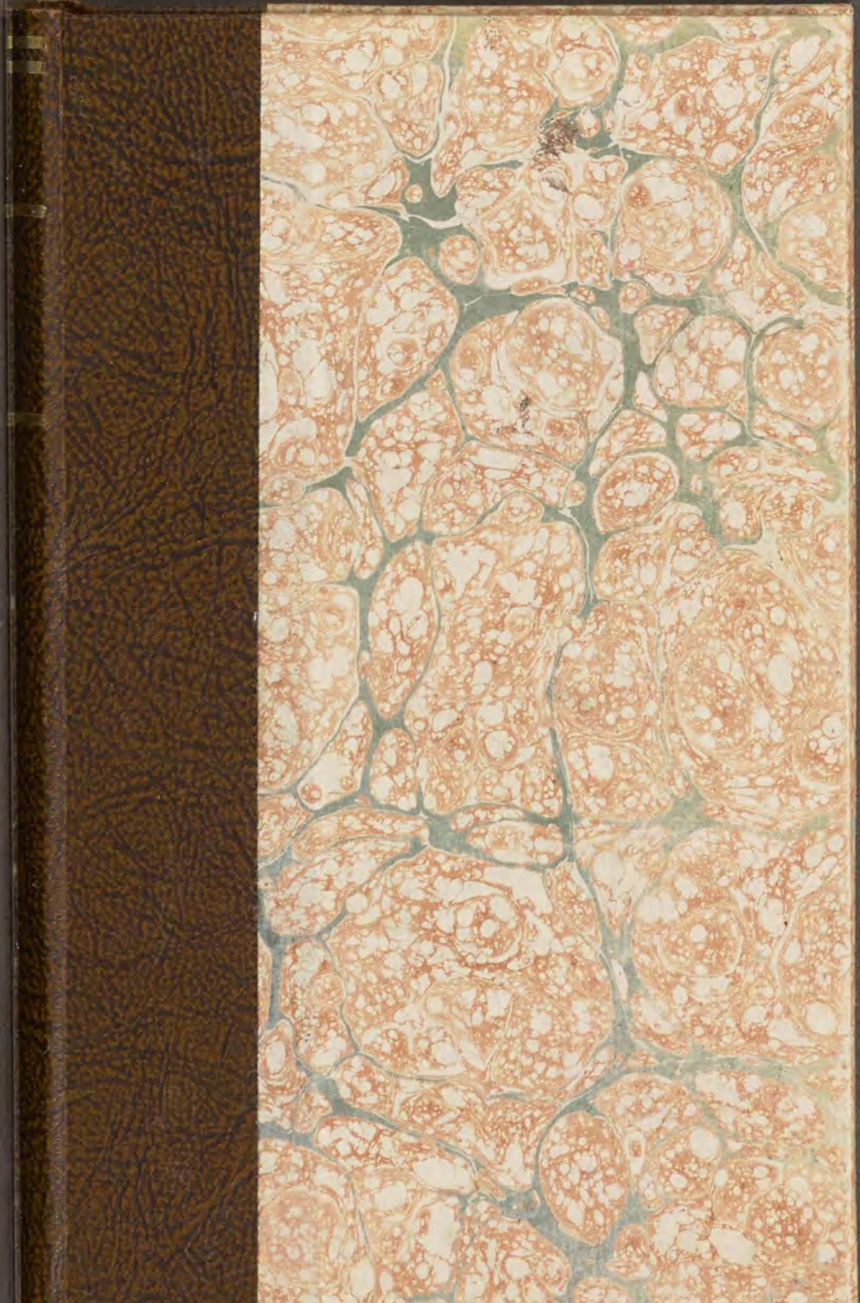

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N Paulding. 125.

MANUAL

OF

ANALYTICAL MINERALOGY.

BY

FREDRICK ACCUM.

THE SECOND EDITION, WITH PLATES.

Published by the same Bookſellers, price One Guinea, in bds.

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ACCUMS Analytical Mineralogy.

of V
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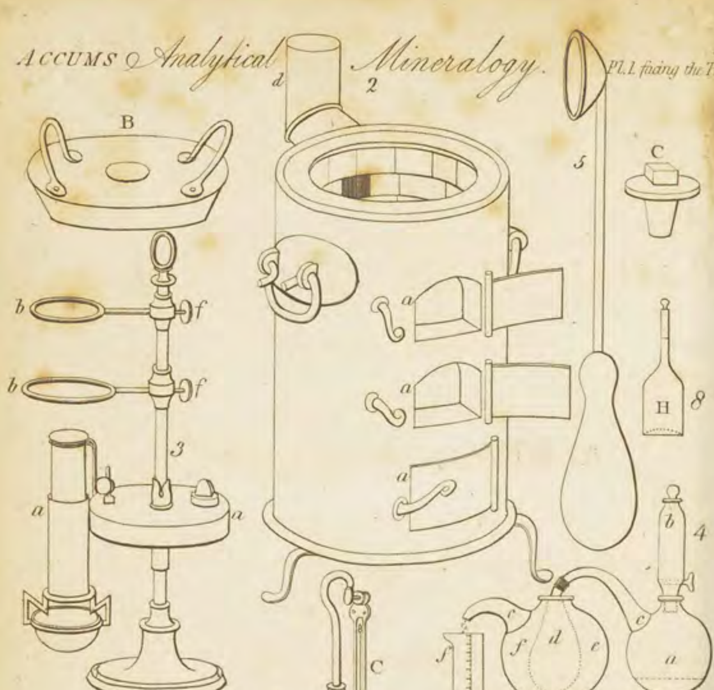

Fig. 1.

A

MANUAL

OF

ANALYTICAL MINERALOGY,

INTENDED TO FACILITATE THE

PRACTICAL ANALYSIS OF MINERALS.

IN TWO VOLUMES.

BY

FREDRICK ACCUM,

HONORARY MEMBER OF THE ROYAL IRISH ACADEMY;
OPERATIVE CHEMIST;
LECTURER ON EXPERIMENTAL CHEMISTRY, AND ON MINERALOGY,
AND PHARMACY.

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FELLOW OF THE

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AS AN ACKNOWLEDGMENT

OF

THE GREAT ADVANTAGES AND IMPROVEMENTS

WHICH

THE SCIENCE OF MINERALOGY HAS RECEIVED

FROM

HIS NUMEROUS AND ADMIRABLE LABOURS,

THIS MANUAL

OF

ANALYTICAL MINERALOGY

IS

RESPECTFULLY INSCRIBED.

PREFACE.

11, *Compton Street, Soho.*

In the lines prefixed to the first edition of this book the reader is informed that the work was not originally drawn up for public inspection, but that it was intended to serve as a text book for my pupils, to render more useful the Series of Lectures I deliver on the subject of which it treats. By the repeated desire of others, whose judgment and advice I respect, it was afterwards re-published in the manner it was originally composed.

The unexpected public and private approbations which the work met with, amongst a scientific public, are flattering proofs that my labours were considered as not altogether useless.

And the rapid sale of an uncommonly large edition, which was disposed of in less than eighteen months after its publication, gives me reason to think that the votaries of the science are numerous. Indeed there is no extravagance in saying that there never was a time in which the science of Mineralogy was cultivated in Great Britain with more ardour and success than at present, and in which it has contributed more strikingly to the improvement of our Arts, and the extension of our Commerce. The foreign mining establishments and manufactures are overwhelmed and greatly ruined by the dreadful political storms in which they have been, and still are, engaged; whereas the British miner can carry on his subterraneous workings without molestation, and with success. The smelter is not driven from his furnace, nor the potter from his lathe, by political commotions; and the theatre of the war which we wage with foreign enemies is, and, whatever they may desperately attempt, will continue to be remote.

In the lines I now present to the judgment of the public, the original plan of the former work has been kept in view: a more enlarged scale however has been pursued, and an endeavour has been made to render the book more useful or perfect, and better adapted for those cultivators of the science, who have neither leisure nor inclination to obtain practical knowledge among the furnaces of the operative chemist, or to turn over the numerous treatises through which the necessary information lies scattered.

