitter taſte. It becomes ſoft with a moderate heat. It readily takes fire, and burns rapidly. By the analyſis of opium, it appears to be compoſed of the ſulphates of lime and of potaſh, extractive matter, gluten, mucilage, reſinous matter, and an oil, beſides the narcotic matter, to which its peculiar properties are owing.

2421 Separation of the narcotic matter. 3. By digeſting opium in water, part of it is diſſolved, and by evaporating the ſolution to the conſiſtence of ſyrup, a gritty precipitate appears, which becomes more copious with the addition of water. This precipitate is compoſed of reſinous and extractive matter, beſides the peculiar narcotic matter which is cryſtallized. When alcohol is digeſted on this precipitate, the reſinous and narcotic matters are diſſolved, and the extractive matter remains behind. As the ſolution cools, the narcotic matter cryſtallizes, but the cryſtals are coloured with a portion of reſin. By repeated ſolutions and cryſtallizations it may be obtained tolerably pure. *

2422 Of alcohol. If alcohol be digeſted on the reſiduum, it becomes of a deep-red colour, the ſame cryſtals are depoſited on cooling, and may be purified in the ſame way from the reſinous matter with which they are contaminated.

2423 Properties. 4. The narcotic matter, or as it is called by Deroſne, the *eſſential ſalt of opium*, when properly purified, is of a white colour, cryſtallizes in right-angled priſms, with a rhomboidal baſe, and has neither taſte nor ſmell. It is inſoluble in cold water, and requires 400 parts of boiling water for its ſolution, from which it is precipitated by cooling. The ſolution does not redden the tincture of turnſole. It is ſoluble in 24 parts of boiling alcohol, and requires about 100 parts when it is cold. When water is added to the ſolution in alcohol, it is precipitated in the form of a white opaque matter.

2424 Action of ether, &c. Ether and the volatile oils diſſolve this ſalt with the aſſiſtance of heat; but on cooling it is depoſited in the form of an oily liquid, and ſome time after cryſtals appear at the bottom of the veſſel.

2425 Of acids. 5. One of the moſt decided characters of this ſubſtance is its eaſy ſolubility in all the acids, and without the aid of heat. It is precipitated from theſe ſolutions by means of an alkali, in the form of white powder. Pure alkalies increaſe the power of its ſolubility in water, and the acids, when not added in exceſs, occaſion a precipitate. When nitric acid is poured on the cryſtals reduced to a coarſe powder, it communicates to them a red colour, and readily diſſolves them. When the ſolution is heated and evaporated, it yields cryſtals of oxalic acid in conſiderable quantity. The reſiduum has a very bitter taſte.

2426 Of heat. 6. When it is thrown on burning coals, it gives out a copious flame. When heated in a ſpoon, it gradually melts like wax. Diſtilled in a retort with a moderate heat, it melts, and afterwards ſwells up, with the evolution of white vapours, which condenſe on the ſides of the veſſel, in the form of a yellow oily matter. There paſſes over, at the ſame time, a little water impregnated with carbonate of ammonia. Towards the end of the proceſs, carbonic acid and carbonated hydrogen gas, with ſome ammonia, are diſengaged. There remains in the retort a light, ſpongy, voluminous maſs of charcoal, which, by burning, gives ſome traces of potaſh. The oily matter depoſited in the neck of the retort is very viſcid, and has a ſtrong aromatic odour, with a pungent, acrid taſte.

2427 Effects on animals. 7. Deroſne tried the effects of this ſubſtance on animals, and in very ſmall quantity. The ſymptoms which appeared, when it was given to dogs, were exactly ſimilar to thoſe which are produced, when a large quantity of crude opium is ſwallowed. They were recovered from its effects by means of vinegar, which he accounts for on the principle of the eaſy ſolubility of this ſubſtance in acids.

2428 Compoſition. 8. From the effects of heat and of nitric acid on this ſubſtance, it appears to be compoſed of oxygen, hydrogen, carbone and azote.

2429 Opium found in other plants. 9. This narcotic ſubſtance is alſo found in the milky juice, and in the extracts which are obtained from ſeveral other plants, as from different ſpecies of *lactuca* or lettuce, *hyoſcyamus niger*, or henbane. The leaves of ſome plants alſo produce ſimilar effects, as thoſe of the *deadly nightſhade*, *fox-glove*, and *conium maculatum* or hemlock.

XII. Of Oils.

2430 Fixed. 1. The nature, properties, and component parts of oils, have already been detailed, when treating of inflammable ſubſtances. Oils are of two kinds, fixed and volatile. Fixed oil exiſts chiefly in the ſeeds of plants, as linſeed oil, almond oil, and rape-ſeed oil. Fixed oil is alſo found in the pulp of ſome fruits, as in that of the olive. Fixed oils are found in thoſe ſeeds which have double lobes, or two cotyledons, and in theſe they are mixed with a quantity of mucilage. Theſe oils are extracted from ſeeds by expreſſion and boiling.

2431 Volatile. 2. Volatile oils are found in all parts of plants, excepting the ſeeds. In ſome plants they exiſt in the root, or the ſtem, and in others in the leaves, the flower, the pulp and rind of the fruit. The peculiar odour by which almoſt all plants are diſtinguiſhed, is ſuppoſed to be owing to a volatile oil. Theſe oils are alſo extracted by expreſſion, and ſometimes by diſtillation.

XIII. Of Wax.

2432 Preparation. 1. Wax of which bees form their combs for containing honey, is collected from vegetables; and a ſimilar ſubſtance being found in different parts of plants, it is to be conſidered as vegetable matter. The varniſh with which the upper ſurface of the leaves of ſome trees is covered, poſſeſſes the properties of bees wax. If the bruiſed leaves are digeſted in water, and afterwards in alcohol, till the ſoluble part is extracted, and the reſiduum be mixed with 6 times its weight of a ſolution of ammonia, and after maceration, the ſolution being poured off and filtered, diluted ſulphuric acid be added in exceſs to ſaturate the alkali, conſtantly ſtirring it, the varniſh precipitates in the form of a yellow powder. It is then to be waſhed with water, and melted with a moderate heat. This ſubſtance is wax.

2433 Properties. 2. Pure wax is of a white colour, has no taſte, and ſcarcely any ſmell. The aromatic ſmell of bees wax is owing to ſome ſubſtance with which it is mixed, for it is entirely removed by expoſure to the air, when the colour at the ſame time diſappears. Pure wax undergoes no change by expoſure to the air. The ſpecific gravity is 0.96. It is inſoluble in water.

2434 Action of heat. 3. Wax becomes ſoft by the application of heat. Unbleached wax melts at the temperature of 142°. When it is pure it requires the temperature of 155°, and then melts into a colourleſs, tranſparent fluid. By increaſing the heat, the wax boils and evaporates; with a red heat the vapour takes fire, and burns with a bright flame.

2435 Acids. 4. The acids have ſcarcely any action on wax. It is bleached by means of oxymuriatic acid, but no other effect is produced.

2436 Alcohol, &c. 5. Wax is ſoluble in boiling alcohol. It requires 20 parts of alcohol to diſſolve one of wax, and as the ſolution cools, the greater part is precipitated. With the addition of water the whole is thrown down. With the

---

* *Ann. de Chim.* xlv. 263.

the aſſiſtance of heat ether diſſolves wax nearly in the ſame proportion, but on cooling it is alſo precipitated.

Wax is ſoluble in the fixed oils with the aid of heat. This compound is known by the name of *cerate*, which is much employed to form plaſters for dreſſing wounds. It is ſoluble alſo in ſome of the volatile oils, as thoſe of turpentine, with the aſſiſtance of heat. As the ſolution cools, part of the wax is precipitated.

2437 Alkalies. 6. Wax combines with the fixed alkalies, and forms with them ſubſtances ſimilar to ſoap.

2438 Compoſition. 7. According to the analyſis of Lavoiſier, wax is compoſed of

Carbone,	82.28
Hydrogen,	17.72
	100.00

2439 Butter of wax. 8. When wax is diſtilled with a temperature above 212°, water comes over, ſome acid, and a little fluid and odorous oil. The oil in the courſe of the proceſs becomes thicker, and at laſt aſſumes the conſiſtency of butter; and hence it has been called *butter* of wax. This ſubſtance by repeated diſtillation is converted into a volatile oil. A coaly matter remains in the retort.

2440 Obtained from many plants. 9. Wax is extracted from a number of plants, poſſeſſing different degrees of conſiſtency, as that from the cacao, called the *butter of cacao;* from the *croton ſebifera*, called the *tallow of croton;* and the myrtle wax extracted from the myrica cerifera, or *candle-berry myrtle* of America. The myrtle wax is obtained from the berries of this plant. They are collected and put into a kettle, and covered with water to the depth of half a foot. Heat is applied, and the berries are preſſed againſt the ſides of the veſſel. The wax melts, and ſwims on the top. It is collected, paſſed through a cloth, dried and melted again, and then caſt into cakes. The wax, it appears, exiſts chiefly in the outer covering of the berries. Myrtle wax is of a pale-green colour; the ſpecific gravity is 1.015. When heated to the temperature of 109°, it melts; with a ſtronger heat it burns, giving out a white flame with little ſmoke; an agreeable aromatic odour is at the ſame time emitted. In its other properties it reſembles bees-wax.

Prouſt has detected wax in the rind of plumbs, oranges, and ſimilar fruits, and in the green fecula of many plants.

XIV. Of Camphor.

2441 Extraction. 1. Camphor is obtained from the *laurus camphorata*, a ſpecies of laurel which grows in China and Japan. It is extracted by ſublimation in an iron pot. The Dutch afterwards purify it by a ſecond ſublimation.

2442 Properties. 2. It is a white, brittle ſubſtance, poſſeſſing a hot acrid taſte. The ſpecific gravity is 0.9887. It is not altered by expoſure to the air, but it is ſo extremely volatile, that it diſappears entirely if left in an open veſſel. It cryſtallizes by ſublimation in cloſe veſſels, in the form of hexagonal plates or pyramids. It is inſoluble in water, although at the ſame time it communicates ſome of its odour.

2443 Action of heat. 3. When a heat about the temperature of 300° is ſuddenly applied, it melts, and then is volatilized. It readily catches fire, and burns with a bright flame, without leaving any reſiduum. It even burns on the ſurface of water. When a ſmall quantity of camphor in a ſtate of inflammation is introduced into a large glaſs veſſel filled with oxygen gas, it burſts out into a vivid flame; the inſide of the veſſel is covered with a black powder, and a great deal of carbonic acid gas is diſengaged. If a little water has been previouſly put into the veſſel, it is impregnated with carbonic and camphoric acids.

2444 Acids. 4. Camphor is ſoluble in the acids, but with the addition of water or an alkali, it is precipitated unchanged. Camphor in ſulphuric acid forms a red ſolution; in nitric acid, a yellow ſolution, which was formerly called *oil of camphor*. By the repeated diſtillation of nitric acid off camphor, it is converted into camphoric acid.

Sulphurous acid, muriatic acid, and fluoric acid, in the ſtate of gas, diſſolve camphor. If oxymuriatic acid gas be made to paſs into a ſolution of camphor in nitric acid, it is immediately changed to a roſe colour, and inſtantly afterwards it becomes yellow, which is permanent during the proceſs. When water is added to the ſolutions of camphor in acids, it is ſeparated. Camphor is alſo ſoluble in water impregnated with carbonic acid gas, and in acetic acid. The latter compound conſtitutes Henry's aromatic vinegar.

5. Alcohol readily diſſolves camphor, but it is precipitated with the addition of water. By diluting alcohol which holds camphor in ſolution with water, juſt ſo much as not to precipitate the camphor, the latter cryſtallizes in the form of feathers. The fixed and volatile oils diſſolve camphor with the aſſiſtance of heat, but on cooling the camphor is precipitated, and cryſtallized, as in the ſolution with alcohol.

2445 Alkalies. 6. Camphor communicates to the alkalies a little of its odour, but is not otherwiſe ſoluble in theſe bodies.

2446 Compoſition. 7. According to the analyſis of Bouillon Lagrange, by diſtilling one part of camphor with two of alumina, formed into a paſte with water in a glaſs retort, the component parts of camphor are carbone and hydrogen; the proportion of carbone being much greater than in oils.

2447 Oil of camphor. In the courſe of the diſtillation, he obtained a volatile oil, of a golden yellow colour, which floated on the ſurface of the water in the receiver. It had an acrid burning taſte, and aromatic odour, ſimilar to that of thyme or roſemary.

2448 Found in many plants. 8. Camphor has been detected in many other plants. It has been extracted from the roots of thyme and ſage, and in theſe plants it ſeems to be combined with volatile oil. If the oil be expoſed to a temperature below 54° in the open air, it evaporates, and the camphor cryſtallizes. It may be alſo obtained by diſtilling the oil in a water bath, under the temperature of 212°, till a third part of the oil paſſes over. Part of the camphor is found cryſtallized in the veſſel, and by repeating the proceſs, the whole may be extracted from the oil. By mixing the camphor with a little dry lime and ſubliming it, it may be purified.

XV. Of Caoutchouc.

2449 Hiſtory. 1. Caoutchouc is a ſoft elaſtic ſubſtance, chiefly obtained

tained from the inſpiſſated juice of two trees, the *hævea caoutchouc* and *jatropha élaſtica*, which are natives of South America. This ſubſtance was firſt brought from America about the beginning of the 18th century. It is called by the inhabitants of *Eſmeraldas*, a province of Quito, *heve*, and by the natives of the province of Mainas, *caoutchouc*.

2450 Preparation. 2. It is extracted by making inciſions in the bark of the tree. A milky juice flows from it, which is collected in proper veſſels. The juice is then applied, one ſtratum above another, on earthen moulds, and ſuffered to dry in the ſun, or before a fire. Various figures are formed on the ſurfaces of the different pieces by means of a pointed inſtrument. They are then expoſed to ſmoke, and when perfectly dry, the moulds are broken. In this ſtate it is brought to Europe. It is generally in the ſhape of bottles, but ſometimes in other forms.

2451 Properties. 3. When caoutchouc is pure, it is of a whitiſh colour; it is ſoft and pliable like leather, extremely elaſtic, and poſſeſſes great tenacity. The ſpecific gravity is 0.9335.

2452 Action of heat. 4. When caoutchouc is expoſed to heat, it readily melts into a matter of the conſiſtence of tar. It burns with a bright white flame, and diffuſes a fetid odour.

5. Sulphuric acid decompoſes caoutchouc; charcoal is precipitated, and the acid is partially converted into ſulphurous acid. It is alſo decompoſed by nitric acid; carbonic acid gas, azotic gas, and pruſſic acid gas are diſengaged, and oxalic acid is formed. Muriatic acid has no action upon it; but if oxymuriatic acid is poured upon the milky juice, the caoutchouc is immediately precipitated, and the acid is converted into muriatic acid. If a given quantity of air be confined in a veſſel over a quantity of this milky juice, the oxygen of the air is abſorbed, and a pellicle of caoutchouc is formed on the ſurface, from which it appears that the formation of caoutchouc is owing to the combination of its baſe with oxygen.

2453 Alcohol. 6. Caoutchouc is inſoluble in alcohol. It is ſoluble in ether, but it is neceſſary that the ether be previouſly waſhed with water. By this treatment it is formed into ſyringes, catheters, and other inſtruments. It is ſoluble in the volatile oils, but it remains ſomewhat glutinous after the evaporation. A mixture of volatile oil and alcohol forms a good ſolvent for caoutchouc, and in this ſtate it may be employed as a varniſh for paper or ſtuffs. A varniſh may alſo be formed with it, by diſſolving it in boiling wax. It is alſo ſoluble in rectified petroleum, and when the ſolution is evaporated, the caoutchouc remains unchanged.

2454 Alkalies. 7. According to ſome, caoutchouc is inſoluble in the alkalies; but according to others, all of theſe bodies are capable of diſſolving it.

2455 Compoſition. 8. By diſtillation caoutchouc yields ammonia, and from this, and its decompoſition by means of ſulphuric and nitric acids, its conſtituent parts muſt be carbone, hydrogen, azote, and oxygen.

2456 Found in different vegetable ſubſtances. 9. Caoutchouc has been detected in different parts of many other plants, but it is mixed with reſinous, gummy, and extractive matters. It has been found in different ſpecies of the miſletoe, in opium and maſtic. It has alſo been extracted from the *artocarpus integrifolia* or bread-fruit tree, the *urceola elaſtica*, and *ficus indica*.

XVI. Of Reſins.

2457 Nature of. 1. Reſinous bodies form a very numerous claſs of vegetable ſubſtances. When volatile oils are expoſed to the air, they become thick after a ſhorter or longer time, and are then found to be converted into a *reſin*. The oil abſorbs oxygen from the air, and is deprived of part of its carbone, which combining with the oxygen of the atmoſphere, forms carbonic acid. Reſinous ſubſtances, therefore, are generally conſidered as volatile oils ſaturated with oxygen. The general properties of reſinous ſubſtances are the following.

2458 Properties. 2. They are ſolid, brittle, and commonly of a yellowiſh colour, with ſome degree of tranſparency. The taſte reſembling volatile oils, is hot and acrid. They have no ſmell. The ſpecific gravity is from 1.0180 to 1.2289. All reſinous bodies are electrics, and when excited by friction, the electricity is negative; hence it is called *reſinous electricity*.

2459 Action of heat. 3. They melt by being expoſed to heat, and burn with a yellow flame, giving out a great quantity of ſmoke. Reſins are inſoluble in water.

2460 Acids, &c. 4. Reſinous ſubſtances are ſoluble in nitric acid; part is precipitated by the addition of water, and the whole by means of the alkalies. With the aſſiſtance of heat they are all ſoluble in alcohol, and in ſulphuric ether. Reſins are ſoluble in ſome of the fixed oils, and alſo in volatile oils.

2461 Alkalies. 5. Reſinous ſubſtances have been found to be ſoluble in the fixed alkalies.

6. We ſhall now enumerate ſome of the reſins which are beſt known.

2462 Roſin. *Roſin.*—This ſubſtance is extracted from different ſpecies of the fir, and the reſinous matter obtained from it has received different names. That procured from the *pinus ſylveſtris* is the common turpentine; from the *pinus larix*, venice turpentine; and from the *pinus balſamea*, balſam of Canada. The turpentine is obtained by ſtripping the bark of the trees; a liquid juice flows out, which gradually hardens. This juice conſiſts of oil of turpentine and roſin. By diſtilling the turpentine the oil paſſes over, and the roſin remains behind. By diſtilling to dryneſs common roſin is obtained. When water is added, while it is yet fluid, and incorporated by agitation, what is called yellow roſin is formed.

2463 Pitch. *Pitch.*—Is a reſinous juice obtained from the *pinus picea*, or pitch pine. It is purified by melting and ſqueezing it through linen bags, and it is then known by the name of *white* or *Burgundy pitch*. White pitch mixed with lamp-black forms black pitch.

2464 Maſtic. *Maſtic.*—This is a reſinous ſubſtance obtained from the *piſtacia lentiſcus*, a tree which grows in the Levant. The fluid which exudes from the tree, concretes into yellowiſh ſemitranſparent brittle grains. It has little taſte, melts and exhales a fragrant odour when heated, and readily diſſolves in alcohol and fixed oils. It contains a little volatile oil.

2465 Sandarac. *Sandarac.*—This reſinous ſubſtance is extracted from the

the juniper. It is a ſpontaneous exudation from this plant in the form of brown tears, which are ſemitranſparent and brittle.

2466 Labdanum. *Labdanum*, or *Ladanum*.—This is the produce of the *ciſtus creticus*, a ſhrub which grows in Candia. It is the exudation of a viſcid juice, which concretes by expoſure to the air. It has a fragrant odour and a bitter taſte.

2467 Dragons-blood. *Dragons-blood*.—This reſinous ſubſtance is a production of the *dracæna draco*, and ſome other plants. It is of a dark-red colour, opaque and brittle. The powder is of a crimſon colour. It melts when it is heated, and readily burns. It has no taſte, is inſoluble in water, but ſoluble in alcohol, to which it communicates a crimſon colour. It is alſo ſoluble in the fixed oils, and gives them a red colour.

2468 Anime. *Reſina animæ*.—This reſin is the produce of a ſpecies of *hymenæa*, or locuſt tree, a native of North America. It is ſoluble in alcohol, and is employed as a varniſh.

2469 Copal. *Copal*.—This reſinous ſubſtance is obtained from a tree, the *rhus copallinum*, a native of North America. The copal moſt preferred is brought from Spaniſh America. It is a light brown, tranſparent ſubſtance. It melts when heated, but is not directly ſoluble in alcohol, or in oil of turpentine, and it is with difficulty ſoluble in fixed oils. Copal forms an excellent varniſh. Indeed it is one of the beſt that is known for beauty and durability.

2470 Varniſh. If copal be treated with oil of turpentine in a cloſe veſſel, from which the vapours are not allowed to eſcape, they exert a great preſſure, which prevents the boiling, and thus the mixture acquires a higher temperature. A conſiderable portion of the copal is thus diſſolved, and with the addition of a little poppy oil it forms an excellent elaſtic varniſh.

If copal be kept melted till a ſour-ſmelling aromatic odour ceaſes to proceed from it, and if it be then mixed with an equal quantity of linſeed oil previouſly rendered colourleſs by expoſure to the ſun, it combines with the oil, and thus forms a varniſh. The ſubſtances varniſhed with this preparation muſt be dried in the ſun.

Copal may be diſſolved in alcohol, by previouſly diſſolving half an ounce of camphor in 16 ounces of alcohol. This ſolution is poured on 4 ounces of copal in a matraſs, which is ſtopped with a cork, and perforated with a pin. When the copal is nearly diſſolved, the proceſs is ſtopped, and the matraſs allowed to cool, before the cork is removed. This ſolution forms a colourleſs varniſh.

Copal, it is ſaid, may be diſſolved in alcohol, by expoſing it to the action of the vapour. This proceſs is conducted by boiling a quantity of alcohol in the bottom of a veſſel, at the top of which a piece of copal is ſuſpended. During the proceſs the copal ſoftens, and falls down like oil into the alcohol.

2471 Elemi. *Elemi*.—This reſinous ſubſtance is the produce of the *amyris elemifera*, a tree which grows in the Eaſt and Weſt Indies. It is ſemitranſparent, of a pale yellow colour, ſoftiſh, and hardens by keeping. It has a ſtrong fragrant ſmell, and when diſtilled it yields a fragrant oil.

2472 Balm of Gilead. *Opobalſamum*, or *balm of Gilead*.—This reſin is procured from another ſpecies of amyris, the *Gileadenſis*, a tree which is a native of Arabia. The beſt kind, which is highly valued by the Turks, is never ſeen in Europe.

2473 Copaiva. *Copaiva*, or *balſam of Copaiva*.—This reſinous ſubſtance is obtained from the *copaiva officinalis*, a tree which is a native of South America. It exudes by wounding the trunk of the tree. It is tranſparent, of a yellowiſh colour, has a pungent taſte and an agreeable ſmell. It is at firſt of the conſiſtence of oil, but afterwards becomes as thick as honey. By diſtillation the volatile oil, with which it is mixed, may be ſeparated, and the reſinous matter remains behind.

2474 Guaiac. *Guaiac*.—This reſin is the produce of the *guaiacum officinale*, a tree which is a native of the Weſt Indies. The reſin exudes ſpontaneouſly in tears, but it is chiefly obtained by cutting the wood into billets, and boring them longitudinally. When one of theſe is heated on the fire, the reſinous matter is melted, and runs through the hole as the wood burns. This reſin is of a browniſh-yellow colour, and has ſome degree of tranſparency. It is ſoluble in alcohol, and has neither ſmell nor taſte. It melts when heated, and when it is thrown on hot coals, it diffuſes an agreeable odour. When ſwallowed in the ſtate of powder, it produces a ſtrong ſenſation of heat in the throat.

2475 Lac. *Lac*.—This reſinous ſubſtance is obtained from the *croton lacciferum*. It is a of deep red colour, with ſome degree of tranſparency. It is the baſis of the finer kinds of ſealing wax, and is employed as a varniſh.

2476 Amber. *Amber*.—This ſubſtance poſſeſſes many of the properties of the reſins, and it has been conſidered by ſome of vegetable origin. It is a brittle hard ſubſtance, tranſparent, ſometimes colourleſs, but often yellow or deep brown. The ſpecific gravity is 1.065, It has neither taſte nor ſmell, except when it is heated, and then it becomes ſoft, and gives out a fragrant odour. It burns with a ſtrong heat, leaving only a ſmall reſiduum. It is inſoluble in water, but alcohol diſſolves a ſmall quantity of it. When the ſolution is concentrated, it becomes milky with the addition of water. The precipitate which is formed is a reſinous ſubſtance. It is ſoluble in the fixed alkalies at a boiling temperature.

2477 Effect of acids. Sulphuric acid converts amber into a black reſinous maſs. It is alſo ſoluble in nitric acid.

2478 Diſtillation. By the diſtillation of amber, carbonic acid gas and carbonated hydrogen gas, an acid liquor, and an oil, which is at firſt thin and tranſparent, but afterwards darker and thicker, is obtained. Succinic acid ſublimes towards the end of the proceſs.

2479 Varniſh. When amber is roaſted, it becomes ſoluble in the oils, and forms a varniſh. This varniſh may be formed by ſpreading the amber on a flat-bottomed iron-pan, and expoſing it to heat till it melts. It is then covered up, and ſet by to cool. One part of this roaſted amber, which has loſt half of its weight, if the proceſs be properly managed, is then to be mixed with three parts of linſeed oil. The mixture is to be expoſed to a gentle heat till the amber is diſſolved. It is then to be removed from the fire, and four parts of the oil of turpentine are to be added when it is nearly cold. The clear part, after it has ſettled, is ſtrained through a linen cloth.

2489 Benzoin. *Benzoin*.—This ſubſtance contains a reſinous matter combined

combined with an acid, and is commonly ranked among balſams. Benzoin is obtained from the *ſtyrax benzoin*, a tree which is a native of Sumatra. It is a brittle ſubſtance, has a fragrant odour when rubbed, and, when it is heated, the acid eſcapes. It may be diſſolved in alcohol, but it is inſoluble in water.

2481 Styrax. *Styrax.*—This ſubſtance, which is in a half-fluid ſtate, exudes from a tree in Arabia. It is of a greeniſh colour, has an aromatic taſte, and an agreeable odour. The benzoic acid, which is one of its component parts, diſſolves in water. The whole of it is ſoluble in alcohol. It abſorbs oxygen, and becomes harder by expoſure to the air.

2482 Storax. *Storax.*—This ſubſtance is procured from the *ſtyrax officinale*, a tree which is a native of the Levant. It is of a brown colour and brittle, has an aromatic taſte, fragrant odour, and is ſoluble in alcohol. It gives out benzoic acid by heat.

2583 Balſam of Tolu. *Balſam of Tolu.*—This ſubſtance is obtained from the *toluifera balſamum*, a tree which is a native of South America. It is of a reddiſh-brown colour, becomes ſolid and brittle when expoſed to the air, and has a very fragrant ſmell.

2484 Of Peru. *Balſam of Peru.*—This is obtained from the *myroxilon peruiferum*, a plant which is a native of South America. The reſin is extracted by boiling the twigs in water. It is of the conſiſtence of honey, has a brown colour, an agreeable ſmell and an acrid taſte. It is ſoluble in alcohol. The acid part is ſoluble in water. Benzoic acid is driven off by heat.

XVII. Of Gum-Reſins.

2485 Conſtituents. 1. This claſs of ſubſtances ſeems to be compoſed of a mixture of reſinous matter with a portion of gummy and extractive matter. They are never obtained from plants by means of ſpontaneous exudation, but are procured by wounding the plants which contain them. The general properties of gum-reſins are the following.

2486 Properties. 2. They are always in the ſolid ſtate, and commonly brittle and opaque. They are ſoftened by heat, but do not melt, and are leſs combuſtible than the reſins. They burn with flame. They have an acrid taſte, with a ſtrong ſmell, ſometimes reſembling garlic. They are partially ſoluble in water, and in alcohol. The ſolution in water is opaque and milky, and the ſolution in alcohol is tranſparent. They are partially ſoluble in vinegar and wine. They are ſoluble in nitric acid, and alſo in the alkalies, with the aſſiſtance of heat.

3. The gum-reſins by diſtillation yield a portion of ammonia, which ſhews that azote forms one of their conſtituent parts.

4. Many of the gum-reſins have been long known in medicine, and ſome of them are of conſiderable importance. We ſhall ſpecify the peculiar properties of the following.

2487 Olibanum. *Olibanum.*—This gum-reſin is chiefly collected in Arabia, from the *juniperus lycia*. It is brought from Mecca to Cairo, and from thence to Europe, in the form of tranſparent brittle grains, not larger than a cheſnut, of a yellow colour, a peculiar aromatic ſmell, but with little taſte. With water it forms a milky fluid, but it is entirely ſoluble in alcohol. When heated it does not melt, but inflames and burns with an agreeable ſmell. It is the frankincenſe of the ancients, and is ſtill employed to diffuſe an agreeable fragrance in the Greek and Romiſh churches.

2488 Scammony. *Scammony.*—This ſubſtance is extracted from the *convolvulus ſcammonia*, a climbing perennial plant which grows in Syria. By cutting the roots, a milky juice flows out, which is collected and dried in the ſun. It is of a dark-gray colour, a bitter acrid taſte, and a nauſeous ſmell. It forms a greeniſh milky fluid with water. It is ſoluble in alcohol. It is employed in medicine as a cathartic.

2489 Euphorbium. *Euphorbium.*—This ſubſtance is obtained from the *euphorbia officinalis*, which is a native of Ethiopia. The milky juice which flows from inciſions made in the plant, is dried in the ſun. It is in the form of ſmall yellow tears. It has no ſmell, and at firſt no perceptible taſte, but it communicates afterwards a burning ſenſation to the mouth. It is ſoluble in alcohol. It has been conſidered as poiſonous.

2490 Aſſafœtida. *Aſſafœtida.*—This gum-reſin is obtained from the *ferula aſſafœtida*, a perennial plant, which is a native of Perſia. It is extracted from the roots by cutting off the extremity. The milky juice flows out, which is dried in the ſun. It is brought to Europe in large irregular maſſes, which are of a whitiſh, reddiſh, or violet hue. It has a ſtrong fetid, alliaceous ſmell, and a bitter acrid taſte. It is but partially ſoluble, both in alcohol and in water It is much employed in medicine as a ſtimulant and antiſpaſmodic.

2491 Ammonia. *Ammoniac.*—This gum-reſin is ſuppoſed to be obtained from another ſpecies of the ferula, a plant which grows in Abyſſinia and in the interior parts of Egypt. It is brought from the Eaſt Indies, uſually in large maſſes, which are compoſed of little lumps or tears, of a milky colour. When expoſed to the air, it is changed to a yellow colour. It has a nauſeous, ſweet taſte, which is ſucceeded by a bitter. It has a peculiar ſmell. It is not fuſible, but when placed on hot coals, it burns away in flame. It forms a milky ſolution with water and vinegar, and it is partially ſoluble in alcohol.

2492 Myrrh. *Myrrh.*—It is not yet known from what plant this ſubſtance is obtained. It is brought from the Eaſt Indies in the form of tears; is light and brittle, of a reddiſh-yellow colour, and an unctuous feel. It has a bitter, aromatic taſte, and a ſtrong, but ſomewhat grateful odour. It does not melt, and burns with difficulty. It is more ſoluble in water than in alcohol. With the former the ſolution is yellow and opaque; with the latter it is tranſparent.

2493 Sarcocol. *Sarcocol.*—This ſubſtance is ſuppoſed to be the product of the *penæa ſarcocolla*. It is brought from Perſia and Arabia, in the form of ſmall whitiſh-yellow grains. It has a bitter and ſomewhat ſweetiſh taſte. It is almoſt entirely ſoluble in water.

2494 Galbanum. *Galbanum.*—This ſubſtance is obtained from the *bubon galbanum*, a perennial plant which grows in Africa. The milky juice ſometimes exudes from the joints of the old plants, but is moſt commonly procured by cutting them acroſs. This juice becomes hard, and is the galbanum brought to Europe. It is in the form of whitiſh-yellow tears, has a bitteriſh acrid taſte, and a peculiar ſmell. It forms a milky ſolution with water, wine, and vinegar. It is ſcarcely ſoluble in alcohol.

It does not melt, but yields a conſiderable proportion of oil by diſtillation.

2495 Sagapenum. *Sagapenum.*—It is only conjectured that this gum reſin is obtained from the *ferula perſica*. It is brought in large maſſes or diſtinct tears from Alexandria. It is of a yellow colour, becomes hot in the hand, but is not fuſible. It has a hot, nauſeous, bitteriſh taſte, and a diſagreeable garlic ſmell. It is ſparingly ſoluble in alcohol, but diſſolves almoſt entirely in water. It yields by diſtillation a fetid volatile oil.

2496 Opoponax. *Opoponax.*—This gum-reſin is obtained from the *paſtinaca opoponax*, a perennial plant which grows wild in the ſouth of Europe. It is obtained by wounding the ſtock or root, and is in the form of round drops or tears, or in irregular maſſes of a reddiſh-yellow colour. It has a bitter, acrid, and ſomewhat nauſeous taſte, with a ſtrong peculiar ſmell. It forms a milky ſolution with water, and yields an eſſential oil by diſtillation.

2497 Gamboge. *Gamboge.*—This gum-reſin is obtained from the *ſtalagmitis cambogioides*, a tree which grows wild in Siam and Ceylon. In Siam it is procured in drops by breaking the leaves and young ſhoots, from which it is ſuppoſed it derived the name of *gum guttæ*. In Ceylon it is obtained by wounding the bark and collecting the juice, which is afterwards dried in the ſun. It is brought from the Eaſt Indies in cakes or rolls. It is of a yellow-orange colour, opaque and brittle, has no ſmell, and little taſte, leaving only a ſlight ſenſe of acrimony when it has been kept in the mouth. It forms a turbid yellow ſolution with water, and is almoſt entirely ſoluble in alcohol. It is employed in medicine, and is a violent cathartic.

2498 Bdellium. *Bdellium.*—Little is known of this ſubſtance, or of the tree from which it is obtained. It is in the form of ſmall pieces or tears of different ſizes, of a golden-yellow colour, with a reddiſh tint. This ſubſtance, or a ſubſtance with the ſame name, was long celebrated among the ancient phyſicians.

XVIII. Of Wood.

2499 Preparation. 1. If a piece of wood be boiled in a great quantity of water till it no longer gives out taſte or ſmell, and if it be afterwards digeſted in alcohol, the ſubſtance which remains is the woody fibre.

2500 Properties. 2. It is either in a fibrous, lamellated, or pulverulent form. This ſubſtance, which is more or leſs coloured, has neither taſte nor ſmell, is not altered by expoſure to the air, and is inſoluble in water and alcohol.

2501 Action of heat. 3. When it is heated in contact with air, it blackens, exhales denſe, acrid, pungent fumes, and leaves behind a coaly matter, which does not change its form. By reducing it to aſhes, it is found to contain a little potaſh, ſulphate of potaſh and lime, and phoſphate of lime. When it is diſtilled in a retort it yields water, acetic acid contaminated with oil, a thick oily matter, carbonated hydrogen, and carbonic acid gaſes, and a portion of ammonia, combined with acetic acid.

2502 Compoſition. 4. By the action of nitric acid on quinquina, which reſembles the woody fibre, Fourcroy obtained from 100 parts, the following products:

Oxalic acid,	56.250
Citric acid,	3.905
Malic acid,	0.388
Acetic acid,	0.486
Azotic gas,	0.867
Carbonate of lime,	8.330
	70.226
Reſiduum,	32.031

A quantity of carbonic acid gas was alſo diſengaged, which was not eſtimated. The increaſe of weight is aſcribed to the oxygen which combined with the baſes of the acids which were formed during the decompoſition of the woody fibre by the nitric acid. The reſiduum, by diſtillation, yielded a yellowiſh fluid mixed with alcohol and ſome acetic acid, a concrete oil ſoluble in alcohol, charcoal, and carbonate of lime, beſides carbonic acid and carbonated hydrogen gaſes. The component parts of wood, therefore, appear to be, oxygen, carbone, hydrogen, azote, and lime.

2503 Proportions of charcoal. The relative proportion of wood in plants has been eſtimated by the proportion of charcoal which they afford. From different woods, Prouſt obtained charcoal in the following proportions.

Black aſh,	25
Guaiac,	24
Pine,	20
Green oak,	20
Heart of oak,	19
Wild aſh,	17
White aſh,	17

XIX. Of Tan.

2504 Preparation. 1. Tan is obtained from a great number of vegetable ſubſtances. It exiſts in conſiderable proportion in oak bark and nut-galls; and it is obtained from the latter by the following proceſs.

Reduce a quantity of nut galls to a coarſe powder, infuſe them in water till it is ſaturated, pour off the liquid, and boil it to dryneſs. A black matter remains, which is *tan*, nearly in a ſtate of purity. It is propoſed alſo to extract tan from nut-galls by other proceſſes. If a ſolution of muriate of tin be added to the infuſion of nut-galls, a copious precipitate of a yellow colour is produced. When this is ſeparated by filtration, and dried, it is in the form of a buff-coloured powder. It is a compound of oxide of tin and tan. It is then mixed with water, and a ſtream of ſulphurated hydrogen gas is paſſed through it. An inſoluble ſulphuret of tin is formed, and the tan is diſſolved in water. By filtration and evaporation of this water to dryneſs, a brown ſubſtance remains, which is tan; but by this proceſs it is not perfectly pure, being mixed with a portion of extractive matter. It has alſo been propoſed to ſeparate tan from the infuſion of nut-galls by means of concentrated ſulphuric or muriatic acid, carbonate of potaſh, or lime water.

2505 Properties. 2. Tan is a brittle ſubſtance, of a brown colour, has a very aſtringent taſte, is ſoluble in water and alcohol, to both of which it communicates a brown colour and very aſtringent taſte.

2506 Action of heat. 3. When it is heated, it becomes black, gives out carbonic acid gas, and burns in the open air, leaving behind a ſmall quantity of lime.

2507 Acids. 4. Tan is precipitated from the infuſion of galls, by means of ſulphuric, nitric, and muriatic acids, and forms with them compounds which are ſoluble in water.

2508 Alkalies. 5. The alkalies combine with tan, and form compounds which are ſoluble in water. A reddiſh brown colour is produced in the liquid by the addition of potaſh or ſoda, and it loſes the property of precipitating gelatine. Ammonia forms a ſimilar compound with the infuſion of galls.

2509 Earths. 6. Moſt of the earths combine with tan, and form with it compounds which are chiefly inſoluble in water. Lime water, added to the infuſion of galls, produces an olive-coloured precipitate. A ſimilar precipitate is obtained by means of barytes, ſtrontites, and magneſia.

2510 Metallic oxides and ſalts. 7. The metallic oxides combine with tan, and form compounds which are nearly inſoluble in water. Similar precipitates are obtained by means of many of the metallic ſalts. The green ſulphate of iron produces no precipitate; but the red ſulphate gives a deep-blue precipitate, which becomes black by expoſure to the air, or when it is dried. This is the baſe of writing ink, as was formerly deſcribed in treating of the ſulphate of iron.

2511 Gelatine. 8. Tan forms an inſoluble compound with gelatine, which is the principle of the important proceſs of tanning leather, and is nothing more than the combination of tan with the animal matter called *gelatine* or *glue*.

2512 Exiſts in the bark chiefly. 9. Tan is chiefly found in the bark of trees; it is alſo found in the leaves, the wood, the ſap, and ſometimes it is obtained by ſpontaneous exudation, as is the caſe with the ſubſtance called *kino*. Several varieties of tan have been found in different vegetable ſubſtances, as in catechu, dragon's blood, ſumach, and fuſtic.

2513 Proportion varies. 10. The quantity of tan varies with the age and ſize of the tree, and at different ſeaſons. The greateſt proportion has been found in the inner bark. Mr Davy aſcertained the quantity of tan obtained from the ſolid matter extracted by water, from an ounce of different vegetable ſubſtances.

	Solid Matter.	Tan.
White inner bark of old oak	108 grs.	72 grs.
young oak	111	77
Spaniſh cheſnut	89	63
Leiceſter willow	117	79
Coloured or middle bark of oak	43	19
Spaniſh cheſnut	41	14
Leiceſter willow	34	16
Entire bark of oak	61	29
Spaniſh cheſnut	53	21
Leiceſter willow	71	33
elm	—	13
common willow	—	11
Sicilian ſumach	165	78
Malaga ſumach	156	79
Souchong tea - -	—	48
Green tea - -	—	41
Bombay catechu - -	—	261
Bengal catechu -	—	231
Nut-galls - -	180	127 *

* *Phil. Tranſ.* 1803.

2514 Proportions in different plants. The following proportions of tan were found by adding a ſolution of glue to the infuſion of the plant in water.

	Proportion of Tan.		Proportion of Tan.
Elm	2.1	Sallow	4.6
Oak cut in winter	2.1	Mountain aſh	4.7
Horſe cheſnut	2.2	Poplar	6.0
Beech	2.4	Hazel	6.3
Willow boughs	2.4	Aſh	6.6
Elder	3.0	Spaniſh cheſnut	9.0
Plum tree	4.0	Smooth oak	9.2
Willow trunk	4.0	Oak cut in ſpring	9.6
Sycamore	4.1	Leiceſter willow	10.1
Birch	4.1	Sumach	16.2*
Cherry tree	4.2		

* *Phil. Tranſ.* 1799.

XX. Of Suber.

2515 Conſtitutes the epidermis. 1. The vegetable ſubſtance denoted by the name of *ſuber* is, according to Fourcroy, the epidermis or outer covering of trees. This ſubſtance is analogous to common cork, which is the epidermis of the *quercus ſuber*, from which the name of this peculiar vegetable ſubſtance is derived.

2516 Properties. 2. It is a light, ſoft, elaſtic ſubſtance, is inſoluble in water, but readily abſorbs this liquid. Common cork is the ſame ſubſtance, having greater denſity, and accumulated in greater quantity.

2517 Action of heat. 3. This matter is very combuſtible, and burns with a white vivid flame, leaving behind a very black, light, voluminous coaly matter. When this matter is diſtilled, it yields ammonia.

2518 Of nitric acid. 4. When cork is treated with nitric acid, carbonic acid gas and nitrous gas are evolved. The cork is decompoſed, and converted, partly into a yellow, ſoft, unctuous matter, which ſwims on the ſurface, and partly into ſuberic acid; the nature and properties of which have been already deſcribed.

XXI. Of Alkalies.

2519 Fixed alkalies only found. 1. The fixed alkalies only have been detected in plants, and there are few plants which do not yield a ſmaller or greater proportion of one of theſe alkalies. It is ſuppoſed that they exiſt in plants, in combination with acetic and carbonic acids.

2520 Potaſh. 2. Potaſh, formerly called *vegetable alkali*, becauſe it was ſuppoſed to exiſt only in vegetables, is found in all plants except thoſe which grow near the ſea. The proceſs for extracting it has been already deſcribed. The vegetables are reduced to aſhes by burning; the aſhes waſhed with water, which is filtered and evaporated to dryneſs. The potaſh remains behind.

3. Shrubby and herbaceous plants yield a greater proportion of aſhes than trees. The branches of trees afford more aſhes than the trunk, and the leaves yield more than the branches. Other ſalts are found mixed with the potaſh, ſuch as the ſulphates of potaſh and of lime, muriate of potaſh, phoſphate of lime, and phoſphate of potaſh; the latter of which has been detected in maize and wheat. In the following table the proportion of aſhes obtained from 100 parts of different plants, and the quantity of potaſh which theſe aſhes yield, are exhibited.

	Aſhes.	Potaſh.
Sallow,	2.8	0.285
Elm,	2.36727	39.——
Oak,	1.351185	0.15343
Poplar,	1.23476	0.07481
Hornbeam,	1.1283	0.1254
Beech,	0.58432	0.14572
Fir,	0.34133	0.00000
Vine branches,	3.379	0.55
Common nettle,	10.67186	2.5033
Common thiſtle,	4.04265	0.53734
Fern,	5.00781	0.6259
Cow thiſtle,	10.5	1.96603
Great river ruſh,	3.85395	0.72234
Feathered ruſh,	4.33593	0.50811
Stems of Turkey wheat,	8.86	1.75
Wormwood,	9.744	7.3
Fumitory,	21.9	7.9
Red clover,		0.078
Vetches,		2.75
Beans with their ſtalks,		2.

2521 Soda.

4. Soda is generally found in all marine plants, and in many others which grow near the ſhore. The proportion of ſoda which many plants containing it yield, is very conſiderable. A hundred parts of the *ſalſola ſoda* afford 19.921 of aſhes, from which may be extracted 1.992 parts of ſoda. It is from different ſpecies of *fuci* that the ſoda or kelp of Britain is obtained. The ſoda of commerce is extracted from two ſpecies of ſalſola, namely the *ſativa* and *vermiculata*, which grow abundantly on the ſhores of Spain and the Mediterranean.

XXII. Of Earths.

2522 Lime.

1. Four of the earths have been detected in vegetables, namely lime, ſilica, magneſia, and alumina. Few plants have been found which do not contain ſome portion of lime. It is the moſt abundant of all the earths in plants.

2523 Silica.

2. Silica has been found in ſeveral plants, and chiefly in the epidermis, ſome of which are almoſt entirely compoſed of this earth. A hundred parts of the epidermis of the following plants yielded the annexed proportions of this earth.

Bonnet cane,	90
Bamboo,	71.4
Common reed,	48.1
Stalks of corn,	6.5

2524 Magneſia.

3. Magneſia is more rarely found in vegetables. It has been detected in conſiderable proportion in the fuci and other ſea plants. The greateſt proportion yet diſcovered is found in the ſalſola ſoda. A hundred parts of this plant have yielded 17.929 of magneſia.

2525 Alumina.

4. Alumina is found in plants in very ſmall quantity.

5. In the following table are exhibited the quantity of earths in general, found in 100 parts of different plants.

2526 Proportion of earths.

Oak,	1.03
Beech,	1.453
Fir,	0.003
Turkey wheat,	7.11
Sun-flower,	3.72
Vine branches,	2.85
Box,	2.674
Willow,	2.515
Elm,	1.96
Aſpen,	1.146
Fern,	3.221
Wormwood,	2.444
Fumitory,	14.000

Herbaceous plants, it appears, contain a greater proportion of earths than trees. In all the kinds of grain which Bergman examined, he found all the four earths. From 100 parts of oat grain, Vauquelin obtained a reſiduum of 3.1591, which by analyſis he found to be compoſed of

Silica,	60.7
Phoſphate of lime,	39.3
	100.0

By burning the ſtem and ſeeds of the ſame grain, the reſiduum by analyſis afforded the following ſubſtances.

Silica,	55
Phoſphate of lime,	15
Potaſh,	20
Carbonate of lime,	5
	95

Some traces of oxide of iron were alſo detected.

XXIII. Of Metals.

2527 Iron and manganeſe.

The only metallic ſubſtances which have certainly been found in plants are iron and manganeſe. Iron has been detected in the aſhes of ſalſola; and manganeſe has been found in the aſhes of the pine, green oak, calendula, vine, and fig-tree. Gold, it is ſaid, has been found in ſome plants, but in very minute proportion.

CHAP. XIX. OF ANIMALS.

2528 Characters.

ANIMALS conſtitute the ſecond diviſion of organized matter. They are diſtinguiſhed from vegetables by texture, form, and component parts. The more characteriſtic differences between animals and vegetables are, the locomotive power of animals, irritability, and ſenſibility. Animal matters paſs to the putrid fermentation, and they are all ſoluble in the alkalies. Sulphuric acid reduces animal ſubſtances to a carbonaceous matter. Carbone is precipitated, and ammonia is diſengaged. Nitric acid acts violently on animal ſubſtances, with the evolution of azotic gas.

In treating of animal matters, we ſhall firſt conſider the functions of living animals; 2. Their decompoſition; and, 3. Their component parts. Theſe ſubjects ſhall occupy the three following ſections.

SECT. I. *Of the* FUNCTIONS *of* ANIMALS.

2529 Cannot be explained on chemical principles.

In taking a view of animal ſubſtances, it is neceſſary to conſider the functions of the living animal, ſo far

far at leaſt as theſe functions admit of explanation on chemical principles. It is beyond the reach of human ſagacity fully to underſtand the ſimpleſt proceſſes in the animal economy. Theſe cannot be explained on chemical or mechanical principles; but to comprehend clearly and fully, even what is known of the functions of living animals, it would be neceſſary to enter into a deſcription of the ſtructure and nature of the organs which are employed in theſe functions. But this is not the province of chemiſtry; it belongs to the ſciences of ANATOMY and PHYSIOLOGY. We muſt therefore content ourſelves with giving a ſhort account of the chemical changes which take place by the action of living animals. The functions of animals which have occupied the attention of chemical phyſiologiſts, and which we propoſe to treat of in this ſection, are reſpiration, digeſtion, ſecretion, and aſſimilation.

I. Of Reſpiration.

2530 A vital function.

1. Reſpiration is to be conſidered as one of the vital functions of animals. No animal can exiſt when it is interrupted, nor indeed can it be ſuſpended, even for the ſhorteſt time, without the hazard of life. In the mechanical part of the function of reſpiration, the air is alternately drawn into the lungs and expelled.

2531 All gaſes not fit for reſpiration.

2. It is well known that all gaſes are not fit for reſpiration. Some indeed, as the carbonic acid gas, the moment they are inhaled, are deſtructive to life. The reſpiration of others, although they are not productive of ſuch ſudden effects, yet at laſt they prove fatal to the animal which is forced to reſpire them. Animals are very differently conſtituted, both with regard to the ſtructure of their reſpiratory organs, and with regard to the quantity of air which muſt be reſpired in order to ſupport life. In theſe reſpects the hot and cold blooded animals are very different from each other; and even among the latter claſs, namely the cold-blooded animals, there are ſome tribes which require a very ſmall quantity of air, and can bear without much ſeeming inconvenience a temporary interruption of this function; but for all animals, whatever be their nature, whatever be their ſtructure, or whatever be the modifications of their reſpiratory ſyſtem, the air of the atmoſphere is the moſt proper for the ſupport of life. It is the oxygen of atmoſpheric air which is neceſſary for the breathing of animals; but although animals live longer in a given quantity of oxygen gas than in atmoſpheric air, as appears from the experiments of Count Morozzo, related in the chaper on oxygen gas, yet it is too powerful, or too ſtimulating for their organs; for to ſuch as have been confined to breathe it, it has been found highly injurious.

2532 Not even pure oxygen.

2533 Some fatal to life.

3. Some of the gaſes prove immediately fatal to life; ſuch for inſtance is carbonic acid gas. It ſeems to be certain that no animal ever made a full inſpiration of this gas, without being deſtroyed. Nay, it is ſo noxious to animal life, that the organs themſelves, by an involuntary action, obſtruct it in its paſſage to the lungs. Other gaſes are equally fatal after a few inſpirations, ſuch as hydrogen and azotic gaſes; and indeed it is probable, if the lungs were completely emptied of air, before the inſpiration of any gas whatever, excepting oxygen gas or atmoſpheric air, a ſingle inſpiration would prove fatal. This, however, is never the caſe; for after the fulleſt expiration, a conſiderable quantity of air remains in the lungs. We may conclude, therefore, that the air of the atmoſphere alone is proper for the reſpiration of animals, and the ſupport of life.

2534 The ſame air can only be once reſpired.

4. After the ſame quantity of atmoſpheric air or oxygen gas has been once reſpired by animals, it becomes totally unfit for farther reſpiration either by the ſame animals or any other. It is then not only deprived of the whole of the oxygen, but is alſo contaminated with noxious gaſes. This even happens to fiſhes and inſects which require a very ſmall quantity of air. If the water in which the former live be deprived of its air, it is equally fatal to them as being immerſed under water is to thoſe animals which live in the air of the atmoſphere.

2535 The quantity.

5. Attempts have been made by phyſiologiſts to aſcertain the quantity of air reſpired by animals. This, it will appear at firſt ſight, muſt be extremely different in different claſſes of animals. Even in the ſame claſs of animals, it is probable that it varies much. The difference of the reſults of experiments to aſcertain this point on man are enormous. No concluſion whatever can be drawn from the number of reſpirations made in a given time, even if this could be determined with any degree of accuracy, which is ſcarcely to be expected. For no function of the body is ſooner influenced by mental affections than the breathing. The very attention to the circumſtance of reckoning the number of reſpirations will have ſome effect in occaſioning conſiderable deviations from the natural number. The number of reſpirations which have been reckoned by ſome is 14 in a minute, while others make the number amount to 27, which ſhews that little dependence can be placed on this mode of calculating the quantity of the air reſpired in a given time. But even if this could be accurately aſcertained, ſtill it would not enable us to aſcertain the quantity of air reſpired. For it is extremely probable that this quantity varies greatly in different men and in different animals, and in the ſame animal at different times, ariſing from cauſes the effects of which either entirely elude obſervation, or are altogether inappreciable. And accordingly we find that the differences of the reſults of the quantity of air taken in at a ſingle inſpiration, or of the quantity calculated in the lungs after expiration, are not leſs than thoſe of the number of reſpirations.

2536 Changes on the air.

6. The nature of the changes which the air inſpired undergoes has been aſcertained with more accuracy, although the experiments made to determine the amount of theſe changes vary conſiderably. Part of the air which is reſpired diſappears; and it has been generally ſuppoſed that it is only the oxygen gas which is taken up. But according to the experiments of Mr Davy part of the azotic gas alſo diſappears and is abſorbed along with the oxygen. Dr Menzies eſtimates the quantity of oxygen gas abſorbed by a man in 24 hours at rather more than 41 oz. troy. Lavoiſier fixes the quantity conſumed by a man in the ſame time at 32½ oz. nearly; and Mr Davy gives as the reſult of

his experiments and calculations about $33\frac{1}{2}$ oz. of oxygen gas, and $4\frac{1}{2}$ of azotic gas, amounting together to about 38 oz.

2537 Gaſes expired.

7. The air thrown out of the lungs by expiration contains a quantity of carbonic acid gas. But here the reſults of experiments to determine the quantity are as widely different as in other points relating to reſpiration. By one it is reckoned at 15 oz. in 24 hours; by another at not leſs than 37 oz.

2538 Water.

8. Water in the ſtate of vapour is alſo thrown out of the lungs during reſpiration. The quantity eſtimated by different philoſophers exhibits the ſame difference of reſults as in the other ſubſtances. According to Hales it is $20\frac{1}{2}$ oz. nearly; according to Lavoiſier it amounts to $28\frac{1}{2}$ oz.

2539 Component parts of the air expired.

9. But although it ſeems difficult or perhaps impoſſible to aſcertain with perfect accuracy the proportions or quantity of each of the ſubſtances thrown out of the lungs, yet it is clearly proved by experiment that the component parts of the air expired are azotic gas, carbonic acid gas, and water in the ſtate of vapour.

2540 Circulation of the blood.

10. The blood, as it flows from the left ſide of the heart, is of a bright red colour. It is conveyed by the arteries to every part of the body. It is then taken up by the veins, and carried back to the heart, by means of the venous ſyſtem. The blood having thus circulated through the body, enters the right ſide of the heart, and has totally changed its colour. It is now of a dark purpliſh red, inſtead of the bright red colour which it poſſeſſed when it paſſed out of the heart, to be diſtributed through the body. But before the blood can paſs to the left ſide of the heart, again to enter the circulation, it muſt paſs through the lungs, where it again acquires the bright red colour. From the lungs it paſſes to the left ſide of the heart, from which it flows as before through the arterial ſyſtem to all parts of the body. The blood then acquires this florid red colour in the lungs. Let us now ſee in what this change conſiſts.

2541 Changes on the blood.

11. This change was aſcribed by ſome of the earlier chemical phyſiologiſts to the abſorption of air. Dr Prieſtley obſerved that venous blood, which was of a dark colour, became of a bright red when expoſed to oxygen gas, and that hydrogen gas produced a contrary effect. The ſame thing has been aſcertained ſince, by many other chemiſts. According to Dr Prieſtley, the blood was deprived of its phlogiſton as it paſſed through the lungs: but according to the theory of Lavoiſier and others, no part of the air inſpired is abſorbed; the blood gives out hydrogen and carbone, which combining with the oxygen of the air, form water and carbonic acid. He ſuppoſed that the quantity of oxygen in the water and carbonic acid expired was equal to that which had diſappeared during reſpiration. According to another theory, the oxygen gas combines with the blood, and while this combination takes place, the carbonic acid gas and water which are expelled from the lungs along with the azotic gas, are given out. According to later experiments, it has been aſcertained that not only the whole of the oxygen of atmoſpheric air, but part of the azote, is abſorbed during reſpiration; and indeed ſome have ſuppoſed that the whole of the atmoſpheric air is abſorbed by the blood unaltered, and that it is only after this abſorption that the decompoſition takes place. The whole of the oxygen and part of the azote are retained, and the remaining part of the azote is thrown out, along with the carbonic acid gas and water, which are expired; but this opinion, as well as moſt others with regard to the nature of the changes that take place during reſpiration, reſts in a great meaſure on plauſible conjecture.

2542 Are the ſubſtances expired formed in the blood?

12. A queſtion has ariſen among chemiſts with regard to the formation of the carbonic acid and the water which are expired; whether it takes place immediately in the lungs, by the direct combination of the oxygen of the air with the carbone and hydrogen of the blood, or whether theſe ſubſtances previouſly exiſted in the blood in a ſtate of combination, and are thrown out during reſpiration.

2543 Purpoſes of reſpiration.

13. What are the purpoſes of theſe changes? What are the uſes of reſpiration in the animal economy? As the blood is the ſource from which are derived the materials for repairing the conſtant waſte of the body, it is neceſſary that means ſhould be provided, to ſupply this waſte, to which the blood is conſtantly ſubjected. This is accompliſhed, as we ſhall find afterwards, by the proceſs of digeſtion, the product of which is conveyed to the blood. But before it can be converted into blood, it muſt undergo certain changes, which take place in the lungs. There is one eſſential part of the blood, and an eſſential part alſo of animal bodies, namely the fibrina, which does not exiſt in the chyle and lymph, which are the ſubſtances conveyed to the blood, to repair its waſte, before they have paſſed through the lungs along with the blood. Hence it is ſuppoſed that one purpoſe of reſpiration is to form the fibrina of the blood.

2544 To form fibrina.

2545 To preſerve temperature.

14. But another great purpoſe of reſpiration in the animal economy is to preſerve the proper degree of temperature neceſſary for the health and life of the animal. It is well known that the temperature of animals is not regulated like inorganized matter by the ſurrounding medium. In whatever temperature animals are placed, except in thoſe extreme degrees of heat or cold which deſtroy life altogether, the temperature of their bodies continues almoſt uniformly the ſame, and this temperature, it appears, correſponds to the quantity of air inſpired. Hence it is that the temperature of the lower orders of animals which require but a ſmall proportion of air, as inſects, fiſhes, and amphibious animals, is not much higher than that of the medium in which they live, and on this account they conſtitute a diviſion of animals which have been diſtinguiſhed by phyſiologiſts by the name of *cold-blooded animals*. The temperature of the warm-blooded animals, whatever be the temperature in which they live, is from 96° to 104°. The temperature of man is about 98°, while that of birds which require a greater proportional quantity of air, is uſually 5° or 6° higher.

2546 Theories of animal heat.

15. The manner in which the temperature of the body is kept up by means of reſpiration, has been thus accounted for, on the principles of Dr Black's theory of latent heat. Part of the latent heat of the air, which was inſpired and combined with the blood, is given out, and thus raiſes the temperature of the blood and that of the whole body through which it circulates.

lates. But if this change took place in the lungs, and all the latent heat of the air inſpired was extricated in that organ, it was urged as an objection to this theory, that the temperature in them would be much higher than in other parts of the body. According to the theory of Lavoiſier and Crawford, the oxygen gas of the air inſpired combines with the hydrogen and carbone which are given out by the blood, forming carbonic acid and water. During this proceſs, which takes place in the lungs, the latent heat of the oxygen becomes ſenſible. Part of it combines with the water and the carbonic acid, and converts them to the ſtate of gas; the remainder combines with the blood, to preſerve the temperature of the body. The capacity of arterial blood for caloric, or the ſpecific caloric of arterial blood, that is, the quantity of caloric which is neceſſary to raiſe it to a given temperature, is much greater than that of venous blood. According to this theory, therefore, the ſpecific caloric of arterial blood, as it circulates through the body, is more and more diminiſhed, till it is at laſt converted into venous blood. In this way it has been propoſed to obviate the objection of the temperature of the lungs being higheſt, if, as it has been ſuppoſed, the whole of the caloric is here evolved; and to account for the uniformity of temperature which exiſts in every part of the body.

2547 Air abſorbed in the ſtate of gas.

16. But if the difference of the ſpecific caloric of arterial and venous blood be not ſufficiently great to account for the phenomena, this objection has been attempted to be removed, by ſuppoſing that the air is abſorbed by the blood in the ſtate of gas, and that the greateſt part of the changes which it undergoes, is effected in the courſe of the circulation. Part of the caloric, it is ſuppoſed, is evolved, when the air combines with the blood, and this portion combining with the carbonic acid and water thrown off, raiſes them to the ſtate of gas, in which ſtate they are emitted during reſpiration. The air abſorbed by the blood gives out the remaining portion of its caloric in the courſe of the circulation, when the oxygen combines with the carbone and forms carbonic acid, and with the hydrogen and forms water; and thus the caloric is gradually evolved during the courſe of the circulation. Such then are two of the important purpoſes which ſeem to be accompliſhed by means of the function of reſpiration; namely, the preſervation of animal temperature, and the complete formation of the blood.

II. Of Digeſtion.

2548 Waſte of the body.

1. The animal body is ſubject to continual waſte, and the quantity of this waſte varies according to the nature and age of the animal. This waſte is repaired by the blood, which muſt conſequently receive ſome ſupplies, to make up for its continual conſumption. On this account, all animals require food or nouriſhment, to compenſate for the waſte of the body, and directly for the conſumption of the blood from which this waſte is ſupplied.

2549 Food of different animals different.

2. Different animals, according to their nature, conſtitution, and circumſtances in which they are placed, require different kinds of food. Some animals live entirely on vegetables, others feed excluſively on animals, while a third claſs feed indiſcriminately both on vegetables and animals. But whatever be the kind of food, or whatever be the nature of the animal, it is all converted, by the proceſs of digeſtion, into the ſame uniform ſubſtance. In moſt animals the food, as it is taken into the mouth, is broken down, mixed with the ſaliva, and conveyed to the ſtomach, and after it has remained there for a ſhort time, it is totally changed, and is converted into the uniform ſubſtance above alluded to, called *chyme*.

2550 Falſe analogies of phyſiologiſts.

3. In attempting to account for the functions of the animal body, chemiſts and phyſiologiſts have been always too much diſpoſed to conſider the changes which take place within the body, as analogous to thoſe which take place on inorganized or dead matter, in ſuppoſed ſimilar circumſtances. Accordingly we find among the ſpeculations of philoſophers, concerning the nature of the function of digeſtion, that it has been aſcribed to fermentation. By one ſet it was aſcribed to one kind of fermentation, namely to the vinous or acetous; and by another ſet this converſion of the food was ſuppoſed to be effected by the putrefactive fermentation. But now, that the nature and circumſtances of the proceſſes of fermentation and digeſtion have been more accurately obſerved, this opinion, it is probable, is univerſally exploded. The experiments of phyſiologiſts, alſo, have led to more rational views concerning this function.

2551 Gaſtric juice.

4. It is now generally admitted, that the converſion of the food into chyme, is effected by the action of a peculiar fluid ſecreted in the ſtomach, from which it has been denominated *gaſtric juice*. This liquid ſeems to poſſeſs different properties in different animals, for thoſe animals which live entirely on vegetables cannot digeſt animal food, and the gaſtric juice of thoſe which have been accuſtomed to live entirely on animals, has no effect on vegetables. It is true, indeed, that the nature of animals in this reſpect, as well as in moſt of their habits, may be completely reverſed, when it is effected by ſlow degrees. All ſubſtances taken into the ſtomach are not equally acted upon by the gaſtric juice. Some of the hardeſt are readily diſſolved, while others ſeemingly leſs compact and durable, remain unaltered. The huſks of grain in the ſtomachs of many animals reſiſt its action, while the hardeſt bone is entirely conſumed.

2552 Its nature unknown.

5. No accurate knowledge has yet been obtained concerning the nature of the gaſtric juice. According to ſome it is of an alkaline nature, and according to others it poſſeſſes acid properties. But this difference of opinion is by no means to be wondered at, if we conſider the difficulty, or perhaps the impoſſibility of obtaining the gaſtric juice in a ſtate of purity, to ſubject it to chemical examination. If it even were poſſible to collect it perfectly pure, its effects could not be the ſame as within the body, ſince all animal matters, the moment they are ſeparated from the living body, begin to undergo new changes, and therefore muſt exhibit new properties. All experiments, therefore, which have been made, to aſcertain the nature of the gaſtric juice, and the proceſs of digeſtion out of the body, muſt be conſidered as entirely inconcluſive. Such experiments ſhew us the effects of this liquid in the ſtate of dead matter, but can lead to no knowledge of its na-

ture and properties while it exiſts in the living body (B).

2553 Food converted into chyme.

6. But whatever be the nature of this liquid, or the proceſs of digeſtion, the food, as we have already obſerved, is broken down in the mouth and mixed with the ſaliva, which in the firſt inſtance, probably contributes much to favour its commencement; for it has been obſerved that the proceſs of digeſtion is conſiderably deranged when the ſecretion of ſaliva is interrupted, or its uſual quantity diminiſhed. All, then, that is certainly known concerning this change is, that the food conveyed to the ſtomach is in a very ſhort time converted into the ſubſtance called chyme.

2554 Which is changed into chyle.

7. The chyme, which is a ſoft, pulpy matter, after being formed in the ſtomach, is carried to the inteſtines, where it is mixed with other ſubſtances, and undergoes new changes. As ſoon as the chyme has paſſed into the inteſtines, it is converted partly into a milky fluid called chyle, and partly into excrementitious matter. Thus it is decompoſed by ſome proceſs, and ſeparated into two parts, one of which is deſtined for the nouriſhment of the body and for repairing its waſte, while the other is ejected.

2555 Chyle ſeparates into two parts.

8. The chyle, ſoon after it is formed from the chyme, mixes with the bile which flows from the liver into the inteſtines. In conſequence of this combination, it is ſuppoſed the excrementitious matter is ſeparated from the chyle, and is thrown out of the body; while the chyle itſelf is taken up by a ſet of veſſels called *lacteals*, which open on the inner ſurface of the inteſtines, and receiving the fluid, convey it to a large trunk in which they all terminate, denominated, from its ſituation in the thorax, the *thoracic duct*. The uſe of the bile is ſuppoſed to be, to ſeparate the excrementitious matter which might prove injurious to the ſyſtem, if it were abſorbed along with the chyle; and for this purpoſe the bile, it is ſuppoſed, is decompoſed; one part, namely its ſaline and alkaline conſtituents, combines with the chyle, by which it becomes more liquid, while another part, namely the reſinous and albuminous matter, combines with the excrement, and in this ſtate acts as a ſtimulant to the inteſtines, ſo that the contents which might otherwiſe prove injurious, if long retained, are ejected.

2556 Is totally changed.

9. As a proof that the food which has been taken into the body has been totally changed, ſubſtances have been detected in the excrement of different animals which did not previouſly exiſt in the food. According to Vauquelin, excrementitious matter is always diſtinguiſhed by an acid property. Benzoic acid has been detected in that of horſes and cows. An acid of a peculiar nature has been found in the dung of pigeons; but in general this matter is much diſpoſed to ferment, and at laſt gives out ammonia.

In the analyſis of the excrement of a hen by Vauquelin, compared with the nouriſhment, he found that the oats which were taken in were compoſed of phoſphate of lime and ſilica, and that the ſhells of the eggs, and the excrements which were examined, conſiſted of phoſphate of lime, carbonate of lime, and ſilica. The proportion of ſilica which was found in the excrement was leſs than the quantity taken in; but the quantity of phoſphate of lime was increaſed, and a quantity of carbonate of lime which did not previouſly exiſt in the food, was formed *.

* *Ann. de Chim.* xxix. 3.

2557 Properties of chyle.

10. The chyle, it has been obſerved, is taken up by the lacteals and conveyed to the thoracic duct. Little is known of its properties, excepting that it poſſeſſes ſome in common with milk. Like it, it coagulates, and divides into a ſerous and oily matter. In the thoracic duct the chyle is mixed with another fluid called the lymph, which is conveyed from all parts of the body by a ſet of veſſels which have been denominated *lymphatics*. This fluid is in conſiderable quantity, is viſcid and colourleſs, but from the difficulty of collecting it, little is known of its properties. The lymph and the chyle, thus mixed togther, are conveyed by the thoracic duct to the blood veſſels. It is mixed with the blood in the veins, and conveyed by them to the right ſide of the heart, from which it is carried to the lungs, where it undergoes the changes already deſcribed in the account of reſpiration, and the whole is converted into arterial blood, which returns to the heart, from whence it is diſtributed to all parts of the body.

2558 Of lymph.

III. Of Secretion.

2559 Matters ſeparated from the blood.

1. In the courſe of the circulation of the blood, different ſubſtances are ſeparated from it, ſome of which are deſtined for the growth and nouriſhment of the body, as in young animals, or for the repair and ſupply of parts that are deſtroyed; while other ſubſtances, which ſeem either to be ſuperfluous, or if retained would be injurious, are thrown out of the body. Theſe ſecretions are performed by peculiar organs, the deſcription and operation of which belong to ANATOMY and PHYSIOLOGY. At preſent we ſhall give a ſhort account of two of the moſt important of theſe ſecretions, namely, the ſecretion of urine, and that of perſpirable matter.

2560 By the kidneys.

Secretion of urine.—The urine, which is an excrementitious matter, is ſeparated from the blood by the action of the kidneys. According to the obſervations of anatomiſts and phyſiologiſts on the ſtructure and office of theſe organs, a great proportion, or even, as ſome ſuppoſe, the whole, of the blood paſſes through them. As the urine ſecreted by theſe organs, ſeems to ſerve no purpoſe in the animal economy, ſince the whole of it is thrown out, it is probable that the ſubſtances of which it is compoſed, or at leaſt their conſtituents, would have proved injurious if they had been retained.

2561 Is an important change.

2. Whatever the change be which takes place on the blood by the action of the kidneys, it is of the utmoſt importance to the health and even to the life of the

---

(B) The ſtomach of young animals contains ſome ſubſtance which has the property of coagulating milk. Acids alſo have this property, from which it has been concluded that the ſubſtance in the ſtomach of young animals, which produces this effect on milk, is of an acid nature: but it ought to be recollected, that it is out of the body, and that it has undoubtedly undergone new changes; and beſides, it is not known exactly what ſubſtances may have the property of inducing this change on milk.

the animal; for if theſe organs are deſtroyed by diſeaſe or accident, the death of the animal is the certain conſequence.

3. By the action of the kidneys on the blood, new ſubſtances make their appearance. Such, for inſtance, are urea and uric acid, which exiſt in the urine, but cannot be detected in the blood; but the baſes or conſtituents of theſe ſubſtances muſt have formed part of ſome of the matters of the blood, which are therefore decompoſed for their evolution; and this decompoſition muſt take place in theſe organs. But although the urine, the ſecreted matter, has been accurately analyzed, and its component parts after it is thrown out of the body pretty well aſcertained, it is yet unknown what are the peculiar changes which the blood undergoes by the action of the kidneys.

2562 Secretion from the ſkin. *Perſpiration.*—1. A conſiderable quantity of matter is ſeparated from the blood by means of a ſet of veſſels on the ſkin of animals. This action is called *perſpiration*, and the ſubſtance emitted, *perſpirable matter.* The attention of phyſiologiſts and chemiſts has been directed to aſcertain the quantity and nature of the matter thus thrown off. To aſcertain the firſt point, many experiments have been made. Sanctorius, an Italian phyſician, was the firſt who made this attempt, by weighing himſelf, and eſtimating the quantity of food which was taken in, and the quantity of excrementitious matter thrown off. The difference, he ſuppoſed, indicated the quantity of matter perſpired; but neither in his experiments, nor in thoſe of many others, who endeavoured to aſcertain the ſame thing, was any eſtimate made of the quantity of matter given out by the lungs.

2563 Quantity. 2. With this diſtinction in view, a ſet of experiments was inſtituted by Lavoiſier and Seguin. The latter was incloſed in a varniſhed bag, which prevented the eſcape of every thing thrown off from the body, excepting what was loſt by reſpiration. Having previouſly weighed himſelf, and having continued the experiment for ſome time, the quantity of matter thrown off by reſpiration was aſcertained, by weighing a ſecond time. By weighing himſelf afterwards without the covering, and repeating the operation at the end of a ſimilar interval, he was thus enabled to aſcertain the quantity loſt by tranſpiration from the ſkin, by ſubtracting what had been previouſly aſcertained by tranſpiration from the lungs, from the whole diminution of weight which was indicated in the laſt experiment. From theſe experiments, the following concluſions were drawn.

a. In a ſtate of health, and when there is no diſpoſition to corpulence, the body returns to the ſame weight once every 24 hours.

b. Indigeſtion retards tranſpiration. The weight is increaſed for four days, and on the fifth the body returns to its original weight.

c. Drink only, and not ſolid food, increaſes the perſpiration. It is leaſt at the moment of taking food, and immediately after.

d. The perſpiration is greateſt during digeſtion.

e. The greateſt quantity of matter perſpired amounted in a minute to 26.25 grains troy; the leaſt to nine grains.

f. The pulmonary tranſpiration is proportionally greater than that of the ſkin. It is greater in winter, on account of the neceſſity of preſerving the temperature of the body.

3. The quantity of matter perſpired is greateſt during hot weather, and in hot climates. The quantity too bears a relation to the quantity of urine. The following are the reſults of the experiments of Rye made in Ireland, on the relative proportion of urine and perſpirable matter, which were excreted in the courſe of one day at different ſeaſons of the year.

	Matter perſpired.	*Urine.*
	Ounces.	Ounces.
Winter,	53	42
Spring,	60	40
Summer,	63	37
Autumn,	50	37

2564 Sweat. 4. When the temperature to which the body is expoſed is much elevated, the quantity of perſpired matter is greatly increaſed, and it then appears in a viſible liquid form called *ſweat.* This anſwers a very important purpoſe in the animal economy, for by this means the equilibrium of temperature is preſerved. The heat which is abſorbed is carried off along with the matter which evaporates from the ſurface of the body, and thus the increaſe of temperature which would otherwiſe prove fatal, is prevented.

2565 Component parts. 5. The next object of chemical phyſiologiſts was to aſcertain the nature of the ſubſtance which is perſpired. This has been found extremely difficult, on account of the ſmall quantity which it has been poſſible to collect. But it has been aſcertained that it conſiſts chiefly of water and carbone, with an oily matter. Phoſphoric acid alſo, and phoſphate of lime, have been detected in the perſpirable matter. In the air which has been confined in contact with the ſkin, carbonic acid gas has been detected; from which it is concluded, that either the carbone muſt have been evolved, and combined with the oxygen of the air, or the oxygen gas muſt have been abſorbed, and combining with the carbone, is given out in the ſtate of carbonic acid. The oily matter which is emitted by the ſkin, is ſuppoſed to occaſion the peculiar ſmell by which animals are diſtinguiſhed. The remarkable circumſtance of a dog being able to trace another animal to a great diſtance by the ſmell, or to diſcover his maſter by the ſame means to a much greater diſtance, is aſcribed to the emiſſion of this matter. The matter perſpired, according to Berthollet, poſſeſſes acid properties, and the acid, he ſuppoſes, is the phoſphoric. Phoſphate of lime has been detected in the ſkins of horſes by Fourcroy and Vauquelin.

2566 Other ſecretions. Beſides theſe, there are other ſecretions which are deſtined for peculiar purpoſes in the animal economy, or immediately connected with the functions of particular organs, or parts of the ſyſtem. Such is the ſecretion of ſaliva in the mouth, of tears in the eyes, of mucus in the noſe, and wax in the ears. The ſecretion of milk in the female is deſtined for the nouriſhment of the offspring; but we ſhall not enter into the deſcription of the organs employed in theſe ſecretions. The nature and properties of the matters ſecreted will come under our conſideration in treating of the different parts of animals.

IV. Of Aſſimilation.

2567 Waſte of the body muſt be repaired.

1. The continual waſte and decay of the body require to be repaired. This, as we have already ſeen, is the purpoſe of taking nouriſhment into the body; part of which being ſubject to the proceſſes of digeſtion and reſpiration, is converted into blood, from which ſource are derived thoſe ſupplies of new matter which are wanted in the formation of new parts, or to make up the general decay of the ſyſtem. New ſupplies of matter are peculiarly neceſſary, in young animals, in which the parts already formed increaſe in ſize and conſiſtency, and in which, in the progreſs of the growth of the body, entirely new parts are evolved. But if there be any thing in the ſpeculations of phyſiologiſts, of the whole matter in the body being periodically changed, even after it has arrived at its full growth, a conſtant ſupply of new matter becomes abſolutely neceſſary. All theſe ſupplies are furniſhed by the blood, and for this purpoſe it is diſtributed to every part of the body. The materials for repairing the general waſte, for increaſing thoſe parts which are already formed, or for the formation of new parts, are all derived from it. From this ſource are derived the moſt fluid, as well as the moſt ſolid parts of the body; the ſaliva of the mouth, and the gaſtric juice of the ſtomach, ſo neceſſary in the function of digeſtion, by which the health and life of the animal are preſerved, as well as the bones and muſcles, which give it ſtrength, firmneſs and motion. The proceſs by which the different ſubſtances which are furniſhed by the blood for the repair of ſome parts and the formation of others, has been diſtinguiſhed by the name of *aſſimilation*, becauſe, in conſequence of new actions and combinations, matter exactly ſimilar to the parts repaired or renewed, is depoſited, which did not previouſly exiſt in the blood.

2568 By particular organs.

2. The changes are effected by the action of peculiar organs or veſſels. Whatever be the nature of the food taken into the ſtomach, it is converted into chyme by the proceſs of digeſtion. This again, by a farther change, as it paſſes into the inteſtines, forms the chyle, which is conveyed to the blood, and after this fluid has undergone the changes which are induced on it by reſpiration, it has acquired thoſe properties which render it fit for the important purpoſes to which it is deſtined.

2569 Which always ſecrete the ſame matter.

3. By the action of the different ſecretory organs, the ſame matter is always ſeparated from the blood, while the animal continues in the healthy ſtate. The perſpirable matter is ſeparated by the glands or veſſels on the ſkin, and the ſaliva is prepared by the glands of the mouth. The matter of bones, of muſcles, or of nerves, is ſeparated and depoſited in thoſe places where it is required, and no other. In the healthy ſtate of the body, muſcular matter is not depoſited among the bones, nor is oſſeous matter mixed with the muſcles.

2570 Functions vary with circumſtances.

4. The moſt aſtoniſhing part of the animal ſyſtem is that power which it poſſeſſes of accommodating itſelf to particular circumſtances. It would be leſs ſurpriſing that the ſame actions and the ſame functions, after they have commenced, ſhould continue to be performed with uniformity and regularity. But, in the animal ſyſtem, new actions take place, or at leaſt thoſe which were comparatively feeble and limited, become more powerful and more extenſive. Thus, a part of the body which has been deſtroyed or removed, is by this new or extended action, completely renovated. A large piece of muſcle in the healthy ſtate of the body is ſoon renewed; and, what is more ſurpriſing, the conſtituent parts of bone are prepared, when neceſſary, and depoſited in thoſe places where large pieces of this ſubſtance have been removed.

2571 Are regulated by the living principle.

5. But although ſome, or perhaps all theſe changes which take place in the different proceſſes going on in the animal ſyſtem, are of a chemical nature, yet they are ſubject to the controul of ſome power, the characteriſtics of which are totally different from thoſe of a chemical or mechanical agent. This is the living principle which counteracts, regulates, and directs the effects of chemical agents. It is by means of this power, that the materials of which the different parts of the body are compoſed, are depoſited in their proper places. It is by means of the ſame power that a greater quantity of matter neceſſary for the renovation of any particular part which has been deſtroyed, is prepared and depoſited exactly in that place where it is wanted; but the power of this agent is limited. Certain ſubſtances taken into the ſtomach, which are unfit for digeſtion or nouriſhment, are immediately rejected; but others are too powerful, and deſtroy the organ itſelf. As the ſtrongeſt proof of the exiſtence and controul of this power, the conſtituent parts of animal bodies begin immediately to decompoſe each other as ſoon as its action has ceaſed. The gaſtric juice of the ſtomach, which acts only on the ſubſtances introduced into it in the living ſtate, has been ſometimes found to corrode and deſtroy the ſtomach itſelf, after death. But the inveſtigation into the nature of this agent, and of its influence on the animal body, belong to PHYSIOLOGY.

SECT. II. *Of the* DECOMPOSITION *of* ANIMAL SUBSTANCES.

2572 Decompoſition of vegetables and animals different.

1. As ſoon as an animal has ceaſed to live, its frame and texture are deſtroyed, the conſtituent parts are ſeparated, they enter into new combinations, new ſubſtances are formed, and the component parts are totally changed. The rapid ſpontaneous decompoſition of animal matters, which has been called *putrefaction*, is one of the moſt ſtriking characters by which they are diſtinguiſhed. Vegetable matters, we have ſeen, when vegetation ceaſes, are alſo ſubject to decompoſition; but in them the proceſs is ſlow and gradual, and many of the products are totally different.

2573 Owing to the difference of compoſition.

2. The remarkable difference between the ſpontaneous decompoſition of vegetables and animals, depends on the difference of the conſtituent parts of theſe two claſſes of organized ſubſtances. Animal matters are compoſed of a greater variety of conſtituent principles, and thus originates a greater variety of action, when the different component parts begin to act on each other. By the numerous and complicated attractions which exiſt among theſe conſtituent principles, decompoſition is more readily effected, and a greater variety of new products make their appearance.

2574 Conditions of putrefaction.

3. But notwithſtanding the variety and complicated ſtructure of animal ſubſtances, total decompoſition or

putrefaction does not take place, except in certain circumſtances, by which the mutual action of the conſtituent principles is promoted. The chief circumſtances neceſſary for the putrefaction of animal matter are, moiſture and moderate heat. Dry animal matters do not undergo any change. Bones, when moiſtened with water, the ſoft parts of animals, but eſpecially the liquid parts, run rapidly on to putrefaction. Heat is alſo neceſſary to promote this change. No putrefaction takes place in animal matters, at or below the freezing temperature. Before it commences, the temperature muſt be elevated ſome degrees above this point, and as the temperature riſes, the rapidity of the proceſs is proportional. This condition, however, has its limits; for when the heat reaches a certain point, ſo far from promoting the proceſs of putrefaction, it is retarded, or altogether interrupted, by carrying off the moiſture. The contact of air was thought neceſſary to favour this proceſs; but although it appears that this is not an eſſential condition, putrefaction goes on more rapidly in the open air, perhaps by receiving and carrying off the elaſtic fluids as they are formed. Matters which have already undergone this change, brought in contact with recent animal ſubſtances, promote and accelerate putrefaction.

2575 Phenomena.

4. When animal matters are placed in favourable circumſtances, the ſolid parts become ſoft, and the liquid parts become more fluid. The colour changes, and is converted into a reddiſh brown, or deep green. The odour, which is at firſt diſagreeable, becomes fetid and inſupportable. An ammoniacal ſmell is alſo diffuſed, but this is only temporary, while the putrid odour continues during the whole proceſs. The liquids become turbid, the ſoft parts are melted into a kind of jelly, accompanied with an inteſtine motion, and an enlargement of the bulk of the whole maſs, owing to the eſcape of elaſtic fluids, which are ſlowly diſengaged. The whole matter is then reduced to one maſs, the ſwelling ceaſes, the bulk is diminiſhed, and the colour deepens. Towards the end of the proceſs, a peculiar odour, ſomewhat aromatic, is emitted. When it ceaſes entirely, there remains behind an unctuous, viſcid, and fetid earthy maſs.

2576 The period different.

5. The duration of this proceſs is extremely various, according to the nature of the ſubſtances and the circumſtances in which they are placed; but it has been divided by ſome into different ſtages. In the firſt there is merely a tendency to putrefaction, accompanied with a very ſlight change of texture and colour. The ſecond change, or incipient putrefaction, exhibits ſome traces of acidity; the parts are more ſoftened, a ſerous matter begins to flow from the relaxed fibres; the colour is more altered, and the putrid fetid odour is exhaled. In the third or more advanced ſtage of putrefaction, the fetid odour is more or leſs mixed with the ſmell of ammonia; the diſſolved putrid matter becomes of a deeper colour, and is diminiſhed in weight by the eſcape of a great quantity of volatile matter. In the laſt ſtage, or when the proceſs is completed, the ammoniacal odour vaniſhes, the fetid ſmell becomes leſs, and is often ſucceeded by ſomething of an aromatic ſmell. The animal matter has diminiſhed greatly in bulk, and has loſt all appearance of organized ſtructure. There remains only a dark brown, earthy ſubſtance, unctuous to the feel, which has been called *animal earth*. But theſe changes are regulated by the particular circumſtances in which the proceſs takes place.

2577 Elaſtic fluids

6. In the courſe of the putrefactive proceſs of animal ſubſtances, different gaſes are ſucceſſively emitted. Theſe are chiefly carbonated, ſulphurated, and phoſphorated hydrogen gaſes, water in the ſtate of vapour, ammonia, and carbonic acid gas. Theſe bodies are evolved and volatilized, carrying with them ſome of the principal conſtituents. Other products, formed at different periods of the proceſs, and of a more fixed nature, make their appearance; ſuch, for inſtance, is an unctuous matter, and a kind of ſoap, formed of this matter and ammonia; ſuch too is nitric acid which is frequently formed during this decompoſition, and is combined with an earthy or alkaline baſe; and ſuch finally is the unctuous earth which remains after the evolution and ſeparation of the former products.

2578 Nature of the proceſs.

7. The proceſs of putrefaction, then, conſiſts in a change produced by the action of affinities, more powerful than thoſe which hold together the conſtituent principles of the animal matter. Theſe conſtituents are, hydrogen, azote, carbone, and oxygen, with a certain proportion of ſulphur, phoſphorus, and different ſpecies of phoſphates. During the decompoſition, a portion of the hydrogen combines with azote to form ammonia, while another portion combines with part of the oxygen to form water; part of the carbone is united with a portion of oxygen, and forms carbonic acid; the union of azote with a third portion of oxygen conſtitutes nitric acid; a combination of hydrogen, carbone, and azote, yields a volatile or fixed oil, according to the proportion of the conſtituents; and finally, the ſaline, earthy, and metallic ſubſtances, which are little ſuſceptible of change, during this proceſs, remain unaltered, and conſtitute the reſiduum. Thus, in taking a general view of the affinities which come into action during this proceſs, the amount of thoſe which tend to combine the hydrogen with the azote to form ammonia; the oxygen with the carbone, to form carbonic acid; the carbonic acid with the ammonia, to form carbonate of ammonia; the hydrogen, carbone and oxygen, to form oil, and this latter with ammonia to conſtitute ſoap, beſide the hydrogen and oxygen to form water, is greater than the ſum of the forces which retain in combination, the hydrogen, the azote, the carbone and oxygen, which are the principal conſtituents of animal compounds.

2579 In the open air.

8. Such are the reſults when the proceſs is conducted in cloſe veſſels; but when the proceſs takes place in the open air, ſimilar reſults are obtained, but in a manner ſomewhat different, according to the nature of the compounds which are formed. In this caſe part of the animal ſubſtance is diſſolved and carried off by the air and the water. The ammonia and carbonic acid are diſſipated as they are formed; part of the carbonated hydrogen is alſo volatilized by the increaſe of temperature, and there is no unctuous matter or ammoniacal ſoap formed.

2580 Cauſe of the fetid odour.

9. It is well known that the odour which proceeds from putrid animal matters is extremely offenſive. This is owing in a great meaſure, to the ſulphurated and phoſphorated hydrogen gaſes diſengaged; but it is not merely offenſive, but noxious to the health, and ſometimes deſtructive to the life of animals. Theſe effects

are

are no doubt owing to the putrid effluvia which are exhaled, and which are taken into the lungs during reſpiration. To counteract the effects of theſe putrid exhalations, attention ſhould be paid to agitate the air of inhabited places by proper ventilation, which may be done by burning wood in the vicinity of infectious air, ſo that the ſmoke may be mixed with it, or by directing currents of water into ſimilar places. To deſtroy the noxious effects of putrid *miaſmata*, which are produced in confined places, frequented by numbers of people, muriatic acid gas, diſengaged from common ſalt by means of ſulphuric acid, has been ſucceſsfully employed. Oxymuriatic acid gas has alſo been propoſed for the ſame purpoſe.

2581 Method of preſerving animal matters. 10. It is an object of conſiderable importance in domeſtic economy, to prevent the proceſs of putrefaction in thoſe animal ſubſtances which are to be preſerved and employed as food. It is alſo an object of ſome importance for many other purpoſes. Different methods have been propoſed to accompliſh this. It is effected by depriving the animal matters entirely of their moiſture, without which the proceſs is interrupted. Animal matters are alſo preſerved by keeping them at the freezing temperature, or below it. The ſame object is attained by covering up matters to be preſerved with ſuch ſubſtances as readily enter into combination with water, and thus prevent its effects upon the animal matters. The acids, ſugar, alcohol, and ſome ſalts, it is ſuppoſed, act in this way, by preventing putrefaction. With the ſame view aromatic and reſinous ſubſtances, volatile oils, camphor, the powder of dried aſtringent, and fragrant plants, charcoal and bitumen, are employed.

SECT. III. *Of the* COMPONENT PARTS *of* ANIMAL SUBSTANCES.

Having giving a ſhort account of the functions of living animals, and of the ſpontaneous decompoſition which takes place after death, we now proceed to take a view of their component parts, as they have been inveſtigated by chemical analyſis. This ſhall be the ſubject of the preſent ſection, which for the ſake of perſpicuity of arrangement, may be ſubdivided under the four following heads: I. Of the conſtituent parts of animal ſubſtances in general. II. Of the liquid parts of animals. III. Of the ſolid parts; and, IV. Of ſubſtances peculiar to different claſſes of animals.

I. Of the Conſtituent Parts of Animal Subſtances in General.

2582 Elements. The ſimple ſubſtances which enter into the compoſition of the different parts of animals, are chiefly azote, carbone, hydrogen, and oxygen, of which, arranged in different proportions, the ſoft parts are compoſed; phoſphorus and lime, which conſtitute the baſis of the hard parts; ſulphur, the fixed alkalies, muriatic acid, iron and mangancſe. But by the conſtituent parts of animals, is here to be underſtood thoſe ſubſtances into which they are reſolved by analyſis. Some of theſe are compound, and ſome are ſimple, as will appear from the following enumeration.

2583 Component parts.

1. Gelatine,
2. Albumen,
3. Fibrina,
4. Urea,
5. Sugar,
6. Oils,
7. Reſins,
8. Phoſphorus,
9. Sulphur,
10. Acids,
11. Alkalies, earths, and metals.

I. Of Gelatine.

2584 Preparation. 1. Glue, a well known ſubſtance in the arts, is gelatine in a ſtate of impurity. This may be obtained pure by repeatedly waſhing the freſh ſkin of an animal in cold water, afterwards boiling it, reducing it to a ſmall quantity by ſlow evaporation, and allowing it to cool. It then aſſumes the form of a ſolid tremulous ſubſtance called jelly. When this ſubſtance is dried in the air, it becomes hard and ſemitranſparent.

2585 Properties. 2. Gelatine has different degrees of hardneſs, and when pure, it is colourleſs and ſemitranſparent. It is brittle, breaks with a vitreous fracture, and has neither taſte nor ſmell.

2586 Action of heat. 3. When it is expoſed to heat, in the dry ſtate, it becomes white, then blackens, and is converted into a coaly matter. Tremulous gelatine melts before it undergoes theſe changes. When it is diſtilled, it affords a watery fluid, impregnated with ammonia and a fetid oil. A voluminous maſs of charcoal remains behind.

2587 Of air and water. 4. Gelatine remains unaltered in the dry ſtate by expoſure to the air; but the ſolution in water is ſoon decompoſed, giving out an acid, the nature of which is unknown, a fetid odour, and ſome ammonia. It is not very ſoluble in water; it increaſes in bulk, and becomes ſoft and tremulous. In this ſtate it ſoon diſſolves in warm water; but as the ſolution cools, it returns to its former ſtate.

2588 Acids. 5. With the aſſiſtance of heat gelatine is readily diſſolved by the acids. Sulphuric acid acts ſlowly on this ſubſtance, and forms a brown ſolution, which becomes gradually darker with the evolution of ſulphurous acids. Nitric acid by digeſtion on gelatine, is decompoſed; azotic gas is evolved, and afterwards a great quantity of nitrous gas. The gelatine is diſſolved and converted partly into oxalic and malic acids, and an oily matter which remains on the ſurface. Muriatic acid readily diſſolves gelatine, and forms a brown-coloured ſolution, from which a white powder is gradually precipitated. When this ſolution is added to the ſolution of tan in water, a copious precipitate is formed.

2589 Alkalies. 6. Gelatine is readily diſſolved by the alkalies, with the aid of heat. There is no action between any of the earths and this ſubſtance.

2590 Metallic oxides. 7. Some of the metallic oxides form precipitates with gelatine in its ſolution in water. The compound thus formed is inſoluble. Similar precipitates are occaſioned by ſome of the metallic ſalts.

2591 Tan. 8. Gelatine forms a copious white precipitate with tan.

tan. A brittle compound is thus produced, which is inſoluble in water, and is not changed by expoſure to the air.

2592 Compoſition. 9. The component parts of gelatine are carbone, hydrogen, azote and oxygen, with ſome traces of phoſphate of lime and of ſoda, but the proportions of theſe ſubſtances have not been determined.

2593 Different kinds. 10. There are various kinds of gelatine, probably ariſing from ſlight variations of the proportions of its conſtituents, or from the addition of other ſubſtances, the nature of which has not been diſtinctly aſcertained. Glue is extracted from different animal ſubſtances, as bones, muſcles, membranes, but eſpecially from ſkins, by firſt ſteeping them in lime-water, to purify them from all extraneous ſubſtances, and afterwards boiling them with pure water. The ſtrongeſt glue is obtained from the ſkins of old animals. What is called *ſize*, is a weaker kind of glue, which is colourleſs and tranſparent, and is extracted from the ſkins of eels, horſes, cats, rabbits, and from ſome kinds of white leather. It is this which is employed in the manufacture of paper, and in gilding and painting. Iſinglaſs, another kind of glue, is extracted from different parts of the ſturgeon, and ſome other fiſh.

2594 Found in different parts of animals. 11. Gelatine forms a principal part, both of the ſolid and fluid parts of animals. It is found in blood and in milk, in the bones, ligaments, ſkin, and other ſolid parts.

2595 Uſes. 12. Animal jelly, which is gelatine, is well known as a very nutritious food, and is much employed in the ſtate of glue, ſize, and iſinglaſs, in numerous arts.

II. Of Albumen.

2596 Obtained from eggs. 1. The white of an egg conſiſts chiefly of albumen. It is combined with a portion of ſoda and ſulphur. From theſe ſubſtances it cannot be ſeparated without decompoſition, ſo that its properties are probably modified by them.

2597 Action of heat. 2. When albumen is expoſed to a heat of about 165° it coagulates into a ſolid white maſs, of different degrees of conſiſtency, according to the duration of the heat applied. This is the characteriſtic property of albumen. In this ſtate it has totally changed its properties. Formerly ſoluble in water, it cannot now be diſſolved in that liquid, either hot or cold.

2598 Cauſe of coagulation. Different opinions have been formed concerning the nature of this change, or the cauſe of the coagulation of albumen. It has been aſcribed by ſome to the abſorption of caloric, and by others to that of oxygen. The former opinion was that of Scheele, and the latter is ſupported by Fourcroy; but this coagulation is found to take place when air is entirely excluded, or without any change being produced on the ſurrounding air. It has been ſuppoſed by others, that the coagulation is produced by the extrication of caloric, as in other caſes when fluid bodies are converted into ſolids. According to an experiment of Fourcroy, this extrication of caloric actually takes place; but it is aſcribed by others to a different arrangement of the particles of the albumen, which is induced by the action of the heat applied.

2599 Properties of uncoagulated albumen. 3. The properties of albumen, it has been obſerved, are very different after coagulation. Before coagulation it is a glary liquid which has ſcarcely any taſte, and no ſmell. When dried in a moderate heat, it becomes brittle and tranſparent, and by being ſpread thin, forms a varniſh. When thus dried, it is not changed by expoſure to the air, but otherwiſe it ſoon becomes putrid.