The whole has therefore been written anew, and the additions that have been made alone exceed twice the contents of the original publication.

I have endeavoured to condense into as narrow a compass as possible the general rules and practical proceedings necessary for the chemical examination of minerals, by pointing out to the student concise directions for conducting the analyses of metallic ores, of earths, stones, and other minerals, so as to enable him to ascertain, with the book in his hand, the nature and composition of all such mineral substances as he may meet with; and to determine the uses to which they may be applied.

And, as it is impossible to advance general rules that might be applicable in all cases, I thought it necessary to illustrate, in a series of experiments, not only the practical operations of analysis of such minerals as are commonly met with, but I have exemplified likewise the processes necessary for the examination of those substances as occur but rarely in nature. To give effect to this undertaking, I have systematically exhibited all the substances which form the empire of the mineral kingdom, and have endeavoured to point out, under each class and genus, the best practical proceedings of the day, so as to present to the student a register of the present state of analytical mineralogy, interspersed with illustrative examples, taken from the Memoirs of Klaproth, Vauquelin, and other celebrated analysts.

I have also endeavoured to detail the respective analyses and individual operations with as much accuracy and fidelity as my slender abilities could suggest. I have seldom entered into explanatory discussions, taking for granted that he who applies his hand to the practical examination of minerals, has previously acquired some slight share of chemical knowledge.

And, although the greater part of the work consists of the labours of others, those who are familiar with the subject, on which it treats, will nevertheless notice various facts and practical proceedings, of which all the praise and all the blame belongs to the author of the work. On these I do not conceive it necessary to make any remarks. If what has been advanced, as far as it goes, be deemed better than what is in general use, the question whence it originated is, in this case, of little consequence to the reader. I am far from entertaining an opinion that the structure of the work is perfect, or that it stands in no need of indulgence: for in the exposition of a science where so many operations of art are to be detailed, and such a multiplicity of complicated facts to be developed, error is almost unavoidable. — These considerations alone will plead my excuse.—Confident that the generalities of the advanced statements may prove useful to the student, I may perhaps expect some approbation from those I wish to instruct, and hope for some indulgence from such as are skilled in the science. I have indeed written for beginners; but if great scholars confess that they have read their grammar, over and over again with profit, the good analyst may perhaps reap some advantage from being reminded—where he cannot be instructed.

LONDON, 1808. FRED. ACCUM.

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ORE OF COLUMBIUM.

ORES OF TANTALIUM.

ORE OF IRIDIUM WITH OSMIUM.

ORE OF CERIUM.

The Work referred to, p. 377, and quoted in several other places of this Manual, will be published on the 1st of December, under the title of

A
SYSTEM
OF
MINERALOGY
AND
MINERALOGICAL CHEMISTRY.
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ERRATA.

Page 20,	line 10,	*dele* as H viz.
42,	1,	*for* Potash, *read* nitrate of potash.
ibid	2,	*for* Barytes *read* nitrate of barytes.
98,	17,	*for* colubium, *read* columbium.
408,		*for* Wavellite, *read* Wavillite.
449,	10,	*for* murite *read* silici-murite.
505,	23,	*for* fig. 1, plate I. *read* fig. 4, plate I.

N. B. The Title Vignette spoken of page 34 is intentionally omitted, being unnecessary.

A
PRACTICAL ESSAY
ON THE
ANALYSIS OF MINERALS.

PART I.

DEFINITION OF MINERALS.

THE name of MINERAL, in the strict sense of the word, denotes only such substances as are found in mines, but the term is generally applied in a more extended view to characterise that class of inorganic and inanimate bodies, which form the solid mass, or rather the external covering of the globe we inhabit; so far at least as the labour of man has hitherto penetrated.

The totality of these substances has received the appellation of the mineral kingdom, in opposition to the two remaining grand divisions of nature, called the vegetable and animal kingdom.

GENERAL CHARACTERS OF MINERAL-SUBSTANCES.

MINERALS absolutely possess no life, nor do they exhibit any phenomena dependant on external organisation. Minerals may increase in size, but their growth is exceedingly different from the growth of organic beings. It does not take place by virtue of nutrition and subsequent expansion of organic matter. It is not affected by external functions, and produces no advantage to the individual. The magnitude of a stone can only be increased by virtue of a mechanical, or chemical application of new matter; it is the result of simple combination of external materials aided by mechanical action, or regulated by chemical affinity. The subjects of the mineral kingdom are absolutely passive, they are acted on by external agencies only, and possess no power of changing that action.

NATURE OF MINERALOGICAL SCIENCE.

MINERALOGY is that department of the science of nature which makes us acquainted with the habitudes and characters of minerals. It teaches the art of distinguishing them, by means of accurate and well-defined characters; the mode of describing them with so much precision, as is sufficient to recognise them with facility whenever they occur, and the art of arranging or classing them in a certain order, called a system.

To accomplish these views it traces the simple distinctions, and even the most minute variegations of properties discoverable amongst the different bodies hitherto known. It observes and marks every possible variety of form, appearance, and structure, under which a mineral is found; and endeavours to define with the strictest attention the mineralogical method and nature of the characters employed, as well as the technical language and nomenclature by which these minute distinctions can be accurately expressed, so as to convey complete instruction.

NATURE OF ANALYTICAL MINERALOGY.

Analytical Mineralogy, or the analysis of minerals, is a branch of philosophical chemistry. It teaches the art of examining minerals, not by the help of external characters, but chiefly by chemical agencies. Its views are directed to the development of the constituent parts of minerals, the order in which they are present, their relative quantities, and the best modes of separating them.

The views of analytical mineralogy are therefore more extended, more intricate and laborious than those which belong to the natural history of these bodies. The latter department of knowledge, unassisted by the labours of mineralogical chemistry is little more than a language composed of words arranged by an arbitrary title; it is from the progress of analytical mineralogy, that the natural history of minerals must receive its principal aid in advancing to a perfect and dignified science: and hence the rapid improvements which have been made in this department of knowledge, has thrown a strong and steady light on some of the most obscure branches of mineralogical science.

The views of analytical mineralogy may appear at first sight immense and intricate. The number of different species of minerals, now known, is between seven and eight thousand.

To separate five or six substances intimately combined together, to exhibit them separate, to ascertain the precise quantity of each ingredient, and even to detect the presence and the weight of substances which do not amount to the $\frac{1}{500}$th part of the whole, would at no very remote period have been considered as a hopeless, if not an impossible task. The great progress which chemistry has made during our own time, has greatly facilitated this branch of enquiry.

The summary field of chemical investigation is nevertheless so vast and spacious that the most diligent enquiry cannot completely traverse it, in all its extents, nor can any continuance of labour exhaust its application.

The practical analysis of minerals consists in a series of chemical operations, calculated either to separate the constituent parts, masked and concealed from our view, so as to exhibit them in a detached state, or to cause them to form new compounds from which their nature and properties may be inferred; a series of chemical processes thus conducted lead to the object desired; namely, the knowledge of the constituent parts of the substance under examination, their respective quantities, and the best modes of separating them.

RE-AGENTS AND TESTS.

To facilitate the analyses of minerals, the substance of which is the object of enquiry, is exposed under different circumstances to the action of various bodies which chemically act on it, or alter its properties so as to produce changes which are striking to the senses, and from which the presence or absence of certain bodies may be inferred. These agents, thus employed, are called chemical tests or re-agents, they enable us to pursue our enquiry according to certain rules founded on experience. The proper application of these bodies, together with the necessary practical proceedings, or artificial arrangements best adapted for the reciprocal action, constitute the operation of analytical mineralogy.