2600 Action of heat. 2601 Acids. 4. Albumen is coagulated by means of the acids. With the aid of heat, ſulphuric acid diſſolves it, and forms a ſolution of a green colour. By the action of nitric acid, azotic gas is diſengaged: the albumen is then diſſolved; nitrous gas is given out, and oxalic and malic acids are formed, beſides a thick oily ſubſtance which appears on the ſurface. The coagulation of albumen does not take place when it is diſſolved in a great proportion of water. Albumen is alſo coagulated by means of alcohol and ether, but if the quantity of water in which it is diſſolved be conſiderable, the coagulation is not effected.

2602 Alkalies. 5. By trituration with a concentrated ſolution of pure potaſh, albumen left at reſt for ſome time, coagulates, and is converted into a ſubſtance reſembling jelly, which is brittle and tranſparent when it is dried. No change takes place on albumen by the action of the earths.

2603 Metallic ſalts. 6. Albumen is precipitated, from its ſolution in water, by many metallic ſalts. The precipitate is white, yellow, or brown, according to the metal employed.

2604 Tan. 7. Tan precipitates albumen from its ſolution in water, in the form of a copious yellow ſubſtance, which is inſoluble in water. It becomes brittle when dry, and is not changed by expoſure to the air.

2605 Properties. *Coagulated albumen.*—Albumen when it is coagulated, acquires new properties. It is then a tough, opaque ſubſtance, of a pearly-white colour, and of a ſweetiſh taſte. It is inſoluble in water, and is leſs ſubject to change. 2606 Action of heat. When it is dried in the temperature of 212°, it is converted into a hard, brittle, yellowiſh ſubſtance, of the tranſparency of horn. When it is ſome time digeſted in water, it becomes ſoft, white, and opaque, like albumen newly coagulated. By long action a ſmall part ſeems to be diſſolved, but no precipitation is formed in this ſolution by the infuſion of tan.

2607 Acids. 8. The mineral acids largely diluted with water, diſſolve a portion of coagulated albumen; but by the addition of the ſame acids in their concentrated ſtate, it is again precipitated. If coagulated albumen be kept in diluted nitric acid for ſeveral weeks, the acid acquires a yellow colour, which gradually deepens; the albumen becomes more opaque, but is not diſſolved. By ſaturating the yellow-coloured acid with ammonia, no precipitate is formed, but it aſſumes a deep orange colour. If the albumen be then introduced into liquid ammonia, the latter aſſumes a deep orange colour, inclining to red. The albumen diſſolves ſlowly, and after the ſolution is completed, it is of a yellowiſh-brown colour. By waſhing and boiling in water, the albumen thus treated with nitric acid, is diſſolved, the liquid becomes of a pale yellow, and aſſumes the form and appearance of jelly, when it is concentrated. If this maſs be diſſolved in boiling water, the ſolution is precipitated by tan; ſo that nitric acid has the property of converting coagulated albumen into gelatine.

2608 Alkalies. 3. Coagulated albumen is readily diſſolved in a ſolution of potaſh by boiling. Ammonia is diſengaged, and a ſoap is formed. If this ſoap be diſſolved in water, and muriatic or acetic acid be added, a precipitate is formed, which alſo has the properties of ſoap. When it is moderately heated, a portion of oil flows out, and a viſcid browniſh ſubſtance remains behind.

2609 Compoſition. 4. Albumen is compoſed of carbone, hydrogen, azote, and oxygen, but the proportions have not been determined. It is ſuppoſed by ſome that it contains a greater proportion of azote than gelatine.

2610 Exiſts in different parts of animals. 5. Albumen conſtitutes an eſſential part in the compoſition of bones and muſcles. Cartilage, horns, and hair conſiſt almoſt entirely of this ſubſtance, as well as the membranous portion of ſhells and ſponge.

2611 Uſes. 6. Albumen is advantageouſly employed for clarifying liquids. The liquid to be purified is mixed with the white of eggs, the ſerous part of the blood, or other ſubſtances containing albumen, and then heated. By the action of heat the albumen is coagulated, and falls to the bottom, carrying with it thoſe ſubſtances which were mixed with the liquid, and occaſioned the opacity, and which, on account of the minuteneſs of the particles, could not be otherwiſe ſeparated.

III. Of Fibrina.

2612 Obtained from blood. 1. Fibrina is readily obtained by allowing blood to remain at reſt for ſome time after it has been drawn from an animal. The clot, which has formed and falls to the bottom, is to be ſeparated, put into a linen cloth, and repeatedly waſhed with water, till the liquid come off inſipid and colourleſs. The fibrous part of the blood, as it has been called, or the fibrina, remains behind. 2613 From muſcle. Mr Hatchet obtained it by cutting lean beef into ſmall pieces, macerating in water for fifteen days, changing the water daily, and ſqueezing it out at the ſame time by preſſure. The muſcular ſubſtance was boiled every day five hours for three weeks in a freſh portion of ſix quarts of water. The fibrous ſubſtance was then preſſed, and dryed with the heat of a water bath. What remained is conſidered as fibrina nearly pure.

2614 Properties. 2. Fibrina is of a white colour, ſoft and elaſtic, when it is recently extracted from blood; and, as it dries, the colour becomes deeper. When it is extracted by boiling and maceration from muſcular matter, it is brittle, has ſome degree of tranſparency, and does not become ſo deep in the colour. It has neither taſte nor ſmell. It is inſoluble in water and alcohol, and is not changed by expoſure to the air.

2615 Action of heat. 3. When it is expoſed to heat, it contracts ſuddenly, and emits the ſmell of burning feathers. It melts with an increaſe of temperature. It yields by diſtillation, water, carbonate of ammonia, a thick fetid oil, carbonic acid, and carbonated hydrogen gas, with ſome traces of acetic acid. The coaly matter which remains behind burns with difficulty, on account of the phoſphate of ſoda, phoſphate and carbonate of lime, with which it is mixed.

2616 Acids. 4. Fibrina is ſoluble in the acids. The ſolution in ſulphuric acid is of a deep brown colour; charcoal is precipitated, and acetic acid formed. When diluted nitric acid is added to fibrina, azotic gas is copiouſly diſengaged. Fibrina kept by Mr Hatchett for 15 days in nitric acid diluted with 3 times its weight of water, gave to the ſolution a yellow colour, and it reſembled in its properties the ſolution of albumen in the ſame acid. By this proceſs, after being diſſolved in boiling water, and concentrated by evaporation, the fibrina is converted into gelatine, which is ſoluble in hot water, and is precipitated by tan. The fibrina in this ſtate alſo is almoſt entirely diſſolved by ammonia, and the ſolution is of an orange colour. Fibrina is diſſolved in boiling nitric acid, in which ammonia produces a precipitate, compoſed chiefly of oxalate of lime. During the action of the nitric acid, pruſſic acid paſſes over, with carbonic acid gas and nitrous gas. Oxalic acid is formed, and a fatty matter appears on the ſurface. Fibrina is alſo ſoluble in muriatic acid, with which it forms a green-coloured jelly. It is diſſolved alſo in acetic, oxalic, tartaric, and citric acids, with the aſſiſtance of heat; and is converted, by concentrating the ſolutions, into a gelatinous maſs. Alkalies precipitate fibrina from its ſolution in the acids, in the form of flakes, which have the properties of gelatine, and are ſoluble in hot water.

5. Concentrated potaſh or ſoda, boiled upon fibrina, forms a deep brown coloured ſolution, which has the properties of ſoap. During the proceſs ammonia is given out.

6. Fibrina is compoſed of carbone, hydrogen, azote, and oxygen, but the proportions are unknown. It is found only in the blood and muſcular parts of animals.

IV. Of Urea.

1. The nature and properties of urea have been chiefly inveſtigated by Fourcroy and Vauquelin. It is obtained from urine. It may be extracted by the following proceſs.

2617 Method of preparing. If a quantity of human urine which has been paſſed a few hours after taking food, be evaporated with a gentle heat, to the conſiſtence of a thick ſyrup, and allowed to cool, it concretes into a cryſtalline maſs. Add to this maſs in ſeparate portions four times its weight of alcohol; with the application of a gentle heat, great part is diſſolved, and what remains conſiſts of different ſaline ſubſtances. Separate the ſolution from the undiſſolved part, and introduce it into a retort. Diſtil with the heat of a ſand-bath, and continue the boiling till the liquid is reduced to the form of a thick ſyrup. The matter which remains in the retort cryſtallizes as it cools. The cryſtals thus formed are *urea*.

2618 Properties. 2. Urea, which is prepared by this proceſs, is cryſtallized in the form of plates, croſſing each other. It is viſcid, reſembling thick honey, and of a yellowiſh white colour. It has a ſtrong acrid taſte, and a fetid alliaceous ſmell. It deliqueſces in the air, and by attracting moiſture is converted into a thick brown liquid. It is very ſoluble in water, and alſo in alcohol. The ſolution in water concentrated is of a brown colour. This ſolution is gradually decompoſed, air is emitted, which is partly compoſed of ammonia, and acetic acid is formed in the liquid. If the ſolution in water be boiled, and as the evaporation goes on freſh portions of water be added, the urea is decompoſed; carbonate of ammonia is diſengaged, while acetic acid is formed and charcoal precipitated.

2619 Action of heat. 3. By the action of heat urea ſoon melts, enlarges in bulk, and evaporates, emitting an extremely fetid ſmell.

ſmell. By diſtillation, benzoic acid firſt paſſes over, afterwards carbonate of ammonia, carbonated hydrogen gas, with a ſmall portion of pruſſic acid and oil. What remains behind conſiſts of charcoal, muriates of ammonia and of ſoda. The benzoic acid, the muriate of ammonia and the muriate of ſoda, are conſidered as extraneous matter, ſo that the products of urea by diſtillation conſiſt of the carbonate of ammonia, carbonated hydrogen gas, and charcoal. The component parts of urea, therefore, are ſuppoſed to be

2620 Compoſition.

Oxygen,	39.5
Azote,	32.5
Carbone,	14.7
Hydrogen,	13.3
	100.0

2621 Action of acids.

4. If one-fourth of its weight of diluted ſulphuric acid be added to the ſolution of urea, and heat be applied, an oily matter appears on the ſurface, which concretes on cooling. Acetic acid is found in the liquid which is collected in the receiver, and ſulphate of ammonia remains in the retort. The whole of the urea may be converted into acetic acid and ammonia by repeated diſtillation.

Nitric acid produces a violent efferveſcence with the cryſtals of urea. The liquid becomes dark red, and during the efferveſcence nitrous gas, azotic gas, and carbonic acid gas are evolved. A concrete white matter remains after the efferveſcence has ceaſed, mixed with a ſmall portion of the red liquid. The reſiduum produces a detonation with the application of heat.

Urea is ſoluble in muriatic acid, but it remains unchanged. A diluted ſolution of urea abſorbs very rapidly oxymuriatic acid gas. Whitiſh flakes appear, which ſoon become brown, and adhere to the ſides of the veſſel. After the abſorption, the ſolution gives out carbonic acid and azotic gaſes. Muriate and carbonate of ammonia remain in the liquid after the efferveſcence ceaſes.

2622 Alkalies.

5. Urea is readily diſſolved in ſolutions of potaſh or ſoda. Ammonia is alſo diſengaged, when urea is diſſolved in ſolutions of barytes, lime, or magneſia. It is alſo diſengaged by triturating pure potaſh in the ſolid ſtate with urea. Heat is produced at the ſame time. The mixture aſſumes a brown colour, and an oily matter is depoſited.

Muriate of ſoda diſſolved in a ſolution of urea in water, affords by evaporation cryſtals in the form of regular octahedrons; but muriate of ammonia diſſolved in the ſame way, cryſtallizes in the form of cubes.

V. Of Sugar.

2623 Extracted from milk.

1. Sugar has only been diſcovered among animal matters in milk and in the urine of perſons labouring under *diabetes*. Sugar is obtained from milk by evaporating freſh whey to the conſiſtence of honey. When it cools, it concretes into a ſolid maſs. This is to be diſſolved in water, and being previouſly clarified with the white of eggs, to be filtered and evaporated to the conſiſtence of ſyrup. Cryſtals of ſugar of milk are depoſited on cooling.

2624 Properties.

2. When ſugar of milk is pure, it is of a white colour, has a ſweetiſh taſte, but no ſmell. It cryſtallizes in the form of regular parallelopipeds, terminating in four-ſided pyramids. The cryſtals are ſemitranſparent. The ſpecific gravity is 1.543. It is ſoluble in ſeven times its weight of water.

2625 Action of heat.

3. When it is burnt, it exhibits the ſame appearances as vegetable ſugar, giving out at the ſame time the odour of caromel. Similar products are obtained by diſtillation as from vegetable ſugar; but the empyreumatic oil has the odour of benzoic acid.

2626 Acids.

4. By means of nitric acid the ſugar of milk is partly converted into ſaclactic acid.

2627 Method of obtaining it.

Sugar from diabetic urine.—This is obtained by evaporating the urine of perſons labouring under diabetes. One twelfth of the weight of urine of a ſweet taſted ſubſtance of the conſiſtence of honey has been obtained by this proceſs. When this ſubſtance is treated with nitric acid, it affords oxalic acid in the ſame proportion as vegetable ſugar, but no ſaclactic acid is formed, as when ſugar of milk is treated in the ſame way. It has not been cryſtallized.

VI. Of Oils.

2628 In different ſtates.

1. The oils which have been detected in animals have the characters of fixed oils. Sometimes they exiſt in the ſolid ſtate, and ſometimes they are liquid. Fat is a copious animal production, which has different degrees of conſiſtence, as it is obtained from different animals. To purify it, it is cut into ſmall pieces, which are to be well waſhed with water, and the membranous and vaſcular parts ſeparated. It is then put into a ſhallow veſſel along with ſome water, and kept melted till the whole of the water is evaporated. It is then of a pure white colour, without taſte or ſmell.

2629 Action of heat.

2. It melts at different temperatures. Hogs lard requires only a temperature of 97°, while the fat extracted from meat by boiling requires a temperature of 127°. When the heat is raiſed to 400°, a white ſmoke is given out; as the heat increaſes it is decompoſed, and becomes black. When hogs lard is diſtilled in a retort, carbonated hydrogen and carbonic acid gaſes, accompanied with a very offenſive ſmell, paſs over. A portion of water is alſo obtained, and a white oil which concretes in the receiver. Acetic acid and a portion of ſebacic acid are alſo found in the receiver. A black maſs remains behind in the retort.

2630 Acids.

3. Fat is inſoluble in water and alcohol. It is diſſolved and decompoſed by the ſtrong acids. If nitric acid be poured upon fat, and a moderate heat applied, the acid is decompoſed, and the fat is converted into a yellow coloured ointment. Fourcroy calls this an oxide of fat; the oxygen of the acid having combined with the oily matter.

2631 Alkalies.

4. Fat combines with the alkalies in the ſame way as other oily ſubſtances, and with them it forms ſoap.

2632 Compoſition.

5. The conſtituent parts of fat, as appears from the products which are obtained from its decompoſition, are oxygen, hydrogen, and carbone.

There are beſides ſome other oily ſubſtances obtained from different parts of animals, as ſpermaceti from the head of the ſpermaceti-whale, ſpermaceti-oil, which is ſeparated in the purification of the ſpermaceti, and train

train oil, extracted from the blubber of the whale, and from other ſea animals.

VII. Of Reſins.

1. Reſinous ſubſtances are found in different parts of animals, or rather they exiſt in thoſe ſubſtances which are ſecreted by animals.

2. A reſinous ſubſtance is extracted from the bile of animals. It is extracted from the freſh bile of the ox, by muriatic acid, in the proportion of one part of the latter to 32 of the former. The mixture remains for ſome hours, is filtered, and a white coagulated ſubſtance is ſeparated. The filtered liquid, which has a fine green colour, is to be evaporated in a glaſs veſſel with a gentle heat. The evaporation is continued till a green-coloured ſubſtance precipitates, which is to be ſeparated, and waſhed with pure water. This ſubſtance is the *reſin of bile*.

2633 Properties. 3. It is of a dark-brown colour, but when ſpread thin, is of a fine green. The taſte is extremely bitter.

2634 Action of heat. 4. When it is heated to the temperature of 122° it melts. By increaſing the heat, it takes fire and burns. It is ſoluble in cold and hot water and alſo in alcohol; but it is precipitated from the latter by water. The alkalies alſo diſſolve this ſubſtance, and form a compound which has the properties of ſoap. This ſubſtance is precipitated from all theſe ſolutions by means of diluted acids.

A reſinous ſubſtance has alſo been diſcovered in human urine, in ambergris, which will be afterwards deſcribed, and in caſtor, civet, and muſk.

VIII. Of Phoſphorus.

2635 Given out during putrefaction. During the putrefaction of animal matters, phoſphorus is given out in the ſtate of phoſphorated hydrogen gas, ſo that it muſt have entered as a conſtituent into theſe matters.

IX. Of Sulphur.

2636 Found in albumen. Albumen is always mixed with a portion of ſulphur. It has been detected in the white of eggs and in milk, in the blood, in the urine and fæces, in the muſcles and in the hair. According to Prouſt ſulphur exiſts in the blood, in combination with ammonia, forming a hydroſulphuret of ammonia.

X. Of Acids.

2637 Enumeration of acids. No leſs than 12 different acids have been detected ready formed in animal bodies. Theſe are,

Sulphuric,
Muriatic,
Phoſphoric,
Carbonic,
Acetic,
Oxalic,
Malic,
Benzoic,
Lactic,
Uric,
Roſacic,
Amniotic.

1. Sulphuric acid has been found combined with ſoda, forming ſulphate of ſoda, in the liquor of the amnios of cows. Sulphate of lime has been detected in the urine of quadrupeds.

2. Muriatic acid exiſts in combination with ſoda in almoſt all the animal fluids, forming muriate of ſoda.

3. Phoſphoric acid is found in great abundance in different parts of animals. The phoſphate of lime conſtitutes the baſis of the bones, and it exiſts alſo in almoſt all the ſolid parts of animals, and in moſt of the fluids. In the blood it is combined with iron.

4. Carbonic acid is found combined with lime in the urine of horſes and cows. It has alſo been detected in freſh human urine.

5. Acetic acid is found in urine; but it has been detected in great abundance in the red ant, and was formerly called *formic acid*, at leaſt combined with malic acid.

6. Oxalic acid has been found in urinary calculi.

7. Malic acid has been found in the liquid obtained from the red ant. This is obtained by bruiſing the ants, and macerating them in alcohol. The alcohol is driven off by diſtillation, and an acid liquid remains behind. By ſaturating this liquid with lime, and adding acetate of lead to the ſolution, a copious precipitate is formed, which is ſoluble in acetic acid, ſo that this liquid contains ſomething beſides acetic acid. If nitrate of lead be mixed with the acid liquid after it is ſaturated with lime, a precipitate is formed, which is the malic acid combined with lead.

8. Benzoic acid has been detected in human urine, and in conſiderable quantity in the urine of cows. It has been found in the blood, white of eggs, in glue, ſilk, or wool, in the ſponge, and in muſhrooms.

9. Lactic acid is obtained from milk, when it becomes ſour. It is alſo ſaid, that it has been found in new milk.

10. Uric acid exiſts in human urine, and forms one of the conſtituents of urinary calculi. One ſpecies of calculus, indeed, is compoſed entirely of this ſubſtance.

11. Roſacic acid is obtained from the urine of perſons labouring under fevers and other diſorders, when the urine depoſits what is called a *lateritious ſediment*.

12. Amniotic acid is obtained from the liquid of the amnios of the cow.

XI. Of Alkalies, Earths, and Metals.

2638 Alkalies. 1. The different alkalies have been found in animal fluids. Potaſh has been found in conſiderable abundance in the urine of quadrupeds. It has alſo been detected in the milk of cows. Soda is found in all the fluids. It is uſually mixed with albumen. It is frequently combined with the phoſphoric and muriatic acids. Ammonia alſo has been detected in urine.

2639 Earths. 2. The earths which have been detected in animals are, lime, magneſia, and ſilica. Lime forms, in combination with phoſphoric acid, the baſis of bones. It is alſo found in the ſame ſtate in the other ſolid parts, as well as in moſt of the fluids. The ſhells of animals are compoſed chiefly of carbonate of lime. Magneſia has been found in human urine, combined with phoſphoric acid and ammonia. It forms alſo one of the component parts of urinary calculi. Silica has only been found in ſimilar concretions.

2640 Metals. 3. The only metal which has been detected in animals is iron, in combination with phoſphoric acid, which forms a conſtituent part of the blood.

II. Fluid Parts of Animals.

We ſhall treat of the animal fluids in the following order :

2641 Enumeration.

1. Blood,
2. Bile,
3. Urine,
4. Milk,
5. Saliva,
6. Tears and mucus of the noſe,
7. Humours of the eye,
8. Wax of the ear,
9. Synovia,
10. Semen,
11. Liquor of the amnios,
12. Fluids ſecreted by diſeaſe.

1. Of the Blood.

2642 Properties. 1. The blood is a fluid of a red colour, which circulates through the body, and is diſtributed by means of the arteries to every part of it, communicating, as we have ſeen, heat and nouriſhment. It is then reconveyed by the veins from the extremities to the heart. Human blood, and that of ſome other animals, is of a fine, purpliſh-red colour, has ſome degree of conſiſtency, ſoft and ſoapy to the feel, of a ſweetiſh ſaline taſte, and a peculiar odour. The blood is found to vary in conſiſtence, ſo that its ſpecific gravity alſo varies from 1.053 to 1.126.

2643 Separates into two parts. 2. When blood, after it has been ſeparated from the body, remains for ſome time at reſt, it ſeparates into two parts. One part called the *clot* or *cruor*, is coagulated, and continues of a red colour; the other part, called the *ſerum*, remains fluid. The uſual proportion of cruor to ſerum, is about one part of the former to three of the latter. This proportion, however, is ſubject to conſiderable variation.

2644 Action of acids. 3. The acids alſo coagulate blood, and decompoſe it. Concentrated ſulphuric acid occaſions a brown colour, with the production of charcoal. It is coagulated by nitric acid, with the evolution of azotic gas, and the production of carbonic and oxalic acids, beſides ſome unctuous matter. Muriatic acid alſo coagulates blood, but without any perceptible change of colour. Oxymuriatic acid renders it as black as ink. Acetic acid alſo produces a coagulation.

2645 Alkalies. 4. The cauſtic alkalies diſſolve the coagulum of blood, even when it has been produced by acids. If they are mixed with blood recently drawn, the coagulation is interrupted. Many ſaline bodies produce a ſimilar effect by preventing coagulation, or decompoſition.

2646 Metallic oxides. 5. The metallic oxides have little perceptible action on blood, except thoſe which readily part with their oxygen. It is then coagulated. Almoſt all metallic ſolutions coagulate blood, and have the property, as well as the alkaline ſalts, of preſerving it from putrefaction.

2647 Vegetable productions. 6. Many vegetable ſubſtances when mixed with blood, prevent its putrefaction, ſuch as ſugar, volatile oils, camphor, reſins. It is coagulated by ſolutions of gum and of ſtarch. Tan produces a copious precipitate in blood, and gallic acid gives a black colour, owing to the iron which is contained in blood. The latter precipitate may be obtained by diluting the blood with a conſiderable proportion of water.

2648 Serum. 7. Blood, by remaining at reſt, it has been obſerved, ſeparates into two parts, the ſerum and the cruor. The ſerum is of a pale, greeniſh, yellow colour, of a thinner conſiſtence than blood; but retains its taſte, ſmell, and ſoapy feel. The ſpecific gravity is about 1.0287. In conſequence of its containing a portion of ſoda, it gives a green colour to ſyrup of violets. Serum coagulates at the temperature of 156°. The ſame effect is produced by adding boiling water. This coagulum is of a grayiſh white colour, reſembling the white of eggs. By breaking the coagulum to pieces, a fluid may be expreſſed from it, which has been called the *ſeroſity* of blood. The reſiduum being waſhed with boiling water, exhibits the properties of albumen.

2649 Gelatine. 8. By diluting ſerum with ſix times its weight of water, and boiling it, the albumen is coagulated. If the remaining liquid be evaporated with a gentle heat, till it is conſiderably concentrated, it aſſumes the form of jelly, and this poſſeſſes the properties of gelatine.

2650 Sulphur. 9. By heating the coagulated ſerum in a ſilver veſſel, the ſilver is blackened, in conſequence of its converſion into a ſulphuret, by combining with ſulphur contained in the coagulum. It has been already mentioned, that this ſulphur exiſts in the blood, in combination with ammonia, in the ſtate of hydroſulphuret.

2651 Different ſalts. 10. The ſerum of blood contains muriate of ſoda, carbonate of ſoda, phoſphate of ſoda, and phoſphate of lime. Theſe ſalts may be obtained by mixing ſerum with double its weight of water, applying heat to coagulate the albumen, which being ſeparated, and the remaining liquid filtered and evaporated, cryſtals are depoſited on cooling. The ſoda exiſts in blood combined with gelatine and albumen, and is in its cauſtic ſtate. It unites with the carbonic acid of the air during the evaporation. The component parts of ſerum, therefore, are the following. 2652 Compoſition of ſerum.

Albumen,
Gelatine,
Hydroſulphuret of ammonia,
Soda,
Muriate of ſoda,
Phoſphate of ſoda,
Phoſphate of lime.

2653 Cruor. 11. The cruor or clot of the blood, the other portion into which it ſpontaneouſly ſeparates, is of a red colour, and has conſiderable conſiſtence. Its ſpecific gravity is about 1.245. By waſhing this ſubſtance with a ſmall quantity of water, and continuing the proceſs till the water paſſes off colourleſs, part of it is diſſolved by the water, and part remains in the ſtate of a ſolid white elaſtic ſubſtance, which is the fibrina of the blood. That part which is held in ſolution by the water contains the colouring matter. This ſolution converts the ſyrup of violets to a green colour. By expoſure to the air it depoſits albumen in the form of flakes. By the evaporation of this ſolution to dryneſs, and the addition of alcohol, part is diſſolved. 2654 Albumen and ſoda. If this ſolution be evaporated, the reſiduum converts vegetable blues to green, and mixes with water like ſoap. This reſiduum contains albumen and ſoda.

2655 Iron. 12. If the watery ſolution be evaporated to dryneſs with a moderate heat, a quantity of iron remains behind, which may be ſeparated by the magnet. It has been ſaid that the quantity of iron in the blood of a healthy man amounts to more than two ounces; but this

this is little better than conjecture, founded on vague calculation. The iron in blood is combined with phoſphoric acid. If the watery ſolution be evaporated to dryneſs, and the reſiduum obtained be calcined

2656 Quantity conjectured.

in a crucible, a red maſs remains, which amounts to 0.0045 of the blood which was employed. Part of this reſiduum, which is phoſphate of iron, is diſſolved by digeſtion in nitric acid. From this it is precipitated of a white colour, by ammonia. With the addition of pure potaſh, the precipitate becomes red. By adding lime water to the ſolution which contains the potaſh, a precipitate is formed, which is phoſphate of lime. By the action of theſe re-agents, it appears that the iron in the blood combined with phoſphoric acid, is in the ſtate of ſub-phoſphate. Phoſphate of iron is inſoluble in water, but ſoluble in the acids. It is partially decompoſed by the alkalies, which carry off part of its acid, and leave the remainder with exceſs of iron. Thus it is that this ſalt is preſerved in the ſtate of ſub-phoſphate, by means of the ſoda which exiſts in the blood.

2657 Fibrina.

13. The method of obtaining fibrina from blood has been already deſcribed. This ſubſtance may be ſeparated by agitating, or ſtirring rapidly with a ſtick, the blood which has been newly drawn from the animal. The fibrina or fibrous matter being well waſhed and dried on paper, loſes about two-fifths of its weight, and becomes hard and brittle. The mean proportion of fibrina in the blood of man has been eſtimated at 0.0028. The fibrina is formed in the blood as it paſſes through the lungs, and is depoſited in the muſcular parts of animal bodies, of which it forms one of the principal conſtituents. When the fibrina is ſeparated from the blood, the latter is no longer diſpoſed to coagulate when it is left at reſt. A flakey matter only is ſeparated, which appears on the ſurface.

2658 Diſtillation.

14. Blood dried with a moderate heat, exhales a quantity of water which poſſeſſes a peculiar odour, owing to a portion of animal matter which it holds in ſolution. If the blood thus dried be diſtilled in a retort, a watery fluid paſſes over, afterwards carbonic acid gas, carbonate of ammonia, which cryſtallizes in the neck of the retort, a fluid oil, carbonated hydrogen gas, and an oily matter of the conſiſtence of butter. A green powder is precipitated from ſulphate of iron by the watery fluid. A portion of this powder is ſoluble in muriatic acid, and a ſmall quantity of Pruſſian blue remains behind, from which it appears that pruſſic acid and an alkali are contained in the watery liquor.

2659 Action of heat.

A quantity of dried blood amounting to 9216 grs. was introduced into a large crucible, and being gradually heated, it became at firſt nearly fluid; it then ſwelled up, gave out abundance of yellowiſh-coloured fetid fumes, and at laſt took fire, and burnt with a white flame. The flame and the fumes ceaſing to be emitted, were ſucceeded by a light, acrid ſmoke, which had the odour of pruſſic acid. When the matter had been deprived of about five-ſixths of its weight, at the end of ſix hours it melted again; a purple flame appeared on the ſurface, with the evolution of denſe acrid fumes, which being collected were found to poſſeſs the properties of phoſphoric acid. One hundred and eighty-one grains of a deep black colour and metallic brilliancy conſtituted the reſiduum. It was attracted by the magnet. From theſe obſervations it appears that the conſtituent parts of the blood are the following.

2660 Compoſition.

1. Water.
2. Fibrina.
3. Albumen.
4. Gelatine.
5. Hydroſulphuret of ammonia.
6. Soda.
7. Subphoſphate of iron.
8. Muriate of ſoda.
9. Phoſphate of ſoda.
10. Phoſphate of lime.
11. Benzoic acid.

2661 Varies at different periods, &c.

15. The conſtituent parts of blood vary conſiderably at different periods of life, and in different ſtates of the body. The colouring matter of the blood of the fœtus has been found to be darker and more copious. It contains no fibrina or phoſphoric acid.

2662 Inflammatory.

16. The blood of perſons labouring under inflammatory diſorders ſeems to poſſeſs different properties from that of perſons in health. It then exhibits, ſoon after it is drawn from the body, what has been called by phyſicians the *buffy coat*, which is conſidered to be the characteriſtic of inflammation. This inflammatory cruſt has been found to conſiſt of fibrina, ſo that the cruor deprived of this matter, becomes ſoft, and is almoſt entirely ſoluble in water. The albumen of the ſerous part has alſo undergone ſome change. It aſſumes a milky appearance when mixed with hot water, and does not coagulate when it is heated.

2663 Diabetic.

17. The ſerum of the blood of perſons labouring under diabetes, is deprived of its ſaline taſte, has the appearance of whey, and ſomewhat of a ſaccharine taſte.

II. Of Bile.

2664 Importance and properties.

1. Bile is an important fluid in the animal economy. It ſeems to perform an eſſential part in the function of digeſtion. It is ſecreted from the liver, and is of a yellowiſh-green colour, has a ſoapy feel, a bitter taſte, and a peculiar odour; but it varies in colour, and in ſome other of its properties, in different animals. It varies alſo in its ſpecific gravity. It has been eſtimated at 1.0246. The experiments which have been made on bile relate chiefly to that obtained from the gall-bladder of the ox, hence denominated *ox-gall*. When bile is ſtrongly agitated, it forms a lather like ſoap, and hence it has been called an *animal ſoap*. It mixes in all proportions with water, to which it communicates a yellow colour.

2665 Action of heat.

2. When bile is expoſed to a moderate heat, it becomes thick, having loſt a great part of its weight. The vapour it exhales has a peculiar offenſive odour. A ſolid brown maſs is thus obtained, which has a bitter, with ſomewhat of a ſweetiſh taſte, becomes ſoft with the heat of the hands, is ductile, attracts moiſture from the air, and is ſoluble in water. This ſubſtance efferveſces ſlightly with acids, and acquires a perceptible odour of muſk or amber, when kept for ſome time. This has been called the *extract of bile*. When this proceſs is conducted in cloſe veſſels, with the heat of a water bath, it gives out a clear aqueous fluid of a diſagreeable odour, which undergoes no particular change by means of re-agents, if the diſtillation has not been carried too far, or the bile has not become in ſome degree putrid. If this latter circumſtance has taken place,

place, the watery product has frequently a ſtrong odour of muſk, and becomes turbid on cooling.

2666 Diſtillation.

When this extract of bile is heated in a retort, it is decompoſed with peculiar appearances. When heat is gradually applied, a watery fluid, which is ſlightly muddy, and of a fetid odour, paſſes over. This fluid precipitates metallic ſalts, and contains almoſt always ſulphurated hydrogen. The matter in the retort enlarges in volume, and the fluid which then comes over is of a brown colour, extremely fetid, and contains carbonate and zoonate of ammonia. Soon after an oil is evolved, which is at firſt liquid, and afterwards becomes of a browniſh colour, thick and empyreumatic, and of a moſt offenſive fetid odour. At the ſame time carbonate of ammonia cryſtallizes on the ſides of the receiver. There is then a copious evolution of an elaſtic fluid, compoſed of carbonic acid, carbonated and ſulphurated hydrogen gaſes, holding in ſolution a ſmall portion of oil. The carbonate of ammonia thus obtained, does not amount to the one-eighth part of the quantity which is extracted from the blood and from the bones of animals, from which it is ſuppoſed that the bile is leſs animalized than many other animal ſubſtances. There remains behind a black ſpongy maſs of coal, which is eaſily burnt. This coaly matter, by expoſure to the air, effloreſces on the ſurface, which is found to be carbonate of ſoda. When it is well burnt, it preſerves a deep gray colour, and there is ſeparated, by means of cold water, nearly half its weight of carbonate of ſoda, a little muriate of ſoda, phoſphate of ſoda, phoſphate of lime, with ſome traces of iron.

2667 Action of acids.

3. Bile is decompoſed by all the acids. A precipitate is formed, which is always of a green colour. Part of this precipitate remains ſuſpended in the ſolution, and is even diſſolved by agitation. The ſolution being filtered, leaves on the filter a portion of coagulated albumen. By evaporation the liquid depoſits a deep green flaky ſubſtance like pitch, which has conſiderable tenacity, ſwells up when put upon hot coals, readily takes fire, and burns like reſinous matter. After the ſeparation of this matter, the liquid affords by evaporation, a ſalt with a baſe of ſoda.

Three different ſaline ſubſtances have been obtained by the action of acids on bile; the firſt with a baſe of ſoda, the ſecond which cryſtallizes in ſmall needles has lime for its baſe, and the third is a cryſtalline matter, of a ſlightly ſweet taſte, which is ſuppoſed to be ſimilar to ſugar. Thus it appears that acids act on bile in three different ways; they coagulate the albumen, which is precipitated; they combine with the ſoda, by ſeparating the oily matter which conſtituted the ſaponaceous part of the bile; and they decompoſe the phoſphoric ſalts.

Concentrated ſulphuric acid coagulates bile in the form of denſe flakes, and communicates to it a deep colour. Nitric acid, after having formed a precipitate of a green colour in the cold, aſſumes a golden yellow colour, when it is heated for a ſufficient length of time. It converts a portion of bile into oxalic and pruſſic acids. Muriatic acid at firſt produces a green precipitate, which afterwards aſſumes a ſhade of a reddiſh violet colour, eſpecially by means of heat. Oxymuriatic acid renders it white and turbid like milk. It changes the properties of the different conſtituents of bile, and occaſions a precipitate ſimilar to that matter which frequently conſtitutes *biliary calculi.*

2668 Phoſphate of lime.

4. When the precipitate from bile by means of the acids is treated with alcohol, and every thing ſoluble in this liquid ſeparated, there remains a whitiſh matter, which is infuſible, nearly inſipid, inſoluble, whether with cold or hot water, but ſoluble in ſolutions of the cauſtic fixed alkalies, which burns on red-hot coals with the odour of horn, and which gives by analyſis, ſimilar products, eſpecially carbonate of ammonia in conſiderable quantity. The coal which remains contains a portion of phoſphate of lime.

2669 Action of alkalies.

5. The alkalies deprive bile of its bitter taſte; but they do not coagulate it.

6. Thus it appears that the conſtituent parts of bile are the following.

Water,
Albumen,
Reſin,
Soda,
Sulphurated hydrogen,
Saccharine matter,
Muriate of ſoda,
Phoſphate of lime,
Phoſphate of ſoda,
Iron.

2670 Uſes.

7. Bile, it has been already obſerved, performs an important part in the function of digeſtion. The albuminous and ſaline parts combine with the chyle, and are conveyed to the blood. The reſinous portion combines with the excrementitious part of the chyle, and is thrown out of the body.

Bile is employed in the arts for removing ſpots of greaſe and oil from woollen ſtuffs. It is alſo employed as a pigment. It is evaporated and reduced to the form of extract, and diluted with a little water, in which ſtate it gives a brown colour.

III. Of Urine.

2671 Properties.

1. The properties of urine vary conſiderably, according to the conſtitution and health of the body, and the period when it is voided after taking food. The urine of a healthy perſon is of a light orange colour, and uniformly tranſparent. It has a ſlightly aromatic odour, in ſome degree reſembling that of violets. It has a ſlightly acrid, ſaline, bitter taſte. The ſpecific gravity varies from 1.005 to 1.033. The aromatic odour, which leaves it as it cools, is ſucceeded by what is called the *urinous ſmell*, which latter is converted to another, and finally, to an alkaline odour. Urine converts the tincture of turnſole into a green colour, from which it is concluded, that it contains an acid.

2672 Phoſphate of lime.

2. By adding a ſolution of ammonia to freſh urine, a precipitate is formed in the ſtate of white powder, which is found to be phoſphate of lime. But if lime water be employed in place of ammonia, a more copious precipitate, of phoſphate of lime, is obtained, from which it is concluded, that the phoſphate of lime is held in ſolution with an exceſs of acid.

2673 Phoſphate of magneſia.

3. A ſmall portion of magneſia is alſo found mixed with the phoſphate of lime which has been precipitated, derived from phoſphate of magneſia, which has been decompoſed by the alkali or lime.

2674 Carbonic acid.

4. The froth which appears when urine is evaporated, is aſcribed to the evolution of carbonic acid gas.

2675 Carbonate of lime.

5. Urine which has been kept in new caſks, depoſits

Component Parts of Animal Subſtances.

fits ſmall cryſtals, which effloreſce in the air. Theſe cryſtals have been found to poſſeſs the properties of carbonate of lime.

2676 Uric acid. 6. A brick-coloured precipitate is frequently formed in urine as it cools. This ſubſtance is uric acid, which exiſts in all urine, and may be obtained by evaporating freſh urine, diſſolving it in pure alkali, and precipitating by means of acetic acid.

2677 Roſacic acid. 7. The urine of perſons labouring under intermitting fevers, and ſome other diſeaſes, depoſits a copious ſediment called the lateritious ſediment, which conſiſts of roſacic acid.

2678 Benzoic acid. 8. Benzoic acid alſo exiſts in urine. It is obtained by evaporating freſh urine to the conſiſtence of a ſyrup, and adding muriatic acid. A precipitate is thus formed, which is benzoic acid. But it may be obtained by evaporating urine to dryneſs, ſeparating the ſaline ſubſtances, and applying heat to the reſiduum. By this proceſs the benzoic acid is ſublimed, and cryſtallized in the receiver. The quantity of benzoic acid is more conſiderable in the urine of horſes and cows than in human urine.

2679 Albumen and gelatine. 6. Albumen or gelatine has been found in urine, and is precipitated by means of an infuſion of tan. The cloud which appears as urine cools, conſiſts of theſe ſubſtances, which are increaſed in proportion during different diſeaſes. The urine of perſons labouring under dropſy contains a large quantity of albumen; and in the urine of thoſe perſons who are ſubject to indigeſtion, the albumen and gelatine are greatly increaſed.

2680 Urea. 10. Urea is the principal conſtituent of urine. The method of obtaining it from urine has been already deſcribed. It is to this ſubſtance that the taſte, ſmell, and peculiar characters of urine are owing. If concentrated nitric acid be poured upon urine, evaporated to the conſiſtence of ſyrup, cryſtals appear, which are the nitrate of urea. The quantity of urea ſecreted is very different in different circumſtances.

2681 Reſin. 11. A reſinous ſubſtance reſembling the reſin of bile has been detected in urine, to which its colour is aſcribed. Urine evaporated to the conſiſtence of extract, mixed with ſulphuric acid and diſtilled, gives out this reſinous matter, which is ſoluble in water and in alcohol. When urea has been ſeparated from urine by evaporation and cryſtallization, a ſaline maſs remains. If this be diſſolved in hot water, and ſpontaneouſly cryſtallized in a cloſe veſſel, two kinds of cryſtals are depoſited. Thoſe at the bottom are in the form of rhomboidal priſms, and conſiſt of phoſphate of ammonia mixed with a little phoſphate of ſoda. The cryſtals in the upper part of the veſſel are in the form of rectangular tables, compoſed chiefly of phoſphate of ſoda. Theſe were formerly called *fuſible ſalt of urine*, *microcoſmic ſalt*.

2682 Muriate of ſoda. 12. Muriate of ſoda was the firſt ſaline ſubſtance detected in urine. It may be obtained by ſlowly evaporating it to the conſiſtence of ſyrup. The ſalt cryſtallizes upon the ſurface, but in this caſe the form of the cryſtals is that of an octahedron, and not the cube, the uſual form. The cauſe of this deviation is aſcribed to the urea.

2683 Muriate of potaſh. 13. Muriate of potaſh is alſo found among the cryſtals which are formed during the evaporation of urine.

Component Parts of Animal Subſtances.

2684 Muriate of ammonia. 14. Muriate of ammonia is one of the ſalts which are found in urine. The cryſtals of this ſalt which are uſually octahedrons, when they are formed in urine aſſume that of the cube, a deviation which is alſo aſcribed to the action of the urea.

2685. Sulphur. 15. Urine contains ſulphur, which may be detected by holding paper ſtained with acetate of lead over urine when it is become putrid. The paper is blackened, which is owing to ſulphur exhaled with the carbonic acid. Sulphate of ſoda and ſulphate of lime have been alſo detected in urine.

2686 Component parts. 16. No leſs than 30 different ſubſtances have been detected in urine by chemical analyſis, the principal of which are the following.

Water,
Phoſphoric acid,
Phoſphate of ſoda,
Phoſphate of ſoda and ammonia,
Phoſphate of ammonia,
Phoſphate of lime,
Phoſphate of magneſia,
Phoſphate of magneſia and ammonia,
Carbonic acid,
Carbonate of lime,
Uric acid,
Urate of ammonia,
Roſacic acid,
Benzoic acid,
Benzoate of ammonia,
Gelatine,
Albumen,
Urea,
Reſin,
Muriate of potaſh,
Muriate of ſoda,
Muriate of ammonia,
Sulphur,
Sulphate of lime,
Sulphate of ſoda.

2687 Putrefaction of urine. 17. Urine is much diſpoſed to ſpontaneous decompoſition. The time when this proceſs commences, and the rapidity of the changes which take place, depend on the quantity of the gelatine and albumen. When the proportion of theſe ſubſtances is conſiderable, the decompoſition is very rapid. This is owing to the great number of ſubſtances, and the united force of their attractions overcoming the exiſting affinities of the different compounds of which freſh urine conſiſts, and eſpecially to the facility with which urea is decompoſed. This ſubſtance is converted during putrefaction into ammonia, carbonic acid, and acetic acid. Hence the ſmell of ammonia is always recognized while urine is undergoing theſe changes. Part of the gelatine is depoſited in a flaky form mixed with mucilage. Ammonia combines with phoſphoric acid, and the phoſphate of lime is precipitated. It combines alſo with phoſphate of magneſia, and forms a triple ſalt. The other acids, the uric, benzoic, the acetic and carbonic acids, are all ſaturated with ammonia. The following ſubſtances, therefore, are obtained from urine by putrefaction.

Ammonia,
Phoſphate of ammonia,
Phoſphate of magneſia and ammonia,
Carbonate of ammonia,
Urate of ammonia,
Acetate of ammonia,
Benzoate of ammonia,
Muriate of ammonia,
Muriate of ſoda.

Products nearly ſimilar are obtained by diſtillation of urine.

2688 Varies in different circumſtances.

18. Such are the properties of human urine in its healthy ſtate; the changes to which it is ſubject, and the products which are obtained, either by means of chemical analyſis or ſpontaneous decompoſition. But the nature and properties of urine vary conſiderably, according to the period of life, the time it is voided after taking food, different ſeaſons of the year, the nature of the food, the influence of paſſions, and diſeaſe.

2689 Urine of infants.

In the urine of infants, no phoſphate of lime is found. The proportion of benzoic acid is conſiderable, and the quantity of urea is ſmall. There is leſs acrimony, odour, and colour. As the period of life advances, the ſaline matters increaſe, eſpecially the phoſphate of lime, which is no longer required for the formation of bone.

2690 After taking food.

The urine, which is paſſed immediately after taking food, is white and colourleſs, and ſeems to contain little elſe but water. It is not till ſeven or eight hours after a repaſt, that the urine is completely formed.

2691 In warm ſeaſons.

Urine voided during the warmer ſeaſons of the year, or by perſons who inhabit hot climates, is high-coloured and acrid, which is aſcribed to a greater proportion of ſaline matter and urea. In winter alſo the urine is red and high-coloured, owing to a greater proportion of the earthy phoſphates and of uric acid, which it then contains. It is no doubt conſiderably influenced by the modification of the action of the ſkin.

2692 Kinds of food.

The food frequently communicates its properties to the urine. The odour of garlic, of reſinous ſubſtances, and ſome aromatics, is often perceptible in the urine a few minutes after theſe ſubſtances are taken into the ſtomach, or even only applied to the ſkin. The fetid odour of the urine of thoſe who have eaten aſparagus, is well known. The colouring matters of ſome ſubſtances are communicated to the urine; ſuch as the red colour of beet-root, the orange-yellow of rhubarb, or the colour of madder.

2693 Paſſions.

The paſſions of the mind have great influence on the ſecretion of urine, both in changing its properties, and increaſing its quantity. In theſe caſes the urine is generally colourleſs, inſipid, and without odour.

2694 Diſeaſes.

But the nature and properties of urine undergo ſtill greater changes during diſeaſe. From theſe changes the empiric has attempted to form prognoſtics of the nature, progreſs, and termination of diſeaſes.

At the commencement of fevers and inflammatory diſorders, the urine is high-coloured, and extremely acrid, ſcarcely becomes turbid on cooling, and depoſits no ſediment. In affections of the liver, ſuch as jaundice, it is of a yellow orange colour, like ſaffron, and communicates its colour to the veſſels into which it is received, or to thoſe ſubſtances which are immerſed in it. It is then called *bilious urine.* It ſeems to contain a portion of the colouring matter of bile. Towards the termination of febrile diſorders, the quantity of urine is increaſed, and it depoſits, as it cools, a cryſtalline or ſcaly matter, of the colour of peach flowers, which is called *critical urine.* The ſediment is compoſed of phoſphate of lime, roſacic and uric acids. During nervous affections, as in hyſteria, the urine is perfectly limpid and colourleſs, inodorous and inſipid.

It has been obſerved, that the urine of gouty perſons contains a ſmaller proportion of acid than uſual. At the commencement of a paroxyſm, the quantity of phoſphoric acid ſeems to be diminiſhed; but it gradually increaſes towards the termination of the fit, and is then in greater proportion than in ordinary health. The urine of perſons labouring under rickets, depoſits a great portion of lime. The urine of an infant who died of worms, was found on analyſis to contain oxalate of lime. In ſome caſes of diabetes, the urine is colourleſs and inſipid; in others it contains a great proportion of ſaccharine matter.

2695 Different animals.

19. The urine of other animals exhibits different characters from that of man, according to their nature, the diverſity of their organs, their food, manner of reſpiration, and the medium in which they live.