To illustrate the agencies of chemical tests, let us suppose that a drop of muriatic acid, when suffered to fall on an unknown substance, occasions an effervescence, we conclude from the phenomenon produced, that the unknown body contains carbonic acid; if a drop of the same fluid occasions a white precipitate when mingled with a solution of the mineral substance under consideration, we then conclude that the unknown body contains either silver or lead; let us suppose that both these metals were present. To separate them from each other we merely pour over the precipitate, liquid ammonia. The silver will become dissolved, and the lead left behind. To pursue our enquiries further, let us suppose that sulphate of iron produced a dark brown precipitate, we conclude from the appearance produced, that gold is present; if liquid ammonia effected a blue precipitate, copper is suspected; if muriate of gold throws down a brown precipitate, it contains tin; if tincture of galls produces a black precipitate, iron, &c. Thus it becomes evident that certain bodies have the property of indicating and separating other bodies, the existance of which is unknown, form compounds of which they form a part. Now the great object in analytical enquiries, is, to find a body x capable of separating a body a, from another body b.

It is by this means that chemical analyses are effected by the help of certain re-agents or tests.

He accordingly, who is able to resolve the problem in the greatest variety of circumstances, is the best analyst. Hence the application of chemical tests facilitates and guides our enquiries, and although the compleat analysis of a mineral demands often an extended series of operations, it is nevertheless certain, that by the simple applications of a few re-agents, many useful analytical enquiries may be accomplished. A mineralogical knowledge of the composition of bodies being generally sufficient in directing the most important application of minerals for useful purposes.

OPERATIONS OF ANALYSIS.

Before we proceed to exhibit the methods, made use of by chemists in analysing minerals, we shall give a short account of those general processes and instruments to which it is necessary to have continually recourse in almost every analysis.

It was once thought, that for the purpose of experimental inquiry, particularly of this nature, a place or laboratory, regularly fitted up with furnaces and other apparatus was absolutely necessary. This is by no means the case. The great improvements which have been made in analytical chemistry have superseded this necessity; and it is now universally admitted, that all the operations of analysis may (in the small way) be conveniently performed, by the help of a few instruments, in the closet of the amateur of the science; and that even all the apparatus, re-agents, and other articles of experiment, necessary for the analysis of minerals, may be comprised in a convenient travelling chest. (See Index Mineralogical Laboratory.)

When the object is to analyse a mineral; for instance an ore, particularly with a view to ascertain the comparative richness with respect to the metal it contains, it is absolutely necessary that specimens of the ore, be taken, from the richest, the poorest, and from that which seems to be of middling quality. This precaution is indispensible, because were the analysis made with a rich specimen, it might raise too flattering expectations; or if with a poor one, it might produce discouragement.

The next step in the analysis of any kind of mineral, consists in separating the substance intended to be examined, from all kind of extraneous matter, with which it is always more or less united. They may be separated by picking, washing, or other mechanical operations, in order that the mineral may be examined pure or unmixt. This being done, its specific gravity must be ascertained. The method of accomplishing this, shall be noticed presently. The substance employed should next be reduced to an impalpable powder by means of the pestle and mortar. This operation is called *pounding*, or *pulverisation*. The bottom of mortars should be concave, and their sides neither so inclined as to allow the substance operated on, to fall to the bottom, between each stroke of the pestle, nor so perpendicular as to collect it too much together and retard the operation. A steel or iron mortar is convenient for dividing large specimens of minerals into smaller pieces, to render them more fit for being reduced to a finer powder in a smaller mortar of Wedgwood's water or agate.

Trituration differs from the process of pulverisation, only in degree; it is performed by giving a rotatory motion to the pestle.

Levigation differs from trituration in the addition of water to the powder operated upon; so as to form the whole mass into a tenacious or rather liquid paste, which is rubbed in the mortar till it is as fine as required. Very hard substances, particularly all stones of the silicious kind must be repeatedly heated to redness, and then suddenly quenched in cold water, to render them sufficiently friable.

Weighing. The quantity of substance thus previously comminuted, should next be accurately determined by the process called *weighing;* for that purpose the operator should be provided with a good balance, and an accurate set of weights. The beam of a good balance should remain in equilibrio without the scales, and when the scales are changed, and should turn sensibly with a small portion of additional weight when loaded. Scales must be defended as much as possible from acid vapours, as their delicacy is impaired by them: for the same reason they never should be overloaded. It is of the utmost consequence in every analysis, to ascertain at all times the precise quantity of any matter which is subjected to examination, and again to distinguish with equal accuracy the quantities of the products. Hence the instruments for weighing are to be regarded as particularly deserving of the young analyst's attention.

It is necessary to have scales and weights for ordinary use, and others for occasions where greater accuracy is necessary. Fine scales should always be kept apart from the laboratory, for otherwise the beam will rust, and the accuracy of the balance be destroyed. They are most conveniently used when suspended from a support, so constructed as to raise the beam when employed for weighing. (See hydrostatic balance.)

Common balances are subject to many imperfections, the principal of which are as follows:

1st. A balance is frequently in equilibrio, when the opposite weights in its scales are not equal. This arises from the points of suspension being not equidistant from the centre of motion; in which case the empty scales may be made to balance each other; yet, when equal weights are put in them, those weights will not balance each other; for as they are suspended at an unequal distance from the centre of motion, their momentums are actually unequal.

The beam is often made too slight: in which case it is apt to be bent more or less by the weights that are put into the scales; and of course the apparent equilibrium cannot be depended upon.

They seldom are sufficiently sensible. This defect arises from various causes, as from the great weight of the beam, from roughness and friction at the point of suspension, from the centre of gravity of the beam being considerably below the centre of motion, &c.

Balances for analysis may be had of a wonderful degree of sensibility; viz. capable of having their equilibrium disturbed by so small a quantity as $\frac{1}{1000}$ part of the weight in each scale.

Weights. As the utility of analytical research depends greatly upon the determination of the quantities of the ingredients and products, not only accurate scales but accurate weights are also necessary. The weights of the analyst should be divided into their several fractions, both vulgar and decimal. All weights should be adjusted by means of repeated and accurate trials in the most delicate scales, and by skilful workmen. It requires a tolerable share of experience and dexterity to use weights properly. The best way of precisely ascertaining the weight of a particular substance, is to weigh it twice, once with the decimal division of the pound, ounce, or grain, and another time with the vulgar fraction or common subdivision, and by comparing these we obtain the utmost accuracy. If a balance be found to turn with a certain addition, is not moved by any smaller weight, a greater sensibility may be given to that balance by producing a tremulous motion in its parts. Thus if the edge of a blunt saw, a file, or similar instrument be drawn along any part of the support of the balance, it will produce a jarring motion, which diminishes the friction of the moving parts so much that the turn will be evident, with one third, or $\frac{1}{4}$ of the addition that would else have been required. In this manner a beam, which will barely turn by the $\frac{1}{10}$ part of a grain, may be made to turn with the $\frac{1}{30}$ or $\frac{1}{40}$ part of a grain.

Decimal Weights. Experimental chemists divide their pound or ounce into decimal parts, and a set of decimal weights are considered as essential to the analyst. The set of decimal weights most convenient for chemical and other operations, is the following: viz. 1000 grains, 900 g. 800 g. 700 g. 600 g. 500 g. 400 g. 300 g. 200 g. 100 g. 90 g. 80 g. 70 g. 60 g. 50 g. 40 g. 30 g. 20 g. 10 g. 9 g, 8 g. 7 g. 6 g. 5 g. 4 g. 3 g. 2 g. 1 g. $\frac{9}{10}$ g. $\frac{8}{10}$ g. $\frac{7}{10}$ g. $\frac{6}{10}$ g. $\frac{5}{10}$ g. $\frac{4}{10}$ g. $\frac{3}{10}$ g. $\frac{2}{10}$ g. $\frac{1}{10}$ g. $\frac{9}{100}$ g. $\frac{8}{100}$ g. $\frac{7}{100}$ g. $\frac{6}{100}$ g. $\frac{5}{100}$ g. $\frac{4}{100}$ g. $\frac{3}{100}$ g. $\frac{2}{100}$ g. $\frac{1}{100}$ g. With these weights the philosopher will always have the same number of weights in his scales as there are figures in the number expressing the weights in grains.

Thus 742,5 grains will be weighed by the weights 700, 40, 2, and $\frac{5}{10}$.

The error of adjustment is the least possible when one weight is in the scale; that is to say, a single weight of 5 grains, is twice as likely to be true as two weights, one of 2, and the other 3 grains, because each of these last has its own probability of error in adjustment.

Pile of Weights. Other weights may be made by a subdivision of a standard weight. If the weight be continually halved, it will produce the common pile, which is the smallest possible number for weighing between its extremes, without placing any weight in the scale with the body under examination. Granulated tin is a very convenient substance to be used in halving, which however is very tedious. The readiest way to subdivide small weights, consists in weighing a certain quantity of small silver wire, and afterwards cutting it into such parts, by measure, as are desired. Or the wire may be wrapped close round two pins, and then cut asunder with a knife. By this means it will be divided into a great number of equal lengths, or small rings. The wire ought to be so thin, as that one of these rings may barely produce a sensible effect on the beam. If any quantity (as, for example, a grain) of these rings be weighed, and the number then reckoned, the grain may be subdivided in any proportion, by dividing that number, and making the weights equal to as many of the rings as the quotient of the division denotes. Then, if 750 of the rings amounted to a grain, and it were required to divide the grain decimally, downwards, $\frac{9}{10}$ would be equal to 675 rings, $\frac{8}{10}$ would be equal to 600 rings, $\frac{7}{10}$ to 525 rings, &c. Small weights may be made of thin leaf silver. Jewellers foil is a good material for weights below the $\frac{1}{10}$ of a grain, as low as to the $\frac{1}{100}$ of a grain; and all lower quantities may be estimated by actually counting the rings of wire, whose value has been determined.

Specific Gravity. By the term specific weight or specific gravity of a body, is understood the weight which any given bulk of matter bears to the weight of another body of the same magnitude, it is called the specific weight because it is the comparative weight of different sorts of matter. Thus the specific weight of mercury is to the specific weight of water as 13 to 1, the meaning of which is, that if a quantity of mercury which exactly fills a certain vessel, and a quantity of water which likewise precisely fills the same vessel, be weighed separately, the quicksilver will weigh 13 times as much as the water, so that if the latter will weigh 1oz. the mercury will weigh 13 oz. The object of finding the specific gravity of bodies is therefore to distinguish them from each other in one of their most obvious qualities, viz. weight of matter contained in a given space. The specific gravity of bodies is as their density; the density of a body is the quantity of matter which it contains under a given bulk; the density of a body is therefore measured by the proportion which its quantity of matter bears to its bulk, for the more numerous the particles of matter are in the same portion of space the greater is the density of the body, and on the contrary, the fewer the particles of matter the less the density. The nature of specific gravity therefore implies comparison; some kind of substance must be fixed upon whose gravity must be made a standard for the gravity of other bodies of equal bulk to be compared with. This standard body should have two properties, first it must be had or come at upon all occasions; and secondly, it should be of as fixed and unalterable a nature as possible that there may be no variation in its gravity, in equal bulks, in different times and places.

Water amongst fluids is that body which possesses in the highest degree the requisite properties for a standard. Distilled water is the least objectionable, next to this rain water, but common water for most purposes will answer very well; hence water is always used as the standard of comparison or as the unit with which all other bodies are compared. The specific gravity is liable to be altered by two causes, viz. by the admixture of other substances, and by an alteration of temperature, for instance, water at 100° is lighter than water at 60°, and still lighter than water at 40°, hence it is absolutely necessary that the water for ascertaining specific gravities should always be used at the same temperature, and should be free from heterogeneous matters.

The most natural way of determining the specific gravity of bodies is to weigh, in a pair of scales, bodies of different sorts, of precisely the same dimensions, and this indeed is a very good practical method for fluids, which may be put successively into the same phial, &c. but the difficulty of forming solids exactly of the same dimensions is so very great that their specific gravities are generally determined by weighing each body both out of water, or in air, and in water, in the manner which will be particularly described, excepting some powdery substances, which in this respect may be treated like fluids. It appears therefore that a fine pair of scales or balance is the principal instrument which is required for determining the specific gravities of bodies, it only requires to have a hook affixed under one of the scale pans. This balance when in use might be held in the operator's hand; but as those experiments require a certain time, and much accuracy, it is adviseable to have them set upon a stand, such as is represented in fig. 1, plate I. the whole apparatus then for determining gravities, goes under the name of the Hydrostatic balance. It consists of the following parts: A balance, such as A. B. C. D. fig. 1, plate I. which should be so sensible as to turn at least with the twentieth part of a grain, when each scale is loaded with a weight of one ounce. An accurate set of weights, especially of grains, such as weights of 10 grains, and of 100 grains, besides the single grains, it being much more commodious to make the computation entirely in grains, or at most in ounces and grains, than to be encumbered with weights of different denominations. A glass jar E. about seven or eight inches high, which is to contain the distilled or rain water, a glass ball of about an inch or an inch and a half in diameter with a bit of fine platina wire about three inches long affixed to it.* A small glass bucket G. A small phial or two, as H. (viz.) of such a shape as to admit of their being easily filled, emptied, and cleaned, and a thermometer I. This hydrostatical balance and apparatus may be had of a very compact form, so as to admit of its being packed up in a pretty small box, but when in use it must be set upon a table, where it must be remarked that the balance may be moved a little up or down, either by means of the string, which goes along the

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* This ball may be either of solid glass, or of hollow glass, partly filled with quicksilver, or with some other heavy substance; in the latter case it generally has a short perforated stem, into the perforation of which the platina wire is fastened. But if it be a solid glass ball, a hole of about one fifth of an inch in length must be drilled in it where the wire is to be fastened. For the sake of expedition in making the computation, it would be proper to make this glass ball of a certain weight expressible by a round number, for instance, of 100, or 500, or 1000 grains.

stand, in the common way, or by some rack work motion, or other mechanical contrivance, which need not be particularly described. We shall now proceed to state the practical methods of determining the specific gravities of bodies of various species.

I.—*Method of ascertaining the Specific Gravity of a Mineral or Solid which is heavier than water.*

Rule.—Suspend the solid by means of a slender wire or thread as may be just sufficient to hold it to the hook under the scale C. so as to hang at the distance of six or seven inches below that scale, and by putting weights in the opposite scale D. find out its exact weight in air, that is out of the water; then place the jar E. about three quarters full of rain, or distilled water, under the scale C. which is the case actually represented in the figure; let the solid body be immersed in the water, and either by removing some of the weights from the scale D. or by putting weights in the scale C. find out its exact weight in water; subtract the latter weight from the former, and note the remainder; lastly, divide the weight of the solid out of the water, by that remainder, and the quotient will express its specific gravity. See the precautions which follow the example. A piece of mineral was found to weigh in air (that is out of the water) 360 grains, and in water 300 grains; the latter weight being subtracted from the former gives 60. Now 360 divided by 60 gives 6, which is the specific gravity sought.

The water in which the solid is to be weighed besides its being distilled or rain water, must be quite clean, its temperature as well as that of the solid must be as near as possible to 62° of Fahrenheit's thermometer, for which purpose the ball of the thermometer must be placed in the water, and the temperature is adjusted by the addition of hot or cold water. If the mineral be soluble in water, as salts, &c. or if it be porous enough to absorb any water, then it must be varnished over with some thin varnish, but in that case some allowance must be made on account of the varnish. When the solid is weighed in water, its upper part ought to be a little way below the surface of the water, and care should be taken that no air bubles are attached to it, for they would partly buoy it up, these may be easily removed by means of a feather. The solid must be of a compact form and free from accidental or artificial vacuities, so as not to harbour any air, for otherwise its specific gravity cannot be ascertained by weighing in water, &c. thus a piece of silver, which is much heavier than water, may be formed into a hollow sphere which will appear to be much lighter than water, for if this sphere were immersed in water, it would displace a quantity of that fluid which is equal not only to the silver, but also to the space which is contained in the sphere,* these precautions must be attended to in the practical performance in the preceding as well as of the following problems of this chapter as far as they may be concerned in them.