2696 The horſe.

The urine of the horſe has a ſtrong peculiar odour. It is turbid when voided, or ſoon after becomes muddy. A pellicle, which is carbonate of lime, forms on the ſurface when it is expoſed to the air. It changes the ſyrup of violets to a green colour, effervesces with acids, and is precipitated by the alkaline carbonates. The urine of the horſe yields no phoſphorus. The component parts of the urine of this animal, as they have been aſcertained by Fourcroy and Vauquelin, are the following:

Carbonate of lime,	0.011
Carbonate of ſoda,	0.009
Benzoate of ſoda,	0.024
Muriate of potaſh,	0.009
Urea,	0.007
Water and mucilage,	0.940
	1.000 *

2697 The cow.

The urine of the cow poſſeſſes nearly the ſame properties as that of the horſe. It has a ſoapy feel, and a ſtrong peculiar odour. It gives a green colour to ſyrup of violets, effervesces with acids, and is not altered by the alkaline carbonates. When it is expoſed to the air, ſmall cryſtals form on the ſurface. Its component parts are,

Carbonate of potaſh,
Sulphate of potaſh,
Muriate of potaſh,
Benzoic acid,
Urea.

2698 The camel.

The urine of the camel is more diſtinguiſhed by its odour than any other, but it is analogous to that of the cow. It is not mucilaginous, and does not depoſit carbonate of lime. The ſpecific gravity of this urine is greater than any other. It produces a ſlight change on the infuſion of violets, communicating a green colour. It effervesces with acids, and furniſhes nitre, ſulphate and muriate of potaſh, with the addition of ſulphuric, nitric, and muriatic acids. It contains

Carbonate of potaſh,
Sulphate of potaſh,
Muriate of potaſh,
Urea.

2699 The rabbit.

The urine of the rabbit, examined by Vauquelin,

---

* *Mem. de l'Inſt.* ii. p. 445.

exhibits ſimilar characters with that of the horſe, the cow, and the camel. It becomes milky, and depoſits carbonate of lime by expoſure to the air. It converts vegetable blues to a green colour, and efferveſces with acids. It contains the following ſubſtances.

Carbonate of lime,
Carbonate of magneſia,
Carbonate of potaſh,
Sulphate of potaſh,
Sulphate of lime,
Muriate of potaſh,
Urea,
Gelatine,
Sulphur.

2700 Guinea pig. The urine of the Guinea pig is analogous in its nature and properties to that of the larger animals already deſcribed.

2701 Graminivorous animals. It appears that the urine of graminivorous animals belonging to the claſs of mammalia, or which live on vegetables in general, contains no phoſphoric ſalts, or uric acid; that it is loaded with carbonate of lime, ſalts having a baſe of potaſh, and benzoic acid. The only ſubſtance which the urine of theſe animals poſſeſſes in common with human urine, is urea.

2702 Carnivorous. The urine of carnivorous animals, of which indeed ſcarcely any thing is known, is ſuppoſed to poſſeſs different properties from that of the animals juſt mentioned. The ſtrong fetid odour of the urine of the cat is well known. Muriate of ammonia has been obtained from the urine of this animal by evaporation; but it is ſuppoſed, from the peculiar odour, that it contains urea.

2703 Of birds. The urine of birds affords a copious ſediment, which ſeems to be carbonate of lime.

2704 Turtle. A ſubſtance which was found in the urinary bladder of the turtle in the form of paſte, and which was examined by Vauquelin, was compoſed of

Muriate of ſoda,
Phoſphate of lime,
Animal matter,
Uric acid.

IV. Of Milk.

2705 Properties. 1. Milk, which is ſecreted in particular organs by the females of viviparous quadrupeds and cetaceous fiſhes, included under the claſs *mammalia*, and deſtined for the nouriſhment of the offſpring, is a white opaque fluid, varying in its properties, according to the different ſpecies of animals, and the nature of their food. The milk of the cow, which is moſt eaſily and moſt abundantly procured, has been chiefly the ſubject of chemical inveſtigation. To it, therefore, the following obſervations are chiefly applied.

2706 Of cows milk. 2. Milk is diſtinguiſhed by an agreeable ſweet taſte, and a peculiar ſmell. But theſe properties belong to it only when it is juſt ſeparated from the cow, for in the courſe of a few hours they are conſiderably different. The ſpecific gravity varies at different periods. It is greater than that of water, and has been found to amount to 1.0324. The boiling and the freezing points of milk are alſo variable.

2707 Separation of cream. 3. If milk be left at reſt for ſome time, it ſeparates into two parts; an unctuous matter, which floats on the ſurface, called *cream*, and a denſer fluid which ſtill retains many of the properties of milk. The quantity of cream obtained from milk, and the time it requires to ſeparate, vary according to the nature of the milk and the temperature.

2708 Its properties. 4. Cream thus obtained is of a yellow colour, and acquires a greater conſiſtence by being expoſed to the air. It is lighter than water, has an unctuous feel, and becomes rancid like oils, by keeping. When it is boiled, a ſmall portion of oil appears on the ſurface. Cream is not ſoluble in alcohol or in oils. When cream is agitated for a longer or ſhorter time, according to the temperature to which the milk has been expoſed during its ſeparation, and perhaps to ſome circumſtances which have not yet been obſerved, it ſeparates into two parts; one, which has a ſolid conſiſtence, is butter, and another which remains fluid.

2709 Butter. 5. Butter is of a yellow colour, and has all the properties of an oil, combined with a portion of the curd and ſerum of the milk. It melts at the temperature of 96°, and mixes readily with other oily matters. When butter is kept for ſome time, it is decompoſed; it becomes rancid, which is aſcribed to the whey and the curd with which it is combined; for when theſe ſubſtances are previouſly ſeparated, it may be preſerved ſweet much longer. Butter yields by diſtillation water, an acid liquid, an oily ſubſtance, which is at firſt fluid, but becomes afterwards concrete. A ſmall portion of carbonaceous matter remains behind.

2710 Changes in the proceſs of churning. 6. When freſh cream, or the whole of the milk freſh drawn from the cow, is churned, it requires the proceſs to be continued a much longer time than when the cream or milk is left to repoſe, as is uſually the caſe, till it has acquired a ſlightly acid taſte. But when cream, which has become ſour, is churned, the butter ſeparated has no acid properties, and the milk which remains is even leſs ſour than the cream previous to the commencement of the proceſs. An acid, therefore, has been evolved, and this acid is ſuppoſed to be the carbonic. When freſh cream or freſh milk is ſubjected to this proceſs, in which the acid has not been formed, it requires greater agitation to complete this previous part of the change which the cream or milk muſt undergo, before the ſeparation of the oily part or the butter. The milk which remains after the butter has been ſeparated, or, as it is called, the butter-milk, has all the properties of milk from which the cream has been ſeparated.

2711 Coagulation. 7. The milk which remains after the ſeparation of the cream, may be coagulated by the addition of ſeveral ſubſtances, particularly by the addition of rennet which is in moſt common uſe, and which is prepared by digeſting the inner coat of the ſtomach of young animals, eſpecially that of the calf. This coagulum ſeparates into two parts, the curd and the ſerum or whey.

2712 Curd. Curd is a white ſolid ſubſtance, and ſomewhat brittle, when the whole of the whey is expreſſed. It is ſoluble in acids, but it is neceſſary that the mineral acids be greatly diluted, and the vegetable acids concentrated.

2713 Cheeſe. Cheeſe is prepared from curd, by ſeparating the whey by expreſſion. The quality of the cheeſe depends upon the quantity of cream which remains in the milk. The beſt cheeſe is obtained by coagulating the milk at the temperature of about 100°, and expreſſing the whey ſlowly and gradually, without breaking down the curd.

If milk be not too much diluted with water, it may be coagulated by a great number of different ſubſtances. Among this number are acids, alcohol, neutral ſalts, gum arabic, and ſugar.

2714 Whey. 8. Whey expreſſed from coagulated milk is of a yellowiſh green colour, and has an agreeable ſweet taſte. If it is boiled, a quantity of curd ſeparates, and after being left at reſt for ſome time, the whole of it is precipitated, and the liquid remains tranſparent and colourleſs. By ſlow evaporation it depoſits white-coloured cryſtals of ſugar of milk, with ſome muriate of potaſh, muriate of ſoda, and a little phoſphate of lime. The liquid which remains after the ſeparation of the ſalts, is converted, by cooling, into a gelatinous ſubſtance. If whey be kept for ſome time, it becomes ſour, by the formation of an acid, which is lactic acid. It is to this acid that the ſpontaneous coagulation of milk, after it remains at reſt for ſome time, is owing.

2715 Koumiſs. 9. If milk, after it has become ſour, be kept in a proper temperature, it ferments, emitting carbonic acid gas, and exhibiting the other phenomena of fermentation. A vinous intoxicating liquor is thus prepared, which has been long known among the Tartars, and called by them *koumiſs*. They prepare it from the milk of the mare.

2716 Vinegar. 10. Milk is ſuſceptible of the acetous fermentation. If about ſix ſpoonfuls of alcohol be added to eight pints of milk, and the liquid be excluded from the air, vinegar will be formed in four or five weeks. Although the air is to be excluded, yet the carbonic acid gas muſt be allowed to eſcape as it is diſengaged.

By the diſtillation of milk with the heat of a water-bath, water paſſes over, after which the milk coagulates, and an oily yellowiſh white ſubſtance remains behind, which, by increaſing the heat, yields a tranſparent liquid, a fluid oil, ammonia, an acid, a thick black oil, and in the end carbonated hydrogen gas. The coaly matter in the retort contains potaſh, muriate of potaſh, phoſphate of lime, and ſometimes muriate of ſoda, with a ſmall portion of magneſia and iron.

The conſtituent parts which enter into the compoſition of milk, are the following:

2717 Compoſition.

1. Water,
2. Oil,
3. Curd,
4. Gelatine,
5. Sugar of milk,
6. Muriate of ſoda,
7. Muriate of potaſh,
8. Phoſphate of lime,
9. Sulphur.

2718 Milk different in different animals. 11. Although the milk of different animals be compoſed nearly of the ſame ſubſtances, the proportions vary ſo much, as to give them very different properties.

2719 Compared. The following are the reſults of the inveſtigations of Deyeux and Parmentier with regard to the properties of the component parts of the milk of different animals compared together.

A. Every kind of milk when left at reſt, produces cream on the ſurface, but it is different in the milk of different animals.

a. In the milk of the cow it is copious, thick, and of a yellow colour.

b. In women's milk it is more liquid, white, and in ſmall quantity.

c. In goats milk it is more abundant than in that of the cow, thicker and whiter.

d. In ewes milk it is nearly as abundant, and of the ſame colour as that of the cow, but has a peculiar taſte.

e. In aſſes milk it is thick, leſs abundant, and in a great meaſure reſembles that of women's milk.

f. In mares milk it is very fluid, and ſimilar in colour and conſiſtence to good cows milk before the cream appears on the ſurface.

2720 Butter. B. Butter obtained from the milk of different animals, has the following comparative properties.

a. That of the cow is ſometimes of a deep yellow, ſometimes pale or white, and has always a conſiderable conſiſtency.

b. It is difficult to ſeparate the butter from the cream of women's milk. It is in ſmall quantity, inſipid, and of a pale yellow. It has been erroneouſly ſuppoſed that no butter could be obtained from this milk.

c. The butter of aſſes milk is always very white, ſoft, and readily diſpoſed to become rancid.

d. The butter from goats milk is eaſily ſeparated from the cream. It is abundant, always white, ſoft, and diſpoſed to become rancid.

e. The butter from ewes milk is of a yellow colour, ſoft, and ſoon becomes rancid.

f. The butter of mares milk is difficult to be obtained and in ſmall quantity. It has little conſiſtence, and is readily decompoſed.

2721 Curd. C. The curd of milk varies in different animals.

a. That from the milk of the cow is bulky, tremulous, and retains a great deal of the ſerum.

b. That from women's milk is in ſmall quantity, little coherent, has an unctuous feel, and retains but a ſmall portion of the whey.

c. The curd of aſſes milk is ſimilar to the former, but without being unctuous.

d. Curd from the milk of the goat is in great proportion, of a firmer conſiſtence than that of the cow, and retains leſs whey.

e. Curd from ewes milk is fat, viſcid, and communicates a ſoft paſte to cheeſe.

f. The curd from mares milk is in very ſmall quantity, and ſimilar to that from women's milk.

2722 Whey. D. The ſerum or whey conſtitutes a very great proportion of the milk, and exhibits the following varieties.

a. Whey from the milk of the cow is of a greeniſh-yellow colour, a ſweet taſte, and contains ſugar of milk and neutral ſalts.

b. The whey from women's milk has little colour, but has a very ſweet taſte, containing a conſiderable proportion of ſaccharine matter.

c. The whey of aſſes milk is colourleſs, and contains leſs ſalts and more ſugar than that of the cow.

d. Whey of the goat is of a ſlight yellow colour, and contains very little ſugar and ſaline matter. The latter conſiſts almoſt entirely of muriate of lime.

e. The whey of ewes milk is always colourleſs, and contains the ſmalleſt quantity of ſugar, and but a ſmall portion of muriate and phoſphate of lime.

f. The whey of mares milk has little colour, and contains a great proportion of ſaccharine matter and of ſaline ſubſtances *.

---

* *Fourcroy*, ix. 435.

Component Parts of Animal Subſtances.

V. Of Saliva.

2723 Properties. 1. The ſaliva which is ſecreted by peculiar glands, and which flows into the mouth, is a clear, viſcid fluid, without taſte or ſmell. Its ſpecific gravity varies from 1.0167 to 1.080. It has generally a frothy appearance, being mixed with a quantity of air.

2724 Combines with oxygen. 2. Saliva has a ſtrong attraction for oxygen, which by trituration it communicates to ſome metallic ſubſtances, as mercury, gold, and ſilver. When ſaliva is boiled in water, albumen is precipitated, and when it is ſlowly evaporated, muriate of ſoda is obtained. A vegetable gluten remains behind, which burns with the odour of pruſſic acid.

2725 Action of acids, &c. 3. Saliva becomes thick by the action of acids. Oxalic acid precipitates lime. Saliva is alſo inſpiſſated by alcohol. It is decompoſed by the alkalies; and the nitrates of lead, of mercury, and of ſilver, precipitate muriatic and phoſphoric acids.

2726 Diſtillation. 4. By diſtillation in a retort, it froths up, affords near four-fifths of its quantity of water nearly pure, a little carbonate of ammonia, ſome oil, and an acid. What remains behind conſiſts of muriate of ſoda, phoſphate of ſoda and of lime. The conſtituent parts of ſaliva are the following.

2727 Compoſition.

1. Water.
2. Mucilage.
3. Albumen.
4. Muriate of ſoda.
5. Phoſphate of ſoda.
6. Phoſphate of lime.
7. Phoſphate of ammonia.

2728 Saliva of the horſe. 5. The ſaliva of the horſe is of a greeniſh yellow colour, a diſagreeable ſmell, a ſaline taſte, and ſoapy feel. It is coagulated by the acids, alcohol, and boiling water. A black earthy reſiduum remains after ſpontaneous evaporation. By diſtillation it yields an inſipid watery liquid, carbonate of ammonia, carbonated hydrogen and carbonic acid gaſes, and a black empyreumatic oil.

2729 Pancreatic juice. 6. The pancreatic juice, it is ſuppoſed, poſſeſſes properties analogous to thoſe of ſaliva, and is deſtined for ſimilar purpoſes, namely to contribute to the ſolution of alimentary ſubſtances, and to their converſion into chyme; but very little is known of its nature and uſes.

VI. Of the Humours of the Eye.

2730 Parts of the eye. 1. The eye is compoſed of three ſubſtances which in anatomy have received the name of humours. Theſe are the aqueous, the vitreous, and the cryſtalline humour or lens. The following obſervations are from Mr Chenevix's experiments on this ſubject *.

2731 Eyes of ſheep. 2. The aqueous humour of the eye of the ſheep is tranſparent like water, and has ſcarcely any taſte or ſmell. The ſpecific gravity is 1.0090. It evaporates ſlowly when expoſed to the air; a coagulum is formed by boiling. When 100 parts are evaporated to dryneſs, eight parts remain behind. None of the metallic ſalts produce any precipitate except nitrate of ſilver, which throws down the muriate of ſilver. Tan alſo produces a precipitate in the aqueous humour. The component parts, therefore, of this ſubſtance are albumen, gelatine, and muriatic acid, or rather muriate of ſoda, as the acid is in combination with ſoda. The vitreous humour exhibited the ſame properties.

3. The cryſtalline lens of the ſheep is ſolid, compoſed of concentric coats, and tranſparent. The ſpecific gravity is 1.1. It has ſcarcely any taſte when it is freſh. It is ſoluble in water, and the ſolution is coagulated by heat. Tan produces a copious precipitate, both before and after coagulation. Its component parts are, therefore, albumen and gelatine, with water.

2732 Human eye. 4. The human eye was found to be compoſed of the ſame ſubſtances. The ſpecific gravity of the aqueous and vitreous humours is 1.0053; of the cryſtalline lens, 1.0790. The ſpecific gravity of the aqueous and vitreous humours of the eye of the ox is 1.008; the cryſtalline lens 1.0765. The compoſition is the ſame as that of the ſheep.

VII. Of Tears and Mucus.

2733 Properties. 1. The tears are ſecreted by the lachrymal gland, for the purpoſe of lubricating the eye. This liquid is tranſparent and colourleſs, has no perceptible ſmell, but a ſaline taſte. It communicates to vegetable blues a permanent green colour. When it is evaporated nearly to dryneſs, cubic cryſtals are formed, which are muriate of ſoda. Soda is in exceſs, becauſe vegetable blues are converted by it to a green colour. A portion of mucilaginous matter, which becomes yellow as it dries, remains after the evaporation. This liquid is ſoluble in water and in alkalies. Alcohol produces a white flaky precipitate, and when it is evaporated muriate of ſoda and ſoda remain behind. By burning the reſiduum, ſome traces of phoſphate of lime and of ſoda are detected. The component parts of tears, are, therefore,

2734 Compoſition.

Water,
Mucilage,
Soda,
Muriate of ſoda,
Phoſphate of lime,
Phoſphate of ſoda.

The mucilage of tears abſorbs oxygen from the atmoſphere and becomes thick, viſcid, and of a yellow colour. It is then inſoluble in water. Oxymuriatic acid produces a ſimilar effect. It is converted into muriatic acid, ſo that it has been deprived of its oxygen.

2735 Mucus. 2. The mucus of the noſe conſiſts of the ſame ſubſtances as the tears; but being more expoſed to the air, it acquires a greater degree of viſcidity from the mucilage abſorbing oxygen.

VIII. Of the Wax of the Ear.

2736 Properties. 1. The wax of the ear, or *cerumen*, is a liquid ſecreted by glands, which are ſituated in the internal ear. It is of a viſcid yellow colour, and becomes concrete by expoſure to the air. The taſte is bitter; it melts with a moderate heat, gives out an aromatic ſmell, and ſtains paper like oil. When thrown upon burning coals, it gives out a white ſmoke, melts, ſwells, becomes dark-coloured, and gives out the odour of ammonia. A light coaly matter remains behind. It forms a kind of emulſion by agitation with water.

2737 Action of alcohol. 2. Alcohol diſſolves a portion of cerumen; the undiſſolved part exhibits the properties of albumen mixed with oil. By evaporating the alcohol, an orange coloured reſiduum, ſimilar to turpentine, is left behind. It has the properties of reſin of bile. This matter is alſo ſoluble

---

* *Phil. Tranſ.* 1802.

ſuble in ether. By burning the albumen of the cerumen, ſome traces of ſoda and phoſphate of lime are detected. The component parts of cerumen are,

2738 Compoſition.

Albumen,
Reſin,
Colouring matter,
Soda,
Phoſphate of lime.

IX. Of Synovia.

2739 Properties. 1. The liquid ſecreted within the capſular ligaments of the joints, to facilitate motion by lubricating theſe parts, is called *ſynovia*. The ſynovia of the ox is a viſcid, ſemitranſparent fluid, of a greeniſh-white colour, which ſoon acquires the conſiſtence of jelly, and not long after becomes again fluid, depoſiting a filamentous matter.

2740 Action of water. 2. Synovia mixes with water, and renders it viſcid. When this mixture is boiled, it becomes milky, and ſome pellicles are depoſited on the ſides of the veſſel. Alcohol produces a precipitate when added to ſynovia. This precipitate is albumen. After this matter is ſeparated, the liquid ſtill remains viſcid; but if acetic acid be added. the viſcidity diſappears, and it becomes tranſparent, depoſiting a white filamentous ſubſtance, which reſembles vegetable gluten. It is ſoluble in cold water, and in concentrated acids and pure alkalies. This fibrous matter is precipitated by acids and alcohol in flakes.

2741 Acids. 3. The concentrated mineral acids produce a flaky precipitate, which is ſoon rediſſolved; but the viſcidity of the liquid is not deſtroyed till they are ſo much diluted with water, that the acid taſte is only perceptible.

2742 Salts ſeparated. 4. When ſynovia is expoſed to dry air, it evaporates, and cubic cryſtals remain in the reſiduum with a white ſaline effloreſcence. The firſt are muriate of ſoda, and the latter carbonate of ſoda. This ſubſtance ſoon becomes putrid, giving out ammonia during its decompoſition. By diſtillation in a retort, it yields water, which ſoon becomes putrid; water containing a portion of ammonia, and an empyreumatic oil, with carbonate of ammonia: by waſhing the reſiduum, muriate and carbonate of ſoda may be obtained. A ſmall portion of phoſphate of lime is found in the coaly matter. The conſtituent parts of ſynovia are the following:

2743 Compoſition.

Fibrous matter	11.86
Albumen	4.52
Muriate of ſoda	1.75
Soda	00.71
Phoſphate of lime	00.70
Water	80.46
	100.00 *

X. Of Semen.

2744 Properties. 1. Semen is ſecreted in the teſtes of male animals; but when it is ejected it is compoſed of two ſubſtances; the one is fluid and milky, and the other of a thick mucilaginous conſiſtence, in which appear a great number of white ſilky filaments, eſpecially if it be agitated in cold water. It has a diſagreeable odour, and an acrid irritating taſte. The ſpecific gravity varies conſiderably, but is always greater than that of water. When it is rubbed in a mortar, it froths up, and acquires the conſiſtence of pomatum from the air with which it mixes. It converts the flowers of mallow and of violets to a green colour, and it precipitates the calcareous and metallic ſalts; which ſhews, that it contains an uncombined alkali. The thick part of the ſemen as it cools, becomes tranſparent, and aſſumes a greater degree of conſiſtence; but it afterwards becomes entirely liquid, even without abſorbing moiſture from the air. This change takes place in about twenty minutes from the time of its emiſſion.

2745 Action of air. 2. If ſemen be expoſed to the air after it has become liquid at the temperature of 60°, it becomes covered with a tranſparent pellicle, and at the end of three or four days depoſits fine tranſparent cryſtals of a line in length, croſſing each other like radii from a center. When they are magnified, they appear to be four-ſided priſms terminated by long four-ſided pyramids. When ſemen is expoſed to a warm air, in conſiderable quantity, it is decompoſed; it aſſumes the colour of the yolk of egg, and becomes acid, either by abſorbing the oxygen from the atmoſphere, or by a different combination and arrangement of its own conſtituent principles. It then emits the odour of putrid fiſh, and is covered with the *byſſus ſeptica*.

2746 Of heat. 3. Heat accelerates the liquefaction of ſemen; and when it has undergone this change it is no longer ſuſceptible of coagulation. It is decompoſed by the application of ſtrong heat. Water is firſt ſeparated; it then blackens, ſwells up, and emits yellow fumes, having an empyreumatic, ammoniacal odour. A light coal remains behind, which burns readily to white aſhes.

2747 Of water. 4. Before it has become fluid, ſemen is not ſoluble in water either cold or hot. To the latter it communicates an opal colour. But in the fluid ſtate it combines readily with either hot or cold water, from which it is ſeparated by alcohol or oxymuriatic acid in the form of white flakes. The alkalies promote the ſolution of ſemen in water.

2748 Of lime. 5. No ammonia is diſengaged from freſh ſemen by means of quicklime; but when it has been expoſed for ſome time to a warm and moiſt air, it is ſeparated in great abundance, ſo that ammonia is formed during its expoſure to the air.

2749 Acids. 6. The acids readily diſſolve ſemen, and this ſolution is not decompoſed by the alkalies; nor indeed is the alkaline ſolution of ſemen decompoſed by the acids. Wine, cyder, and urine alſo diſſolve ſemen, but it is in conſequence of the acid which is combined with theſe liquids. Water acidulated with ſulphuric acid acquires the ſame property. Oxymuriatic acid coagulates ſemen in white flakes which are inſoluble in water and in acids. The ſame acid produces the coagulation of fluid ſemen. This is owing to the abſorption of oxygen derived from the acid which is converted into muriatic acid.

2750 Salts. 7. Barytic ſalts are not decompoſed by the ſeminal fluid which has been liquefied in a cloſe veſſel; but when it has undergone this change in the open air, rhomboidal cryſtals are formed with the addition of theſe ſalts. The calcareous and metallic ſalts are decompoſed by ſemen in both conditions. From theſe facts

---

* *Annal. de Chim.* xiv. p. 123.

facts it appears that ſemen contains an uncombined alkali, which has not the property of decompoſing the barytic ſalts till it has combined with the carbonic acid from the atmoſphere.

2751 Semen contains phoſphate of lime. 8. The cryſtals which form in ſemen by ſpontaneous evaporation in the open air, and which are entangled in the viſcid matter, may be ſeparated by adding water. Theſe cryſtals have neither ſmell nor taſte. They melt under the blow-pipe into a white opake globule which is ſurrounded with a yellowiſh flame. This ſalt is inſoluble in water, and is not acted on by the alkalies; but is ſoluble in the mineral acids without efferveſcence, from which ſolutions, lime water, the alkalies, and oxalic acid throw down a precipitate. Alcohol added to the concentrated muriatic ſolution of this ſubſtance, diſſolves part of it, which exhibits all the characters of muriate of lime; and there remains another ſubſtance which melts under the blow-pipe into a green tranſparent glaſs ſoluble in water, which precipitates lime water and reddens vegetable blues. This ſalt, therefore, as is demonſtrated from theſe experiments, is phoſphate of lime. After the formation of the above ſalts, a great number of ſmall, white, opake bodies appear on the ſurface. They are alſo phoſphate of lime.

2752 And ſoda. 9. By burning 40 grains of dried ſemen in a crucible, it firſt became ſoft, and then gave out the odour of burnt horn accompanied with yellow fumes. It blackened and emitted the odour of ammonia. The coaly matter which remained was lixiviated with water. This was evaporated and afforded cryſtals in the form of rhomboidal plates, which efferveſced with acids; with ſulphuric acid afforded ſulphate of ſoda, and with muriatic acid formed muriate of ſoda. The alkali, therefore, was ſoda.

10. The alkaline matter being ſeparated, the reſiduum was ſtill expoſed to ſtrong heat, and furniſhed 13 grs. of white aſhes which had the following properties. By the action of the blow-pipe it is converted into an opake white enamel which attracts moiſture from the air, is ſoluble in acids, and the ſolution has all the characters of phoſphate of lime. The component parts of ſemen therefore are

2753 Compoſition.

Water	90
Mucilage	6
Soda	1
Phoſphate of lime	3
	100 *.

XI. Of the Liquor of the Amnios.

1. This liquid is ſecreted in the *amnios* or bag which ſurrounds the fœtus in the uterus. It is very different in different animals, ſo far at leaſt as its nature and properties have been inveſtigated. The liquor of the amnios of women and cows only has been examined. The following are the reſults of the experiments of Vauquelin and Buniva on theſe liquids *.

2754 Properties. 2. This liquid in women is of a milky colour, an agreeable odour and a ſaline taſte. It becomes tranſparent by filtering and ſeparating ſome coagulated matter which is ſuſpended in it, and which communicates the white colour. The ſpecific gravity is 1.005. It ſeems to contain both an acid and an alkali; for it converts ſyrup of violets to a green colour, and reddens the tincture of turnſole. It froths when agitated, becomes opaque when heated, and exhales the odour of the white of egg.

2755 Action of heat. 2756 Acids. 3. It is rendered more tranſparent by acids; but alcohol and the alkalies occaſion a flaky precipitate, which is like glue when it is dried. The infuſion of nut-galls gives a copious brown precipitate; and nitrate of ſilver produces a white precipitate, which being inſoluble in nitric acid, is muriate of ſilver.

4. By ſlow evaporation this liquid aſſumes a milky appearance; a tranſparent pellicle forms on the ſurface, and a very ſmall reſiduum is left. By adding water to the reſiduum, and evaporating the ſolution, muriate and carbonate of ſoda are obtained. The aſhes which remain, after burning the reſiduum, conſiſt of carbonate of ſoda, phoſphate and carbonate of lime. During the burning a ſtrong, fetid, ammoniacal odour is exhaled.

2757 Compoſition. 5. From theſe experiments, it appears that this liquid conſiſts of a great proportion of water, of albumen, muriate of ſoda, of ſoda, phoſphate of lime, and lime.

2758 Cruſt on the fœtus. 6. A white ſhining ſoft ſubſtance, ſomewhat reſembling ſoap, is depoſited on the body of the fœtus in the uterus. It is inſoluble in water, alcohol, and oils. The cauſtic alkalies diſſolve a portion of it, and form a kind of ſoap. It decrepitates on burning coals, then dries, blackens, and gives out the odour of an empyreumatic oil. It leaves behind a coaly matter, which burns with difficulty. When it is heated in a crucible of platina, it decrepitates, while an oily matter exudes. It then curls up like horn, inflames, and leaves behind gray aſhes, which efferveſce with acids, and which ſeem to be compoſed chiefly of carbonate of lime.

2759 Compoſition. 7. This matter ſeems to be a mixture of animal mucilage and fat, originating from the albumen, which has undergone ſome peculiar change. The parts of a fœtus which have remained in the uterus after death, have been found converted into a fatty matter.

2760 Characters. *Liquor of the amnios of the cow.*—1. This liquid differs from the former in being of a reddiſh brown colour, in having an acid bitter taſte, an odour reſembling the extracts of ſome vegetables, and the viſcidity of a ſolution of gum. The ſpecific gravity is 1.028. It reddens the tincture of turnſole, forms a copious precipitate with muriate of barytes, and with alcohol a precipitate of a reddiſh matter.

2761 Amniotic acid. 2. When it is evaporated, a thick ſcum forms on the ſurface, which is eaſily ſeparated, and which, on cooling, is found to contain white cryſtals of a ſlightly acid taſte. A viſcid matter like honey appears, by continuing the evaporation. When this matter is treated with boiling alcohol, it furniſhes, on cooling, an acid which cryſtallizes in ſhining needles. This is the *amniotic acid* which has been already deſcribed. The matter which remains after the ſeparation of the cryſtals is inſoluble in alcohol, and is firm and tenacious.

2762 Sulphate of ſoda obtained. 3. Having extracted the whole of the acid, if the evaporation be continued till the liquid acquire the conſiſtence of a ſyrup, large tranſparent cryſtals are formed, which have a bitter taſte, and are ſoluble in water. Theſe cryſtals were found to be ſulphate of ſoda,

---

* *Vauquelin, Ann. de Chim.* ix. 64—80.

* *Ann. de Chim.* xxxiii. 269.

ſoda, which are obtained in a ſtate of purity, by burning the reſiduum of a quantity of the liquid evaporated to dryneſs, diſſolving the coaly reſiduum in water, and evaporating.

2763 Animal matter. 4. The animal matter which accompanies the ſaline ſubſtances, is of a reddiſh brown colour and a peculiar taſte, very ſoluble in water, but inſoluble in alcohol, which even ſeparates it from water. It neither combines with tan, nor is it ſuſceptible of being converted into jelly, ſo that it does not poſſeſs the properties of animal mucilage. When it is heated ſtrongly, it ſwells up, exhales at firſt the odour of burning mucilage, afterwards that of ammonia and an empyreumatic oil; and, at laſt, that of pruſſic acid. When it is burnt, there remains behind a bulky coal, the aſhes of which are white, and contain phoſphate of magneſia and a ſmall portion of phoſphate of lime.

2764 Compoſition. 5. The conſtituent parts of the liquor of the amnios of the cow, are the following.

Water,
Acid,
Sulphate of ſoda,
Animal matter.

XII. Of Fluid Morbid Secretions.

1. During the diſeaſed action of the veſſels of different parts of the body, liquids are ſecreted, as, for inſtance, when the muſcular or bony parts are wounded, a matter is exuded, which continues to flow till the wound is healed up; in dropſical diſeaſes a liquid is ſecreted in the different cavities of the body; and when the ſkin is irritated by the action of bliſters, a fluid collects between the cuticle and true ſkin.

Liquor of dropſy.—This liquid is of a yellowiſh green colour, has ſometimes conſiderable tranſparency, but is ſometimes turbid. In its chemical properties it ſeems to correſpond with the ſerum of the blood.

Liquor of bliſters.—The liquor which is ſecreted by the action of bliſters is uſually tranſparent. The conſtituent parts are the ſame as thoſe of the ſerum of the blood. Two hundred parts of this liquid yielded

Albumen,	36
Muriate of ſoda,	4
Carbonate of ſoda,	2
Phoſphate of lime,	2
Water,	156
	200 *

Pus.—What is called healthy pus is about the conſiſtence of cream, and of a yellowiſh-white colour, an inſipid taſte, and when it is cold, without ſmell. It produces no change on vegetable blues.

2765 Action of heat. 2. When pus is expoſed to a moderate heat, it dries, and aſſumes the appearance of horn. By diſtillation it gives out water in conſiderable proportion, ammonia and ſome gaſeous ſubſtance and an empyreumatic oil; a ſhining coaly matter remains behind, the aſhes of which, after being burnt, afforded ſome traces of iron.

2766 Of air and acids. 3. When this liquid is expoſed to the air, it becomes acid. It is ſoluble in ſulphuric acid, forming with it a purple-coloured ſolution. With the addition of water the pus ſeparates, and the dark colour diſappears. With concentrated nitric acid it forms a yellow coloured ſolution, which effervesces during the combination. Water produces a precipitate. Pus is alſo ſoluble in muriatic acid, and is ſeparated by means of water. Pus is not ſoluble in alcohol, but is thickened; nor is it ſoluble in the oils.

2767 Alkalies. 4. A whitiſh ropy fluid is formed by the addition of a ſolution of the fixed alkalies, and by adding water the pus is precipitated. Pure ammonia forms with pus a tranſparent jelly, and diſſolves it in conſiderable proportion.

2768 Metallic ſalts. 5. A precipitate is occaſioned by means of nitrate of ſilver, and it is ſtill more copious with nitrate and oxymuriate of mercury.

2769 To diſtinguiſh pus. 6. The following teſts have been given to diſtinguiſh pus from mucus, which is of conſiderable importance in caſes where the formation of pus is ſuſpected in the lungs.

1. Pus is ſoluble in ſulphuric acid, and precipitated by water. Mucus ſwims. 2. Pus may be diffuſed through water, diluted ſulphuric acid, and brine; but mucus is not. 3. Pus is ſoluble in alkaline ſolutions, and is precipitated by water; but this is not the caſe with mucus.

2770 Varies in its properties. 7. Theſe are the properties of pus when it is ſecreted from a ſore which is ſaid to be in good condition, or in a diſpoſition to heal. Its properties are very different in what are called ill-conditioned ſores. In theſe caſes the matter ſecreted is thin, fetid, and acrid. Matter ſecreted by cancerous ſores, which has been examined, converts the ſyrup of violets to a green colour, and from this matter ſulphurated hydrogen gas is ſeparated by means of ſulphuric acid. This gas is ſuppoſed to exiſt in combination with ammonia.

Subdiviſion III. Of the Solid Parts of Animals.

2771 Enumeration. The following are the ſolid parts of animals, which we ſhall treat of in the order in which they are enumerated.

1. Bones,
2. Skin,
3. Muſcles,
4. Cartilage, tendons, &c.
5. Brain and nerves,
6. Hair and nails,
7. Morbid concretions.

I. Of the Bones.

2772 Of different denſity. 1. The bones are thoſe parts of animals which give firmneſs, ſtrength, and ſhape to the body. Bones are very different with regard to ſolidity and denſity, not only in different parts of the body, but even in the ſame bone. The ſpecific gravity, therefore, of bones, muſt be various. They are of a white colour, of a lamellated ſtructure, and inflexible.

2773 Action of heat. 2. When bones are burnt, they are converted into a white, porous, inſipid ſubſtance, which ſtill retains the ſhape of the bone.

2774 Contains fat. 3. When bones are broken into ſmall pieces, and boiled in water, a conſiderable quantity of fat riſes to the ſurface; an oily matter, therefore, is one of the conſtituent parts of bones.

2775 Gelatine. 4. If the boiling be continued for a greater length of time, the water diſſolves another ſubſtance, which being concentrated and left at reſt, aſſumes a gelatinous form.

---

* Ann. de Chim. xiv. 225.

form. Bones, therefore, contain a portion of gelatine.

2776 Cartilage. 5. If bone is kept for ſome time in diluted muriatic acid, it is converted into a white flexible ſubſtance, which retains the ſhape of the bone. It becomes brittle and ſemitranſparent when dried; it is ſoluble in nitric acid, and when this acid is diluted, it is converted by its action into gelatine. It forms a ſoap with the fixed alkalies. From theſe properties it reſembles coagulated albumen. This ſubſtance, which is called cartilage, is the firſt part of the bone which is formed.

2777 Salts. 6. Beſides theſe ſubſtances, bones contain a conſiderable proportion of earthy ſalts. Theſe are phoſphate of lime, which is in great proportion; carbonate of lime in ſmaller proportion, with a ſtill ſmaller of ſulphate of lime.

2778 Compoſition. 7. The component parts of bones, therefore, are earthy ſalts, cartilage, gelatine, and fat. The following table exhibits the proportion of theſe conſtituent parts in the bones of different animals. It was drawn up by Merat-Guillot. A hundred parts of bone were employed, and as much dried as poſſible, and to this quantity the proportions ſpecified refer *.

Names.	Gelatine.	Phoſphate of lime.	Carbonate of lime.	Loſs.
Human bones taken from a burying ground.	16.	67	1.5	15.5
Human bones dried but not buried.	23.	63	2	2
Bones of the ox	3.	93	2	2
———— calf	25.	54	—	21
———— horſe	9.	67.5	1.25	22.25
———— ſheep	16.	70.0	0.5	13.5
———— elk	1.5	90.0	1.0	7.5
———— hog	17.82	52.0	1.0	30.0
———— hare	9.0	80.5	1.0	5.0
———— pullet	6.0	72.0	1.5	20.5
———— pike	12.0	64.0	1.0	23.0
———— carp	6.0	45.0	0.5	48.5

2779 Of teeth. 8. The human teeth have been analyzed by Mr Pepys, and he found the conſtituents of different teeth, and different parts of the teeth, to be the following.

	Teeth of adults.	Shedding teeth of children.	Roots of the teeth.
Phoſphate of lime	64	62	58
Carbonate of lime	6	6	4
Cartilage	20	20	28
Loſs	10	12	10
	100	100	100

He found the following to be the component parts of the enamel of the teeth.

Phoſphate of lime	78
Carbonate of lime	6
Loſs and water	16
	100

But according to Fourcroy and Vauquelin the enamel is compoſed of

Phoſphate of lime	72.9
Gelatine and water	27.1
	100.0

II. Of the Skin.

2780 Conſiſts of three parts. 1. The ſkin, which forms the external covering of animals, conſiſts of three parts; the epidermis or cuticle, the true ſkin, and a ſoft ſubſtance called the *rete mucoſum*, which lies between the cuticle and true ſkin.

2781 Epidermis. 2. The epidermis, which may be ſeparated from the cutis, by macerating the ſkin in hot water, is a thin elaſtic ſubſtance, which is inſoluble in water and in alcohol.

2782 Action of acids, &c. 3. Sulphuric and muriatic acids have little action for ſome time on this ſubſtance; but it is immediately converted into a yellow colour by means of nitric acid, and at laſt entirely decompoſed. It is entirely ſoluble in the cauſtic fixed alkalies. From theſe properties the epidermis is ſuppoſed to be coagulated albumen in a peculiar ſtate of modification.

2783 Cutis. 4. The cutis or true ſkin is denſer and thicker. When it is heated, it firſt contracts, then ſwells up, exhaling a fetid odour, and leaving behind a denſe maſs of charcoal. By diſtillation the ſame products are obtained as from fibrina.

2784 Action of acids. 5. The ſkin is ſoftened by weak acids, is rendered tranſparent, and is at laſt diſſolved. It is converted into oxalic acid and fat by nitric acid, with the evolution of azotic gas and pruſſic acid. It is converted by means of the concentrated alkalies into oil and ammonia.

2785 Contains gelatine. 6. After maceration for ſome time in water, a ſmall proportion of gelatine may be obtained, by evaporating the water; but if the ſkin be boiled for a conſiderable time in water, it is entirely diſſolved, and the liquid, by evaporation, aſſumes the conſiſtence of jelly. The ſkin is thus converted into glue. It is from the ſkins of animals that glue is chiefly extracted; and it is obtained of different degrees of ſtrength from the ſkins of different animals.

2786 Tanning. 7. As ſkin conſiſts chiefly of gelatine, it combines readily with tan. This compound forms leather; and the proceſs by which it is effected is called *tanning*, for the detail of which ſee the article Tanning.

2787 Rete mucoſum. 8. The mucous ſubſtance, or *rete mucoſum*, lies between the epidermis and true ſkin. It is this which gives the black colour to the ſkins of negroes. It is deprived of its colour, even in the living body, by means of oxymuriatic acid. The foot of a negro became nearly white by being kept for ſome time in water impregnated with this acid. The black colour, however, returned in a few days.

III. Of

---

* *Ann. de Chim.* xxxiv. 71.

III. Of the Muſcles.

1. The muſcular, or fleſhy parts of animals, are of a reddiſh-white colour, and fibrous ſtructure. If a
2788 Structure. quantity of muſcular ſubſtance is ſeparated into ſmall pieces, it becomes white. If the water be heated,
2789 Action of cold water. it coagulates. Albumen and a portion of fibrina are obtained. It becomes gelatinous by farther evaporation; and, when the proceſs is carried on to dryneſs, and alcohol added, a peculiar matter is diſſolved; which, after the alcohol is expelled by heat, appears of a reddiſh brown colour, has an aromatic ſmell, and a very acrid taſte; and it is ſoluble both in water and alcohol. The gelatine formed in the maſs evaporated to dryneſs, with a little phoſphate of ſoda and ammonia, remains undiſſolved by the alcohol. When this extractive matter is diſtilled, it affords an acid, which is combined with ammonia.

2790 Boiling. By boiling the ſame muſcular matter for ſome time in water, another portion of albumen is obtained; and, when the water is concentrated by evaporation it is converted into a jelly; and by treating with alcohol as before, after evaporating to dryneſs, the extractive matter is taken up, and the gelatine and phoſphoric ſalts remain undiſſolved. The fibres of the muſcle are then of a gray colour, inſoluble in water, and become brittle when dry. This ſubſtance is fibrina, which conſtitutes the chief part of muſcular matter.

2791 Nitric acid. 2. If muſcular matter be diſſolved in nitric acid, and ammonia added to the ſolution, a precipitate of phoſphate of lime is obtained; but no phoſphate of lime is obtained, when treated in this way, after being long boiled in water, for it is either combined with the gelatine, or is thus rendered ſoluble. Carbonate of lime, however, is found after boiling the muſcular ſubſtance, and is converted into oxalate of lime by means of nitric acid.

2792 Compoſition. 3. The conſtituent parts of muſcular matter are the following:

Fibrina,
Albumen,
Gelatine,
Extractive,
Phoſphate of ſoda,
Phoſphate of ammonia,
Phoſphate of lime,
Carbonate of lime.

2793 Properties of muſcular matter for food. 4. From the difference of ſolubility of the ſubſtances which enter into the compoſition of muſcular matter, and the different effects of heat on theſe ſubſtances, the ſenſible qualities at leaſt muſt vary conſidera-
2794 Boiled. bly, according to the manner in which this matter is prepared for food. Accordingly, when the fleſh of animals is boiled, thoſe parts which are ſoluble in water, combine with it. Theſe are, the gelatine, the extractive matter, and part of the ſaline bodies. It is
2795 Roaſted. to theſe that the nutritious property of ſoups is aſcribed. But when the fleſh of animals is roaſted, it has a much higher flavour, in conſequence of theſe ſubſtances not being ſeparated from it, and particularly the extractive matter, on which the odour and flavour depend. This extractive matter, according to Fourcroy, compoſes the brown cruſt which is formed on fleſh during its roaſting.

2796 Different properties. 5. The muſcular part of different animals, from its ſenſible qualities at leaſt, ſeems to poſſeſs very different properties. Hence the difference in the taſte, flavour, and nutritious quality, of the fleſh of different animals.

2797 Converſion of muſcular matter into ſpermaceti. 6. When the muſcular parts of animals are expoſed for a conſiderable length of time to the action of running water, they are converted into a peculiar ſubſtance, reſembling in ſome meaſure ſpermaceti. The ſame change indeed, in ſimilar circumſtances, takes place on the other ſoft parts of animals. This was firſt obſerved in the year 1786, in the Innocents burying-ground in Paris, where great numbers of bodies were thrown together into the ſame pit. The time which was required for this converſion was ſuppoſed to be in general about thirty years. But it has ſince been found, that animal matters are converted into a ſubſtance exactly ſimilar, and in a much ſhorter period, by expoſing them to the action of running water.

2798 Properties. 7. The matter produced by this change is of a white colour, ſoft and unctuous to the feel, and melts like tallow. It is decompoſed by diluted acids, and an oily matter, with which it is mixed, is ſeparated. By the action of alkalies and lime, ammonia is evolved. By expoſure to the air, it is deprived of its white colour; the ammonia is almoſt entirely carried off, and a ſubſtance reſembling wax remains behind. The oily matter which is ſeparated by a diluted acid, is of a white colour and concrete. It becomes of a grayiſh brown colour by drying, and aſſumes a cryſtalline, lamellated texture, like ſpermaceti. At the temperature of 126° it melts. It is ſoluble in alcohol at the temperature of 120°. It forms a ſoap with alkalies, and burns like oil; but exhales a diſagreeable odour, which is the chief objection to its uſe as a ſubſtitute for oil, as it is ſuppoſed it may be obtained at a cheaper rate. A manufacture indeed has been eſtabliſhed at Briſtol for the preparation of this ſubſtance.

IV. Of Membranes, Tendons, and Ligaments.

2799 Membranes 1. Membranes are thoſe parts of the body which include ſome of the internal parts of animals. Many of them are extremely thin, and they poſſeſs different degrees of tranſparency. They become pulpy by maceration in water, and by boiling are almoſt entirely converted into gelatine, ſo that they are chiefly compoſed of this ſubſtance. No phoſphate of lime or other ſaline matter has been detected in the membranous ſubſtances hitherto analyzed.

2800 Tendons. 2. Tendons are reduced by boiling to a gelatinous ſubſtance, ſo that they are compoſed of a ſimilar matter with membranes.

2801 Ligaments. 3. The ligaments afford a portion of gelatine by boiling, but are not, like the two former, entirely reduced to jelly, ſo that ſome other ſubſtance beſides gelatine enters into the compoſition of ligaments.

V. Of the Brain and Nerves.

2802 Action of water, &c. 1. The matter of the brain and nerves has a ſoft, ſoapy feel, and a cloſe texture. When expoſed to the air at the temperature of 60°, it ſoon becomes putrid, exhaling an offenſive ſmell, and giving out a conſiderable quantity of ammonia. It is not ſoluble in cold water; but triturated with water in a mortar, a part is diſſolved, and if this be heated moderately, it coagulates. If ſulphuric acid be added to this ſolution, white flakes appear on the ſurface, and the liquid aſſumes a red colour. Similar flakes are produced by the action of nitric acid, but the colour of the liquid is yellow. If nitric acid be added till a ſlight acidity is produced, a coagulum of a white colour ſeparates, which is inſoluble in water and alcohol, is ſoftened by heat, and becomes tranſparent when it is dried. This matter, therefore, poſſeſſes many of the properties of albumen.

2803 Sulphuric acid. 2. If a quantity of brain be triturated with diluted ſulphuric acid, part is diſſolved, and part is coagulated. The liquid part is colourleſs, and when it is evaporated, it becomes black, while ſulphurous acid is exhaled, and cryſtals are formed. When it is evaporated to dryneſs, a black maſs remains behind. By diluting this with water, charcoal ſeparates. The matter therefore is entirely decompoſed, ammonia is diſengaged, and combines with the acid, forming ſulphate of ammonia. By evaporating the water, ſulphate of ammonia and ſulphate of lime, phoſphoric acid, and phoſphates of ſoda and ammonia are obtained; and theſe ſalts may be ſeparated by means of alcohol. Theſe ſalts, however, exiſt in brain in ſmall proportion. 2804 Nitric acid. By treating in the ſame way a quantity of brain with nitric acid, part is diſſolved, and part coagulated. When the ſolution, which is tranſparent, is evaporated till the acid is concentrated, carbonic acid and nitrous gaſes are evolved; a great quantity of ammonia is ſeparated with effervefcence, and charcoal remains behind, mixed with oxalic acid.

2805 Of heat. 3. If a quantity of brain be evaporated to dryneſs with a gentle heat, a portion of tranſparent liquid ſeparates, and the reſiduum aſſumes a brown colour when it is dried. The weight of this reſiduum does not exceed one-fourth of the quantity employed. If the reſiduum be repeatedly boiled with alcohol, more than one-half is diſſolved; and when the alcohol cools, it depoſits a yellowiſh white ſubſtance in the form of ſhining plates, which may be reduced to a kind of ductile paſte. It becomes ſoft with the heat of boiling water, and blackens with an increaſe of temperature, exhaling empyreumatic and ammoniacal fumes; a charred matter remains behind. By evaporating the alcohol, a yellowiſh black matter is depoſited, which reddens paper ſtained with turnſole.

2806 Alkalies. 4. Brain is ſoluble in concentrated cauſtic potaſh; and during the ſolution, a great quantity of ammonia is given out.

VI. Of Hair and Nails.

2807 Different in appearance. 1. If we include all thoſe ſubſtances which form the covering of animals, as briſtle, hair, wool, and down, under the general name of hair, and particularly as they poſſeſs nearly the ſame properties, we ſhall find that it varies greatly in ſize, in length, and colour, in different animals, and even in different parts of the body of the ſame animal.

2808 Action of water. 2. If hair be boiled in water, a quantity of gelatine is obtained, and by continuing the boiling, the hair becomes ſo brittle, that it crumbles to pieces. The part which remains, after the gelatine has been ſeparated, ſeems to be coagulated albumen. But beſides gelatine and albumen, it appears from the combuſtion of hair, that it contains a portion of oily matter. Berthollet obtained by the diſtillation of a quantity of hair, carbonate of ammonia, water having the ſmell of burnt hair, ſome oil, and elaſtic fluids which were probably carbonated hydrogen and carbonic acid gaſes. The oil was of a browniſh colour, and was concrete in the ordinary temperature of the atmoſphere. 2809 Diſtillation. It was ſoluble in alcohol, and burnt with a vivid flame. The charcoal which remained could ſcarcely be calcined, but ſome of its particles were attracted by the magnet.

2810 Acids. 3. The acids ſoften and deſtroy the colour of hair. It is decompoſed by ſulphuric acid with the aſſiſtance of heat; charcoal is depoſited, and carbonic acid gas given out. Nitric acid communicates a yellow colour to hair, and diſſolves it with the aid of heat. An unctuous matter is ſeparated, and oxalic acid is formed. Muriatic acid at firſt whitens hair; but it becomes yellow when it dries. Oxymuriatic acid alſo bleaches hair; but at the ſame time deſtroys its texture. It is converted into a pulp when it is introduced into oxymuriatic acid gas.

2811 Alkalies. 4. Hair is ſoluble in the alkalies, and is converted into a reddiſh-coloured ſoap, with the evolution of ammonia. If muriatic acid be added to the ſolution of hair in potaſh, ſulphurated hydrogen gas is evolved, from which it appears that hair contains ſulphur. Silver is blackened by the ſame ſolution.

2812 Metallic oxides. 5. The metallic oxides alſo have the effect of blackening hair. It is in this way that the hair is dyed black. The red oxide of lead, the acetate of lead, and ſometimes even the nitrate of lead, and the nitrates of mercury and ſilver, are employed for this purpoſe.

2813 Nails. *Nails.*—The nails are conſidered as an elongation of the epidermis. They are attached to it, and ſeparate when it is removed. They become ſoft by long maceration in water. There is no precipitate formed in this ſolution with tan. Nails are ſoluble in the acids and the alkalies. They are ſtained with metallic oxides, and combine with colouring matters. 2814 Compoſition. From theſe properties the nails are conſidered as a kind of coagulated albumen, with a ſmall proportion of phoſphate of lime, and according to ſome, carbonate of lime.

VII. Of Morbid Concretions.

2815 Found in different parts of the body. 1. Earthy matters are frequently found in different parts of animal bodies, which are to be conſidered as extraneous, and occaſioning, at leaſt in the human body, ſome of the ſevereſt diſorders to which it is ſubject. Theſe earthy matters are generally combined with an acid, and in ſome caſes entirely compoſed of an acid. Theſe ſubſtances, which have been called *concretions*, and *calculi*, are formed, ſometimes in the ſolid parts of the body, but chiefly among the fluids.

2816 Pineal. *Pineal concretions.*—Theſe concretions are almoſt always found in the pineal gland of the human brain. They are indeed ſo rarely wanting in the brain, that they are conſidered as natural, as they do not ſeem to produce any inconvenience or diſeaſe. They have been found to conſiſt of phoſphate of lime, mixed with ſome animal matter.

2817 Salivary. *Salivary concretions.*—Concretions form in the ſalivary glands, and in the ducts which convey the ſecreted ed fluid from theſe glands to the mouth. The component parts of theſe concretions have been found to be alſo phoſphate of lime and animal mucilage.

2818 Tartar of the teeth.

The tartar of the teeth is compoſed of the ſame ſubſtance. When this was examined with the microſcope, it ſeemed to be compoſed of ſmall ſhining grains united to each other, and containing a great number of pores or ſmall angular cavities, reſembling the cells of polypi, on account of which ſome naturaliſts have aſcribed its formation to inſects; but it is more natural to ſuppoſe, that it is a cryſtalline arrangement of the ſaline matter of which it is compoſed.

Concretions have alſo been found in the pancreas, and its ducts, and are ſuppoſed to conſiſt of the ſame materials.

2819 Pulmonary.

Pulmonary concretions.—Theſe concretions are formed in the lungs during aſthmatic and phthiſical diſorders. They are ſmall hard bodies, unequal and rough, of a gray or reddiſh colour, which become white as they dry in the air. They are alſo compoſed of phoſphate of lime mixed with animal matter.

2820 Inteſtinal.

Inteſtinal concretions.—Theſe are more rarely met with in the human body. When they are found, they have been generally formed on the ſtones of fruits, or ſome other hard body which has been ſwallowed. They are more frequent in the inteſtines of the inferior animals, as in thoſe of the horſe. Some that have been examined were of a gray colour, and of a radiated or cryſtallized ſtructure. The component parts of a ſtone of this deſcription, analyzed by Berthollet, were the following.

2821 Compoſition.

Magneſia	18.0
Phoſphoric acid	26.0
Ammonia	3.2
Water	46.0
Animal matter	4.0
	97.2 *.

2822 Biliary compoſed.

Biliary concretions.—Biliary concretions, or calculi, are formed, either in the liver itſelf, in the gall-bladder or in the gall ducts, hence they have alſo been called *gall-ſtones.* Some found in the liver itſelf, are compoſed of phoſphate of lime combined with ſome animal matter. The calculi which have been found in the gall bladder, are different, both in ſtructure and compoſition. Some of them ſeem to be compoſed of concentric layers of inſpiſſated bile. Theſe have different degrees of conſiſtence; they are ſometimes friable, and of a brown or reddiſh colour. The gall-ſtones of the ox, which are uſed by painters, are of this kind. Another kind of biliary calculi differ only from the former in having a ſmooth, whitiſh or grayiſh covering, reſembling ſpermaceti. They are ſometimes found in conſiderable numbers in the gall-bladder.

2823 Of inſpiſſated bile.

2824 Of a ſubſtance like ſpermaceti.

2825 Of ſhining plates.

A third ſpecies is of a white or gray colour, opaque, or ſemitranſparent. Theſe are compoſed of ſhining cryſtalline plates, or have a radiated ſtructure. They are frequently ſolitary, and are then about the ſize, and have the form of a pigeon's egg. The nucleus of this kind of gall-ſtone is compoſed of inſpiſſated bile.

2826 Or mixed.

A fourth ſpecies is compoſed of different proportions of the ſpermaceti ſubſtance and the concrete bile. Theſe are the moſt frequent of all the kinds of gall-ſtones, and are alſo the moſt numerous. They are of a deep green or olive colour. Sometimes they exhibit internally, ſmall ſhining plates of a deep yellow colour.

2827 Action of alkalies, &c.

All theſe calculi are ſoluble in the cauſtic alkalies, in ſolutions of ſoap, in fixed and volatile oils, in alcohol, and partially in ether.

2828 Urinary calculi.

1. *Urinary concretions.*—Theſe concretions which are frequently formed in the urinary bladder of man, and produce one of the moſt excruciating diſorders to which he is ſubject, have long attracted attention, with a view to prevent their formation, or to effect their diſſolution after they have been formed. Little, however, has yet been done, to accompliſh either of theſe ends; but the nature of the concretions themſelves has been carefully inveſtigated, and their component parts minutely examined by different chemiſts. Among theſe the labours of Fourcroy and Vauquelin are not the leaſt conſpicuous. Urinary calculi are found, either in the kidneys, the ureters, or the urinary bladder itſelf. Calculi, as found in the kidneys, vary conſiderably in ſize, form, colour, and internal ſtructure. They are uſually ſmall, round, concrete bodies, ſmooth and ſhining externally, of a reddiſh-yellow colour, and ſo hard as to be ſuſceptible of a poliſh. They paſs readily along the ureters to the bladder, and from thence are ejected along with the urine. It is the formation of theſe ſmall concretions which conſtitutes the diſeaſe called *gravel.* Some of theſe concretions ſometimes remain in the kidneys, and increaſing in volume by receiving new additions of matter, form large calculi. This happens, however, but rarely. The calculi which have been found in the ureters, have originated from the kidneys, and being too large to paſs along the ureters, receive new additions of matter as it is depoſited from the urine, and enlarge in ſize, at the ſame time dilating the ureter.

2829 Found in different parts of the organs.

But by far the moſt common are thoſe which are found in the bladder itſelf. Theſe calculi have either originated from ſmall concretions formed in the kidneys, and theſe paſſing along the ureters into the bladder, form a nucleus on which ſucceſſive layers of matter are depoſited from the urine; or they have their origin and complete formation in the bladder itſelf, or have been formed on ſome extraneous ſubſtance introduced into the bladder through the urethra. The firſt are the moſt frequent.

2830 Phyſical properties.

2. The form of urinary calculi is various, but they are frequently of a ſpheroidal or egg-ſhape, or compreſſed on two ſides. Sometimes they are polygonal, which happens when there are ſeveral in the bladder at the ſame time. Some have been found of nearly a cubical form. Their extremities are frequently either pointed or obtuſe. Their ſize is extremely various. Sometimes they are not larger than ſmall beans, while ſome have been of ſuch an extraordinary ſize as to fill the bladder itſelf; but they are moſt frequently from the ſize of a pigeon's egg, to that of a hen's egg. Some are of a yellowiſh-brown colour, reſembling wood. Theſe are compoſed of uric acid. Thoſe which are white, or grayiſh-white, conſiſt of the earthy phoſphates, and thoſe which are of a deep gray or blackiſh colour, are compoſed of oxalate of lime. Some exhibit all theſe different ſhades mixed together. The ſurface of urinary calculi

---

* Ann. de Chim. xxiii. 130.

calculi is ſometimes ſmooth and poliſhed ; ſometimes it is rough and unequal, and tuberculated. Some urinary calculi having their ſurface mamellated, are called *mulberry ſtones*, from ſome reſemblance to a cluſter of mulberries. Some of the white calculi are ſoft and ſmooth, ſemitranſparent, and covered with ſhining cryſtals. The ſpecific gravity varies from 1.213 to 1.976. The odour of urinary calculi is ſometimes perceptibly urinous and ammoniacal, which is diſcovered by raſping or ſawing them ; ſometimes it is faint and earthy, as in the white calculi ; and ſometimes it reſembles that of ivory ſawed or raſped, and is analogous to the odour of ſemen. Mulberry calculi are diſtinguiſhed by this odour.

2831 Conſtituent parts.

3. The following ſubſtances have been diſcovered in urinary calculi.

Uric acid,
Urate of ammonia,
Phoſphate of lime,
Phoſphate of magneſia and ammonia,
Oxalate of lime,
Carbonate of lime,
Silica,
Animal matter.

2832 Uric acid.

Uric acid exiſts in almoſt all urinary calculi. Many calculi indeed are entirely formed of it ; but it is found in greater or ſmaller proportion, in almoſt all that have been analyzed. The nature and properties of this acid have been already deſcribed. The calculi compoſed of it are of a brown colour, are ſmooth and poliſhed, and have the appearance of wood. When this ſubſtance is triturated with a concentrated ſolution of potaſh or ſoda, it forms a thick ſaponaceous matter, which is precipitated by diluted acids. It is diſſolved by nitric acid, and is converted into a red colour. This acid is a compound of azote, carbone, hydrogen, and oxygen ; and when decompoſed by chemical agents, it is converted into ammonia, malic, oxalic, pruſſic, and carbonic acids.

2833 Urate of ammonia.

Urate of ammonia, the next ſubſtance found in urinary calculi, is alſo ſoluble in potaſh and ſoda, but the ſolution is accompanied with a copious evolution of ammonia. Calculi compoſed of this ſubſtance, conſiſt of thin layers, and are not always ſmooth. They are generally of a ſmall ſize, and reſemble an infuſion of coffee. The earthy phoſphates are frequently interpoſed between the layers of calculi compoſed of this ſubſtance, and it is often mixed with phoſphate of ammonia and magneſia.

2834 Phoſphate of lime.

Phoſphate of lime frequently enters into the compoſition of calculi. It is uſually in thin layers, which are friable, and have little conſiſtency. They are of a grayiſh-white colour, and opaque, without taſte or ſmell. The phoſphate of lime is uſually mixed with gelatinous matter ; is ſoluble in different acids, and is precipitated by the alkalies. Some calculi have been diſcovered entirely compoſed of phoſphate of lime.

2835 Of ammonia.

Phoſphate of ammonia and magneſia is in the form of white, ſemitranſparent layers, and it is ſometimes found cryſtallized on the ſurface of calculi in the form of priſms. When it is reduced to powder it is of a brilliant white, very ſoluble in diluted acids, and is decompoſed by the fixed alkalies.

2836 Oxalate of lime.

Oxalate of lime is uſually mixed with phoſphate of lime and uric acid, but ſometimes it is combined only with animal matter in mulberry calculi. The calculi compoſed of it are of a dark green colour, and extremely hard. It diſſolves with difficulty in diluted nitric acid, and is decompoſed by the carbonates of potaſh and ſoda.

2837 Carbonate of lime.

The carbonate of lime conſtitutes the greateſt part of ſome urinary calculi.

2838 Silica.

Silica has been rarely found in calculous concretions. It was detected mixed with phoſphate of lime, only in two mulberry calculi, which were extremely hard.

2839 Animal matter.

In all calculous concretions there is a quantity of animal matter, which unites or cements together the layers or particles of the hard ſubſtances of which they are compoſed. This animal matter ſeems to poſſeſs the properties of albumen. Sometimes it ſeems to be compoſed of albumen mixed with urea, of coagulated albumen, or gelatine.

2840 Divided into three genera and 12 ſpecies.

4. Fourcroy and Vauquelin have analyzed more then 600 calculi, and by comparing the properties of each, they have arranged them into three genera and 12 ſpecies. The firſt genus comprehends thoſe ſpecies which are compoſed of one ſubſtance. Theſe are the three following :

1. Uric acid,
2. Urate of ammonia,
3. Oxalate of lime.

The ſecond genus includes thoſe ſpecies which are compoſed of two ſubſtances. It conſiſts of the following ſeven ſpecies :

1. Uric acid and the earthy phoſphates, in diſtinct layers.
2. Uric acid and the earthy phoſphates intimately mixed together.
3. Urate of ammonia, and the phoſphates in diſtinct layers.
4. The two preceding intimately mixed.
5. Earthy phoſphates mixed or in thin layers.
6. Oxalate of lime and uric acid in layers.
7. Oxalate of lime and earthy phoſphates in layers.

The third genus conſiſts of two ſpecies, which are compoſed of three or four ſubſtances.

1. Uric acid or urate of ammonia, earthy phoſphates and oxalate of lime.
2. Uric acid, urate of ammonia, earthy phoſphates, and ſilica.

We ſhall now ſtate the general characters of theſe different ſpecies.

Genus I.

Species 1. *Uric acid*.—Theſe calculi are eaſily known by their colour, which reſembles wood. It is reddiſh, or yellowiſh. They are of a radiated, denſe, fine texture, completely ſoluble in pure alkalies, without emitting any odour. They vary greatly in ſize, and have generally a ſmooth poliſhed ſurface. The ſpecific gravity is from 1.276 to 1.786. It uſually exceeds 1.5. Of 600 calculi which were analyzed by Fourcroy and Vauquelin, 150 conſiſted of pure uric acid. The ſand or gravel which is formed in the kidneys, uſually belongs to this ſpecies.

2. *Urate of ammonia*.—Calculi compoſed of this ſubſtance, are uſually of ſmall ſize, ſoluble in cauſtic fixed alkalies, with the evolution of ammonia, of the colour

of

of the infuſion of coffee, and are compoſed of fine layers which are eaſily ſeparated. The ſurface is commonly ſmooth, and ſometimes ſhining and cryſtalline. The ſpecific gravity is from 1.225 to 1.720. They are ſoluble in hot water, at leaſt when reduced to powder. The external layer is ſometimes pure uric acid. This ſpecies is rare.

Oxalate of lime.—This ſpecies is eaſily recognized by its rough, mamellated ſurface, from which thoſe calculi have received the name of mulberry ſtones. The colour is brown, they are of a cloſe hard texture, and when raſped or ſawed, emit the odour of ſemen. They are ſoluble with difficulty in acids, and are inſoluble in the pure alkalies. The ſpecific gravity is from 1.428 to 1.976. This ſpecies frequently conſtitutes the nucleus of other calculi.

Genus II.

Species 1. *Uric acid and earthy phoſphates in diſtinct layers.*—This ſpecies is known by its ſurface, which is white like chalk, friable and ſemitranſparent. The external layer is compoſed of the phoſphate of lime, or of ammonia and magneſia. The nucleus conſiſts of uric acid, and when the calculus of this ſpecies is ſawed aſunder, two ſubſtances of which it is compoſed are diſtinctly ſeen. It is indeed only then that the ſpecies can be recogniſed. Calculi of this deſcription are not uncommon, and they are generally of the largeſt ſize of all the urinary calculi. The ſpecific gravity is very variable.

2. *Uric acid and earthy phoſphates intimately mixed.*—This ſpecies contains numerous varieties, from the different proportion of the conſtituent parts. Sometimes the uric acid and the earthy phoſphates are arranged in layers ſo thin, that they are ſcarcely perceptible. Sometimes they are ſo mixed together that they can only be detected by analyſis. But ſometimes the layers are ſufficiently diſtinct. The ſpecific gravity is from 1.213 to 1.739. This ſpecies of calculus is common.

3. *Urate of ammonia and the phoſphates in diſtinct layers.*—In this ſpecies the nucleus conſiſts of urate of ammonia; and the external layers are moſt frequently compoſed of the earthy phoſphates mixed together, or more rarely of phoſphate of ammonia and magneſia. This ſpecies is uſually of ſmall ſize; its ſpecific gravity is from 1.312 to 1.761. It is not very common.

4. *Urate of ammonia and earthy phoſphates mixed.*—The calculi belonging to this ſpecies are very rare. They are of a pale-yellow colour, and of leſs ſpecific gravity than the ſecond ſpecies of this genus, which they reſemble in external characters. When they are treated with potaſh, ammonia is diſengaged. This ſpecies is uſually of ſmall ſize.

5. *Earthy phoſphates mixed, or in thin layers.*—This ſpecies is diſtinguiſhed by its pure white colour. They are of a friable texture, inſoluble in alkalies, and ſoluble in diluted acids. This ſpecies is pretty common, and often of a large ſize. The concretions formed on extraneous matters introduced through the urethra into the bladder, are of this kind. The ſpecific gravity varies from 1.138 to 1.471.

6. *Oxalate of lime and uric acid in diſtinct layers.*—In this ſpecies the nucleus conſiſts of oxalate of lime, and it is covered with a layer of uric acid. From external appearance they are not diſtinguiſhed from thoſe entirely compoſed of uric acid, till they are ſawed aſunder. The ſpecific gravity varies from 1.341 to 1.754.

7. *Oxalate of lime and earthy phoſphates in layers.*—The oxalate of lime conſtitutes the nucleus, and the earthy phoſphates compoſe the external covering in this ſpecies of calculus. It can only be diſtinguiſhed by being ſawn aſunder. The calculi belonging to this ſpecies vary greatly in form and ſize, but they are always white externally. The ſpecific gravity is from 1.168 to 1.752.

Genus III.

Species 1. *Uric acid, urate of ammonia, the earthy phoſphates and oxalate of lime.*—In this ſpecies there are frequently three diſtinct layers. The center or nucleus is compoſed of oxalate of lime; the next of uric acid or urate of ammonia; and the outermoſt of the earthy phoſphates, which are uſually mixed with uric acid, or urate of ammonia. The calculi of this ſpecies can only be diſtinguiſhed by ſawing them in two. There are many varieties of this ſpecies, from the different proportions and the different arrangement of the conſtituent parts.

2. *Uric acid, urate of ammonia, earthy phoſphates, and ſilica.*—In the calculi belonging to this ſpecies, the ſilica ſeems to hold the place of the oxalate of lime. It is mixed with uric acid and urate of ammonia, and covered with the phoſphate of lime. This is the rareſt ſpecies of all that have been examined.

2841 Cauſes of urinary calculi.

5. The inveſtigation of the cauſe of the formation of calculous concretions has occupied a great deal of the attention of phyſiologiſts and phyſicians, and undoubtedly it is one of the moſt important on which the reſearches of man can be employed; for by obviating the cauſe of this diſorder, its terrible effects might be prevented. Unfortunately, however, little is yet known on this intricate ſubject. In many caſes, indeed, the formation of urinary calculi is obviouſly owing to the introduction of ſome extraneous ſubſtance into the bladder by the urethra. But this mode of formation is comparatively rare, and the calculi thus formed are compoſed of the earthy phoſphates, which are depoſited from the urine. All urine contains uric acid. This forms one of the moſt common ſpecies of calculi. The particles of gravel which are formed in the kidneys, conſiſt of this acid, ſo that it very often forms the nucleus of calculous concretions. But the production of an exceſſive quantity of uric acid, in whatever way this takes place, ſeems to be the moſt powerful cauſe of the production of urinary calculi. It has been obſerved too, that the urine of thoſe perſons in whom theſe concretions are moſt frequent, is loaded with an unuſual proportion of animal matter. This forms the cementing ſubſtance of theſe concretions. In the formation of theſe concretions it would appear that the different ſubſtances of which they are compoſed, are ſecreted at different times, or in different proportions, ſince the different ſucceſſive layers of calculi are compoſed of totally diſtinct ſubſtances. It is perhaps difficult or impoſſible to explain the formation of thoſe calculi in which oxalic acid is a conſtituent part. This acid has ſcarcely ever been detected in the urine, at leaſt of adults, ſo that it muſt be produced by ſome morbid action

tion by which ſome of the animal fluids are converted into this ſubſtance.

2842 Solvents. 6. It has long been an object with phyſicians, to diſcover the means of diſſolving theſe ſubſtances after they have been formed; and the empiric has not been idle in offering his noſtrums which are held out as ſolvents of the ſtone, and which it is no wonder are eagerly received with the hope of relief from one of the moſt dreadful maladies which can afflict mankind. Nothing, however, can be done with this view on rational principles, without previouſly knowing the nature and properties of the ſubſtances which are to be diſſolved; and even when this is known, it muſt appear, from conſidering the function of digeſtion, and the changes which all ſubſtances taken into the ſtomach, undergo, that little can be expected from the exhibition of remedies in this way. After being ſubjected to the different proceſſes of digeſtion, reſpiration, and ſecretion, the properties of theſe ſubſtances are totally changed, ſo that they can only produce ſome general effect on the ſyſtem, and can have no ſpecific action on particular organs. It has therefore been propoſed by the French chemiſts, to employ theſe ſubſtances which poſſeſs the property of diſſolving urinary calculi out of the body, by injecting them through the urethra into the bladder.

It has been found by experiment, that calculi compoſed of uric acid, or urate of ammonia, are ſoluble in ſolutions of pure potaſh and ſoda, even when theſe ſolutions are ſo much diluted with water that they may be taken internally, without producing any inconvenience.

Experiments have alſo ſhewn, that calculi compoſed of the earthy phoſphates are ſoluble in nitric and muriatic acids, ſo much diluted that they may be taken internally without the ſmalleſt injury.

Calculi compoſed of oxalate of lime are leſs eaſily diſſolved. They, are, however, ſoluble in diluted ſolutions of carbonate of potaſh or ſoda.

2843 Methods of uſing. The firſt difficulty, however, which preſents itſelf in the uſe of theſe ſolvents, is to diſcover the nature and compoſition of the concretion to be diſſolved. This can only be done by employing ſome of the ſolutions, and examining them after they have remained for ſome time, or as long as they can be retained in the bladder. If a weak ſolution of potaſh has been injected, it is to be filtered, as ſoon as it is thrown out; and if on the addition of a little diluted muriatic acid, or vinegar, a white precipitate appears, the calculus is to be conſidered as compoſed of uric acid. But if this ſolution has been employed for ſome time, and no precipitate is produced in this way, the ſolution for the phoſphates is then to be employed, and when it is paſſed, after remaining ſome time in the bladder, a precipitate will be formed with the addition of ammonia. This precipitate will be phoſphate of lime.

If no effect is produced by any of theſe ſolutions, and if the ſeverity of the ſymptoms continues, there is ſome probability that the calculus conſiſts of oxalate of lime. This, it has been obſerved, is the moſt difficult of ſolution. It may be diſſolved, however, although ſlowly, in nitric acid greatly diluted with water, or in weak ſolutions of the carbonates of potaſh or ſoda. Theſe ſolutions, therefore, muſt be employed when the others have failed. The effects of theſe ſolutions muſt be judged of by the alleviation of the ſymptoms, or by the actual examination of the ſtone itſelf at different times, by means of the catheter, or ſound. Whatever ſolution is employed, it ought to be of the temperature of the body, and ſo much diluted as not to irritate or injure the internal ſurface of the bladder to which it is applied. Before the injection is made, the urine ſhould be evacuated, and the injection retained, for at leaſt, a quarter of an hour, from that to an hour, or as long as it can be done without inconvenience. The injections ſhould be repeated at firſt three or four times a-day, and afterwards increaſed to ſix or eight times. As calculous concretions are frequently ſeveral years in forming, it is obvious that they muſt require a long time to diſſolve them, ſo that the uſe of injections, if any relief is to be obtained from them, muſt be long continued.

2844 In other animals. 7. Calculous concretions are not unfrequent in the urinary organs of other animals. They have been found in the horſe, in the dog, the rabbit, the hog, and the rat. They are moſt frequently compoſed of carbonate of lime with ſome animal matter; ſometimes of phoſphate of lime, of phoſphate of ammonia, and of carbonate of lime and phoſphate of lime; but no traces of uric acid have yet been detected in theſe concretions.

2845 Chalk-ſtones. *Gouty concretions.*—1. Concretions, which are commonly called *chalk-ſtones*, are ſometimes formed in the joints of thoſe who have been long ſubject to the gout. They have been diſcovered by chemical analyſis to be compoſed of uric acid and ſoda.

2846 Properties. 2. Theſe concretions are of a white colour, irregular in their form, and of a fine granulated texture. When they are boiled for a few minutes, in 100 times their weight of water, they are entirely diſſolved. Sulphuric acid added to this ſolution, produces a white precipitate, which aſſumes the form of ſmall needles, which are cryſtals of uric acid. The remaining liquid, by being evaporated, affords ſulphate of ſoda.

2847 Action of alkalies. 3. By treating a quantity of gouty concretion with 100 times its weight of a concentrated ſolution of potaſh with the aid of heat, it is almoſt entirely diſſolved, exhaling at the ſame time the faint odour of animal matter. When the liquid is filtered, and muriatic acid added, it produces a white precipitate, which is uric acid. From this it appears, that gouty concretions poſſeſs ſimilar properties with thoſe formed in the urinary organs, excepting that they contain a greater proportion of animal matter.

2848 Acids, &c. 4. When it is diſſolved in a ſmall quantity of diluted nitric acid, it tinges the ſkin with a roſe colour, and when evaporated, leaves a roſe-coloured deliqueſcent reſiduum. By diſtillation this ſubſtance yields ammonia, pruſſic acid, and an acid ſublimate.

2849 Artificial formation. 5. If a ſmall portion of uric acid be triturated with ſoda and a little warm water, they combine; and after the ſuperfluous alkali has been waſhed out, the remainder has all the chemical properties of gouty matter *.

Subdiviſion IV. Of Subſtances Peculiar to Different Animals.

Having briefly detailed the nature and properties of thoſe ſubſtances which are common to animals, we ſhall now take a general view of ſome ſubſtances which are peculiar

---

* *Phil. Tranſ.* 1797. p. 386.

peculiar to different animals, and we ſhall treat of theſe according to the order in which they are arranged in natural hiſtory.

I. Of Subſtances peculiar to the Claſs Mammalia.

The ſubſtances peculiar to this claſs of animals are the following.

1. Ivory,
2. Horn,
3. Hartſhorn,
4. Wool,
5. Muſk,
6. Civet,
7. Caſtor,
8. Ambergris,
9. Spermaceti,
10. Bezoards.

2850 Ivory. 1. *Ivory*, which is the teeth of the elephant, is a bony ſubſtance, of a fine compact texture, white colour, and ſo hard as to be ſuſceptible of a fine poliſh. It is compoſed, like the bones, of gelatinous matter and phoſphate of lime, and when it is diſtilled it furniſhes water, a thick oil, and carbonate of ammonia; and when calcined to whiteneſs, it leaves pure phoſphate of lime.

The component parts of ivory are, according to Merat-Guillot, the following.

Phoſphate of lime,	64.0
Carbonate of lime,	0.1
Gelatine,	24.0
Loſs,	11.9
	100.0

2851 Horn. 2. *Horn.*—The ſubſtance called horn, poſſeſſes different properties from that of bone. This matter is produced in the horns of different animals, as thoſe of oxen, ſheep, and goats. It has ſome degree of tranſparency, and when heated it becomes ſo ſoft and flexible, that it may be made to aſſume different ſhapes, and formed into different inſtruments and utenſils. Horn yields a very ſmall proportion of earthy matter. The other conſtituent parts ſeem to be coagulated albumen and gelatine.

The following are the proportions of the conſtituents of hartſhorn.

Phoſphate of lime,	57.5
Carbonate of lime,	1.0
Gelatine,	27.0
Loſs,	14.5
	100.0

2852 Hartſhorn. 3. *Hartſhorn.*—The conſtituent parts of hartſhorn, from the analyſis which has been made, are exactly the ſame as thoſe of bone, but they contain a greater proportion of gelatinous matter.

2853 Wool. 4 *Wool* is a kind of long hair, very fine and ſoft, which is a covering to different animals, eſpecially the ſheep. It has been conſidered as nearly analogous in its nature and properties to hair. It is entirely ſoluble in the cauſtic alkalies, and forms with them a ſoapy matter, which has been employed, it is ſaid, with advantage, as a ſubſtitute for ſoap, in different manufactures.

2854 Muſk. 5. *Muſk* is a ſubſtance which is ſecreted in a bag ſituated near the umbilical region of the muſk deer (*moſchus moſchifer*). It has an unctuous feel, is of a dark-reddiſh brown colour, has a very bitter taſte, and is diſtinguiſhed by a ſtrong aromatic ſmell. It is partially ſoluble in water, to which it communicates the odour. A ſmall portion of it alſo may be diſſolved in alcohol, but it does not retain the odour. Muſk is ſoluble in ſulphuric and nitric acid; but in theſe ſolutions the odour is diſſipated. The ſmell of ammonia is given out by the action of the fixed alkalies on muſk. When it is laid on red hot iron, it takes fire, and is almoſt entirely conſumed, leaving only a ſmall portion of gray aſhes. During its combuſtion it gives out the fetid odour of urine. Muſk ſeems to poſſeſs many of the properties of the volatile oils, but its component parts have not been determined.

2855 Civet. 6. *Civet.*—This ſubſtance is extracted from a ſmall bag near the anus of the *viverra civeta*, or *civet cat*. It is of a yellow colour, and of the conſiſtence of butter. When firſt extracted it is ſaid to be white. It has a very ſtrong ſmell, and ſlightly acrid taſte; it combines readily with oils, and is much employed as a perfume.

2856 Caſtor. 7. *Caſtor.*—This ſubſtance is extracted from two bags ſituated near the anus of the beaver. The beſt caſtor is obtained from the large bag; that which is ſecreted in the ſmall bag is ſaid to be of an inferior quality. When caſtor is firſt taken from the animal, it is nearly fluid, and of a yellow colour. After it is expoſed for ſome time to the atmoſphere, it becomes hard, and of a darker colour, aſſuming a reſinous appearance. It has an acrid, bitter, and nauſeous taſte, and a ſtrong aromatic ſmell, which it loſes by drying. It becomes ſoft in water, and communicates to it a pale yellow colour. This infuſion converts vegetable blues to a green colour. When it has been long macerated in water, the infuſion becomes of a deeper colour, and yields by evaporation extractive matter, which is ſoluble in alcohol and in ether. A reſinous matter is precipitated from the ſolution in alcohol, by means of water, which has ſimilar properties with the reſin of bile. According to the analyſis of Lagrange, the component parts of caſtor are the following:

Carbonate of potaſh,
———— lime,
———— ammonia,
Iron,
Reſin,
Mucilaginous extractive matter,
Volatile oil.

2857 Ambergris. 8. *Ambergris.*—This is a ſubſtance which is ſuppoſed to be formed in the inteſtines of the ſpermaceti whale. It is frequently found floating in the ſea. For its natural hiſtory, ſee AMBERGRIS, and CETOLOGY *Index*.

It is a ſoft light ſubſtance, of an aſh-gray colour, with browniſh-yellow and white ſtreaks. It has an inſipid taſte, but an agreeable odour. The ſpecific gravity is from 0.844 to 0.849. It melts at the temperature of 122°, and with the heat of boiling water is completely diſſipated in white ſmoke, leaving a ſmall trace of charcoal. By diſtillation an acid fluid is firſt obtained, and a light volatile oil; and there remains behind a voluminous maſs of charcoal. By ſublimation benzoic acid is ſeparated.

Ambergris is inſoluble in water. Concentrated ſulphuric acid ſeparates a ſmall portion of charcoal.

It is diſſolved in nitric acid. During the ſolution, nitrous gas, azotic gas, and carbonic acid gas are evolved. A reſinous matter is obtained by evaporating the ſolution. Ambergris is ſoluble in the alkalies, with the aſſiſtance of heat. It is alſo ſoluble in the oils, in alcohol and ether. By the analyſis of Bouillon la Grange the conſtituent parts of ambergris are the following:

2858 Compoſition.

Adipocire	52.7
Reſin	30.8
Benzoic acid	11.1
Charcoal	5.4
	100.0 *

The ſubſtance called *adipocire* poſſeſſes the mixed or intermediate properties of fat and wax. This name was firſt given by Fourcroy to the matter into which the dead bodies found in the Innocents burying-ground were converted. In appearance and ſome of its properties it alſo reſembles ſpermaceti.

2859 Spermaceti. 9. *Spermaceti.*—This is a production of the ſame whale which yields the preceding ſubſtance. It is an oily matter which ſurrounds the brain. It is ſeparated from a fluid oil, with which it is mixed, by expreſſion. Spermaceti is alſo found in other cetaceous fiſhes, and in other parts of the body, mixed with the oil.

2860 Properties. It is a fine white ſubſtance of a cryſtallized texture, very brittle, and has little taſte or ſmell. It cryſtallizes in the form of ſhining ſilvery plates. It melts at the temperature of 112°. With a greater heat it may be diſtilled without change; but, by repeated diſtillation, it is decompoſed, and partly converted into a brown acid liquid. It is ſoluble in boiling alcohol, but it ſeparates when the ſolution cools. It is alſo ſoluble in ether both cold and hot. In the hot ſolution it concretes on cooling into a ſolid maſs.

2861 Action of acids, &c. Spermaceti is ſcarcely at all ſoluble in the acids. It combines readily with the pure alkalies, with ſulphur, and with the fixed oils. By expoſure to the air it becomes rancid. The uſes of ſpermaceti are well known, and particularly in the manufacture of candles.

2862 Bezoards. 10. *Bezoards.*—Theſe are calculous concretions which are found in the inteſtines of different animals belonging to this claſs, particularly the horſe. Some of very large ſize have been found in the elephant and the rhinoceros. Theſe ſubſtances were once celebrated on account of their medical virtues, and they were formerly diſtinguiſhed into oriental and occidental. The firſt were moſt highly valued, and frequently bore a high price, eſpecially the bezoards obtained from a ſpecies of goat which inhabits the Aſiatic mountains. Some that have been examined were compoſed entirely of vegetable matter. In general the nucleus is of vegetable matter, on which phoſphate of ammonia and magneſia or phoſphate of lime have been depoſited. Theſe ſubſtances are diſtinguiſhed by a ſtrong aromatic odour when they are rubbed or reduced to powder. The brown or golden-coloured matter which has been obſerved on the grinding teeth of ruminating animals is found to be of the ſame nature with the bezoards which are formed in the inteſtines.

II. Of Subſtances peculiar to the Claſs of Birds.

The ſubſtances which are peculiar to this claſs of animals are the following.

1. Eggs.
2. Feathers.
3. Excrement.
4. Membrane of the ſtomach.

2863 Eggs. 1. *Eggs.*—In a chemical view, three parts of an egg merit attention. Theſe are the ſhell or external covering, the white, and the yolk. The white of egg, which conſiſts of albumen, has been already deſcribed, ſo that it now only remains to give ſome account of the ſhell and the yolk.

2864 Shells. The ſhells of the eggs of birds which have been analyzed are compoſed of ſimilar conſtituents with bone, but in very different proportions. The following is the reſult of the analyſis of Vauquelin.

Carbonate of lime	89.6
Phoſphate of lime	5.7
Animal matter	4.7
	100.0 *

2865 Yolk. The yolk of egg is of a ſoft conſiſtence, a yellow colour, and of a mild oily taſte. It becomes ſolid by boiling, and crumbles eaſily into ſmall particles. By heating gently after it has been boiled, and by expreſſion, an oily liquid of a yellow colour and inſipid taſte is obtained. It is diſtinguiſhed by the properties of fixed oil. What remains after ſeparating the oil is albumen, ſtill coloured with a ſmall portion of oil. By boiling this reſiduum in water, a portion of gelatine is obtained, ſo that the yolk of egg is compoſed of oil, albumen, gelatine, and water.

2866 Compoſition.

2867 Feathers. 2. *Feathers*—are conſidered as poſſeſſing ſimilar properties with hair. According to ſome, the ſolid part, or quill, may be reduced to the gelatinous ſtate by boiling; but according to others, no gelatine whatever can be detected. The quill part is therefore ſuppoſed to conſiſt chiefly of coagulated albumen. It becomes ſoft by the action of acids and alkalies.

2868 Excrement 3. *Excrement.*—This matter in birds is very different from that of the animals included in the claſs mammalia. It is generally of a white colour, leſs liquid, and leſs fetid. It is commonly accompanied with a glary matter of different degrees of tranſparency, analogous to the white of egg. This ſeems to be owing to a quantity of albumen which is ſecreted in the oviduct. The white part of this matter is compoſed of carbonate and phoſphate of lime and albumen. The colouring matter ſeems to be part of the food.

2867 Membrane of the ſtomach. 4. *Membrane of the ſtomach.*—The internal ſurface of the gizzard, or muſcular part of the ſtomach of birds, is covered with a wrinkled membrane, which is ſuſceptible of conſiderable extenſion, and through the pores of which gaſtric juice is copiouſly ſecreted. This membrane is eaſily ſeparated from the muſcular part. When it is boiled in water, it is converted into jelly, and communicates to the water the property of reddening vegetable blues, and coagulating milk. When it is dried and reduced to powder, it produces the ſame effect.

---

* Ann. de Chim. xlvii. 84.

* Ann. de Chim. xxix. 6.

III. Of Matters peculiar to Animals in the Amphibious Claſs.

2868 Poiſon of the viper.

1. *Poiſon of the Viper.*—Some of the animals belonging to the ſnake tribe, ſecrete a peculiar fluid in the mouth, which is of a poiſonous quality. The poiſon of the viper is a yellow, viſcid liquid, ſomewhat reſembling oil. It is ſecreted in two ſmall bags, and from them conveyed to the fangs of the animal, which are hollow and perforated, and when it bites, the liquid is ſqueezed out of the bag, and flows through the teeth into the wound. It has no ſmell. It becomes thick by expoſure to the air, and is converted into a tranſparent jelly; but it retains its poiſonous property long after it is ſeparated from the animal. It is ſoluble in water by agitation, but if thrown into the water when extracted from the veſicle, it falls inſtantly to the bottom like a heavy oil. It is ſoluble in warm water after it is dried, but not ſoluble in alcohol, or coagulated by boiling water. Acids and alkalies produce no perceptible change upon this matter. It is precipitated from its ſolution in water by alcohol. It reſembles gum in ſo many of its properties, that it has been called an *animal gum.*

2869 Toad.

2. *Liquid ſecreted from the tubercles on the head of the Toad.*—It has been long ſuppoſed that the liquid ſecreted on the head of the toad is of a poiſonous quality; but although it is ſaid by ſome naturaliſts, that this fluid, brought in contact with the ſkin, produces inflammation, yet there ſeems to be no poſitive proof of this effect.

2870 Tortoiſe ſhell.

3. *Tortoiſe-ſhell.*—This ſubſtance, which forms a ſtrong covering and defence to the body of the turtle, poſſeſſes many of the properties of horn; for it may be ſoftened with heat, or in boiling water, and ſhaped into any form which may be wanted. It is compoſed of a number of hard plates or membranes, of different degrees of thickneſs, cloſely applied to each other. It becomes ſoft by maceration in nitric acid, and by burning it yields a very ſmall proportion of phoſphate of lime and ſoda, with ſome ſlight traces of iron.

IV. Of Subſtances peculiar to Fiſhes.

2871 Scales.

1. *Scales*—generally poſſeſs a ſilvery whiteneſs, and are compoſed of different laminæ. In many of their properties they reſemble horn. By long boiling in water they become ſoft, and when they are kept for ſome hours in nitric acid, they are converted into a tranſparent membranous ſubſtance. By ſaturating the acid with ammonia, a precipitate is formed, which is phoſphate of lime. The conſtituent parts of ſcales, therefore, are membrane and phoſphate of lime.

2872 Bones.

2. *Bones of fiſhes.*—Theſe are compoſed of the ſame conſtituents as thoſe of other animals, but have a greater proportion of animal matter. In ſome they are ſoft, flexible, and ſemitranſparent, and hence they are called *cartilaginous.* In others they are hard and ſolid, having the uſual appearance of bone.

3. *Fiſh oil.*—A great quantity of oil is extracted from the ſoft parts of different kinds of fiſh, and eſpecially from the blubber of the whale. It is uſually denominated *train oil.* It is obtained, either by expreſſion, or by boiling. It is ſuppoſed that the oil obtained from the blubber of the whale, and from other fiſhes, poſſeſſes different properties, which are aſcribed to the difference in the function of reſpiration of cetaceous and other fiſhes; but how far this difference really exiſts, does not ſeem to have been accurately aſcertained. Fiſh oil is diſtinguiſhed by a diſagreeable ſmell, and it has long been an object to deprive it of this odour, as it is much employed in domeſtic economy and in many arts. By agitating the oil with a ſmall portion of ſulphuric acid, and adding water, the oil when left at reſt, riſes to the ſurface conſiderably purified. A portion of coagulated matter has ſeparated, and the water is milky.

V. Of Subſtances peculiar to Inſects.

1. *Wax.*—The nature and properties of this ſubſtance have already been deſcribed as a vegetable production.

2873 Propolis.

2. *Propolis.*—This is a ſubſtance collected by bees, and with which they cover the bottom of the hive, or any foreign matters which happen to be introduced into it, which they cannot remove. It is the ſubſtance which they collect on their legs and thighs. It is perhaps more properly to be conſidered as a vegetable production. It poſſeſſes more tenacity than wax, but has much of its ductility. It is inſipid to the taſte, but is diſtinguiſhed by an aromatic odour. It is partially ſoluble in alcohol, to which it communicates a red colour. Another portion is diſſolved in boiling alcohol, and part precipitates as the ſolution cools, which has the properties of wax. A reſinous maſs is obtained by concentrating the ſolution in alcohol and boiling in water. It is ſemitranſparent and brittle. An acid was detected in the water in which it was boiled. The reſinous ſubſtance is ſoluble in fixed and volatile oils. The following are the conſtituent parts of propolis.

Pure reſin	57
Pure wax	14
Extraneous matter	14
Loſs and acid	15
	100 *.

2874 Honey.

3. *Honey.*—This has alſo been conſidered as a vegetable production, as it is collected from plants by bees. It is of a white or yellowiſh colour, of a granular ſoft conſiſtence, and has an aromatic ſmell; but theſe properties vary according to the plants from which it is collected, or the climate in which they grow. By diſtillation honey yields nearly the ſame products as ſugar. It is converted into oxalic acid by means of nitric acid. It is very ſoluble in water, and is even ſomewhat deliqueſcent. It readily paſſes to the vinous fermentation, and affords a fermented liquor which has been called *hydromel.* It is partially ſoluble in alcohol, and by this means ſugar may be extracted from it. The component parts of honey are ſugar, mucilage, and an acid. If pure honey be melted, and carbonate of lime be added till the efferveſcence ceaſes, the ſugar is ſeparated, and is depoſited in cryſtals.

2875 Cantharides.

4. *Cantharides* are a ſpecies of fly, (the *meloe veſicatorius*, Lin.) which are much employed, from a peculiar property they poſſeſs, to raiſe bliſters on the ſkin. For this purpoſe the whole of the inſect is reduced

---

* *Nichol. Jour.* v. p. 49.

duced to powder. Cantharides have been ſubjected to analyſis; and by ſucceſſive treatment with water, alcohol, and ether, four different ſubſtances have been extracted. 1. Three eighths of their weight conſiſt of extractive matter, of a reddiſh-yellow colour, very bitter, and which yields by diſtillation an acid liquor. 2. A little more than one-tenth of the weight conſiſts of a concrete oil, ſomething of the nature of wax, which is of a green colour and very acrid taſte. To this is owing the peculiar odour of cantharides. This ſubſtance yields by diſtillation, a very pungent acid ſubſtance and a thick oil. 3. About one-fiftieth of a yellow concrete oil, which ſeems to communicate the colour to the inſect, is alſo obtained. 4. About one-half the weight of a ſolid matter remains, the nature of which has not been aſcertained. The bliſtering effect of cantharides ſeems to depend on the green waxy matter, part of which is extracted by means of warm water, and it is entirely ſoluble in ether.

2876 Millepedes. *Millepedes.*—Theſe inſects, which are different ſpecies of oniſcus, were formerly employed in medicine. By diſtillation with the heat of a water bath, they yield a watery liquid, which converts the ſyrup of violets to a green colour, and by this proceſs they are deprived of five-eighths of their weight. By treating them afterwards with water and alcohol they furniſh one-fourth of their weight of an extractive and waxy matter; the latter is ſoluble in ether. The muriates of potaſh and lime have been detected in the expreſſed juice of theſe inſects.

2877 Ants. *Ants.*—Theſe inſects contain an acid liquid which they emit from the mouth when they are irritated, or when they are bruiſed on paper. This liquid converts vegetable blues to red; and it has been obſerved that ſtreaks of the ſame colour are communicated to blue flowers, over which the inſects creep. The acid obtained from ants, and particularly from the *formica rufa*, or red ant, was formerly conſidered as poſſeſſing peculiar properties, and thence denominated *formic acid;* but it has been lately aſcertained to conſiſt of a mixture of acetic and malic acids.

2878 Lac. *Lac.*—This is a ſubſtance which is formed on the branches of ſeveral plants, as the *ficus indica*, the *ficus religioſa*, and eſpecially the *croton lacciferum*. It is produced by the puncture of an inſect, but is conſidered as belonging to vegetable ſubſtances, among which the general properties have been already deſcribed, as well as the properties of an acid obtained from it, among the acids.