2. *Method of ascertaining the Specific Weight of Minerals that are sufficiently heavy to sink in water, which are not soluble in that fluid, but are too small to be tied by means of a thread.*

Rule.—Suspend the glass bucket G. by the

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* It is for this reason that a ship might be made of iron, of copper, or in short of any substance, whose specific gravity far exceeds that of water, and yet it would float as well as a ship which is made of wood in the usual way.

interposition of a thread or wire to the hook of the scale C. and find its weight in air, then place the substance which is to be tried in it, and weigh it again, the former weight subtracted from the latter, leaves the weight of the substance in air, this being done, the same operation must be repeated in water, that is, let the loaded bucket be weighed in water, then remove its contents and weigh the bucket alone in water, subtract the latter weight from the former and the quotient is the weight in water of the substance under examination; having thus obtained the weight of that substance, in water and out of water, you will then proceed according to the preceding problem. (viz.) Subtract its weight in water from its weight in air, and note the remainder. Divide its weight in air by this remainder the quotient will express its specific gravity. Observe the general precautions stated before. By this means the specific gravity of diamonds, and other small precious stones as also of grains of platina, gold dust, of filings of metal, of mercury, &c. may be ascertained.

Example. The glass bucket being suspended from the hook of the scale C. was counterpoised by weights in the opposite scale D. some gold dust was then placed in it, and by adding more weights into the scale, D. its weight (viz.) of the gold dust alone was found to be 460,6 grains, the loaded bucket was then weighed in water, and was found to weigh 736,1 grains, and after having removed the gold dust from the bucket, the latter by itself was found to weigh in water 300 grains, which being subtracted from 736,1 left 436,1 grains for the weight of the gold in water; then this weight of the gold in water (viz. 436,1) was subtracted from its weight in air, (viz. 460,6) and the remainder was 24,5. Lastly, the weight of the gold in air, viz. 460,6 was divided by the remainder 24,5, and the quotient 18,8 expressed the specific gravity of the gold dust.

3. *Method of ascertaining the specific gravity of minerals or solid bodies lighter than water, or such as will not sink in it.*

Rule.—Take another body of a compact form, but much heavier than an equal bulk of water, so that when this body is connected with the body in question they may both sink in water. This being prepared, ascertain the weight of the lighter body in air, and the weight of the heavier body in water; then tie, by means of thread, both bodies together, but not so closely as to exclude the water from, or to harbour bubbles of air between them; and weigh them both in water. Now, since the heavy body is partly buoyed up by the lighter body, the weight of both in water will be less than the weight of the heavier body alone: subtract the former from the latter, and add the remainder to the weight of the lighter body in air; for this sum is the weight of a quantity of water equal in bulk to the lighter body, therefore, the weight of the lighter body in air must be divided by the last mentioned sum, and the quotient will express the specific gravity of the lighter body. Observe the general precautions as before stated.

Example. A piece of elm being varnished, in order to prevent its absorbing any water, was found to weigh in air 920 grains. A piece of lead, which was chosen for this purpose, was found to weigh in water 911,7 grains. The piece of elm and the piece of lead were tied together, and being suspended from the hook of the scale C, &c. in the usual manner, were found to weigh in water 331,7 grains (viz.) 580 grains less than the lead alone, therefore 580 was added to 920 (viz.) to the weight of the elm in air, and made up the sum of 1500. Lastly, 920 was divided by 1500, and the quotient 0,6133 expressed the specific gravity of the piece of elm. It is almost superfluous to observe, that the specific gravity of bodies that are lighter than water are less than unity.

4. *Method of ascertaining the specific gravities of small bodies (such as saline powders, &c.) which are soluble in water.*

Rule.—The substance in question must be reduced into fine powder, unless it be already in that shape. Take a clean glass phial, furnished with a ground stopper, put it in one of the scales of the balance, and counterpoise it by placing weights in the opposite scale; then fill the phial with the powder in question, ramming it as close as possible, and quite up to the top. This done, replace the phial in the same scale in which it stood before, and by adding more weights in the opposite scale, find out the exact weight of the powder alone. Now remove the powder from the phial; fill the latter with rain or distilled water, and placing it in the scale as before, ascertain the weight of the water alone. By this means you have the weights of equal quantities of the powder and of water, which are exactly as their specific gravities; but the specific gravity of water is not expressed by unity, therefore say, as the weight of the water is to the weight of the powder, so is unity to a fourth proportional, which is the specific gravity of the powder, when that of water is reckoned unity; that is, divide the weight of the powder by the weight of the water, and the quotient will express the specific gravity of the powder. In certain cases, the saline substances, or other small bodies, if the reducing them to powder be objected to, may be weighed in the bucket; but, instead of water, they must be weighed in some other fluid, in which they are not soluble, and whose specific gravity is already known; for the specific gravities thus found may be easily referred to that of water.

Example. The phial full of a certain salt, was found to weigh 630 grains (meaning the salt alone, independent of the phial) and the same phial full of rain water was found to weigh 450 grains (viz. the water alone) therefore 630 was divided by 450, and the quotient 1,4 expressed the specific gravity of the salt.

5. *Method of ascertaining the specific gravities of mineral waters and other fluids.*

Rule.—This may be done either by the method last mentioned, which indeed is the most proper, as being the most accurate for nice experiments, or in the following manner: suspend the glass ball F, or a piece of metal, to the hook of the scale C, and find successively its weight in air, its weight in water, and its weight in any other fluid you wish to try. Subtract its weight in water from its weight in air, and the remainder is its loss in weight, when weighed in water. Also, subtract its weight in the other fluid from its weight in air, and the remainder is its loss of weight in the other fluid. Now those two last weights are exactly as the specific gravities of the two fluids respectively, but the specific gravity of water is not in this case expressed by unity; therefore say, as the loss of weight in water is to the loss of weight in the other fluid, so is unity to a fourth proportional; that is, divide the loss of weight in the other fluid by the loss of weight in water, and the quotient will express the specific gravity of the other fluid. For this purpose, a glass ball, with a bit of platina wire, are preferable to other substances, because, amongst all the variety of fluids, there are fewer that have any action upon glass and platina, than upon any other solid; yet they are corroded by one or two fluids, and therefore, when these are to be tried, the method before stated must be adopted, but the phial must consist of such a substance as is not liable to be corroded by the fluid in question; or the glass phial may be lined in the inside with a film of bees wax, which is easily done by warming the phial, for this film will prevent its being corroded.

Example. A glass ball, which weighed 100 grains in air, was found to weigh 60 grains in water, and 70 grains in another fluid; so that the loss of weight in water was 40 grains, and the loss of weight in the other fluid was 30 grains; therefore 30 was divided by 40 and the quotient 0,75 expressed the specific gravity of the other fluid.

Solution is a most general process of analysis. It is the diminution of the aggregation of any solid substance, in consequence of its entering into a new chemical combination. This process consists in affusing upon the substance to be dissolved, a fluid employed as solvent; suffering it to stand in the cold, or assisting the action of the bodies upon each other by heat according to the nature of the substance. Solution may be performed in glass matrasses, or Florence flasks. The vessel employed should not be above $\frac{1}{3}$ full. It should be tied over with a piece of wet bladder, and pierced with one or more small holes made with a pin, so that the evaporation of the fluid may be retarded as much as possible. The flask may be heated over the lamp-furnace, (see title page). Solution is accelerated by shaking and agitating the mixture. Perfect transparency and permanent suspension of the solid are marks of perfect solution, by which it is distinguished from simple mixture, or mechanical diffusion.

Precipitation is the reverse of solution. It consists in separating a dissolved body from the solvent or substance which held it in solution by the intervention of another body. The substance separated is called the precipitate. Long conical glasses answer very well for this process.

Filtration is employed for separating solids from fluids, particularly when the former do not subside, or at least very slowly. To filter substances, white paper freed from size, alum, &c. (filtering paper,) is folded in a conical form, called a filter, and placed in a glass funnel. The substance to be filtered is then poured upon the filter gradually. That part of the fluid which passes first, is seldom clear; it must always be poured back again upon the filter, until, by the swelling of the fibres of the paper, the fluid acquires complete transparency. It is of advantage in filtration to introduce glass rods, bleached pack-thread, or straw, between the filter and the funnel, to prevent the paper from adhering too closely to the latter. Acids, alcalies, and other corrosive fluids, are best filtered by means of a glass funnel filled with pounded glass, a few large pieces being first put in the neck of the funnel, smaller ones over these, and the finer powder placed over all. The porosity of this kind of filter retains much of the fluid, but it may be recovered by gently pouring on it as much water; the fluid will then be displaced and pass through, and the water be retained in its place.

Decantation differs from filtration merely in degree, it is the expedient by which such fluids are separated from solids, as differ considerably in specific gravity. The heavier body falling to the bottom speedily, so as to allow the supernatant fluid to be decanted, either wholly or in part, without disturbing the heavier part. Decantation is best performed from tall cylindrical glass vessels, furnished with a spout or lip.

Elutrition is confined to such mineral substances on which water has no action. It is performed for separating them from foreign articles and impurities of a different specific gravity, in which case they are said to be washed; or for separating the impalpable powders obtained by trituration and levigation from the coarser particles. This process depends upon the property that very fine or light powders have, of remaining for some time suspended in water. It is performed by diffusing the powder or paste, formed by levigation, through plenty of water, in a tall cylindrical vessel, letting it stand a sufficient time until the coarser particles settle at the bottom, and then pouring off the liquid in which the finer or lighter particles are suspended. (See analysis of gold dust.) Fresh water may be poured on the residuum, and the operation repeated: or the coarser particles which fall to the bottom may be previously levigated a second time.

Evaporation is a chemical process intended for separating volatile, from fixed bodies, by converting the former into vapour by means of heat. It is performed in sections of glass spheres, or shallow basons of Wedgwood's-ware, supported by the rings of the lamp-furnace; (see title vignette.) Small quantities of fluids may be conveniently evaporated in watch glasses, whose absolute weigh is marked on the outside by means of a diamond. Evaporation is promoted by enlarging the surface of the fluid, and by agitation.

Distillation is a process of evaporation performed in close vessels, so as to collect the products. Distillation is performed by means of the *Retort* and *Receiver*. The retort is a globular vessel either of glass or earthen-ware, with a neck extending in a curved direction from one side of the globe, terminating in an open point or mouth. (See title vignette.) The materials to be distilled are introduced into the body of the retort, and heat is applied, to cause the substance to boil. To the neck of the retort is adapted a receiver, or globular vessel, with a short straight neck, wide enough to allow the neck of the retort to be introduced into it. (See title vignette.) It is intended to condense and receive from the retort, the fluid that distils over.

Abstraction is that species of distillation in which a fluid once distilled is again distilled off, from the same substance from which it was obtained.

Reduction is the operation employed for restoring oxids of metals to the metallic state, by the intervention of another body, which acts chemically upon them. It is performed in crucibles, or other vessels, by the action of heat, and addition of different substances.

Roasting or *Ustulation* is a process to be performed upon metallic ores, by exposing them in a crucible, or other convenient vessel, to the action of heat in contact with air. The volatile parts are thus driven off, and the ore is prepared for farther analysis.

Vitrification is the fusion of such substances as are capable of assuming the brightness, transparency, and hardness of glass. Crucibles are employed for this process.

Stratification consists in arranging solid substances in layers, with intermediate *strata* of other substances, in order to expose them in a crucible to heat, so as to cause them to act upon each other. See analysis of ores of zinc.

Granulation is employed for the mechanical division of some metals. It is performed either by stirring the melted metal with an iron rod, until it cools, or by pouring it into water, and stirring it continually, or by pouring it into a covered box, previously well rubbed with chalk, and agitating it until the metal cools, when the rolling motion will be converted into a rattling one. The adherent chalk is to be washed away: Or the melted metal may be poured through a perforated iron ladle.

Fusion is the conversion of a solid into a liquid, by the application of heat. The substance thus rendered fluid, is said to be fused or melted. A minute quantity of a substance may be fused by the flame of a candle or lamp, urged by the *blow-pipe.* The best blow-pipe is a conical tube, furnished with a small pipe near the base, to which jets or caps of different perforations may be adapted at pleasure. The air is either forced into the blow-pipe by the lungs of the operator, or by means of double bellows attached to the instrument. The substance to be fused must be placed upon a piece of excavated charcoal, or held in a spoon, made of gold, or platina. The quantity of the substance examined by the blow-pipe should not exceed the size of a pepper-corn. If larger quantities of substances are intended to be fused, the vessels in which the operation is to be performed are called *crucibles* or *melting-pots.*

Crucibles are made of different materials. It is absolutely necessary to have a crucible of perfectly pure silver. Those of earthen-ware should be of various sizes and shapes. The larger are generally conical, with a small spout, for the convenience of pouring out the melted matters. The smaller crucibles are truncated triangular pyramids. Those known in commerce by the name of *Hessian crucibles* are in every respect superior to those manufactured in this country. The black-lead crucibles made of clay and black-lead are very durable, but hey cannot be used for alkaline fluxes, or saine matters. Crucibles which ring clearly when truck, and which are of an uniform thickness, nd have a reddish brown colour, without black pots, are the best: they should never be placed upon the grate of the furnace, but always on a piece of brick, or other support of stone or arthen-ware. When the fusion of a metallic ubstance is completed, the substance may either e permitted to cool in the crucible, or it may be poured into a heated mould, anointed with tallow (never with oil), or what is still better, covered with a thin coating of chalk; which being previously diffused in water, may be conveniently applied with a brush, and then evaporating the water completely, by heating the mould. Conical moulds, for receiving fused substances, are called *casting cones*; bar-shaped ones, are called *ingots*.

For performing the operations of analysis which require the aid of heat, and particularly the process of fusion, a *portable universal furnace*, and an *improved lamp-furnace*, are the chief instruments necessary. The operator who is provided with them may perform all the operations of mineralogical chemistry, which require a very low or very intense heat. Descriptions of the best furnaces of that kind as well as of the instruments of experiment, enumerated in the opposite page, will be given hereafter.

In the conducting of experiments, I cannot recommend better general rules than those advanced by Mr. Henry, in his valuable Epitome of Chemistry, p. 2; namely, let every jar or phial have a label affixed to it, denoting the substance it may contain (except in cases where the nature of the contents is evident from mere inspection) and the date and object of the experiment. I would caution the student not to engage in many different experiments at once; the consequences of which are, that the attention is distracted, and that many interesting changes pass unnoticed. It will contribute to form a habit of accurate observation, if the appearances that occur in experiments be regularly and distinctly noted down; and such an exercise will tend also to facilitate the acquirement of the art of describing chemical phenomena; to do which, with selection and precision, is very far from being an universal talent.

The summary apparatus and instruments, necessary for the analysis of minerals, are the following:

INSTRUMENTS OF EXPERIMENT.

A portable universal furnace.
A lamp furnace.
A blow-pipe, and platina spoon.
Crucibles of silver, platina, black lead, cast-iron, and earthen-ware, of different sizes and shapes.

Crucible-stands and covers.

Crucible and other tongs of various shapes.

A spirit lamp.

A portable forge.

Mortars of Wedgwood's ware, of glass, cast-iron, and porphiry.

Florence flasks, digesters, and assay jars.

A goniometer for measuring the angles of crystals.

A mineralogical electrometer.

A hydrostatic balance.

Accurate beams, scales, and weights in decimals.

A cubic inch measure, and graduated glass measures for fluids.

Glass funnels of biscuit ware, of different areas, fluted and plain.

An apparatus for separating deliquescent salts.

Filtering paper, and filtering stands for supporting funnels

Test tubes, and stand.

Glass rods, for stirring corrosive fluids.

Evaporating basons of glass, of biscuit ware, of silver, and platina.

Iron ladles, with lips, in sizes.

Precipitating glasses.

An apparatus for drying precipitates.

A small anvil stand, and mineralogical hammers.

Cylinders of zinc, tin, copper, and iron.

A magnetic needle and stand.

A deep magnifier.