2879 Silk. *Silk.*—This is the production of ſeveral inſects, either for the purpoſe of covering up their eggs, or forming a net to catch their prey, as is the caſe with many of the ſpider tribe, or to cover up the inſect during one of the ſtages of its metamorphoſis. The ſilk of commerce is uſually obtained from the *phalæna bombyx*, or ſilk-worm. This ſubſtance is prepared in the body of the larva of the inſect, from which it is protruded through ſeveral ſmall orifices in very fine threads; and with this it forms a covering for itſelf while it remains in the ſtate of chryſalis or pupa.

Silk is a very elaſtic ſubſtance, and is of a white or reddiſh yellow colour, when it is produced by the inſect. The elaſticity of ſilk has been aſcribed to a varniſh with which it is covered, of a gummy or gelatinous nature, which is precipitated by tan and muriate of tin. The yellow colour of ſilk is aſcribed to a reſinous matter which is ſoluble in alcohol. By diſtillation ſilk yields a large proportion of ammonia. It is ſoluble in ſulphuric, nitric, and muriatic acids. By nitric acid it is partly converted into oxalic acid, and a fatty matter which ſwims on the ſurface.

2880 Cochineal. *Cochineal.*—This is an inſect which breeds on the leaves of the *cactus coccinelliferus* Lin. ſometimes called opuntia or nopal. The plant is cultivated in Mexico, for the purpoſe of rearing the inſects, which are collected, dried, and employed as a beautiful dye ſtuff. By burning, the ſame reſults are obtained as from other animal matters; but with boiling water it gives a crimſon violet colour, which becomes red and yellow by the action of acids, while a precipitate is formed of the ſame colour. The metallic ſolutions added to this decoction, alſo produce a coloured precipitate. The muriate of tin throws down a beautiful red precipitate. The evaporated reſiduum of the decoction of cochineal, treated with alcohol, gives a fine red colour, and this, by evaporating the alcohol, aſſumes the form of a reſin. Oxymuriatic acid converts the ſolution of this ſubſtance into a yellow colour, from which the proportion of colouring matter may be in ſome meaſure eſtimated, by the quantity of acid requiſite to deſtroy its colour. Cochineal is well known by its producing a beautiful ſcarlet colour. It may be kept for any length of time, at leaſt in a dry place, without being deprived of its colouring matter. It has retained this property for 130 years. Cochineal is employed in the preparation of the beautiful lake called *carmine*.

2881 Kermes. *Kermes.*—This alſo is an inſect which is employed in dyeing, from whence it has been called *coccus infectorius*. It is the *coccus ilicis* Lin. and is produced on a ſmall kind of oak, the *quercus coccifera*. The inſect attaches itſelf to the bark of the tree by a ſoft ſubſtance, which poſſeſſes many of the properties of caoutchouc.

When the living inſect is bruiſed, it gives out a red colour. It has a ſlightly bitter, rough, pungent taſte, but its ſmell is not unpleaſant. The dried inſect, or the kermes, imparts this odour and taſte to water and to alcohol, and communicates alſo to theſe liquids a deep red colour. By evaporation, an extract of the ſame colour is obtained. It is employed in dyeing, and has been alſo uſed in medicine.

2882 Crabs eyes. *Crabs eyes.*—The ſubſtance which has received this name, merely from its form, is a concrete body, convex on one ſide, and concave on the other. Two of theſe bodies are uſually found in the ſtomach of the crab, about the time that it changes its ſhell. After the ſhell is fully formed, they are no longer found, ſo that they are ſuppoſed to furniſh the materials of the new ſhell. They are entirely compoſed of carbonate of lime, a ſmall proportion of phoſphate of lime, and gelatine.

The cruſtaceous coverings of the crab, lobſter, and ſimilar animals, are compoſed of carbonate of lime, phoſphate of lime, and animal matter, or cartilage.

VI. Of Subſtances peculiar to Teſtaceous Animals.

The only ſubſtances to be mentioned peculiar to this

this claſs of animals are, ſhells, mother of pearl, and pearl.

2883 Shells. 1. *Shells.*—Such as have been particularly examined by Mr Hatchett, are divided into two claſſes. In the one he includes thoſe which have the appearance of porcelain, and have an enamelled ſurface, which he calls *porcellaneous ſhells*. Such are the various ſpecies of *voluta* and *cypræa*. Theſe ſhells were found by analyſis to be compoſed of carbonate of lime, with a ſmall portion of animal gluten.

2884 Mother of pearl. 2. *Mother of pearl.*—The ſecond claſs comprehends thoſe which are generally covered with a ſtrong epidermis, under which is the ſhell, compoſed chiefly of the ſubſtance called *nacre*, or *mother of pearl*. Such are the *oyſter*, the *river muſſel*, the *haliotis iris*, and the *turbo olearius*. In theſe the proportion of carbonate of lime is ſmaller, and that of the animal matter, greater.

2885 Pearl. 3. *Pearl.*—This is a concretion formed in ſeveral ſpecies of ſhells, as in ſome ſpecies of the oyſter and the muſſel. It is conſidered by ſome as a morbid concretion, owing to an exceſs of the ſhelly matter, or to a wound of the ſhell containing the animal. Pearls are of a ſilvery or bluiſh-white colour, irideſcent and brilliant. The refraction of the light is aſcribed to the lamellated ſtructure, for they conſiſt of concentric layers of carbonate of lime and membrane alternately arranged. The conſtituent parts of pearl are the ſame as mother of pearl.

VII. Subſtances peculiar to Zoophytes.

2886 Zoophytes. The zoophytes, many of which have been examined by Mr Hatchett, are compoſed of carbonate of lime, phoſphate of lime, and animal matter of different degrees of conſiſtency. In ſome the conſtituents are only carbonate of lime and a gelatinous matter. Such are ſome ſpecies of the madrepore, as the *madrepora muricata*, *virginea*, and *labyrinthica*; ſome ſpecies of millepore, as the *millepora cerulea* and *alcicornis*, and the *tubipora muſica*. Others again are compoſed of carbonate of lime and a membranaceous ſubſtance. Such are the *madrepora faſcicularis*, the *millepora celluloſa* and *faſcialis*, and the *iris hippuris*. White coral and articulated coralline are compoſed of ſimilar ſubſtances. Another diviſion of zoophytes are compoſed of carbonate of lime, a ſmall portion of phoſphate of lime, and membrane. Such are the *madrepora polymorpha*, the *gorgonia nobilis* or *red coral*, and the *gorgonia ſetoſa*; but ſome of the zoophytes are alſo found to conſiſt chiefly of animal matter, with ſcarcely any portion of earthy ſubſtance. To this diviſion belong ſome ſpecies of gorgonia, and many ſpecies of ſponge.

CHAP. XX. *Of Arts and Manufactures.*

In this chapter it was intended to give a general view of the application of the principles of chemiſtry to different arts and manufactures, ſuch as the manufacture of ſoap, of glaſs and porcelain; the arts of dyeing, bleaching and tanning. In this view it was propoſed to explain the principles of theſe arts and manufactures, ſo far as they depend on chemiſtry, leaving the detail to the different treatiſes on thoſe ſubjects in the courſe of the work. But the unavoidable length to which this article has extended, obliges us to refer our readers for the whole to the different treatiſes.

APPENDIX.

After the chapter on earths was printed off, we received the account of a new earth diſcovered by Klaproth.

Of *Ochroit*. This earth was diſcovered in a mineral to which Klaproth has given the name of ochroites, of which the external characters are the following:

1. The colour of this mineral is between carmoiſin red, clove-brown, and reddiſh-brown. It is compact, breaks ſplintering in irregular but not very ſharp or angular pieces. It is perfectly opaque, the powder is reddiſh-gray; it is not very hard, but brittle. The ſpecific gravity is 4.60. This mineral is found in the mine of Baſnætes, near Riddarhytta in Weſtmannland.

2887 Analyſis of the ochroites. A. "*a*. A piece of the mineral, after having been ignited to redneſs, loſt two per cent. Its reddiſh colour had been changed to brown. Its figure had ſuffered no alteration.

"*b*. One hundred grains of the finely levigated mineral ignited for half an hour, loſt five grains. Its colour was changed to a dark brown.

B. *a*. One hundred grains of ochroit, after being mixt with 200 grains of carbonate of potaſh, were ſtrongly ignited, the maſs which could not be rendered fluid, was reddiſh gray, and brittle. On being diffuſed through water, as uſual, the obtained ſolution was colourleſs. It remained perfectly tranſparent; a proof that it did not contain tungſten oxide; nitrate of ſilver, mercury, lead, barytes, &c. proved the abſence of acids.

b. The inſoluble reſidue of the laſt proceſs was boiled in nitro-muriatic acid, the ſiliceous earth being ſeparated, the ſolution was decompoſed by potaſh, and the whole boiled for ſome time. The alkaline fluid after being neutralized with muriatic acid, and then mingled with carbonate of potaſh, ſuffered no change.

C. *a*. Two hundred grains of the finely pulverized mineral, were firſt boiled in two ounces of muriatic acid, to which half an ounce of nitric acid was gradually added, and the digeſtion continued for ſome time. The whole became thus diſſolved except the ſilex contained in the mineral. Its quantity amounted to 68 grains.

b. To the ſolution obtained in the laſt proceſs, carbonate of ammonia was added ſo long, till no permanent precipitate was produced. On letting fall into it ſuccinate of ammonia, a curdly precipitate fell, which vaniſhed again on agitation, leaving merely a pale red precipitate of ſuccinate of iron. This being collected, waſhed, dried, and ſtrongly ignited, yielded nine grains of oxide of iron.

c. The fluid thus freed from iron, and now colourleſs, was decompoſed by carbonate of ammonia. The precipitate obtained was white, and weighed 168 grains; on being deprived of water and carbonic acid by heat, its white colour changed to cinnamon-brown. It weighed 109 grains.

d. All the water employed for waſhing the different precipitates were mingled, evaporated to dryneſs, and the ammoniacal ſalt volatilized; a minute quantity of a muriate was obtained, the baſis of which could not be determined.

2888 Peculiar earth.

From what follows it will become evident, that the cinnamon-brown precipitate (*c.*) which forms the principal part of the foſſil, is a peculiar earth, diſtinct from all the others hitherto known. The characteriſtic property which it poſſeſſes of acquiring a light-brown colour after being heated, has induced me to call it ochroit earth (A), which may alſo ſerve for the mineral itſelf.

According to this analyſis, 100 parts of the ochroit of Riddarhytta contain,

Ochroit earth,	54,50
Silex,	34
Oxide of iron,	4
Water, &c. (A. *b.*)	5
Loſs,	2
	100

Characteriſtic Properties of Ochroit Earth.

2889 Ochroit earth combines with carbonic acid.

1. Ochroit earth is capable of combining with carbonic acid during its precipitation from acids by carbonated alkalies, and ſtrongly conſolidating a portion of water.

One hundred grains of the earth precipitated by carbonate of ammonia, and ſtrongly dried, loſt on being neutralized by nitric acid, 23 grains: 100 grains of the ſame earth loſt, after being ſtrongly ignited, 35 grains: 100 parts of carbonate ochroit, therefore, conſiſts of

Ochroit earth	65
Carbonic acid	23
Water -	12
	100

2. Ochroit earth, after being freed from carbonic acid and water, by heat, always appears in the form of a cinnamon-brown powder. The intenſity of the colour is in proportion to the heat applied. This colour is not owing to the preſence of iron, or mangaueſe, &c. but it is a characteriſtic property of the earth.

3. Ochroit earth included in a charcoal crucible, and expoſed to the heat of the porcelain furnace, ſuffered no change whatever.

4. Urged by the blow-pipe, it becomes phoſphoreſcent; fuſed with phoſphate of ſoda and ammonia, it becomes tinged by it, without effecting a ſolution of the earth. The ſalt acquires merely a marbled lemon-yellow colour. Borax has likewiſe no chemical effect upon it. This ſalt only effects a mechanical diviſion. The earth always appears diffuſed through the borax in minute *flocculi*.

5. Ochroit earth mixed in different proportions with proper fluxes, and applied for painting of porcelain, proved unſucceſsful. The painted articles were light-brown, but the colour was not uniform; a proof that no combination had been effected.

6. Ochroit earth combined with carbonic acid is eaſily ſoluble with efferveſcence in acids. The taſte of the ſolution is very rough and aſtringent. The concentrated ſolution is of an amethyſt-red colour; diluted with water, it becomes colourleſs. Ignited ochroit earth, on the contrary, is difficultly ſoluble in acids in the cold; if nitric acid be employed, the ſolution is yellowiſh red.

7. The combination of ochroit earth with ſulphuric acid, is cryſtallizable. The figure of the cryſtals formed in the maſs of the fluid is the octahedron. They are heavy, of a pale-amethyſt colour, and difficultly ſoluble in water; but the ſulphate of ochroit, with exceſs of acid, is more ſoluble; the figure of the cryſtals formed on the ſides of the veſſel, is needle-ſhaped, radiating from a centre. They are more ſoluble than the former.

8. If a ſolution of ſulphate of ſoda be mingled with a ſolution of muriate or nitrate of ochroit, a mutual decompoſition takes place. A white inſoluble precipitate is formed, conſiſting of ſulphuric acid united to the ochroit earth. This combination may be decompoſed by boiling it with double its weight of carbonate of ſoda. By this means ochroit earth may be obtained very pure.

9. Ochroit earth is likewiſe ſoluble in ſulphurous acid, the ſolution cryſtallizes in needles of a pale amethyſt colour.

10. Muriatic acid diſſolves ochroit earth, and yields cryſtals, the figure of which is the priſm. It is ſoluble in alcohol without imparting to its flame any particular colour.

12. Acetite of ochroit could not be cryſtallized, but yielded an adheſive maſs.

13. Nitrate and muriate of ochroit are decompoſable by carbonated earths and alkalies, the precipitate is milk-white. Alkalies and earths freed from carbonic acid, occaſion a yellowiſh-gray precipitate.

14. Pruſſiate of potaſh precipitates ochroit from all its neutral ſolutions, milk-white. The precipitate is ſoluble in muriatic and nitric acid (B).

15. Tincture of galls occaſions no change in the ſolutions of this earth.

16. Hydroguretted hydroſulphuret of ammonia precipitates the ſolution of ochroit earth, yellowiſh white.

17. Water impregnated with ſulphurated hydrogen occaſions no change in the ſolutions of ochroit earth.

18. Succinates precipitate ochroit earth white.

19. Phoſphate

(A) From the Greek word ωχρος, (*flaveſcens*), browniſh-yellow.

(B) If the earth contained the muriates and quality of iron, it becomes by this means manifeſted.

19. Phoſphate of ſoda occaſions in the ſolutions of this earth a white precipitate, which again vaniſhes by the addition of nitric or muriatic acid.

20. Tartrites of potaſh alſo precipitate this earth white.

21. Oxalates effect a like decompoſition, the oxalate of ochroit, however, is not ſoluble in nitric or muriatic acids.

22. Alkalies and alkaline carbonates do not act on ochroit earth.

23. Ammonia feebly acts on it, under certain circumſtances, as may be evinced from the following experiment:

A ſolution of nitrate of ochroit, prepared by diſſolving 100 grains of carbonate of ochroit (not abſolutely free from iron,) in nitric acid, was decompoſed by carbonate of ammonia, and digeſted in the fluid, containing a conſiderable quantity of carbonate of ammonia in exceſs, for ſome days. The fluid which had acquired a yellow colour, was ſeparated and neutralized by ſulphuric acid, and then ſet in a warm place. A gray precipitate was thus obtained, which, on being dried, weighed $1\frac{1}{4}$ grains. This precipitate, after being diſſolved in nitric acid, yielded a blue precipitate by pruſſiate of potaſh; this being ſeparated, a white flocculent precipitate fell down by dropping into the remaining fluid carbonate of potaſh. This method is, therefore, applicable for ſeparating a minute quantity of iron, that may be contained in the fluid.

2890
General remarks and characters of the ochroit earth.

"From what has been ſtated, it becomes obvious, that the ochroit earth bears the neareſt relation to yttria; for, like this, it forms a connecting link between the earths and the metallic oxides. Like yttria, it has the property of forming a reddiſh coloured ſalt with ſulphuric acid, and is precipitable by pruſſiate of potaſh; but differs from yttria, that it does not form ſweet ſalts, that it is not (at leaſt very ſparingly) ſoluble in carbonate of ammonia; and that, when ignited, it acquired a cinnamon-brown colour. It farther differs from yttria by not being ſoluble in borax or phoſphate of ſoda when urged upon charcoal before the blow-pipe, which ſalts eaſily effect a ſolution of yttria, and melt with it alſo into a pellucid pearl" *.

---

* *Nichol. Jour.* viii. p. 212.

ERRATA in CHEMISTRY.

P. 483. l. 22. col. 1ſt. For *Berthollet* read *Bartholdi*.

P. 508. l. 10. col. 2d. It is ſaid that Mr Keir found that ſulphuric acid froze at 45° Fahrenheit. This is only inferred from the thermometer being ſtationary at 45° during the melting of the frozen acid. A greater degree of cold was always found neceſſary for its congelation. *Phil. Tranſ.* 1787. p. 279.

EXPLANATION of the PLATES.

Plate CXLII.

Fig. 1. Repreſents Harriſon's pendulum conſtructed on the principle of the unequal expanſion of metals.

Fig. 2. The calorimeter of Lavoiſier and Laplace, ſee page 476.

Fig. 3. Iron bottle and bent gun-barrel for procuring oxygen gas from mangane. The black oxide is reduced to powder, and introduced into the bottle A. The bent tube is put on the mouth of the bottle at C, and luted with the materials deſcribed at the foot of page 490. The bottle is then expoſed to a red heat, and the gas which comes over is received in jars on the pneumatic apparatus.

Fig. III. and 4. repreſent the apparatus for the decompoſition of water. See page 496.

Fig. 5. Pneumatic trough for collecting gaſeous bodies. Suppoſe a quantity of ſulphurated hydrogen gas is to be collected, which is deſcribed in page 505. The iron filings and ſulphur which were melted together in a crucible, and which then form a black brittle maſs, are to be introduced into the glaſs veſſels. Fig. 6. B is a bent tube ground to fit the mouth D, and is air-tight. To the other mouth C is fitted the ground ſtopper A. One end of the bent tube is fitted into the mouth D, and the other placed under the glaſs jar F on the ſhelf of the pneumatic trough E, which is filled with water about an inch above the ſurface of the ſhelf. The jar is alſo previouſly filled with water, cautiouſly inverted, and ſet on the ſhelf. The apparatus being thus adjuſted, muriatic acid is poured into the opening C, and the ground ſtopper is immediately replaced. A violent efferveſcence takes place, a great quantity of gas is diſengaged, and as there is no other way for it to eſcape it paſſes into the glaſs jar. When this is filled, it is removed to another part of the ſhelf; another jar which was previouſly filled with water is put into its place, and ſo on till the whole gas is collected.

Fig. 7. Papin's digeſter. A is the body of the veſſel, which has been generally made of copper or iron, very thick and ſtrong. BB are two ſtrong bars fixed to the ſides of the veſſel. To the upper end of theſe bars is fixed the croſs bar C, through which paſſes a ſtrong ſcrew D, which preſſes on the lid of the veſſel at E, ſo that it is enabled to reſiſt the elaſtic force of the vapour; and the water can thus be raiſed to a higher temperature than the ordinary boiling point.

Fig. 8. This repreſents an apparatus for diſtillation. A is the furnace, B is the body of the ſtill, which is generally made of copper; C is the top or head, made of the ſame metal. The vapour as it riſes from the liquid by the application of heat, paſſes along the tube D, which communicates with a ſpiral tube in the refrigeratory E, which being filled with cold water, the vapour is condenſed, and paſſes out at the other extremity of the tube F, and is received in the veſſel G.

Plate CXLIII.

Fig. 9. Glaſs Retort.

Fig. 10. Tubulated retort.

Fig. 11. Glaſs Alembic.

Fig. 12. Solution glaſs.

Fig. 13. Crucible.

Fig. 14. Apparatus for obtaining muriatic acid from muriate of ſoda by ſulphuric acid. The muriate of ſoda is introduced into the retort A, and by means of the bent tube B the ſulphuric acid is added. The matraſs C is adapted to the retort, to receive the portion of impure ſulphuric acid and muriatic acid which paſſes over towards the end of the operation. D, E, and F, are bottles containing water; the quantity of which ſhould be equal in weight to that of the ſalt employed. Theſe bottles are furniſhed with tubes of ſafety G G; or the tube of ſafety may be applied as H in the bottle E.

Fig. 15. Apparatus for impregnating fluids with gaſes. A is a tubulated retort which is joined to B, a tubulated receiver, from which a bent tube C paſſes to the ſecond receiver D. This laſt communicates with the bottle F by means of the bent tube E. The end of the tube C which enters the receiver D, is furniſhed with a valve which prevents the return of any gas from the receiver D to the receiver B, in caſe a vacuum ſhould take place in the courſe of the operation in the receiver B, or in the retort A. The gas which is not abſorbed by the water in the receiver D, paſſes through the tube E to the bottle F.

Fig. 16. A gazometer, which is a convenient apparatus for holding gaſes. It is uſually made of tin plate. A is an inverted veſſel, which exactly fits another, which is fixed within the cylinder B. When it is preſſed down to the bottom of the cylinder, water is poured in, by which means the ſmall quantity of air which remains in the intermediate ſpaces, is forced out, and the gas to be preſerved may be introduced at the lower ſtop-cock C. The veſſel A is nearly balanced by the weights DD, which are connected with it by means of the cords *a a a a*, which move on the pullies *b b b b*. As the gas enters the apparatus, it forces up the veſſel A, and in this way it may be completely filled. It is forced out by turning the ſtop-cock E, and preſſing down the veſſel A, and may be conveyed into a pneumatic apparatus, and received in jars by means of the flexible tube F.

INDEX.

Fig. 1.

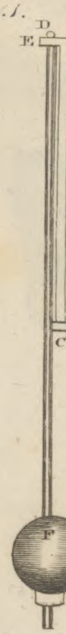


Fig. 2.

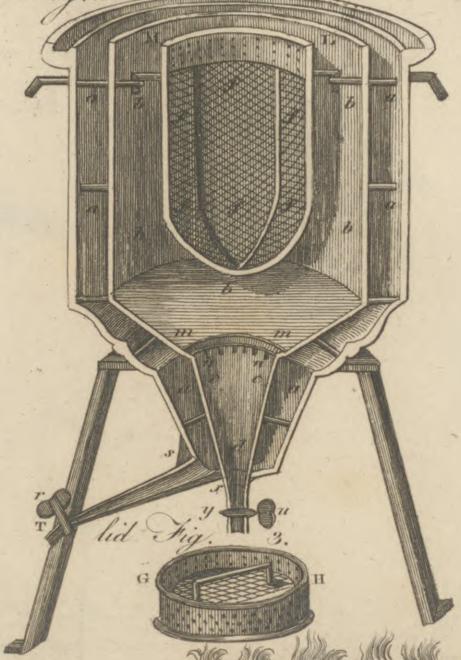


Fig. 3.

Fig. 5

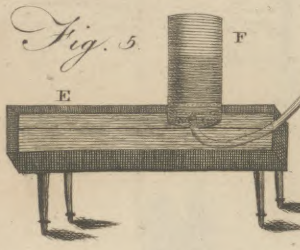


Fig. 6.

Fig. III.

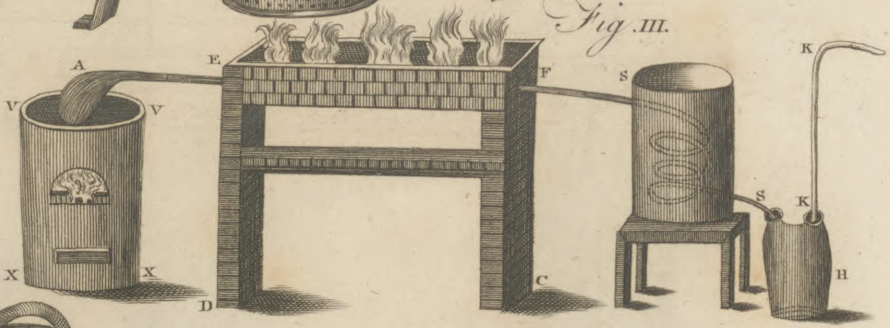


Fig. 8.

Fig. 4.

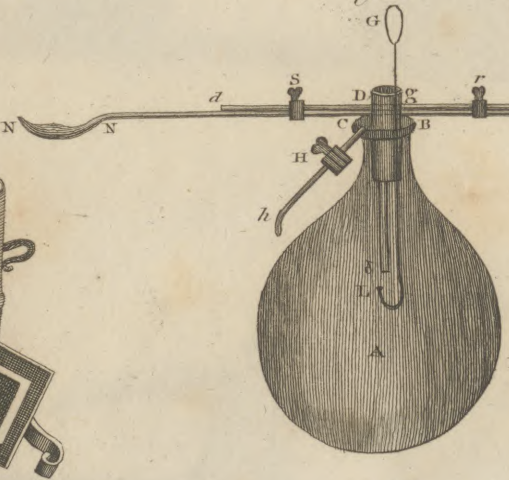
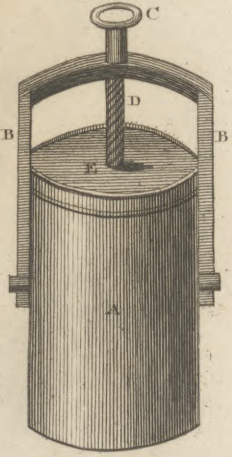


Fig. 7.



A.Bell Prin. Wal. Sculptor fecit.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

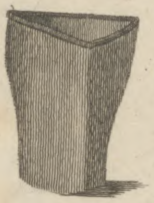


Fig. 14.

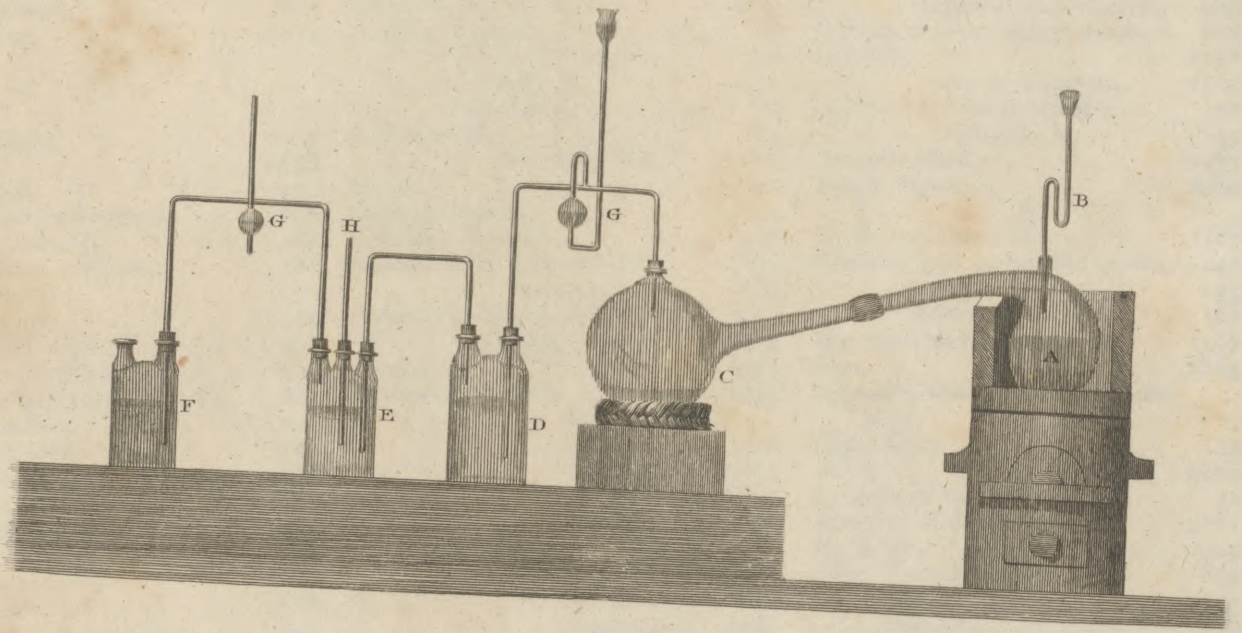
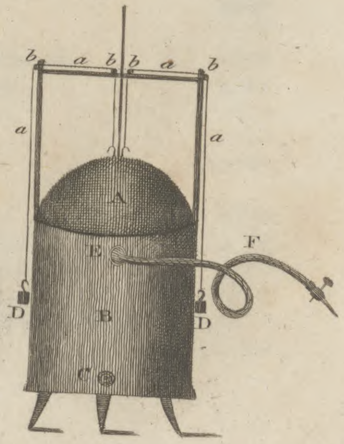


Fig. 15.

Fig. 16.



A. Bell Prin. Wal. Sculptor fecit.

CHEMNITZ, Martin, a famous Lutheran divine, the diſciple of Melancthon, was born at Britzen in Brandenburg, in 1522. He was employed in ſeveral important negociations by the princes of the ſame communion; and died in 1589. His principal work is the examen of the Council of Trent, in Latin.

CHEMOSH. See Chamos.

CHEMOSIS, a diſeaſe of the eyes, proceeding from an inflammation; wherein the white of the eye ſwells above the black, and overtops it to ſuch a degree, that there appears a ſort of gap between them. Others define it to be an elevation of the membrane which ſurrounds the eye, and is called the *white;* being an affection of the eye, like white fleſh.

CHENOPODIUM, Goose-Foot, or *Wild Orach:* See Botany *Index*.

CHEPELIO, an iſland in the bay of Panama and province of Darien, in South America, ſituated about three leagues from the city of Panama, which it ſupplies with proviſions. W. Long. 81. N. Lat. 9.

CHEPSTOW, a market town of Monmouthſhire in England, ſeated on the river Wye near its mouth, in W. Long. 2. 40. N. Lat. 51. 40.

CHEQ, or Cherif, the prince of Mecca, who is, as it were, high-prieſt of the law, and ſovereign pontiff of all the Mahometans of whatever ſect or country they be. See Caliph.

The grand ſignior, ſophis, moguls, khans of Tartary, &c. ſend him yearly preſents, eſpecially tapeſtry to cover Mahomet's tomb withal, together with a ſumptuous tent for himſelf, and vaſt ſums of money to provide for all the pilgrims during the 17 days of their devotion.

CHERASCO, a ſtrong and conſiderable town of Italy, in Piedmont, and capital of a territory of the ſame name, with a ſtrong citadel belonging to the king of Sardinia, where he retired in 1706, during the ſiege of Turin. It is ſeated at the confluence of the rivers Sturia and Tanaro, upon a mountain. E. Long. 7. 55. N. Lat. 44. 35.

CHERBURG, a ſea port town of France, in Normandy, with a harbour and Auguſtine abbey. It is remarkable for the ſea-fight between the Engliſh and French fleets in 1692, when the latter were beat, and upwards of twenty of their men of war burnt near Cape la Hogue. The Britiſh landed here in Auguſt 1758, and took the town, with the ſhips in the baſon, demoliſhed the fortifications, and ruined the other works which had been long carried on for enlarging the harbour and rendering it more ſafe and convenient. Within theſe few years it has been attempted again to improve the harbour, and rebuild the works; but after conſiderable progreſs had been made, a great part of them ſuddenly gave way, and the enterpriſe it is thought will not be again reſumed. E. Long. 1. 38. N. Lat. 49. 38.

CHEREM, among the Jews, is uſed to ſignify a ſpecies of annihilation. See Annihilation.

The Hebrew word *cherem*, ſignifies properly to *deſtroy*, *exterminate*, *devote*, or *anathematiſe*.

Cherem is likewiſe ſometimes taken for that which is conſecrated, vowed, or offered to the Lord, ſo that it may no longer be employed in common or profane uſes. No devoted thing that a man ſhall devote unto the Lord, of all that he hath of man and beaſt, and of the field of his poſſeſſion, ſhall be ſold or redeemed; every devoted thing is moſt holy to the Lord: none devoted, which ſhall be devoted of men, ſhall be redeemed, but ſhall ſurely be put to death. There are ſome who aſſert that the perſons thus devoted were put to death; whereof Jephtha's daughter is a memorable example. Judges xi. 29. &c.

Cherem is alſo uſed for a kind of excommunication in uſe among the Jews. See Niddui.

CHERESOUL, or Chahrzul, a town of Turkey in Aſia, capital of Curdiſtan, and the ſeat of a beglerbeg. E. Long. 45. 15. N. Lat. 36. 0.

CHERILUS, of Samos, a Greek poet, flouriſhed 479 years before Chriſt. He ſung the victory gained by the Athenians over Xerxes, and was rewarded with a piece of gold for every verſe. His poem had afterwards the honour of being rehearſed yearly with the works of Homer.

CHERLERIA. See Botany *Index*.

CHERLESQUIOR, in Turkiſh affairs, denotes a lieutenant general of the grand ſignior's armies.

CHERMES, in *Zoology*, a genus of inſects belonging to the order of inſecta hemiptera. See Entomology *Index*.

Chermes Mineral. See Kermes.

CHERRY-island, an iſland in the northern ocean; lying between Norway and Greenland, in E. Long. 20. 5. N. Lat. 75. 0.

Cherry-Tree. See Prunus, Botany *Index*.

CHERSO, an iſland in the gulf of Venice, with a town, of the ſame name near Croatia, belonging to the Venetians. The air is good, but the ſoil ſtony; however, it abounds in wine, cattle, oil, and excellent honey. E. Long. 15. 5. N. Lat. 45. 8.

CHERSONESUS, among modern geographers, the ſame with a peninſula; or a continent almoſt encompaſſed round with the ſea, only joining to the main land by a narrow neck or iſthmus. The word is Greek χερσονησος; of χερσος, *land*, and νησος, *iſland;* which ſignifies the ſame. In ancient geography, it was applied to ſeveral peninſulas; as the Cherſoneſus Aurea, Cimbrica, Taurica, and Thracica, now thought to be Malacca, Jutland, Crim Tartary, and Romania.

CHERT, Petrosilex, *Lapis Corneus*, the *Hornſtein* of the Germans. See Mineralogy *Index*.

CHERTZEY, a market town of Surrey in England, about ſeven miles weſt from Kingſton upon Thames. W. Long. 30. N. Lat. 51. 25.

CHERUB, (plural, Cherubim); a celeſtial ſpirit, which in the hierarchy is placed next to the ſeraphim. See Hierarchy.

The term *cherub*, in Hebrew, is ſometimes taken for a calf or ox. Ezekiel ſets down the face of the cherub as ſynonymous to the face of an ox. The word *cherub*, in Syriac and Chaldee, ſignifies to *till* or *plow*, which is the proper work of oxen. Cherub alſo ſignifies *ſtrong* and *powerful*. Grotius ſays, that the cherubim were figures much like that of a calf. Bochart thinks likewiſe, that the cherubim were more like to the figure of an ox than to any thing beſides; and Spencer is of the ſame opinion. Laſtly, St John, in the Revelation, calls cherubim *beaſts*. Joſephus ſays the cherubim were extraordinary creatures, of a figure unknown to mankind. Clemens of Alexandria believes,

lieves, that the Egyptians imitated the cherubim of the Hebrews in the repreſentations of their ſphinxes and their hieroglyphical animals. All the ſeveral deſcriptions, which the ſcripture gives us of cherubim, differ from one another; but all agree in repreſenting them as a figure compoſed of various creatures, as a man, an ox, an eagle, and a lion. Such were the cherubim deſcribed by Ezekiel. Thoſe which Iſaiah ſaw, and are called *ſeraphim* by him, had the figure of a man with ſix wings; with two whereof they covered their faces, with two more they covered their feet, and with the two others they flew. Thoſe which Solomon placed in the temple at Jeruſalem are ſuppoſed to have been nearly of the ſame form. Thoſe which St John deſcribes in the Revelations were all eyes before and behind, and had each ſix wings. The firſt was in the form of a lion, the ſecond in that of a calf, the third of a man, and the fourth of an eagle. The figure of the cherubim was not always uniform, ſince they are differently deſcribed in the ſhapes of men, eagles, oxen, lions, and in a compoſition of all theſe figures put together. Moſes likewiſe calls theſe ſymbolical or hieroglyphical repreſentations, which were embroidered on the veils of the tabernacle, *cherubim* of coſtly work. Such were the ſymbolical figures which the Egyptians placed at the gates of their temples and the images of the generality of their gods, which were commonly nothing but ſtatues compoſed of men and animals.

CHERVIL. See CHÆROPHYLLUM, BOTANY *Index*.

CHESAPEAK, in America, one of the largeſt bays in the known world. Its entrance is between Cape Charles and Cape Henry in Virginia, 12 miles wide; and it extends 270 miles to the northward, dividing Virginia and Maryland. Through this extent it is from 7 to 18 miles broad, and generally about 9 fathoms deep; affording many commodious harbours, and a ſafe and eaſy navigation. It receives the waters of the Suſquehannah, Potomak, Rappahannock, York, and James rivers, which are all large and navigable.

CHESELDEN, WILLIAM, an eminent anatomiſt and ſurgeon, was born at Burrow on the Hill, in the county of Leiceſter, deſcended from an ancient family in the county of Rutland, whoſe arms and pedigree are in Wright's "Hiſtory of Rutland." He received the rudiments of his profeſſional ſkill at Leiceſter; and married Deborah Knight, a citizen's daughter, by whom he had one daughter, Williamina Deborah. In 1713 he publiſhed his Anatomy of the Human Body, one volume 8vo; and in 1723, A Treatiſe on the High Operation for the Stone. He was one of the earlieſt of his profeſſion who contributed by his writings to raiſe it to its preſent eminence. In the beginning of 1736, he was thus honourably mentioned by Mr Pope: "As ſoon as I had ſent my laſt letter, I received a moſt kind one from you, expreſſing great pain for my late illneſs at Mr Cheſelden's. I conclude you was eaſed of that friendly apprehenſion in a few days after you had diſpatched your's, for mine muſt have reached you then. I wondered a little at your query, Who Cheſelden was? It ſhows that the trueſt merit does not travel ſo far any way as on the wings of poetry: he is the moſt noted and moſt deſerving man in the whole profeſſion of chirurgery; and has ſaved the lives of thouſands by his manner of cutting for the ſtone." He appears to have been on terms of the moſt intimate friendſhip with Mr Pope, who frequently, in his Letters to Mr Richardſon, talks of dining with Mr Cheſelden, who then lived in or near Queen Square. In February 1737, Mr Cheſelden was appointed ſurgeon to Chelſea hoſpital. As a governor of the Foundling Hoſpital, he ſent a benefaction of 50l. to that charity, May 7. 1751, incloſed in a paper with the following lines:

> 'Tis what the happy to th' unhappy owe;
> For what man gives, the gods by him beſtow. POPE.

He died at Bath, April 11. 1752, of a diſorder ariſing from drinking ale after eating hot buns. Finding himſelf uneaſy, he ſent for a phyſician, who adviſed vomiting immediately; and if the advice had been taken, it was thought his life might have been ſaved. By his direction, he was buried at Chelſea.

CHESHIRE, a maritime county of England, bounded by Lancaſhire on the north; Shropſhire and part of Flintſhire, on the ſouth; Derbyſhire and Staffordſhire, on the eaſt and ſouth-eaſt; and Denbighſhire, and part of Flintſhire, on the weſt and north-weſt. It extends in length about 44 miles, in breadth 25; and is ſuppoſed to contain 125,000 inhabitants. Both the air and ſoil in general are good. In many places of the country are peat-moſſes, in which are often found trunks of fir-trees, ſometimes ſeveral feet under ground, that are uſed by the inhabitants both for fuel and candles. Here alſo are many lakes and pools well ſtored with fiſh; beſides the rivers Merſey, Weaver, and Dee, which laſt falls into a creek of the Iriſh ſea near Cheſter. This county alſo abounds with wood: but what it is chiefly remarkable for, is its cheeſe, which has a peculiar flavour, generally thought not to be inferior to any in Europe; (ſee CHEESE). The principal towns are, Cheſter the capital, Cholmondely, Namptwitch, &c.

William the Conqueror erected this county into a palatinate, or county-palatine, in favour of his nephew Hugh Lupus, to whom he granted the ſame ſovereignty and juriſdiction in it that he himſelf had in the reſt of the iſland. By virtue of this grant, the town of Cheſter enjoyed ſovereign juriſdiction within its own precincts; and that in ſo high a degree, that the earls held parliaments, conſiſting of their barons and tenants, which were not bound by the acts of the Engliſh parliament: but the exorbitant power of the palatinates was at laſt reduced by Henry VIII.; however, all caſes and crimes, except thoſe of error, foreign plea, foreign voucher, and high-treaſon, are ſtill heard and determined within the ſhire. The earls were anciently ſuperiors of the whole county, and all the landholders were mediately or immediately their vaſſals, and under the like ſovereign allegiance to them as they were to the kings of England; but the earldom was united to the crown by Edward III. ſince which time, the eldeſt ſons of kings of England have always been earls of Cheſter, as well as princes of Wales. Cheſhire ſends four members to parliament; two for the county, and two for the capital.

CHESNE, ANDREW DU, ſtyled the father of French hiſtory,

hiſtory, was born in 1584. He wrote, 1. A hiſtory of the popes. 2. A hiſtory of England. 3. An inquiry into the antiquities of the towns of France. 4. A hiſtory of the cardinals. 5. A bibliotheca of the authors who have written the hiſtory and topography of France, &c. He was cruſhed to death by a cart, in going from Paris to his country houſe at Verriere, in 1640.

CHESNUT-TREE. See FAGUS, BOTANY *Index*.

CHESS, an ingenious game performed with different pieces of wood, on a board divided into 64 ſquares or houſes; in which chance has ſo ſmall a ſhare, that it may be doubted whether a perſon ever loſt a game but by his own fault.

Each gameſter has eight dignified pieces, viz. a king, a queen, two biſhops, two knights, and two rooks, alſo eight pawns: all which, for diſtinction's ſake, are painted of two different colours, as white and black.

As to their diſpoſition on the board, the white king is to be placed on the fourth black houſe from the corner of the board, in the firſt and lower rank; and the black king is to be placed on the fourth white houſe on the oppoſite, or adverſary's, end of the board. The queens are to be placed next to the kings, on houſes of their own colour. Next to the king and queen, on each hand, place the two biſhops; next to them, the two knights; and laſt of all, on the corners of the board, the two rooks. As to the pawns, they are placed, without diſtinction, on the ſecond rank of the houſe, one before each of the dignified pieces.

Having thus diſpoſed the men, the onſet is commonly begun by the pawns, which march ſtraight forward in their own file, one houſe at a time, except the firſt move, when it can advance two houſes, but never moves backwards: the manner of their taking the adverſary's men is ſidewiſe, in the next houſe forwards; where having captivated the enemy, they move forward as before. The rook goes forward or croſswiſe through the whole file, and back again. The knight ſkips backward and forward to the next houſe, ſave one, of a different colour, with a ſideling march, or a ſlope, and thus kills his enemies that fall in his way, or guards his friends that may be expoſed on that ſide. The biſhop walks always in the ſame colour of the field that he is placed in at firſt, forward and backward, aſlope, or diagonally, as far as he liſts. The queen's walk is more univerſal, as ſhe takes all the ſteps of the before-mentioned pieces, excepting that of the knight; and as to the king's motion, it is one houſe at a time, and that either forward, backward, ſloping, or ſidewiſe.

As to the value of the different pieces, next to the king is the queen, after her the rooks, then the biſhops, and laſt of the dignified pieces comes the knight. The difference of the worth of pawns, is not ſo great as that of noblemen; only, it muſt be obſerved, that the king's biſhop's pawn is the beſt in the field, and therefore the ſkilful gameſter will be careful of him.

It ought alſo to be obſerved, that whereas any man may be taken, when he falls within the reach of any of the adverſary's pieces, it is otherwiſe with the king, who, in ſuch a caſe, is only to be ſaluted with the word *check*, warning him of his danger, out of which it is abſolutely neceſſary that he move; and if it ſo happen that he cannot move without expoſing himſelf to the like inconveniency, it is check-mate, and the game is loſt. The rules of the game are,

1. In order to begin the game, the pawns muſt be moved before the pieces, and afterwards the pieces muſt be brought out to ſupport them. The king's, queen's, and biſhop's pawns, ſhould be moved firſt, that the game may be well opened; the pieces muſt not be played out early in the game, becauſe the player may thereby loſe his moves: but above all, the game ſhould be well arranged before the queen is played out. Uſeleſs checks ſhould alſo be avoided, unleſs ſome advantage is to be gained by them, becauſe the move may be loſt, if the adverſary can either take or drive the piece away.

2. If the game is crowded, the player will meet with obſtructions in moving his pieces; for which reaſon he ſhould exchange pieces or pawns, and caſtle (A) his king as ſoon as it is convenient, endeavouring at the ſame time to crowd the adverſary's game, which may be done by attacking his pieces with the pawns, if the adverſary ſhould move his pieces out too ſoon.

3. The men ſhould be ſo guarded by one another, that if a man ſhould be loſt, the player may have it in his power to take one of the adverſary's in return; and if he can take a ſuperior piece in lieu of that which he loſt, it would be an advantage, and diſtreſs the adverſary.

4. The adverſary's king ſhould never be attacked without a force ſufficient; and if the player's king ſhould be attacked without having it in his power to attack the adverſary's, he ſhould offer to make an exchange of pieces, which may cauſe the adverſary to loſe a move.

5. The board ſhould be looked over with attention, and the men reconnoitred, ſo as to be aware of any ſtroke that the adverſary might attempt in conſequence of his laſt move. If, by counting as many moves forward as poſſible, the player has a proſpect of ſucceſs, he ſhould not fail doing it, and even ſacrifice a piece or two to accompliſh his end.

6. No man ſhould be played till the board is thoroughly examined, that the player may defend himſelf againſt any move the adverſary has in view; neither ſhould any attack be made till the conſequences of the adverſary's next move are conſidered; and when an attack may with ſafety be made, it ſhould be purſued without catching at any bait that might be thrown out in order for the adverſary to gain a move, and thereby cauſe the deſign to miſcarry.

7. The queen ſhould never ſtand in ſuch a manner before the king, that the adverſary, by bringing a rook or biſhop, could check the king if ſhe were not there; as it might be the loſs of the queen.

(A) *Caſtle his king*, is to cover the king with a caſtle; which is done by a certain move which each player has a right to whenever he thinks proper.

8. The adverſary's knight ſhould never be ſuffered to check the king and queen, or king and rook, or queen and rook, or the two rooks at the ſame time; eſpecially if the knight is properly guarded: becauſe, in the two firſt caſes, the king being forced to go out of check, the queen or the rook muſt be loſt; and in the two laſt caſes a rook muſt be loſt at leaſt for a worſe piece.

9. The player ſhould take care that no guarded pawn of the adverſary's fork two of his pieces.

10. As ſoon as the kings have caſtled on different ſides of the board, the pawns on that ſide of the board ſhould be advanced upon the adverſary's king, and the pieces, eſpecially the queen and rook, ſhould be brought to ſupport them; and the three pawns belonging to the king that is caſtled muſt not be moved.

11. The more moves a player can have as it were in ambuſcade, the better; that is to ſay, the queen, biſhop, or rook, is to be placed behind a pawn or a piece, in ſuch a poſition as that upon playing that pawn or piece a check is diſcovered upon the adverſary's king, by which means a piece or ſome advantage is often gained.

12. An inferior piece ſhould never be guarded with a ſuperior, when a pawn would anſwer the ſame purpoſe; for this reaſon, the ſuperior piece may remain out of play; neither ſhould a pawn be guarded with a piece when a pawn would do as well.

13. A well ſupported pawn that is paſſed often coſts the adverſary a piece; and when a pawn or any other advantage is gained without endangering the loſs of the move, the player ſhould make as frequent exchanges of pieces as he can. The advantage of a paſſed pawn is this: for example, if the player and his adverſary have each three pawns upon the board, and no piece, and the player has one of his pawns on one ſide of the board, and the other two on the other ſide, and the adverſary's three pawns are oppoſite to the player's two pawns, he ſhould march with his king as ſoon as he can, and take the adverſary's pawns: If the adverſary goes with his king to ſupport them, the player ſhould go on to queen with his ſingle pawns; and then if the adverſary goes to hinder him, he ſhould take the adverſary's pawns, and move the others to queen (B).