Watch glasses for evaporating minute quantities of fluids.

Muffles and cupels.

A steel graver, for trying the hardness of minerals.

Steel and ivory palette knives.

Glass retorts and receivers, in sizes, plain and tubulated.

Retort and hydrostatic funnels.

Ingots and casting cones.

Glass syphons.

A chemical thermometer, with naked bulb.

An apparatus for ascertaining the quantity of carbonic acid contained in mineral substances.

LIST OF RE-AGENTS, OR TESTS

Sulphuric acid
Nitric acid
Muriatic acid
Alcohol
Boracic acid

Muriate of gold
———— Barytes
Muriate of Ammonia
Liquid Ammonia
Nitrate of Silver

Crystallized Potash
Hydrate of Barytes
Carbonate of soda freed from its water of crystallization
Muriate of Tin
———— Platina
White Flux
Oxalate of ammonia
Acetate of Silver
Black Flux

Nitrate Potash
———— Barytes
Succinate of Soda
Tincture of Galls
———— Cabbage
Prussiate of Potash
———— Mercury
———— Ammonia
Phosphate of Soda and ammonia
Test Papers.

A select Collection of CHEMICAL RE-AGENTS *prepared under the direction, and in the Laboratory of the Author, together with the most essential* APPARATUS *and* INSTRUMENTS *for analyzing minerals may be had as a companion to this Essay, forming a* PORTABLE MINERALOGICAL LABORATORY.

Lutes also form a necessary part of chemical apparatus. They are compositions of various substances intended,

a. To close the joinings of apparatus.
b. To coat glass and other vessels.
c. To line furnaces.

Lutes of the first description are commonly employed to confine elastic vapours. They should therefore possess the following properties:

a. Compactness.
b. The capability of resisting acid vapours.
c. The power of resisting a certain intensity of heat.
d. Facility of removal after the operation.

Viscid substances, as flour, starch, and gum, possess the first and last properties in a sufficient degree; they are therefore employed when the heat is moderate, and the vapour not corrosive. They are mixed with water, and spread upon slips of paper or linen, which are wrapped round the joinings of the vessels, and if necessary, secured with packthread.

Slips of bladder macerated in water, and applied with the inside next the vessels, are employed in the same circumstances; but from their great contraction on drying, they are apt to break weak vessels.

A paste formed of almond or linseed meal and water, or mucilage, forms a very close and plastic lute, which is easily removed.

Quicklime reduced to powder and well incorporated with a sixth part of muriate of soda, or with white of egg diluted with water, applied on slips of linen, dries easily, and becomes very hard. It is used for the distillation of the concentrated acids; but for this purpose burnt gypsum and water answers very well. Both these lutes must be used as soon as they are prepared, as they harden very quickly.

Chalk and oil, or glaziers putty, is a very compact lute. As it becomes so hard as not to be easily removed, it is principally used for luting tubes into vessels for pneumatic purposes.

A paste of powdered tobacco pipe-clay and drying oil, or, what is still better, amber varnish, is very close, adhesive, and plastic, and is easily removed; but as it softens with heat, it must be secured by slips of linen or thread, and will not adhere to the vessels unless they are perfectly dry.

The same clay beat up with as much sand as it will bear, without loosing its tenacity, with the addition of cut tow and a sufficient quantity of water, furnishes a very good lute, which has the advantage of resisting a considerable heat, and it is applicable where the fat lute would be melted or destroyed.

Clay and sand, in the proportion of one to four, form an excellent lute, capable of resisting very high temperatures, and the greatest number of corrosive substances.

Eight parts of yellow wax melted with one of oil of turpentine, with or without the addition of some resinous substances, according to the degree of pliability and consistence required, form a very close and compact lute, through which the subtile corrosive vapours will not escape. But it is softened and liquefied by heat, therefore cannot be used for purposes where high temperatures are required.

The lute employed for the coating of glass vessels, with the intention of making them stronger and capable of resisting violent heats, without softening, consists of four parts of sand and one of clay, made into a very thin mass, and applied in successive layers, taking care that each coat be perfectly dry before another be laid on.

In every instance where a lute is applied it is absolutely necessary to allow it to dry before the process is began; and even the fat lute, by the exposure to the air during a few days after its application, is much improved in its quality. Lutes composed of clay and sand are perfectly useless, except they be permitted to dry. In applying a lute, the part immediately over the junction of the vessel should swell outwards, and its diameter should be gradually diminished at each side.

The junctures of vessels which are to be luted to each other must previously be accurately and firmly fitted, by introducing between them, when necessary, short bits of wood or cork, or if the disproportion be very great, by means of a cork fitted to the one vessel, having a circular hole bored through it, through which the neck of the other vessel or tube passes.

After being thus fitted, the lute is rolled and worked between the fingers till it be softened, and is then formed into small cylinders, which are successively applied to the junctures, taking care that each piece be made to adhere firmly and perfectly close in every part before another is put on. Lastly, the whole is secured by the slips of linen or bladder.

In many cases to permit the escape of elastic vapours, a small hole is made through the lute with a pin, or the lute is perforated by a small quill, fitted with a stopper. This, however, is seldom necessary.

FUEL AND APPLICATION OF HEAT.

As caloric is an agent of the most extensive utility in the chemical operations of mineralogy, it is necessary that we should be acquainted with the means of employing it in the most economical and efficient manner.

The rays of the sun are used to accelerate spontaneous evaporation; the only attentions necessary are to expose as large a surface of the fluid as possible.

The combustion of different substances is a much more powerful and certain source of heat. Alcohol, oil, tallow, wood, turf, coal, charcoal, and coke, are all occasionally employed.

Alcohol, oil, and melted tallow, are burnt in lamps of various constructions. These afford a very uniform, though not very high temperature.

Alcohol has the great advantage of burning without smoke. But oil burnt upon a cylindrical wick, so contrived that the air has free access both to the outside and to the inside of the cylinder, as in Argand's lamp, may be made to produce a considerable temperature of great uniformity, and without the inconvenience of smoke.

Wood, turf, coal, charcoal, and coke, are burnt in grates and furnaces. Wood has the advantage of kindling readily, but affords a very unsteady temperature, is inconvenient from its flame, smoke, and soot, and requires much attention. The heavy and dense woods give the greatest heat, burn longest, and leave a dense charcoal.

Dry turf gives a permanent heat, and does not require so much attention as wood; but its smoke is copious and penetrating, and the empyreumatic smell which it imparts to every thing it comes in contact with adheres to them with great obstinacy. The heavy turf of marshes is preferable to the light superficial turf.

Coal is the fuel most commonly used in the laboratory. Its heat is considerable and sufficiently permanent, but it produces much flame and smoke.

Charcoal, especially of the dense woods, is a very convenient and excellent fuel. It burns without flame or smoke, and gives a strong, uniform, and permanent heat, which may be easily regulated, especially when it is not in too large pieces, and is a little damp.

Coke, or charred coal, possesses similar properties to charcoal. It is less easily kindled, but is capable of producing a higher temperature. *The best fuel for general purposes of the laboratory, however, is coke and charcoal mixt together; two or three parts of the former to one of the latter*, broken into pieces of the size of a walnut.

For experiments in the small way, spirits of wine is upon the whole the neatest and most convenient fuel, and hence the spirit lamp may be employed for most operations of analysis as a very convenient furnace.

GENERAL VIEW
OF
THE SOLID PART
OF
THE EARTH.

If we contemplate the solid parts of the globe, we behold an immense assemblage of heterogeneous bodies. We perceive it to be arranged with an irregularity of distribution, which may well excite our surprize, and arrest our attention. Stones, metallic substances, inflammable fossils, saline bodies, either in lapideous or in metallic aggregation, or else in a state of comminution, are the only proper component parts of the whole.