14. When the game is near finiſhed, each party having only three or four pawns on each ſide of the board, the kings muſt endeavour to gain the move in order to win the game. For inſtance, when the player brings his king oppoſite to the adverſary's with only one ſquare between, he will gain the move.

15. If the adverſary has his king and one pawn on the board, and the player has only his king, he cannot loſe the game, provided he brings his king oppoſite to the adverſary's, when the adverſary is directly before or on one ſide of his pawn, and there is only one ſquare between the kings.

16. If the adverſary has a biſhop and one pawn on the rook's line, and this biſhop is not of the colour that commands the corner ſquare the pawn is going to, and the player has only his king, if he can get into that corner, he cannot loſe; but, on the contrary, may win by a ſtale (C).

17. If the player has greatly the diſadvantage of the game, having only his queen left in play, and his king happens to be in a poſition to win, as above-mentioned, he ſhould keep giving check to the adverſary's king, always taking care not to check him where he can interpoſe any of his pieces that make the ſtale; by ſo doing he will at laſt force the adverſary to take his queen, and then he will win the game by being in a ſtale-mate.

18. The player ſhould never cover a check with a piece that a pawn puſhed upon it may take, for fear of getting only the pawn in exchange for the piece.

19. A player ſhould never crowd his adverſary up with pieces, for fear of giving a ſtale-mate inadvertently, but always ſhould leave room for his king to move.

By way of corroborating what has been already ſaid with reſpect to this game, it is neceſſary to warn a player againſt playing a timid game. He ſhould never be too much afraid of loſing a rook for an inferior piece; becauſe although a rook is a better piece than any other except the queen, it ſeldom comes into play to be of any great uſe till at the end of the game; for which reaſon it is often better to have an inferior piece in play, than a ſuperior one to ſtand ſtill, or moving to no great purpoſe. If a piece is moved, and is immediately drove away by a pawn, it may be reckoned a bad move, becauſe the adverſary gains a double advantage over the player, in advancing at the ſame time the other is made to retire; although the firſt move may not ſeem of conſequence between equal players, yet a move or two more loſt after the firſt, makes the game ſcarcely to be recovered.

There never wants for variety at this game, provided the pieces have been brought out regularly; but if otherwiſe, it often happens that a player has ſcarce any thing to play.

Many indifferent players think nothing of the pawns, whereas three pawns together are ſtrong; but four, which conſtitute a ſquare, with the aſſiſtance of other pieces, well managed, make an invincible ſtrength, and in all probability may produce a queen when very much wanted. It is true, that two pawns with a ſpace between are no better than one; and if there ſhould be three over each other in a line, the game cannot be in a worſe way. This ſhows that the pawns are of great conſequence, provided they are kept cloſe together.

Some middling players are very apt to riſk loſing the game in order to recover a piece: this is a miſtake; for it is much better to give up a piece and attack the enemy in another quarter; by ſo doing, the player has a chance of ſnatching a pawn or two from,

---

(B) *To queen*, is to make a queen; that is, to move a pawn into the adverſary's back row, which is the rule at this game when the original one is loſt.

(C) When the king is blocked up ſo as to have no move at all.

or gaining ſome advantage over, the adverſary, whilſt his attention is taken up in purſuing this piece.

If the queen and another piece are attacked at the ſame time, and that by removing the queen the piece muſt be loſt; provided two pieces can be gained in exchange for the queen, the queen ſhould be given up, it being the difference of three pieces, and conſequently more than the value of the queen. By loſing the queen, the game is not thrown into that diſorder which it would otherwiſe have been; in this caſe it would be judicious to give the queen for even a piece, or a pawn or two; it being well known among good players, that he who begins the attack, and cannot maintain it, being obliged to retire, generally loſes the game.

A player ſhould never be fond of changing without reaſon, becauſe the adverſary, if he is a good player, will ruin his ſituation, and gain a conſiderable advantage over him. But rather than loſe a move, when a player is ſtronger than the adverſary, it is good play to change, for he thereby increaſes his ſtrength.

When the game is almoſt drawn to a concluſion, the player ſhould recollect that his king is a capital piece, and conſequently ſhould keep him in motion; by ſo doing, he generally gets the move, and often the game.

As the queen, rook, and biſhop, operate at a diſtance, it is not always neceſſary in the attack to have them near the adverſary's king.

If a man can be taken with different pieces, the player ſhould take his time, and conſider which of thoſe pieces is the beſt to take it with.

If a piece can be taken almoſt at any time, the player ſhould not be in a hurry about it, but try to make a good move elſewhere before he take it.

A player ſhould be cautious how he takes his adverſary's pawn with his king, as it often happens to be a ſafeguard to it.

After all that has been ſaid, it is ſtill neceſſary for us to adviſe thoſe who would play well at this game, to be very cool and attentive to the matter in queſtion: for it is impoſſible that any perſon in the univerſe can be capable of playing at cheſs if their thoughts are employed elſewhere. The laws at this game are,

1. If a player touches his man, he muſt play it; and if he quits it, he cannot recal it.

2. If by miſtake or otherwiſe a falſe move is played, and the adverſary takes no notice of it till he hath played his next move, it cannot be recalled by either of the parties.

3. If a player miſplaces the men, and he plays two moves, it is at the option of the adverſary to permit him to begin the game or not.

4. If the adverſary plays or diſcovers a check to a player's king, and give no notice of it, the player may let him ſtand ſtill till he does.

5. After the king is moved, a player cannot caſtle.

Saraſin has an expreſs treatiſe on the different opinions of the origin of the Latin *ſchacchi*, whence the French *ethecs*, and our *cheſs*, is formed. Menage is alſo very full on the ſame head. Leunclavius takes it to come from *Uſcoches*, famous Turkiſh robbers: P. Sirmond, from the German *ſcache*, "theft;" and that from *calculus*. He takes *cheſs* to be the ſame with the *ludus latrunculorum* of the Romans, but miſtakenly. This opinion is countenanced by Voſſius and Salmaſius, who derive the word from *calculus*, as uſed for *latrunculus*, G. Toloſanus derives it from the Hebrew, *ſcarch, valavit, et mat mortuus*; whence *check* and *checkmate*. Fabricius ſays, a celebrated Perſian aſtronomer, one Schatrenſcha, invented the game of *cheſs*; and gave it his own name, which it ſtill bears in that country. Nicod derives it from *ſchecque*, or *xeque*, a Mooriſh word for lord, king, and prince. Bochart adds that *ſcach* is originally Perſian; and that *ſcachmat* in that language, ſignifies the king is dead.—The opinion of Nicod and Bochart, which is likewiſe that of Scriverius, appears the moſt probable.

Mr Twiſs mentions a ſmall treatiſe on cheſs, written, as he ſuppoſes, about 400 years ago; at the end of which is a repreſentation of a round cheſs-board, with directions for placing the men upon it. In this the knight can cover the 64 ſquares on the board at as many moves. The board is divided into theſe 64 parts by four concentric circles, having an empty ſpace in the middle; and each of theſe is divided into 16 parts. Number 1 is placed in the outermoſt circle; number 2 in the third circle counting inwards, in the diviſion to the right hand of the former; number 3 is placed in the outermoſt circle, in the diviſion to the right hand of 2; 4 in the third circle counting inwards to the right hand of three; and thus alternately from the firſt to the third, and from the third to the firſt circle, till the round is completed by 16 on the third circle to the left hand of 1. Number 17 is then placed on the diviſion of the innermoſt circle to the right hand of 1; 18 on the ſecond circle counting inwards, to the right hand of 17; and thus alternately from the fourth to the ſecond, and from the ſecond to the fourth circles, until the round is completed by 32, directly below number 1. Number 33 then is placed on the third circle directly to the right hand of number 2; 34 on the fourth circle, to the right hand of 4; and thus alternately between the third and fourth circles, until the round is again completed by 48 on the fourth circle, directly below number 33. The numbers are now placed in a retrograde faſhion; 50 on the outer circle in that diviſion immediately to the right hand of 1; 51 on the third circle, to the left hand of 2; and directly below number 32; 52 is then placed on the outer circle, immediately on the left hand of 1; 53 on the third circle directly to the left hand of 16; and thus alternately on the firſt and third circles, until the laſt ground is completed by 64 between the number 3 and 5. On this round cheſs-board, ſuppoſing the black king to be placed in number 48 on the fourth circle, the queen ſtands on number 17 at his left hand; the biſhops in 33 and 2; the knights 18 and 47; the caſtles in 3 and 50; the pawns on 19, 4, 49, 64, and 46 51, 32, 1. The white king will then ſtand in 25, oppoſite to the black queen; the white queen in 40 oppoſite to the black king, and ſo on. In playing on a board of this kind, it will be found, that the power of the caſtle is double to that in the common game, and that of the biſhop only one half; the former having 16 ſquares to range in, and the laſt only four. The king can caſtle only one way; and it is very difficult to bring the game to a concluſion.

With regard to the origin of the game at cheſs, we are much in the dark. Though it came to us from

the

the Saracens, it is by no means probable that they were the original inventors of it. According to ſome, it was invented by the celebrated Grecian hero Diomedes. Others ſay, that two Grecian brothers, Ledo and Tyrrheno, were the inventors; and that being much preſſed with hunger, they ſought to alleviate the pain by this amuſement.

According to Mr Irwin it is a game of Chineſe invention. During his reſidence in India, he found that a tradition of this nature exiſted among the Bramins, with whom he frequently played the game. While he was at Canton in 1793, he gives the following account of the information which he acquired relative to the origin of the game of cheſs. "A young mandarin, of the profeſſion of arms, having an inquiſitive turn, was my frequent viſitor; and, what no queſtions could have drawn from him, the accidental ſight of an Engliſh cheſs-board effected. He told me, that the Chineſe had a game of the ſame nature; and, on his ſpecifying a difference in the pieces and board, I perceived, with joy, that I had diſcovered the deſideratum of which I had been ſo long in ſearch. The very next day my mandarin brought me the board and equipage; and I found, that the Bramins were neither miſtaken touching the board, which has a river in the middle to divide the contending parties, nor in the powers of the king, who is intrenched in a fort, and moves only in that ſpace, in every direction. But, what I did not before hear, nor do I believe is known out of this country, there are two pieces, whoſe movements are diſtinct from any in the Indian or European game. The mandarin, which anſwers to our biſhop, in his ſtation and ſidelong courſe, cannot, through age, croſs the river; and a rocket-boy, ſtill uſed in the Indian armies, who is ſtationed between the lines of each party, acts literally with the motion of the rocket, by vaulting over a man, and taking his adverſary at the other end of the board. Except that the king has his two ſons to ſupport him, inſtead of a queen, the game, in other reſpects, is like ours; as will appear in the plan of the board and pieces I have the honour to encloſe, together with directions to place the men and play the game.

"As the young man who had diſcovered this to me was of a communicative and obliging diſpoſition, and was at this time purſuing his ſtudies in the college of Canton, I requeſted the favour of him to conſult ſuch ancient books as might give ſome inſight into the period of the introduction of cheſs into China; to confirm, if poſſible, the idea that ſtruck me of its having originated here. The acknowledged antiquity of this empire, the unchangeable ſtate of her cuſtoms and manners, beyond that of any other nation in the world; and more eſpecially the ſimplicity of the game itſelf, when compared to its compaſs and variety in other parts, appeared to give a colour to my belief. That I was not diſappointed in the event, I have no doubt will be allowed, on the peruſal of the tranſlation of a manuſcript extract, which my friend Tinqua brought me, in compliance with my deſire; and which, accompanied by the Chineſe manuſcript, goes under cover to your lordſhip. As the mandarin ſolemnly aſſured me that he took it from the work quoted, and the tranſlation has been as accurately made as poſſible, I have no heſitation to deliver the papers as authentic.

"From theſe premiſes I have therefore ventured to make the following inferences:—That the game of cheſs is probably of Chineſe origin. That the confined ſituation and powers of the king, reſembling thoſe of a monarch in the earlier parts of the world, countenance this ſuppoſition; and that, as it travelled weſtward, and deſcended to later times, the ſovereign prerogative extended itſelf, until it became unlimited, as in our ſtate of the game. That the agency of the princes, in lieu of the queen, beſpeaks forcibly the nature of the Chineſe cuſtoms, which exclude females from all power or influence whatever; which princes, in its paſſage through Perſia, were changed into a ſingle vizier, or miniſter of ſtate, with the enlarged portion of delegated authority that exiſts there; inſtead of whom, the European nations, with their uſual gallantry, adopted a queen on their board (D). That the river between the parties is expreſſive of the general face of this country, where a battle could hardly be fought without encountering an interruption of this kind, which the ſoldier was here taught to overcome; but that, on the introduction of the game into Perſia, the board changed with the dry nature of the region, and the conteſt was decided on terra firma. And laſtly, that in no account of the origin of cheſs, that I have read, has the tale been ſo characteriſtic or conſiſtent as that which I have the honour to offer to the Iriſh academy. With the Indians, it was deſigned by a Bramin to cure the melancholy of the daughter of a rajah. With the Perſians, my memory does not aſſiſt me to trace the fable; though, if it were more to the purpoſe, I think I ſhould have retained it. But, with the Chineſe, it was invented by an experienced ſoldier, on the principles of war. Not to diſpel love-ſick vapours, or inſtruct a female in a ſcience that could neither benefit nor inform her; but to quiet the murmurs of a diſcontented ſoldiery; to employ their vacant hours in leſſons on the military art, and to cheriſh the ſpirit of conqueſt in the boſom of winter quarters. Its age is traced by them on record near two centuries before the Chriſtian era; and among the numerous claims for this noble invention, that of the Chineſe, who call it, by way of diſtinction, *chong kè*, or *the royal game*, appears alone to be indiſputable."

Tranſlation of an Extract from the Concum, or Chineſe Annals, reſpecting the Invention of the Game of Cheſs, delivered to me by Tinqua, a Soldier Mandarin of the Province of Fokien.

"Three hundred and ſeventy-nine years after the time

(D) That on the acquiſition of ſo ſtrong a piece as the vizier, the paö were ſuppreſſed, this as poſſeſſing powers unintelligible, at that time, to other nations; and three pawns added, in conſequence to make up the number of men; and that as diſcipline improved, the lines, which are ſtraggling on the Chineſe board, might have been cloſed on ours.

time of Confucius, or one thouſand nine hundred and ſixty-five years ago, Hung Cochu, king of Kiangnan, ſent an expedition into the Shenſi country, under the command of a mandarin, called Hanſing, to conquer it. After one ſucceſsful campaign, the ſoldiers were put into winter quarters; where, finding the weather much colder than what they had been accuſtomed to, and being alſo deprived of their wives and families, the army, in general, became impatient of their ſituation, and clamorous to return home. Hanſing, upon this, revolved in his mind the bad conſequences of complying with their wiſhes. The neceſſity of ſoothing his troops, and reconciling them to their poſition, appeared urgent, in order to finiſh his operations in the enſuing year. He was a man of genius, as well as a good ſoldier; and having contemplated ſome time on the ſubject, he invented the game of cheſs, as well for an amuſement to his men in their vacant hours, as to inflame their military ardour, the game being wholly founded on the principles of war. The ſtratagem ſucceeded to his wiſh. The ſoldiery were delighted with the game; and forgot, in their daily conteſts for victory, the inconveniences of their poſt. In the ſpring the general took the field again; and, in a few months, added the rich country of Shenſi to the kingdom of Kiangnan, by the defeat and capture of its king, Choupayuen, a famous warrior among the Chineſe. On this conqueſt Hung Cochu aſſumed the title of emperor, and Choupayuen put an end to his own life in deſpair.

Explanation of the Poſition, Powers and Moves of the Pieces on the Chineſe Cheſs-board, or Chong Kè, (*Royal Game*).

" As there are nine pieces inſtead of eight, to occupy the rear rank, they ſtand on the lines between, and not within, the ſquares. The game is conſequently played on the lines.

" The king, or chong, ſtands in the middle line of this row. His moves reſemble thoſe of our king, but are confined to the fortreſs marked out for him.

" The two princes, or ſou, ſtand on each ſide of him, and have equal powers and limits.

" The mandarins, or tchong, anſwer to our biſhops, and have the ſame moves, except that they cannot croſs the water or white ſpace in the middle of the board to annoy the enemy, but ſtand on the defenſive.

" The knights, or rather horſes, called *māā*, ſtand and move like ours in every reſpect.

" The war-chariots, or tchè, reſemble our rooks or caſtles.

" The rocket-boys, or paö, are pieces whoſe motions and powers were unknown to us. They act with the direction of a rocket, and can take none of their adverſary's men that have not a piece or pawn intervening. To defend your men from this attack it is neceſſary to open the line between, either to take off the check on the king, or to ſave a man from being captured by the paö. Their operation is, otherwiſe, like that of the rook. Their ſtations are marked between the pieces and pawns.

" The five pawns, or ping, make up the number of the men equal to that of our board. Inſtead of taking ſideways, like ours, they have the rook's motion, except that it is limited to one ſtep, and is not retrograde. Another important point, in which the ping differs from ours, is that they continue in *ſtatu quo*, after reaching their adverſary's head quarters. It will appear, however, that the Chineſe pieces far exceed the proportion of ours; which occaſions the whole force of the conteſt to fall on them, and thereby precludes the beauty and variety of our game, when reduced to a ſtruggle between the pawns, who are capable of the higheſt promotion, and often change the fortune of the day. The poſts of the ping are marked in front *."

But according to Sir William Jones, this game is of Hindoo invention. " If evidence were required to prove this fact (ſays he †), we may be ſatisfied with the teſtimony of the Perſians, who, though as much inclined as other nations to appropriate the ingenious inventions of a foreign people, unanimouſly agree that the game was imported from the weſt of *India* in the ſixth century of our era. It ſeems to have been immemorially known in *Hindoſtan* by the name of *Cheturanga*, i. e. the four *angá's*, or members of any army; which are theſe, *elephants*, *horſes*, *chariots*, and *foot-ſoldiers;* and in this ſenſe the word is frequently uſed by epic poets in their deſcription of real armies. By a natural corruptions of the pure Sanſcrit word, it was changed by the old Perſians into *Chetrang;* but the Arabs, who ſoon after took poſſeſſion of their country, had neither the initial nor final letter of that word in their alphabet, and conſequently altered it further into *Shetranj*, which found its way preſently into the modern *Perſian*, and at length into the dialects of India, where the true derivation of the name is known only to the learned. Thus has a very ſignificant word in the ſacred language of the Brahmins been transformed by ſucceſſive changes into *axedrez*, *ſcacchi*, *échecs*, *cheſs*, and, by a whimſical concurrence of circumſtances, has given birth to the Engliſh word *check*, and even a name to the *exchequer* of Great Britain."

It is confidently aſſerted, that Sanſcrit books on *cheſs* exiſt in Bengal; but Sir William had ſeen none of them when he wrote the memoir which we have quoted. He exhibits, however, a deſcription of a very ancient *Indian* game of the ſame kind, but more complex, and in his opinion more modern, than the ſimple cheſs of the *Perſians*. This game is alſo called *Chaturanga*, but more frequently *Chaturaji*, or the *four kings*, ſince it is played by four perſons repreſenting as many princes, two allied armies combating on each ſide. The deſcription is taken from a book called *Bhawiſhya Purán;* in which the form and principal rules of this factitious warfare are thus laid down: " Eight ſquares being marked on all ſides, the *red* army is to be placed on the eaſt, the *green* to the ſouth, the *yellow* to the weſt, and the *black* to the north. Let the *elephant* (ſays the author of the *Purán*) ſtand on the left of the *king;* next to him the *horſe;* then the *boat;* and before them all, four *foot-ſoldiers;* but the *boat* muſt be placed in the angle of the board."

" From this paſſage (ſays the preſident) it clearly appears, that an army with its four *angás* muſt be placed on each ſide of the board, ſince an *elephant* could not ſtand, in any other poſition, on the left hand of each *king;* and RADHACANT (a Pandit) informed me, that

---

* *Iriſh Tranſ.* vol. v.

† *Aſiatic Reſearches*, vol. ii. mem. 9.

the board conſiſted, like ours, of 64 ſquares, half of them occupied by the forces, and half vacant. He added, that this game is mentioned in the oldeſt law books, and that it was invented by the wife of a king, to amuſe him with an image of war, while his metropolis was beſieged in the ſecond age of the world. A *ſhip* or *boat* is abſurdly ſubſtituted, we ſee, in this complex game, for the *rat'h*, or armed *chariot*, which the *Bengaleſe* pronounce *rot'h*, and which the Perſians changed into *rokh*; whence came the *rook* of ſome European nations; as the *vierge* and *fal* of the French are ſuppoſed to be corruptions of *ferz* and *fil*, the *prime miniſter* aad *elephant* of the Perſians and Arabs."

As fortune is ſuppoſed to have a great ſhare in deciding the fate of a battle, the uſe of dice is introduced into this game to regulate its moves; for (ſays the Purán) "if *cinque* be thrown, the *king* or a *pawn* muſt be moved; if *quatre*, the *elephant*; if *trois*, the *horſe*; and if *deux*, the *boat*. The *king* paſſes freely on all ſides, but over *one* ſquare only; and with the ſame limitation the *pawn* moves, but he advances ſtraight forward, and kills his enemy through an angle. The *elephant* marches in all directions as far as his driver pleaſes; the *horſe* runs obliquely, traverſing the ſquares; and the *ſhip* goes over two ſquares diagonally." The *elephant*, we find, has the powers of our *queen*, as we are pleaſed to call the *general* or *miniſter* of the Perſians; and the *ſhip* has the motion of the piece to which we give the unaccountable appellation of *biſhop*, but with a reſtriction which muſt greatly leſſen its value.

In the *Purán* are next exhibited a few general rules and ſuperficial directions for the conduct of the game. Thus, "the *pawns* and the *ſhip* both kill and may be voluntarily killed; while the *king*, the *elephant*, and the *horſe*, may ſlay the foe, but muſt not expoſe themſelves to be ſlain. Let each player preſerve his own forces with extreme care, ſecuring his *king* above all, and not ſacrificing a ſuperior to keep an inferior piece." Here (ſays the preſident) the commentator on the *Purán* obſerves, that the *horſe*, who has the choice of *eight* moves from any central poſition, muſt be preferred to the *ſhip*, which has only the choice of *four*. But the argument would not hold in common game, where the *biſhop* and *tower* command a whole line, and where a knight is always of leſs value than a tower in action, or the biſhop of that ſide on which the attack is begun. "It is by the overbearing power of the *elephant* (continues the *Purán*) that the king fights boldly; let the whole army therefore, be abandoned in order to ſecure the *elephant*. The king muſt never place one *elephant* before another, unleſs he be compelled by want of room, for he would thus commit a dangerous fault; and if he can ſlay one of two hoſtile elephants, he muſt deſtroy that on his left hand."

What remains of the paſſage which was copied for Sir William Jones relates to the ſeveral modes in which a partial ſucceſs or complete victory may be obtained by any one of the four players; for, as in a diſpute between two allies, one of the kings may ſometimes aſſume the command of all the forces, and aim at a ſeparate conqueſt. Firſt, "When any one king has placed himſelf on the ſquare of another king (which advantage is called *ſinhaſana* or the *throne*) he wins a ſtake, which is doubled if he kill the adverſe monarch when he ſeizes his place; and if he can ſeat himſelf on the throne of his ally, he takes the command of the whole army." Secondly, "If he can occupy ſucceſſively the thrones of all the three princes, he obtains the victory, which is named *cheturaji*; and the ſtake is doubled if he kill the laſt of the three, juſt before he takes poſſeſſion of his throne; but if he kill him on his throne, the ſtake is quadrupled. Both in giving the *ſinhaſana* and the *cheturaji* the king muſt be ſupported by the *elephants*, or by all the forces united." Thirdly, "When one player has his own king on the board, but the king of his partner has been taken, he may replace his captive ally, if he can ſeize both the adverſe kings; or if he cannot effect their capture, he may exchange his king for one of them, againſt the general rule, and thus redeem the allied prince, who will ſupply his place." This advantage has the name of *nripacriſhta* or *recovered by the king*. Fourthly, "If a *pawn* can march to any ſquare on the oppoſite extremity of the board, except that of the king, or that of the ſhip, he aſſumes whatever power belonged to that ſquare." Here we find the rule, with a ſlight exception, concerning the advancement of *pawns*, which often occaſions a moſt intereſting ſtruggle at our common cheſs; but it appears that, in the opinion of one ancient writer on the Indian game, this privilege is not allowable when a player has three pawns on the board; but when only one pawn and one ſhip remains, the pawn may advance even to the ſquare of a king or a ſhip, and aſſume the power of either. Fifthly, According to the people of *Lancè*, where the game was invented, "there could be neither victory nor defeat if a king were left on the plain without force; a ſituation which they named *cacacaſht'ha*." Sixthly, "If three ſhips happen to meet, and the fourth ſhip can be brought up to them in the remaining angle, this has the name of *vrihannauca*; and the player of the fourth ſeizes all the others."

The account of this game in the original Sanſcrit is in verſe.

This game was very faſhionable in former times in every part of Europe; though in this country it is not now very common, probably on account of the intenſe application of thought required to play at it. It has long been a favourite of the Icelanders and other northern people. There is little difference between their game and ours.

The game of cheſs has been generally practiſed by the greateſt warriors and generals; and ſome have even ſuppoſed that it was neceſſary for a military man to be well ſkilled in this game. It is a game which has ſomething in it peculiarly intereſting. We read that Tamerlane was a great cheſs-player, and was engaged in a game during the very time of the deciſive battle with Bajazet the Turkiſh emperor, who was defeated and taken priſoner. It is alſo related of Al Amin the caliph of Bagdad, that he was engaged at cheſs with his freedman Kuthar at the time when Al Mamun's forces were carrying on the ſiege of that city with ſo much vigour that it was on the point of being carried by aſſault. Dr Hyde quotes an Arabic hiſtory of the Saracens, in which the caliph is ſaid to have cried out when warned of his danger, Let me alone, for I ſee checkmate againſt Kuthar! We are told that Charles I. was at cheſs when news were brought of the final intention of the Scots to ſell him to the Engliſh; but ſo little was he diſcompoſed by this alarming intelligence,

telligence, that he continued his game with the utmoſt compoſure; ſo that no perſon could have known that the letter he received had given him information of any thing remarkable. King John was playing at cheſs when the deputies from Rouen came to acquaint him that their city was beſieged by Philip Auguſtus; but he would not hear them until he had finiſhed his game.

The following remarkable anecdote we have from Dr Robertſon in his Hiſtory of Charles V. John Frederic, elector of Saxony, having been taken priſoner by Charles, was condemned to death. The decree was intimated to him while at cheſs with Erneſt of Brunſwic, his fellow-priſoner. After a ſhort pauſe, and making ſome reflection on the irregularity and injuſtice of the emperor's proceedings, he turned to his antagoniſt, whom he challenged to finiſh the game. He played with his uſual ingenuity and attention; and having beat Erneſt, expreſſed all the ſatisfaction that is commonly felt on gaining ſuch victories. He was not, however, put to death, but ſet at liberty after five years confinement.

In the Chronicle of the Mooriſh kings of Granada we find it related, that in 1396, Mehemed Balba ſeized upon the crown in prejudice of his elder brother, and paſſed his life in one continual round of diſaſters. His wars with Caſtile were invariably unſucceſsful; and his death was occaſioned by a poiſoned veſt. Finding his caſe deſperate, he deſpatched an officer to the fort of Salabreno to put his brother Juzaf to death, leſt that prince's adherents ſhould form any obſtacle to his ſon's ſucceſſion. The alcayde found the prince playing at cheſs with an *alfaqui* or prieſt. Juzaf begged hard for two hours reſpite, which was denied him; at laſt with great reluctance the officer permitted him to finiſh the game; but before it was finiſhed a meſſenger arrived with the news of the death of Mehemed, and the unanimous election of Juzaf to the crown.

We have a curious anecdote of Ferrand count of Flanders; who having been accuſtomed to amuſe himſelf at cheſs with his wife, and being conſtantly beaten by her, a mutual hatred took place; which came to ſuch a height, that when the count was taken priſoner at the battle of Bovines, ſhe ſuffered him to remain a long time in priſon, though ſhe could eaſily have procured his releaſe.

The game of cheſs has undergone conſiderable variations ſince it was firſt invented. We have it on good authority, that among the eaſtern nations, the piece now called the *queen* was formerly called the *vizir* or king's miniſter, and that the powers of the queen herſelf were but very ſmall. The cheſs-boards uſed by Tamerlane were larger, and contained many more ſquares than thoſe at preſent in uſe. Carrera invented two new pieces to be added to the eight commonly in uſe. One of theſe, which he calls *Campione*, is placed between the king's knight and caſtle; the other, named *Centaur*, between the queen's knight and caſtle, has the move of the biſhop and knight united. This invention, however, did not ſurvive its author. In another of this kind, the two additional pieces are called the *centurion* and *decurion*; the former, ſituated between the king and his biſhop, in its move the ſame with that of the queen, but only for two ſquares; the latter moves as the biſhop, but only one ſquare at a time. This, like the former, died with its inventor. The cheſs-board of Tamerlane was a parallelogram, having 11 ſquares one way and 12 the other. In the Memoirs of the late Marſhal Keith, we find it related, that he invented an amuſement ſomething ſimilar to that of cheſs, with which the king of Pruſſia was highly entertained. Several thouſand ſmall ſtatues were caſt by a founder; and theſe were ranged oppoſite to each other as if they had been drawn up in an army; making the different movements with them as in real ſervice in the field.

A very complicated kind of game at cheſs was invented by the late duke of Rutland. At this the board has 14 ſquares in breadth, and 10 in height, which make in all 140 houſes: and there are 14 pawns on each ſide, which may move either one, two, or three ſquares the firſt time. The other pieces were the king, queen, two biſhops, two knights, a crowned caſtle uniting the move of the king and caſtle, and a common caſtle. On the other ſide of the king was a *concubine*, whoſe move united that of the caſtle and knight, two biſhops, a ſingle knight, a crowned caſtle, and a common one. In this game the pawns are of very little uſe; and by the extent of the board, the knights loſe much of their value, which conſequently renders the game more defective and leſs intereſting than the common one.

There is an amuſing variety at the game of cheſs, in which the king with eight pawns engages the whole ſet, by being allowed to make two moves for every one of his adverſary. In this he is almoſt certain of coming off victorious; as he can make his firſt move into check, and the ſecond out of it. Thus he can take the queen when ſhe ſtands immediately before her king, and then retreat; for he cannot remain in check. He cannot be check-mated unleſs his adverſary has preſerved his queen and both caſtles.

CHESS-*trees*, (*toquets d'anjure*); two pieces of wood bolted perpendicularly, one on the ſtarboard, and another on the larboard ſide of the ſhip. They are uſed to confine the *clue*, or lower corners of the main-ſail; for which purpoſe there is a hole in the upper part, through which the rope paſſes that uſually extends the clue of the ſail to windward. See TACK.

The cheſs-trees are commonly placed as far before the main-maſt as the length of the main-beam.

CHEST, in commerce, a kind of meaſure, containing an uncertain quantity of ſeveral commodities.

A cheſt of ſugar, v. g. contains from 10 to 15 hundred weight; a cheſt of glaſs, from two hundred to three hundred feet; of Caſtile ſoap, from two and a half to three hundred weight; of indigo, from one and a half to two hundred weight, five ſcore to the hundred.

CHEST, or *Thorax*. See ANATOMY *Index*.

CHESTER, commonly called *Weſt-Cheſter*, to diſtinguiſh it from many other Cheſters in the kingdom; the capital of Cheſhire in England. It is a very ancient city, ſuppoſed to have been founded by the Romans; and plainly appears to have been a Roman ſtation by the many antiquities which have been and are ſtill diſcovered in and about the town. It was among the laſt places the Romans quitted; and here the Britons maintained their liberty long after the Saxons had got poſſeſſion of the reſt of their country. At preſent it it is a large well-built, wealthy city, and carries on a conſiderable trade. Mr Pennant calls it *a city without parallel*, on account of the ſingular ſtructure of the four principal ſtreets. They are as if excavated out of the earth, and ſunk many feet beneath the ſurface: the carriages drive far beneath the level of the kitchens on a line with ranges of ſhops. The houſes are moſtly of wood, with galleries, piazzas, and covered walls before them; by which not only the ſhops, but thoſe who are walking about the town, are ſo hid, that one would imagine there were ſcarce any inhabitants in it, though it is very populous. But though by this contrivance ſuch as walk the ſtreets are ſcreened from rain, &c. yet the ſhops are thereby rendered dark and inconvenient. The back courts of all the houſes are on a level with the ground; but to go into any of the four principal ſtreets, it is neceſſary to deſcend a flight of ſeveral ſteps.

Cheſter is a biſhop's ſee. It was anciently part of the dioceſe of Litchfield; one of whoſe biſhops removing the ſeat of his ſee hither in the year 1075, occaſioned his ſucceſſors to be frequently ſtyled *biſhops of Cheſter*. But it was not erected into a diſtinct biſhopric until the general diſſolution of monaſteries, when King Henry VIII. in the year 1541, raiſed it to this dignity, and allotted the church of the abbey of St Werburg for the cathedral, ſtyling it the *cathedral church of Chriſt and the bleſſed Virgin*; adding the biſhopric to the province of Canterbury: but ſoon after he disjoined it from Canterbury, and added it to the province of York. When this abbey was diſſolved, its revenues were valued at 1003l. 5s. 11d. This dioceſe contains the entire counties of Cheſter and Lancaſter, part of the counties of Weſtmorland, Cumberland, and Yorkſhire, two chapelries in Denbighſhire, and five pariſhes in Flintſhire; amounting in all to 256 pariſhes, of which 101 are impropriations. This biſhopric is valued in the king's books at 420l. 1s. 8d. and is computed to be worth annually 2700l.; the clergy's tenth amounting to 435l. 12s. To this cathedral belong a dean, two archdeacons, a chancellor, a treaſurer, ſix prebendaries, and other inferior officers and ſervants. W. Long. 3. 0. N. Lat. 53. 12.

Cheſter *le-Street*, the *Cuneaceſtre* of the Saxons; a ſmall thoroughfare town between Newcaſtle and Durham, with a good church and fine ſpire. In the Saxon times this place was greatly reſpected on account of the relicks of St Cuthbert, depoſited here by Biſhop Eardulf, for fear of the Danes, who at that time (about 884) ravaged the country. His ſhrine became afterwards an object of great devotion. King Athelſtan, on his expedition to Scotland, paid it a viſit, to obtain, by interceſſion of the ſaint, ſucceſs on his arms; beſtowed a multitude of gifts on the church; and directed, in caſe he died in his enterpriſe, that his body ſhould be interred there. At the ſame time that this place was honoured with the remains of St Cuthbert, the biſhopric of Lindesfarn was removed here, and endowed with all the lands between the Tyne and the Were, the preſent county of Durham. It was ſtyled *St Cuthbert's patrimony*. The inhabitants had great privileges, and always thought themſelves exempt from all military duty, except that of defending the body of their ſaint. Cheſter-le-Street may be conſidered as the parent of the ſee of Durham: for when the relicks were removed there, the ſee in 995 followed them. Tanner ſays, that probably a chapter of monks, or rather ſecular canons, attended the body at this place from its firſt arrival: but Biſhop Beke, in 1286, in honour of the ſaint, made the church collegiate, and eſtabliſhed here a dean and ſuitable eccleſiaſtics; and among other privileges, gave the dean a right of fiſhing on the Were, and the tythe of fiſh.

New-Chester, a town of Pennſylvania in America, and capital of a county of that name. It is ſeated on the Delawar; and has a fine capacious harbour, admitting veſſels of any burden. W. Long. 74. 7. N. Lat. 40. 15.

CHESTERFIELD, a market-town of Derbyſhire in England, pleaſantly ſituated on a hill between two ſmall rivers. It has the title of an earldom; and a conſiderable market for corn, lead, and other country commodities. The houſes are for the moſt part built of rough ſtone, and covered with ſlate. W. Long. 1. 25. N. Lat. 53. 20.

Chesterfield, *Earl of*. See Stanhope.

CHEVAL *de* Frise, a large piece of timber pierced, and traverſed with wooden pikes, armed or pointed with iron, five or ſix feet long. See Plate CXXXVII.

The term is French, and properly ſignifies a *Frieſland horſe*; as having been firſt invented in that country.—It is alſo called a *Turnpike* or *Turniquet*.

Its uſe is to defend a paſſage, ſtop a breach, or make an entrenchment to ſtop the cavalry. It is ſometimes alſo mounted on wheels, with artificial fires, to roll down in an aſſault. Errand obſerves, that the prince of Orange uſed to incloſe his camp with *Chevaux de Friſe*, placing them one over another.

CHEVALER, in the manege, is ſaid of a horſe, when in paſſaging upon a walk or trot, his off fore-leg croſſes or overlaps the near fore-leg every ſecond motion.

CHEVALIER, a French term, ordinarily ſignifying a Knight. The word is formed of the French, *cheval* "horſe," and the barbarous Latin *cavallus*.

It is uſed, in heraldry, to ſignify any *cavalier* or horſeman armed at all points; by the Romans called *cataphractus eques*: now out of uſe, and only to be ſeen in coat-armour.

CHEVAUX *de* Frise. See *Cheval de Friſe*.

CHEVIN, a name uſed in ſome parts of England for the Chub.

CHEVIOT, or (Tiviot) hills, run from north to ſouth through Northumberland and Cumberland; and were formerly the borders or boundaries between England and Scotland, where many a bloody battle has been fought between the two nations; one of which is recorded in the ballad of Chevy-chaſe. Theſe hills are the firſt land diſcovered by ſailors in coming from the eaſt into Scotland.

CHEVISANCE, in *Law*, denotes an agreement or compoſition, as an end or order ſet down between a creditor and his debtor, &c. In the ſtatutes, this word is moſt commonly uſed for an unlawful bargain or contract.

CHEVREAU, Urban, a learned writer, born at Lundun in 1613. He diſtinguiſhed himſelf in his youth by his knowledge of the belles lettres; and became ſecretary

cretary of ſtate to Queen Chriſtina of Sweden. Several German princes invited him to their courts; and Charles Lewis, the elector palatine, retained him under the title of counſellor. After the death of that prince, he returned to France, and became preceptor to the duke of Maine. At length retiring to Lundun, he died there in 1701, aged 88. He was the author of ſeveral books; and amongſt others of an Univerſal Hiſtory, which has been often reprinted.

CHEVRON, or Cheveron, in *Heraldry*. See Heraldry.

CHEWING-balls, a kind of balls made of aſafœtida, liver of antimony, bay wood, juniper-wood, and pellitory of Spain; which being dried in the ſun, and wrapped in a linen cloth, are tied to the bit of the bridle for the horſe to chew; they create an appetite; and it is ſaid, that balls of Venice-treacle may be uſed in the ſame manner with good ſucceſs.

CHEYKS. See Bengal, N° 17.

CHEYNE, Dr George, a phyſician of great learning and abilities, born in Scotland in 1671, and educated at Edinburgh under the great Dr Pitcairn. He paſſed his youth in cloſe ſtudy, and with great temperance; but coming to ſettle at London, when about 30, and finding the younger gentry and free-livers to be the moſt eaſy of acceſs and moſt ſuſceptible of friendſhip, he changed on a ſudden his former manner of living, in order to force a trade, having obſerved this method to ſucceed with ſome others. The conſequence was, that he grew daily in bulk, and in intimacy with his gay acquaintance; ſwelling to ſuch an enormous ſize, that he exceeded 32 ſtone weight; and he was forced to have the whole ſide of his chariot made open to receive him into it; he grew ſhort-breathed, lethargic, nervous, and ſcorbutic; ſo that his life became an intolerable burden. In this deplorable condition, after having tried all the power of medicine in vain, he reſolved to try a milk and vegetable diet; the good effects of which quickly appeared. His ſize was reduced almoſt a third; and he recovered his ſtrength, activity, and cheerfulneſs, with the perfect uſe of all his faculties. In ſhort, by a regular adherence to this regimen, he lived to a mature period, dying at Bath in 1742, aged 72. He wrote ſeveral treatiſes that were well received; particularly, "An Eſſay on Health and Long Life;" and "The Engliſh Malady, or a Treatiſe of Nervous Diſeaſes;" both the reſult of his own experience. In ſhort, he had great reputation in his own time, both as a practitioner and as a writer; and moſt of his pieces paſſed through ſeveral editions. He is to be ranked among thoſe phyſicians who have accounted for the operations of medicines and the morbid alterations which take place in the human body, upon mechanical principles. A ſpirit of piety and of benevolence, and an ardent zeal for the intereſts of virtue, are predominant throughout his writings. An amiable candour and ingenuouſneſs are alſo diſcernible; and which led him to retract with readineſs whatever appeared to him to be cenſurable in what he had formerly advanced. Some of the metaphyſical notions which he has introduced into his books may perhaps juſtly be thought fanciful and ill-grounded; but there is an agreeable vivacity in his productions, together with much openneſs and frankneſs, and in general great perſpicuity.

CHIABRERA, Gabriel, eſteemed the Pindar of Italy, was born at Savona in 1552, and went to ſtudy at Rome. The Italian princes, and Urban VIII. gave him public marks of their eſteem. He wrote a great number of poems; but his lyric verſes are moſt admired. He died at Savona in 1638, aged 86.

CHIAN earth, in *Pharmacy*, one of the medicinal earths of the ancients, the name of which is preſerved in the catalogues of the materia medica, but of which nothing more than the name has been known for many ages in the ſhops.

It is a very denſe and compact earth; and is ſent hither in ſmall flat pieces from the iſland of Chios, in which it is found in great plenty at this time. It ſtands recommended to us as an aſtringent. They tell us, it is the greateſt of all coſmetics; and that it gives a whiteneſs and ſmoothneſs to the ſkin, and prevents wrinkles, beyond any of the other ſubſtances that have been celebrated for the ſame purpoſes.

CHIAOUS, a word in the original Turkiſh ſignifying "envoys," are officers to the number of five or ſix hundred in the grand ſignior's court, under the command of a chiaous baſchi. They frequently meet in the grand viſir's palace, that they may be in readineſs to execute his orders, and carry his diſpatches into all the provinces of the empire. The chiaous baſchi aſſiſts at the divan, and introduces thoſe who have buſineſs there.

CHIAPA, the capital of a province of the ſame name in Mexico, ſituated about 300 miles eaſt of Acapulco. W. Long. 98. 0. N. Lat. 16. 30.

Chiapa el Real, a town of Mexico, in a province of the ſame name, with a biſhop's ſee. Its principal trade conſiſts in chocolate-nuts, cotton, and ſugar. W. Long. 98. 35. N. Lat. 16. 20.

Chiapas de los Indos, a large and rich town of North America, in Mexico, and in a province of the ſame name. The governor and moſt of the inhabitants are originally Americans. W. Long. 98. 5. N. Lat. 15. 6.

CHIARI, Josesh, a celebrated Italian painter, was the diſciple of Carlo Maratti; and adorned the churches and palaces of Rome with a great number of fine paintings. He died of an apoplexy in 1727, aged 73.

Chiari, a town of Italy, in the province of Breſcia, and territory of Venice, 7 miles weſt of Breſcia, and 27 eaſt of Milan. Here the Imperialiſts gained a victory over the French in 1701. E. Long. 18. 18. N. Lat. 45. 30.

CHIARO scuro. See *Claro-Obſcuro*.

CHIAVENNA, a handſome, populous, and large town of Swiſſerland, in the country of the Griſons. It is a trading place, eſpecially in wine and delicate fruits. The governor's palace and the churches are very magnificent, and the inhabitants are Roman Catholics. It was at one period during the late conteſt with France, the ſcene of much carnage and bloodſhed. It is ſeated near the lake Como. E. Long. 9. 29. N. Lat. 46. 15.

CHIAUSI, among the Turks, officers employed in executing the vizirs, baſhaws, and other great men: the orders for doing this, the grand ſignior ſends them wrapped up in a black cloth; on the reception of which they immediately perform their office.

CHICANE, or Chicanery, in *Law*, an abuſe of judiciary

judiciary proceeding, tending to delay the cauſe, to puzzle the judge, or impoſe upon the parties.

Chicane, in the ſchools, is applied to vain ſophiſms, diſtinctions, and ſubtleties, which protract diſputes, and obſcure the truth.

CHICHESTER, the capital city of the county of Suſſex, was built by Ciſſa, the ſecond king of the South Saxons, and by him called *Ciſſan Cæſter*. It is ſurrounded with a wall, which has four gates anſwering to the four cardinal points; from which run two ſtreets, that croſs one another in the middle and form a ſquare, where the market is kept, and where there is a fine ſtone piazza built by Biſhop Read. The ſpace between the weſt and ſouth gates is taken up with the cathedral church and the biſhop's palace. It has five pariſh-churches; and is ſeated on the little river Lavant, which waſhes it on all ſides except the north. This city would have been in a much more flouriſhing condition if it had been built by the ſea-ſide; however, the inhabitants have endeavoured to ſupply this defect in ſome meaſure, by cutting a canal from the city down to the bay. The principal manufactures of the town are malt and needles. The market of Chicheſter is noted for fiſh, wheat, barley, malt, and oats; the fineſt lobſters in England are bred in the Lavant; and it is obſervable, that this river, unlike moſt others, is very low in winter, but in ſummer often overflows its banks. Chicheſter is a city and county of itſelf; it is governed by a mayor, recorder, aldermen, common-council without limitation, and four juſtices of the peace choſen out of the aldermen; and it ſends two members to parliament. It is a biſhop's ſee. The cathedral church was anciently dedicated to St Peter. It was new built by Radulph, the twenty-fifth biſhop; but being deſtroyed by fire, it was again built by Seffridus II. the twenty-ninth biſhop. This ſee hath yielded to the church two ſaints, and to the nation three lord chancellors, two almoners, and one chancellor to the univerſity of Oxford. Anciently the biſhops of Chicheſter were confeſſors to the queens of England. This dioceſe contains the whole of the county of Suſſex (excepting 22 pariſhes, peculiars of the archbiſhop of Canterbury), wherein are 250 pariſhes, whereof 112 are impropriated. It hath two archdeacons, viz. of Chicheſter and Lewes; is valued in the king's books at 667l. 1s. 3d. and is computed to be worth annually 2600l. The tenths of the whole clergy is 287l. 2s. $0\frac{3}{4}$d. To the cathedral belong a biſhop, a dean, two archdeacons, a treaſurer, a chancellor, thirty-two prebendaries, a chanter, twelve vicars-choral, and other officers. W. Long. 50. N. Lat. 50. 50.

CHICK, or Chicken, in *Zoology*, denotes the young of the gallinaceous order of birds, eſpecially the common hen. See Phasianus, Ornithology *Index*.

Chick-Weed. See Alsine, Botany *Index*.

Chicken-Pox. See Medicine *Index*.

CHICKLING-pea, a name given to the Lathyrus. See Botany *Index*.

CHICUITOS, a province of South America, in the government of Santa-Cruz de la Sierra. The chief riches conſiſt of honey and wax; and the original inhabitants are very voluptuous, yet very warlike. They maintained bloody wars with the Spaniards till 1690; ſince which, ſome of them have become Chriſtians. It is bounded by la Plata on the north eaſt, and by Chili on the weſt.

CHIDLEY, or Chimley, a market-town of Devonſhire, ſituated in W. Long. 4. 0. N. Lat. 51. 0.

CHIEF, a term ſignifying the head or principal part of a thing or perſon. Thus we ſay, the chief of a party, the chief of a family, &c. The word is formed of the French *chef*, "head;" of the Greek κεφαλη, *caput*, "head;" though Menage derives it from the Italian *capo*, formed of the Latin, *caput*.

Chief, in *Heraldry*, is that which takes up all the upper part of the eſcutcheon from ſide to ſide, and repreſents a man's head. *In chief*, imports ſomething borne in the chief part or top of the eſcutcheon.

CHIEFTAIN, denotes the captain or chief of any claſs, family, or body of men. Thus the chieftains or chiefs of the Highland clans, were the principal noblemen or gentlemen of their reſpective clans. See Clans.

CHIELEFA, a ſtrong town of Turkey in Europe, in the Morea. It was taken by the Venetians in 1685; but after that the Turks retook it, with all the Morea. E. Long. 22. 21. N. Lat. 26. 50.

CHIGI, Fabio, or Pope Alexander VII. was born at Sienna in 1599. His family finding him a hopeful youth, ſent him early to Rome, where he ſoon engaged in a friendſhip with the marquis Pallavicini, who recommended him ſo effectually to Pope Urban VIII. that he procured him the poſt of inquiſitor at Malta. He was ſent vice-legate to Ferrara, and afterward nuncio into Germany: there he had an opportunity of diſplaying his intriguing genius; for he was mediator at Munſter, in the long conference held to conclude a peace with Spain. Cardinal Mazarin had ſome reſentment againſt Chigi, who was ſoon after made a cardinal and ſecretary of ſtate by Innocent X. but his reſentment was ſacrificed to political views. In 1655, when a pope was to be choſen, Cardinal Sacchetti, Mazarin's great friend, finding it was impoſſible for him to be raiſed into St Peter's chair, becauſe of the powerful oppoſition made by the Spaniſh faction, deſired Cardinal Mazarin to conſent to Chigi's exaltation. His requeſt was granted, and he was elected pope by the votes of all the 64 cardinals who were in the conclave: an unanimity of which there are but few inſtances in the election of popes. He ſhowed uncommon humility at his election, and at firſt forbade all his relations to come to Rome without his leave; but he ſoon became more favourable to his nephews, and loaded them with favours. It is aſſerted that he had once a mind to turn Proteſtant. The newſpapers in Holland beſtowed great encomiums upon him; and acquainted the world that he did not approve of the cruel perſecutions of the Waldenſes in Piedmont. There is a volume of his poems extant. He loved the *Belles-Lettres*, and the converſation of learned men. He was extremely fond of ſtately buildings: the grand plan of the college *Della Sapienza*, which he finiſhed, and adorned with a fine library, remains a proof of his taſte in architecture. He died in 1667.

CHILBLAIN (*pernio*), in *Medicine*, a tumor affecting the feet and hands; accompanied with an inflammation, pains, and ſometimes an ulcer or ſolution of continuity: in which caſe it takes the denomination of *chops* on the hands, and of *kibes* on the heels. Chilblain is compounded of *chill* and *blain; q. d.* a blain or ſore contracted by cold. *Pernio* is the Latin name adopted by phyſicians; and is derived by Voſſius from *perna*, "a gammon of bacon," on account of ſome reſemblance. *Chap* alludes to *gape*, both in ſound and appearance. *Kibes*, in Welch *kibws*, may be derived from the German *kerben*, "to cut;" the ſkin, when broke, appearing like a cut.

Chilblains are occaſioned by exceſſive cold ſtopping the motion of the blood in the capillary arteries. See the article Pernio.

CHILD, a term of relation to *parent*. See Parent and Children.

Bartholine, Paré, Licetus, and many other writers, give an account of a petrified child, which has ſeemed wholly incredible to ſome people. The child, however, which they deſcribe, is ſtill in being; and is kept as a great rarity in the king of Denmark's muſeum at Copenhagen. The woman who was big with this, lived at Sens in Champagne in the year 1582; it was cut out of her belly, and was univerſally ſuppoſed to have lain there about 20 years. That it is a real human fœtus, and not artificial, is evident to the eyes of any obſerver; and the upper part of it, when examined, is found to be of a ſubſtance reſembling the gypſum or ſtone whereof they made the plaſter of Paris: the lower part is much harder, the thighs and buttocks being a perfect ſtone of a reddiſh colour, and as hard as common quarry ſtone: the grain and ſurface of this part appears exactly like that of the calculi or ſtones taken out of human bladders: and the whole ſubſtance, examined ever ſo nearly, and felt ever ſo carefully, appears to be abſolute ſtone. It was carried from Sens to Paris, and there purchaſed by a goldſmith of Venice; and Frederic III. king of Denmark purchaſed it of this man at Venice for a very large ſum, and added it to his collection of rarities.

Child-Bed. }
Child Birth. } See Midwifery.

Child-Wit, a power to take a fine of a bond-woman unlawfully gotten with child, that is, without conſent of her lord. Every reputed father of a baſe child got within the manor of Writtel in Eſſex, pays to the lord a fine of 3s. 4d.; where, it ſeems, child-wit extends to free as well as bond women.

CHILDERMAS-day, or *Innocents Day*, an anniverſary held by the church of England on the 28th of December, in commemoration of the children of Bethlehem maſſacred by order of Herod.

CHILDREN, the plural of Child.

Mr Derham computes, that marriages, one with another, produce four children not only in England but in other parts alſo.

In the genealogical hiſtory of Tuſcany, written by Gamarini, mention is made of a nobleman of Sienna, named Pichi, who of three wives had 150 *children;* and that, being ſent ambaſſador to the pope and the emperor, he had 48 of his ſons in his retinue. In a monument in the church-yard of St Innocent, at Paris, erected to a woman who died at 88 years of age; it is recorded, that ſhe might have ſeen 288 *children* directly iſſued from her. This exceeds what Hakewell relates of Mrs Honeywood, a gentlewoman of Kent, born in the year 1527, and married at 16 to her only huſband R. Honeywood of Charing, Eſq. and died in her 93d year. She had 16 *children* of her own body; of which three died young, and a fourth had no iſſue: yet her *grandchildren*, in the ſecond generation, amounted to 114; in the third, to 228; though in the fourth they fell to 9. The whole number ſhe might have ſeen in her life-time, being 367. $16+14+228+9=367$. So that ſhe could ſay the ſame as the diſtich does of one Dalburg's family at Bazil:

Mater[1] *ait natæ*[2], *dic natæ*[3] *filia natam*[4],
Ut moneat, natæ[5] *plangere, filiolam*[6].

Management of Children. See Infant.

Overlaying of Children, is a misfortune that frequently happens; to prevent which, the Florentines have contrived an inſtrument called *arcuccio*. See Arcuccio.

Children are, in *Law*, a man's iſſue begotten on his wife. As to *illegitimate children*, ſee Bastard.

For the legal duties of parents to their children, ſee the articles Parent and Bastard.

As to the duties of children to their parents, they ariſe from a principle of natural juſtice and retribution. For to thoſe who gave us exiſtence, we naturally owe ſubjection and obedience during our minority, and honour and reverence ever after; they who protected the weakneſs of our infancy, are entitled to our protection in the infirmity of their age; they who by ſuſtenance and education have enabled their offſpring to proſper, ought, in return, to be ſupported by that offspring, in caſe they ſtand in need of aſſiſtance. Upon this principle proceed all the duties of children to their parents, which are enjoined by poſitive laws. And the Athenian laws carried this principle into practice with a ſcrupulous kind of nicety, obliging all children to provide for their father when fallen into poverty; with an exception to ſpurious children, to thoſe whoſe chaſtity had been proſtituted with conſent of their father, and to thoſe whom he had not put in any way of gaining a livelihood. The legiſlature, ſays Baron Monteſquieu, conſidered, that, in the firſt caſe, the father, being uncertain, had rendered the natural obligation precarious; that, in the ſecond caſe, he had ſullied the life he had given, and done his children the greateſt of injuries, in depriving them of their reputation; and that, in the third caſe, he had rendered their life (ſo far as in him lay) an inſupportable burden, by furniſhing them with no means of ſubſiſtence.

Our laws agree with thoſe of Athens, with regard to the firſt only of theſe particulars, the caſe of ſpurious iſſue. In the other caſes, the law does not hold the tie of nature to be diſſolved by any miſbehaviour of the parent; and, therefore, a child is equally juſtifiable in defending the perſon, or maintaining the cauſe or ſuit, of a bad parent as of a good one; and is equally compellable, if of ſufficient ability, to maintain and provide for a wicked and unnatural progenitor, as for one who has ſhown the greateſt tenderneſs and parental piety. See further the article *Filial Affection.*

CHILI,

CHILI, a province of South America, bounded by Peru on the north, by the province of La Plata on the eaſt, by Patagonia on the ſouth, and by the Pacific ocean on the weſt, lying between 75 and 85 degrees of weſt longitude; and between 25 and 45 of ſouth latitude; though ſome comprehend in this province Patagonia and Terra del Fuego.

The firſt attempt of the Spaniards upon this country was made by Almagro in the year 1535, after he and Pizarro had completed the conqueſt of Peru. He ſet out on his expedition to Chili with a conſiderable body of Spaniards and auxiliary Indians. For 200 leagues he was well accommodated with every neceſſary by the Indians, who had been ſubjects of the emperors of Peru: but reaching the barren country of Charcas, his troops became diſcontented through the hardſhips they ſuffered; which determined Almagro to climb the mountains called *Cordilleras*; in order to get the ſooner into Chili; being ignorant of the invaluable mines of Potoſi, contained in the province of Charcas, where he then was. At that time the Cordilleras were covered with ſnow, the depth of which obliged him to dig his way through it. The cold made ſuch an impreſſion on his naked Indians, that it is computed no leſs than 10,000 of them periſhed on theſe dreadful mountains, 150 of the Spaniards ſharing the ſame fate; while many of the ſurvivors loſt their fingers and toes through the exceſs of cold. At laſt, after encountering incredible difficulties, Almagro reached a fine, temperate, and fertile plain on the oppoſite ſide of the Cordilleras, where he was received with the greateſt kindneſs by the natives. Theſe poor ſavages, taking the Spaniards for deputies of their god Virachoca, immediately collected for them an offering of gold and ſilver worth 290,000 ducats: and ſoon after brought a preſent to Almagro worth 300,000 more. Theſe offerings only determined him to conquer the whole country as ſoon as poſſible. The Indians among whom he now was had acknowledged the authority of the Peruvian incas, or emperors, and conſequently gave Almagro no trouble. He therefore marched immediately againſt thoſe who had never been conquered by the Peruvians, and inhabited the ſouthern parts of Chili. Theſe ſavages fought with great reſolution, and diſputed every inch of ground; but in five months time the Spaniards had made ſuch progreſs, that they muſt infallibly have reduced the whole province in a very little time, had not Almagro returned to Peru, in conſequence of a commiſſion ſent him from Spain.

In 1540, Pizarro having overcome and put Almagro to death, ſent into Chili, Baldivia or Valdivia, who had learned the rudiments of war in Italy, and was reckoned one of the beſt officers in the Spaniſh ſervice. As he penetrated ſouthwards, however, he met with much oppoſition; the confederated caziques frequently gave him battle, and diſplayed great courage and reſolution; but could not prevent him from penetrating to the valley of Maſiocho, which he found incredibly fertile and populous. Here he founded the city of St Jago; and finding gold mines in the neighbourhood, forced the Indians to work in them: at the ſame time building a caſtle for the ſafety and protection of his new colony. The natives, exaſperated at this ſlavery, immediately took up arms; attacked the fort; and though defeated and repulſed, ſet fire to the outworks, which contained all the proviſions of the Spaniards. Nor were they diſcouraged by this and many other defeats, but ſtill continued to carry on the war with vigour. At laſt, Valdivia, having overcome them in many battles, forced the inhabitants of the vale to ſubmit; upon which he immediately ſet them to work in the mines of Quilotta. This indignity offered to their countrymen redoubled the fury of thoſe who remained at libery, Their utmoſt efforts, however, were as yet unable to ſtop Valdivia's progreſs. Having croſſed the large rivers Maulle and Hata, he traverſed a vaſt tract of country, and founded the city of La Conception on the South-ſea-coaſt. He erected fortreſſes in ſeveral parts of the country, in order to keep the natives in awe; and built the city called *Imperial*, about 40 leagues to the ſouthward of Conception. The Spaniſh writers ſay, that the neighbouring valley contained 80,000 inhabitants of a peaceable diſpoſition; and who were even ſo tame as to ſuffer Valdivia to parcel out their lands among his followers, while they themſelves remained in a ſtate of inactivity. About 16 leagues to the eaſtward of Imperial, the Spaniſh general laid the foundations of the city *Villa Rica*, ſo called on account of the rich gold mines he found there. But his ambition and avarice had now involved him in difficulties from which he could never be extricated: He had extended his conqueſts beyond what his ſtrength was capable of maintaining. The Chileſians were ſtill as deſirous as ever of recovering their liberties. The horſes, fire-arms, and armour of the Spaniards, indeed, appeared dreadful to them; but thoughts of endleſs ſlavery were ſtill more ſo. In the courſe of the war they had diſcovered that the Spaniards were vulnerable and mortal men like themſelves; they hoped, therefore, by dint of their ſuperiority in numbers, to be able to expel the tyrannical uſurpers. Had all the nations joined in this reſolution, the Spaniards had certainly been exterminated; but ſome of them were of a pacific and fearful diſpoſition, while others conſidered ſervitude as the greateſt of all poſſible calamities. Of this laſt opinion were the Araceans, the moſt intrepid people in Chili, and who had given Valdivia the greateſt trouble. They all roſe to a man, and choſe Capaulican, a renowned hero among them, for their leader. Valdivia, however, received notice of their revolt ſooner than they intended he ſhould, and returned with all expedition to the vale of Araccea; but before he arrived, 14,000 of the Chileſians were there aſſembled under the conduct of Capaulican. He attacked them with his cavalry, and forced them to retreat into the woods; but could not obtain a complete victory, as they kept continually ſallying out and haraſſing his men. At laſt Capaulican, having obſerved that fighting with ſuch a number of undiſciplined troops only ſerved to contribute to the defeat and confuſion of the whole, divided his forces into bodies of 1000 each. Theſe he directed to attack the enemy by turns; and, though he did not expect that a ſingle thouſand would put them to flight, he directed them to make as long a ſtand as they could; when they were to be relieved and ſupported by another body; and thus the Spaniards would be at laſt wearied out and overcome. The event fully anſwered his expectations. The Chileſians maintained a fight for ſeven or eight hours, until the Spaniards, growing faint for want of refreſhment, retired precipitately. Valdivia ordered them to poſſeſs a paſs at ſome diſtance from the field, to ſtop the purſuit; but this deſign being diſcovered to the Chileſians by the treachery of his page, who was a native of that country, the Spaniards were ſurrounded on all ſides, and cut in pieces by the Indians. The general was taken and put to death; ſome ſay with the tortures uſually inflicted by thoſe ſavages on their priſoners; others, that he had melted gold poured down his throat; but all agree, that the Indians made flutes and other inſtruments of his bones, and preſerved his ſkull as a monument of their victory, which they celebrated by an annual feſtival. After this victory the Chileſians had another engagement with their enemies; in which alſo they proved victorious, defeating the Spaniards with the loſs of near 3000 men; and upon this they bent their whole force againſt the colonies. The city of Conception, being abandoned by the Spaniards, was taken and deſtroyed: but the Indians were forced to raiſe the ſiege of Imperial; and their progreſs was at laſt ſtopped by Garcia de Mendoza, who defeated Capaulican, took him priſoner, and put him to death. No defeats, however, could diſpirit the Chileſians. They continued the war for 50 years; and to this day they remain unconquered, and give the Spaniards more trouble than any other American nation. Their moſt irreconcilable enemies are the inhabitants of Araccea and Tucapel, thoſe to the ſouth of the river Bobia, or whoſe country extends towards the Cordilleras.—The manners of theſe people greatly reſemble thoſe of North America, which we have already deſcribed under the article AMERICA; but they ſeem to have a more warlike diſpoſition. It is a conſtant rule with the Chileſians never to ſue for peace. The Spaniards are obliged not only to make the firſt overtures, but to purchaſe it by preſents. They have at laſt been obliged to abandon all thoughts of extending their conqueſts, and reduced to cover their frontiers by erecting forts at proper diſtances.

The Spaniſh colonies in Chili are diſperſed on the borders of the South-ſea. They are parted from Peru by a deſert of 80 leagues in breadth; and bounded by the iſland of Chiloe, at the extremity next the ſtraits of Magellan. There are no ſettlements on the coaſt, except thoſe of Baldivia, Conception iſland, Valparaiſo, and Coquimbo or La Serena, which are all ſea-ports. In the inland country is St Jago, the capital of the colony. There is no culture nor habitation at any diſtance from theſe towns. The buildings in the whole province are low, made of unburnt brick, and moſtly thatched. This practice is obſerved on account of the frequent earthquakes; and is properly adapted to the nature of the climate, as well as the indolence of the inhabitants.

The climate of Chili is one of the moſt wholeſome in the whole world. The vicinity of the Cordilleras gives it ſuch a delightful temperature as could not otherwiſe be expected in that latitude. Though gold mines are found in it, their richneſs has been too much extolled; their produce never exceeds 218,750l. The ſoil is prodigiouſly fertile. All the European fruits have improved in that happy climate. The wine would be excellent if nature were properly aſſiſted by art: and the corn-harveſt is reckoned a bad one when it does not yield a hundred fold. With all theſe advantages, Chili has no direct intercourſe with the mother-country. Their trade is confined to Peru, Paraguay, and the ſavages on their frontiers. With theſe laſt they exchange their leſs valuable commodities, for oxen, horſes, and their own children, whom they are ready to part with for the moſt trifling things. This province ſupplies Peru with great plenty of hides, dried fruit, copper, ſalt-meat, horſes, hemp, lard, wheat, and gold. In exchange it receives tobacco, ſugar, cocoa, earthen-ware, woollen cloth, linen, hats, made at Quito, and every article of luxury brought from Europe. The ſhips ſent from Callao on this traffic were formerly bound to Conception Bay, but now come to Valparaiſo. The commerce between this province and Paraguay is carried on by land, though it is a journey of 300 leagues, 40 of which lie through the ſnows and precipices of the Cordilleras; but if it was carried on by ſea, they muſt either paſs the ſtraits of Magellan or double Cape Horn, which the Spaniards always avoid as much as poſſible. To Paraguay are ſent ſome woollen ſtuffs called *ponchos*, which are uſed for cloaks; alſo wines, brandy, oil, and chiefly gold. In return they receive wax, a kind of tallow fit to make ſoap, European goods, and negroes.

Chili is governed by a chief, who is abſolute in all civil, political, and military affairs, and is alſo independent of the viceroy. The latter has no authority except when a governor dies; in which caſe he may appoint one in his room for a time, till the mother-country names a ſucceſſor. If, on ſome occaſions, the viceroy has interfered in the government of Chili, it was when he has been either authorized by a particular truſt repoſed in him by the court, or by the deference paid to the eminence of his office; or when he has been actuated by his own ambition to extend his authority. In the whole province of Chili there are not 20,000 white men, and not more than 60,000 negroes, or Indians, able to bear arms. The military eſtabliſhment amounted formerly to 2000 men; but the maintaining of them being found too expenſive, they were reduced to 500 at the beginning of this century.

CHILIAD, an aſſemblage of ſeveral things ranged by thouſands. The word is formed of the Greek χιλιας, *mille*, "a thouſand."

CHILIAGON, in *Geometry*, a regular plain figure of 100 ſides and angles. Though the imagination cannot form the idea of ſuch a figure, yet we may have a very clear notion of it in the mind, and can eaſily demonſtrate that the ſum of all its angles is equal to 1996 right ones: for the internal angles of every plane figure are equal to twice as many right ones as the figure hath ſides, except thoſe four which are about the centre of the figure, from whence it may be reſolved into as many triangles as it has ſides. The author of *l'Art de Penſer*, p. 44. has brought this inſtance to ſhow the diſtinction between imagination and conceiving.

CHILIARCHA, or CHILIARCHUS, an officer in the the armies of the ancients, who had the command of a thouſand men.

CHILIASTS in church-hiſtory. See MILLENARIANS.

CHILLINGWORTH, WILLIAM, an eminent divine of the church of England, was born at Oxford in 1602, and bred there. He made early great proficiency in his ſtudies, being of a very quick genius. He was an expert mathematician, as well as an able divine, and a very good poet. Study and converſation at the univerſity turning upon the controverſy between the church of England and that of Rome, on account of the king's marriage with Henrietta daughter to Henry IV. king of France, Mr Chillingworth forſook the church of England, and embraced the Romiſh religion. Dr Laud, then biſhop of London, hearing of this, and being greatly concerned at it, wrote Mr Chillingworth; who expreſſing a great deal of candour and impartiality, that prelate continued to correſpond with him. This ſet Mr Chillingworth on a new inquiry; and at laſt determined him to return to his former religion. In 1634 he wrote a confutation of the arguments which had induced him to go over to the church of Rome. He ſpoke freely to his friends of all the difficulties that occurred to him; which gave occaſion to a groundleſs report, that he had turned Papiſt a ſecond time, and then Proteſtant again. His return to the communion of the church of England made a great noiſe, and engaged him in ſeveral diſputes with thoſe of the Romiſh perſuaſion. But in 1635 he engaged in a work which gave him a far greater opportunity to confute the principles of the church of Rome, and to vindicate the Proteſtant religion, under the title of "The Religion of Proteſtants a ſafe Way to Salvation." Sir Thomas Coventry, lord keeper of the great ſeal, offering him preferment, Mr Chillingworth refuſed to accept it on account of his ſcruples with regard to the ſubſcription of the 39 articles. However, he at laſt ſurmounted theſe ſcruples; and being promoted to the chancellorſhip of the church of Sarum, with the prebend of Brixworth in Northamptonſhire annexed to it, he complied with the uſual ſubſcription. Mr Chillingworth was zealouſly attached to the royal party; and, in Auguſt 1643, was preſent in King Charles I.'s army at the ſiege of Glouceſter, where he adviſed and directed the making certain engines for aſſaulting the town. Soon after, having accompanied the Lord Hopton, general of the king's forces in the weſt, to Arundel caſtle in Suſſex, he was there taken priſoner by the parliamentary forces under the command of Sir William Waller, who obliged the caſtle to ſurrender. But his illneſs increaſing, he obtained leave to be conveyed to Chicheſter, where he was lodged at the biſhop's palace; and, after a ſhort ſickneſs, died in 1644. He hath left ſeveral excellent works behind him.

CHILMINAR. See PERSEPOLIS.

CHILO, one of the ſeven ſages of Greece, and of the ephori of Sparta the place of his birth, flouriſhed about 556 years before Chriſt. He was accuſtomed to ſay that there were three things very difficult: "To keep a ſecret; to know how beſt to employ our time; and to ſuffer injuries without murmuring." According to Pliny, it was he who cauſed the ſhort ſentence, *Know thyſelf*, to be written in letters of gold in the temple of Delphos. It is ſaid that he died with joy, while embracing his ſon, who had been crowned at the Olympic games.

CHILOE, an iſland lying near the coaſt of Chili, in South America, under the 43d degree of ſouth latitude. It is the chief of an archipelago of 40 iſlands, and its principal town is Caſtro. It rains here almoſt all the year, inſomuch that nothing but Indian corn, or ſome ſuch grain, that requires but little heat to ripen it, can ever come to perfection. They have excellent ſhell-fiſh, very good wild-fowl, hogs, ſheep, and beeves; as alſo a great deal of honey and wax. They carry on a trade with Peru and Chili; whither they ſend boards of cedar, of which they have vaſt foreſts.

CHILTENHAM, a town in Glouceſterſhire, ſix miles from Glouceſter; noted for its purgative chalybeate ſpring, which has rendered it of late years a place of faſhionable reſort. This water, which operates with great eaſe, is deemed excellent in ſcorbutic complaints, and has been uſed with ſucceſs in the gravel.

CHILTERN, a chain of chalky hills forming the ſouthern part of Buckinghamſhire, the northern part of the county being diſtinguiſhed by the name of the *Vale*. The air on theſe heights is extremely healthful: The ſoil, though ſtony, produces good crops of wheat and barley; and in many places it is covered with thick woods, among which are great quantities of beech.—*Chiltern* is alſo applied to the hilly parts of Berkſhire, and it is believed has the ſame meaning in ſome other counties. Hence the HUNDREDS lying in thoſe parts are called the *Chiltern Hundreds*.

CHILTERN *Hundreds, Stewards of*. Of the hundreds into which many of the Engliſh counties were divided by King Alfred for the better government, the juriſdiction was originally veſted in peculiar courts; but came afterwards to be devolved to the county courts, and ſo remains at preſent; excepting with regard to ſome, as the *chilterns*, which have been by privilege annexed to the crown. Theſe having ſtill their own courts, a *ſteward* of thoſe courts is appointed by the chancellor of the exchequer, with a ſalary of 20s. and all fees, &c. belonging to the office: And this is deemed an appointment of ſuch profit, as to vacate a ſeat in parliament.

CHIMÆRA, a port town of Turkey in Europe, ſituated at the entrance of the gulf of Venice, in the province of Epirus, about 32 miles north of the city Corfu, near which are the mountains of Chimæra, which divide Epirus from Theſſaly. E. Long. 20. 40. N. Lat. 40. 20.

CHIMÆRA, in fabulous hiſtory, a celebrated monſter, ſprung from Echidna and Typhon. It had three heads; that of a lion, a goat, and a dragon; and continually vomited flames. The fore parts of its body were thoſe of a lion, the middle was that of a goat, and the hinder parts were thoſe of a dragon. It generally lived in Lycia, about the reign of Jobates, by whoſe orders Bellerophon, mounted on the horſe Pegaſus, overcame it. This fabulous tradition is explained by the recollection that there was a burning mountain in Lycia, whoſe top was the reſort of lions on account of its deſolate wilderneſs; the middle which was fruitful, was covered with goats; and at the bottom the marſhy ground abounded with ſerpents. Bellerophon is ſaid to have conquered the Chimæra, becauſe he deſtroyed the wild beaſts on that mountain, and rendered it habitable. Plutarch ſays that it was the captain of ſome pirates who adorned their ſhip with the images of a lion, a goat, and a dragon.

By a *chimæra* among the philoſophers, is under-

Fig. 1.
The Notes of the 100 Psalm tune.

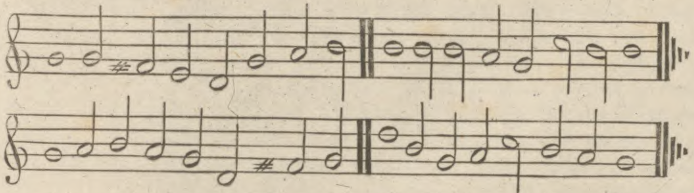
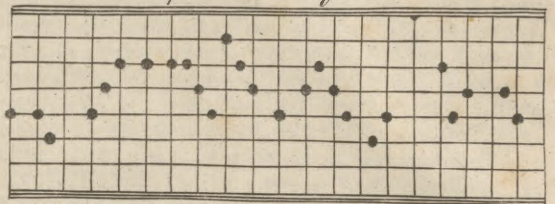


Fig. 2.
A Table for dividing the Chime barrel of the 100 Psalm tune.



CIPHER.

Fig. 3.

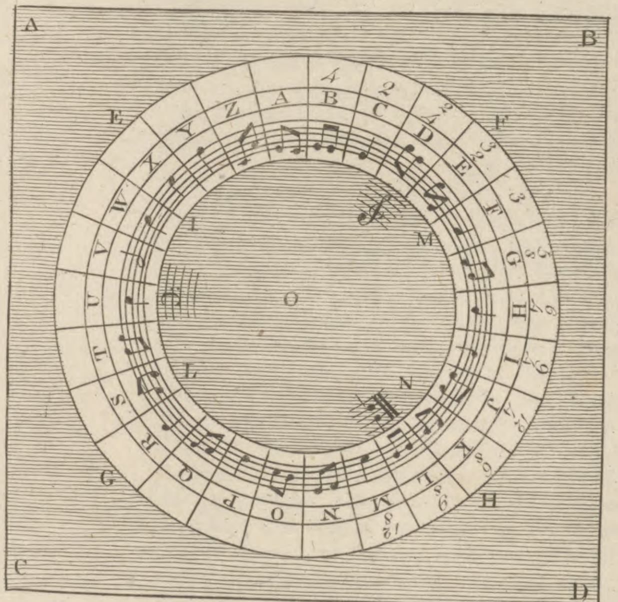


Fig. 4.

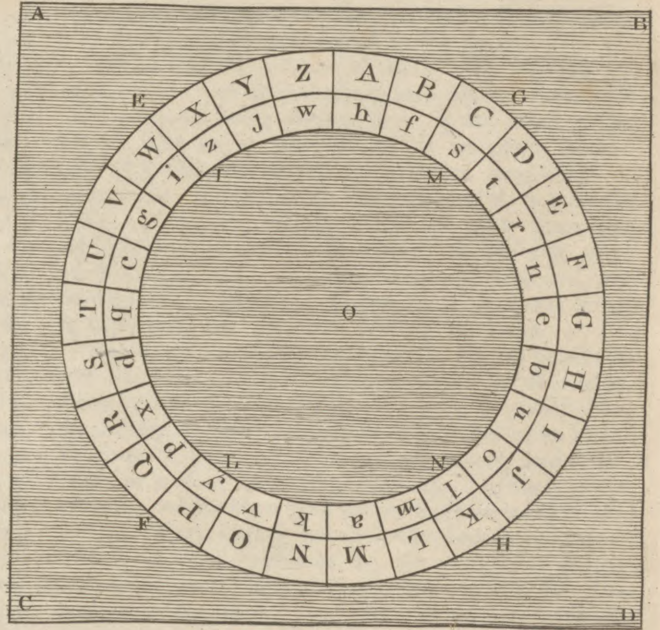


Fig. 5.

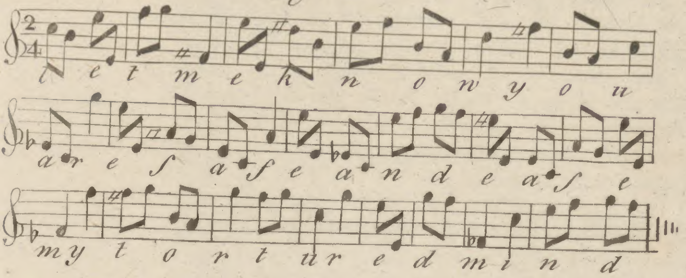


Fig 6

Ma un jvc iumm svar
vgrx qv cd jvc dbhmm
bhgr h yrkduvk hkt—
jvc ahj dqumm ahlr
h dbha vyyvduquvk—

Fig. 7.

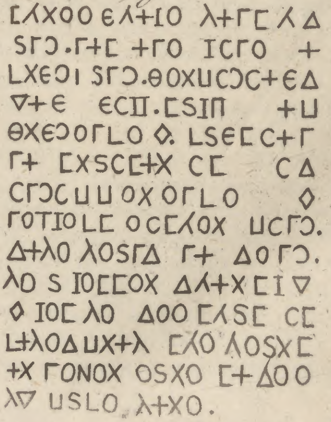


Fig. 8.

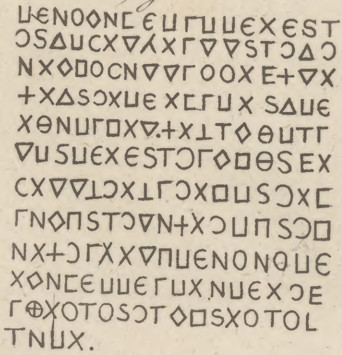
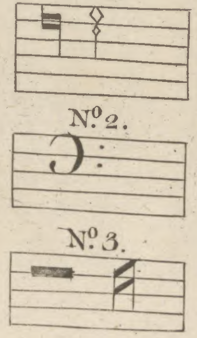


Fig. 9.

CLEFF.



A. Bell Prin. Wal. Sculptor.

ſtood a mere creature of the imagination, compoſed of ſuch contradictions and abſurdities as cannot poſſibly anywhere exiſt but in thought.

CHIMES of a Clock, a kind of periodical muſic, produced at equal intervals of time, by means of a particular apparatus added to a clock.

In order to calculate numbers for the chimes, and adapt the chime-barrel, it muſt be obſerved, that the barrel muſt turn round in the ſame time that the tune it is to play requires in ſinging. As for the chime-barrel, it may be made up of certain bars that run athwart it, with a convenient number of holes punched in them to put in the pins that are to draw each hammer: and theſe pins, in order to play the time of the tune rightly, muſt ſtand upright, or hang down from the bar, ſome more, ſome leſs. To place the pins rightly, you may proceed by the way of changes on bells, viz. 1, 2, 3, 4; or rather make uſe of the muſical notes. Obſerve what is the compaſs of your tune, and divide the barrel accordingly from end to end.

Thus, in the examples on Plate CXLIV. each of the tunes is eight notes in compaſs; and accordingly the barrel is divided into eight parts. Theſe diviſions are ſtruck round the barrel; oppoſite to which are the hammer-tails.

We ſpeak here as if there were only one hammer to each bell, that it may be more clearly apprehended; but when two notes of the ſame ſound come together in a tune, there muſt be two hammers to the bell to ſtrike it: ſo that if in all the tunes you intend to chime of eight notes compaſs, there ſhould happen to be ſuch double notes on every bell, inſtead of eight you muſt have ſixteen hammers; and accordingly you muſt divide the barrel, and ſtrike ſixteen ſtrokes round it, oppoſite to each hammer tail; then you are to divide it round about into as many diviſions as there are muſical bars, ſemibreves, minims, &c. in the tune.

Thus the hundredth-pſalm tune has 20 ſemibreves, and each diviſion of it is a ſemibreve: the firſt note of it alſo is a ſemibreve; and, therefore, on the chime-barrel muſt be a whole diviſion, from five to five; as you may underſtand plainly, if you conceive the ſurface of a chime-barrel to be repreſented by the above figures, as if the cylindrical ſuperficies of the barrel were ſtretched out at length, or extended on a plane: and then ſuch a table, ſo divided, if it were to be wrapped round the barrel, would ſhow the places where all the pins are to ſtand in the barrel; for the dots running about the table are the places of the pins that play the tune.

Indeed, if the chimes are to be complete, you ought to have a ſet of bells to the gamut notes; ſo as that each bell having the true ſound of *ſol*, *la*, *mi*, *fa*, you may play any tune with its flats and ſharps; nay, you may by this means play both the baſs and treble with one barrel: and by ſetting the names of your bells at the head of any tune, that tune may eaſily be transferred to the chime-barrel, without any ſkill in muſic: but it muſt be obſerved, that each line in the muſic is three notes diſtant; that is, there is a note between each line, as well as upon it.

CHIMNEY, in *Architecture*, a particular part of a houſe, where the fire is made, having a tube or funnel to carry off the ſmoke. The word *chimney* comes from the French *cheminée;* and that from the Latin *caminata*, "a chamber wherein is a chimney;" *caminata*, again, comes from *caminus;* and that from the Greek *καμινος*, "a chimney;" of *καιω*, *uro*, "I burn."

Chimneys are uſually ſuppoſed a modern invention; the ancients only making uſe of ſtoves: but Octavio Ferrari endeavours to prove chimneys in uſe among the ancients. To this end, he cites the authority of Virgil,

Et jam ſumma procul villarum culmina fumant:

and that of Appian, who ſays, "That of thoſe perſons proſcribed by the triumvirate, ſome hid themſelves in wells and common ſewers, and ſome on the tops of houſes and chimneys;" for ſo he underſtands *καπνωδεις υπωροφιας*, *fumaria ſub tecto poſita*. Add, that Ariſtophanes, in one of his comedies, introduces his old man, Polycleon, ſhut up in a chamber, whence he endeavours to make his eſcape by the *chimney*.

Chimnies, in Profeſſor Beckman's opinion, are comparatively of modern invention. We ſhall lay before our readers ſome obſervations from his elaborate diſſertation on this ſubject. He thus explains the above paſſage of Virgil.

"When the triumviri, ſays Appian *, cauſed thoſe who had been proſcribed by them to be ſought for by the military, ſome of them, to avoid the bloody hands of their perſecutors, hid themſelves in wells, and others, as Ferrarius tranſlates the words, *in fumaria ſub tecto, qua ſcilicet fumus è tecto evolvitur* (A). The true tranſlation, however, (ſays Mr Beckmann) is *fumoſa cœnacula*. The principal perſons of Rome endeavoured to conceal themſelves in the ſmoky apartments of the upper ſtory under the roof, which, in general, were inhabited only by poor people; and this ſeems to be confirmed by what Juvenal † expreſsly ſays, *Rarus venit in cœnacula miles*.

* *De bellis civilib.* lib. iv. p. 962, Edit. Tollii.

† *Sat.* x. ver. 17.

"Thoſe paſſages of the ancients which ſpeak of ſmoke riſing up from houſes, have with equal impropriety been ſuppoſed to allude to chimneys, as if the ſmoke could not make its way through doors and windows. Seneca ‡ writes, 'Laſt evening I had ſome friends with me, and on that account a ſtronger ſmoke was raiſed; not ſuch a ſmoke, however, as burſts forth from the kitchens of the great, and which alarms the watchmen, but ſuch a one as ſignifies that gueſts are arrived.' Thoſe whoſe judgments are not already warped by prejudice, will undoubtedly find the true ſenſe of theſe words to be, that the ſmoke forced its way through the kitchen windows. Had the houſes been built with chimney-funnels, one cannot conceive why the watchmen ſhould have been alarmed when they obſerved a ſtronger ſmoke than uſual ariſing from them; but as the kitchens had no convenience of that nature, an apprehenſion of fire, when extraordinary entertain-

‡ *Epiſt.* 64.

(A) *Ες καπνωδεις υπωροφιας, η των τεγων ταις κεραμισι βυομεναις.*

ments were to be provided in the houſes of the rich for large companies, ſeems to have been well founded; and on ſuch occaſions people appointed for that purpoſe were ſtationed in the neighbourhood to be conſtantly on the watch, and to be ready to extinguiſh the flames in caſe a fire ſhould happen. There are many other paſſages to be found in Roman authors of the like kind, which it is hardly neceſſary to mention; ſuch as that of Virgil *,

> *Et jam ſumma procul villarum culmina fumant.*

and the following words of Plautus †, deſcriptive of a miſer:

> *Quin divum atque hominum clamat continuo fidem,*
> *Suam rem periiſſe, ſeque eradicarier,*
> *De ſuo tigillo fumus ſi qua exit foras.*

"The paſſage of Ariſtophanes above alluded to, however, (ſays the profeſſor) which, according to the uſual tranſlation, ſeems to allude to a common chimney, can, in my opinion, eſpecially when we conſider the illuſtration of the ſcholiaſts, be explained alſo by a ſimple hole in the roof, as Reiſke has determined; and indeed this appears to be more probable, as we find mention made of a top or covering (τηλια) with which the hole was cloſed."

It has been ſaid that the inſtances of chimneys remaining among the ruins of ancient buildings are few, and that the rules given by Vitruvius for building them are obſcure; but it appears that there exiſt *no* remains of ancient chimneys; and that Vitruvius gives *no* rules, either obſcure or perſpicuous, for building what, in the modern acceptation of the word, deſerves the name of a chimney.

"The ancient maſon-work ſtill to be found in Italy does not determine the queſtion. Of the walls of towns, temples, amphitheatres, baths, aqueducts, and bridges, there are ſome though very imperfect remains, in which chimneys cannot be expected; but of common dwelling houſes none are to be ſeen, except at Herculaneum, and there no traces of chimneys have been diſcovered. The paintings and pieces of ſculpture which are preſerved, afford us as little information; for nothing can be perceived in them that bears the ſmalleſt reſemblance to a modern chimney.

"If there were no funnels in the houſes of the ancients to carry off the ſmoke, the directions given by Columella, to make kitchens ſo high that the roof ſhould not catch fire, was of the utmoſt importance. An accident of the kind, which that author ſeems to have apprehended, had almoſt happened at Beneventum, when the landlord who entertained Mæcenas and his company was making a ſtrong fire in order to get ſome birds ſooner roaſted.

> ——————— *ubi ſedulus hoſpes*
> *Pæne arſit, macros dum turdos verſat in igne;*
> *Nam vaga per veterem dilapſo flamma culinam*
> *Vulcano ſummum properabat lambere tectum* ‡.

Had there been chimneys in the Roman houſes, Vitruvius certainly would not have failed to deſcribe their conſtruction, which is ſometimes attended with conſiderable difficulties, and which is intimately connected with the regulation of the plan of the whole edifice. He does not, however, ſay a word on this ſubject; neither does Julius Pollux, who has collected with great care the Greek names of every part of a dwelling-houſe; and Grapaldus, who in later times made a collection of the Latin terms, has not given a Latin word expreſſive of a modern chimney *."

"*Caminus* ſignified, as far as I have been able to learn, firſt a chemical or metallurgic furnace, in which a crucible was placed for melting and refining metals; ſecondly, a ſmith's forge; and, thirdly, a hearth on which portable ſtoves or fire-pans were placed for warming the apartment. In all theſe, however, there appears no trace of a chimney." Herodotus relates (lib. viii. c. 137.), that a king of Libya, when one of his ſervants aſked for his wages, offered him in jeſt the ſun, which at that time ſhone into the houſe through an opening in the roof, under which the fire was perhaps made in the middle of the edifice. If ſuch a hole muſt be called a chimney, our author admits that chimneys were in uſe among the ancients, eſpecially in their kitchens; but it is obvious that ſuch chimneys bore no reſemblance to ours, through which the ſun could not dart his rays upon the floor of any apartment.

"However imperfect may be the information which can be collected from the Greek and Roman authors reſpecting the manner in which the ancients warmed their apartments, it nevertheleſs ſhews that they commonly uſed for that purpoſe a large fire-pan or portable ſtove, in which they kindled wood, and, when the wood was well lighted, carried it into the room, or which they filled with burning coals. When Alexander the Great was entertained by a friend in winter, as the weather was cold and raw, a ſmall fire-baſon was brought into the apartment to warm it. The prince, obſerving the ſize of the veſſel, and that it contained only a few coals, deſired his hoſt, in a jeering manner, to bring more wood or frankincenſe; giving him thus to underſtand that the fire was fitter for burning perfumes than to produce heat. Anacharſis, the Scythian philoſopher, though diſpleaſed with many of the Grecian cuſtoms, praiſed the Greeks, however, becauſe they ſhut out the ſmoke and brought only fire into their houſes *. We are informed by Lampridius, that the extravagant Heliogabalus cauſed to be burned in theſe ſtoves, inſtead of wood, Indian ſpiceries and coſtly perfumes †. It is alſo worthy of notice, that coals were found in ſome of the apartments of Herculaneum, as we are told by Winkelmann, but neither ſtoves nor chimneys."

It is well known to every ſcholar, that the uſeful arts of life were invented in the eaſt, and that the cuſtoms, manners, and furniture of eaſtern nations, have remained from time immemorial almoſt unchanged. In Perſia, which the late Sir William Jones ſeems to have conſidered as the original country of mankind, the methods employed by the inhabitants for warming themſelves have a great reſemblance to thoſe employed by the ancient Greeks and Romans for the ſame purpoſe. According to De la Valle, the Perſians make fires in their apartments, not in chimneys as we do, but in ſtoves, in the earth, which they call, *tennor*. "Theſe ſtoves conſiſt of a ſquare or round hole, two ſpans or a little more in depth, and in ſhape not unlike an Italian caſk. That this hole may throw out heat ſooner, and with more ſtrength, there is placed in it an iron veſſel

of

---

* *Eclog.* i. ver. 83.

† *Aulular.* act. ii. ſc. 4.

‡ *Horat.* lib. i. ſat. 5.

* *Franciſci Marii Grapaldi de partibus ædium libri.*

† *Plutarch. Sympoſ.* lib. vi. 7. p. 602.

‡ *Æl. Lamprid Vita Heliogab.* cap. 31.

of the ſame ſize, which is either filled with burning coals, or a fire of wood and other inflammable ſubſtances is made in it. When this is done, they place over the hole or ſtove a wooden top, like a ſmall low table, and ſpread above it a large coverlet quilted with cotton, which hangs down on all ſides to the floor. This covering condenſes the heat, and cauſes it to warm the whole apartment. The people who eat or converſe there, and ſome who ſleep in it, lie down on the floor above the carpet, and lean, with their ſhoulders againſt the wall, on ſquare cuſhions, upon which they ſometimes alſo ſit; for the *tennor* is conſtructed in a place equally diſtant from the walls on both ſides. Thoſe who are not very cold only put their feet under the table or covering; but thoſe who require more heat can put their hands under it, or creep under it altogether. By theſe means the ſtove diffuſes over the whole body, without cauſing uneaſineſs to the head, ſo penetrating and agreeable a warmth, that I never in winter experienced any thing more pleaſant. Thoſe, however, who require leſs heat let the coverlet hang down on their ſide to the floor, and enjoy without any inconvenience from the ſtove the moderately heated air of the apartment. They have a method alſo of ſtirring up or blowing the fire when neceſſary, by means of a ſmall pipe united with the tennor or ſtove under the earth, and made to project above the floor as high as one chooſes; ſo that the wind, when a perſon blows into it, becauſe it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occaſion to uſe this ſtove, both holes are cloſed up, that is to ſay, the mouth of the ſtove and that of the pipe which conveys the air to it, by a flat ſtone made for that purpoſe. Scarcely any appearance of them is then to be perceived, nor do they occaſion inconvenience, eſpecially in a country where it is always cuſtomary to cover the floor with a carpet, and where the walls are plaſtered. In many parts theſe ovens are uſed to cook victuals, by placing kettles over them. They are employed alſo to bake bread; and for this purpoſe they are covered with a large broad metal plate, on which the cake is laid; but if the bread is thick and requires more heat, it is put into the ſtove itſelf *."

The profeſſor farther obſerves, the oldeſt account of them which he finds is an inſcription at Venice, which relates, that in the year 1347 a great many chimneys were thrown down by an earthquake. It would appear, however, that in ſome places they had been in uſe for a conſiderable time before that period; for De Gataris, in his hiſtory of Padua, relates, that Franceſco de Carraro, lord of Padua, came to Rome in 1368, and finding no chimneys in the inn where he lodged, becauſe at that time fire was kindled in a hall in the middle of the floor, he cauſed two chimneys like thoſe which had *long* been uſed at Padua to be conſtructed by maſons and carpenters, whom he had brought along with him. Over theſe chimneys, the firſt ever ſeen at Rome, he affixed his arms, which were ſtill remaining in the time of De Gataris, who died of the plague in 1405.

Method of Building CHIMNEYS *that will not ſmoke.* Workmen have different methods of drawing up the funnels of chimneys, generally according to their own fancies and judgments, and ſometimes according to the cuſtoms of places. They are ſeldom directed by ſound and rational principles. It will be found for the moſt part, that the ſmoking of chimneys is owing to their being carried up narrower near the top than below, or zig-zag, all in angles; in ſome caſes, indeed, it is owing to accidental cauſes; but, for the moſt part, to thoſe two above mentioned. Where they are carried up in the pyramid or tapering form, eſpecially if the houſe be of a conſiderable height, it is ten to one but they ſometimes ſmoke. The air in the rooms, being rarefied, is forced into the funnel of the chimney, and receives from the fire an additional force to carry up the ſmoke. Now it is evident, that the further up the ſmoke flies, the leſs is the force that drives it, the ſlower it muſt move, and conſequently the more room in proportion it ſhould have to move in; whereas in the uſual way it has leſs, by the ſides of the chimney being gathered cloſer and cloſer together.

The method here propoſed of carrying up chimneys will be objected to by ſome thus: The wider a chimney is at the top, ſay they, the more liberty has the wind to blow down. Very true; but is it not reſiſted in going down, both by the form of the chimney and other evident cauſes, ſo that it muſt return again? In the other way, when the wind blows down, the reſiſtance being leſs, the wind and ſmoke are, if we may uſe the expreſſion, impriſoned, and make the ſmoke puff out below. This method has proved effectual after all others had failed; and that in a houſe placed in the worſt ſituation poſſible, namely, under a high mountain to the ſouthward, from which ſtrong blaſts blow down upon it. A vent was carried up without angles, as perpendicular as poſſible; and was made about three or four inches wider at top than at the bottom: the funnel was gathered in a throat directly above the fire-place, and ſo widening upwards. Since that time the houſe has not only ceaſed to ſmoke, but when the doors ſtand open, the draught is ſo ſtrong that it will carry a piece of paper out at the chimney head. See more on this ſubject and the improvements by Count Rumford under the article SMOKE.

CHIMNEY-Money, otherwiſe called *Hearth-money*, a duty to the crown on houſes. By ſtat. 14. Char. II. cap. 2. every fire-hearth and ſtove of every dwelling or other houſe, within England and Wales (except ſuch as pay not to church and poor), was chargeable with 2s. per annum, payable at Michaelmas and Lady-day to the king and his heirs and ſucceſſors, &c.; which payment was commonly called *chimney-money*. This tax, being much complained of as burdenſome to the people, has been ſince taken off, and others impoſed in its ſtead; among which that on windows has by ſome been eſteemed almoſt equally grievous.

CHIMPANZEE, in *Natural Hiſtory*. See SIMIA.

END OF THE FIFTH VOLUME.

---

* *Hiſt. of Invent.* II, 88.

DIRECTIONS FOR PLACING THE PLATES of VOL. V.

PART I.	Page.
Plate CXXXI. CXXXII. to face	14
CXXXIII.	74
CXXXIV:	112
CXXXV.	260
CXXXVI.	282
CXXXVII.	320
CXXXVIII. CXXXIX.	318
CXL. CXLI.	358
PART II.	
CXLII. CXLIII.	774
CXLIV.	79