The traces of some great revolutions visible in every part of the globe, have at all times arrested the attention of mankind. Whether we excavate the plains, penetrate into the caverns of mountains, or scale their rugged flanks, every where the spoils of organised bodies are buried in those beds which form the external coat of our earth. Immense masses of shells are found at great distances from every sea, and at immense heights. Banks of slate contain fish, and beds of coal display impressions of vegetables, at elevations or at depths equally astonishing. Here beds of shells, extending for many miles under ground, cover others which contain only vegetables: there the bodies of fish are placed above land animals, and they in their turn are covered by strata, containing the remains of plants and shells. Torrents of lava, and heaps of pumice-stone, the products of subterraneous fire, mingle in other places with the inhabitants of the ocean. It is under the equator that we find living animals analogous to the shells and fossil fish of the North, and in the icy regions of the arctic circle are the remains of those indigenous to the torid zone.

A force of incredible extent has every where distated those very regions and rocky pavements of the earth, which our imagination paints as the abodes of everlasting silence and rest.

INTERNAL STRUCTURE AND MEAN DENSITY OF THE EARTH.

The internal constitution of the earth is little known. The deepest excavation that have been made by human art do not exceed 2400 feet, or less than half a mile; which is a very short distance indeed when compared with the diameter of the earth, which is about 7947 English miles: so that whatever lies below that depth is utterly unknown. The substances which have been extracted from those excavations are not in general of a nature different from those which in some particular places have been found immediately upon the surface. These substances are in general arranged in strata, variously inclined to the horizon, and of a thickness not very equal. Some indeed have supposed that they follow each other, in a certain order almost throughout the globe; but this opinion appears to rest on slight foundations.

The mean density of the earth, deduced from the observations made by Dr. Maskelyne on the sides of Schehallien, an insulated mountain in Perthshire, is 4½, reckoning water, as usual, the standard of comparison. Mr. Cavendish has lately assigned a greater quantity, or about 5½, from a very elegant experiment on the principle of torsion, which Coulomb employed so successfully in a variety of delicate researches. Perhaps the true proportion will be found to lie between these limits. The observations of Dr. Maskelyne, however skilfully conducted by that eminent astronomer, were performed under the most unfavourable circumstances, in a foggy climate and rainy season. And Mr. Cavendish's experiment was not perhaps made on a scale sufficient to afford very great precision. Nor is it at all improbable, that the apparent force of attraction was in some degree augmented by a slight infusion of magnetic virtue; for the masses of lead which discovered their mutual appetency might yet contain a certain admixture of iron, in a state of such intimate combination as to resist the action of chemical solvents.

We are disposed to think that, instead of selecting a conical hill with a view to ascertain the deviation of the plummet, it would be more eligible to place the observer successively on the opposite sides of a narrow vale, bounded by two ranges of lofty mountains which run from east to west. Those stations would be very commodious for determining the altitude of a star, and their true distance could be found trigonometrically with the utmost exactness. The mountains themselves might be surveyed by considering them as composed of a number of parallel and vertical slices, formed by planes, in the direction of the meridian. The best scene that I am acquainted with for attempting these operations is in the Upper Valais, where the Rhone holds a westerly course; and the enormous Alps, in a double chain, having more than a mile of perpendicular height, approach at their lower flanks perhaps within two or three miles.

GEOLOGICAL THEORIES.

Different opinions have been formed concerning the question, in what manner our earth was brought into the present distribution of its parts.

An origination of this globe out of a chaos was the general belief of the ancients. Moses, in the beginning of the Pentateuch gives an account of a series of successive changes, which he represents as the first which took place, from the moment at which matter was made subject to the laws it obeys to that æra at which it was finally fit for the residence and support of animals, and had living inhabitants, brute and human, placed upon it.

In modern times, different classes of speculatists have attempted to investigate the circumstances which must have attended the origin of it.

Divines have endeavoured to justify the account of Moses, by an appeal to the present laws of nature: but Burnet and others have been easily convicted of supposing primæval states of things utterly incompatible with these laws.

Chemists have conceived that the origin of the earth, in its present form, is from a general liquidity of its whole matter: others again have attributed it to the action of fire.

Astronomers have been persuaded that it was owing to the action of some comet, or to an altered arrangement of the planets.

Others have conceived the idea of a world perhaps without beginning, but by the action of internal fires, with volcanic orifices, continually lacerated, undermined, and subverted, with the constant rise of a new earth, the residue and product from those fires, by which the former was demolished.

Others, again, have fancied a continual flitting of the ocean around the globe; by which that which was lately land becomes now the bottom of the sea, and that which is now covered by the sea is again to become land.

These fanciful opinions, to say nothing of the impious nature of some of them, have generally rather resembled philosophical dreams than the conceptions of waking and sober reason. Their authors, in forming them, have been too often guided by imagination more than judgment; and have laboured rather to support a favourite hypothesis than to consult the voice of authentic history, or patiently to examine the materials and structure of the fabric which they undertook to describe.

And, although there has been in modern times a wonderful variety of fanciful productions, under the name of geological theories, we are by no means to imagine that nothing has been usefully done in this department of natural history. Amidst all the splendid rubbish with which it has been incumbered, some precious treasures have been brought to light. Amidst the speculations which have *darkened counsel,* large additions have been made to our knowledge of this important subject. These may be briefly summed up in the following particulars.

The *materials* for the formation of a correct and rational theory of the earth have been greatly augmented during the last age. Enlightened mineralogists, practical miners, and patient chemical experimenters, have been engaged, throughout the century, in making accurate observations; in visiting foreign countries; in exploring the bowels of the earth; in comparing the strata of every portion of the globe; in examining their form, direction, extension, and connexion; in analysing their component parts; and in collecting a multitude of facts, which have all tended to throw light on the origin and history of our planet. By means of the useful discoveries which these inquirers have made, we are furnished with weapons for beating down false theories, and with information enabling us to pursue our investigations further, and with more advantage.

Difficulties have been lately removed which were once supposed, by some, to militate strongly against the *possibility* of a *general*

Deluge. Early geologists, for want of accurate information, supposed that all the waters of the globe were not sufficient to cover the whole earth to such a depth as the sacred historian describes. It was asserted that the mean depth of the ocean did not exceed a quarter of a mile, and that only half of the surface of the globe was covered by it. On these data Dr. Keil computed, that *twenty-eight* oceans would be requisite to cover the whole earth to the height of *four miles*, which he judged to be that of the highest mountains; a quantity, which, at that time, was utterly denied to exist. But further progress in mathematical and physical knowledge has since shown, that the different seas and oceans contain at least *forty-eight* times as much water as they were supposed to do, and much more than enough for the extent ascribed to the deluge in the sacred history.*

While difficulties which were supposed to render the deluge *impossible* have been removed by the investigations of modern philosophers, many facts have been, at the same time, brought to light, showing the *possibility*, and even *certainty*, of that mighty inundation. In every

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* Kirwan's *Geological Essays*, p. 66, 67.

valley and mountain support for revelation has been found. *Marine shells* have been discovered in situations so elevated, and under circumstances so remarkable, as to prove that they were left there by a flood extending over the whole globe; and what confirms this conclusion is, that shells peculiar to different shores and climates very distant from each other have been found in promiscuous heaps, plainly showing that they could have been brought together only by an extensive inundation. The bones of *elephants* and of *rhinoceros* have been found, in a multitude of instances, far distant from the regions in which they are found to live, and where, from the nature of the climate, they could never exist in the living state: and between the climates which they might have inhabited, and the places in which they are now found, too many mountains intervene to suppose them carried thither by any other means than a *general deluge.*[*] The most patient and accurate examinations of detached mineral substances, and of the strata of the globe, which late inquirers have made, afford every reason to believe that the earth was for a considerable time wholly overflowed

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[*] Kirwan's *Geological Essays*, p. 54, *et seq.*

with water. And, to crown all, as voyagers and travellers have explored new regions of the earth, they have found, every where, the indications of geological phenomena confirmed and supported by the notices of tradition. Accordingly, it is very remarkable that a great majority of modern theorists have embraced the *Neptunian* doctrines; and even such of them as rejected the Mosaïc account of the deluge have been compelled to seek for other means of immerging the present continents in the ocean.

Finally, the researches of modern geologists have given abundant confirmation to the sacred history, not only with respect to the general *deluge*, but also with regard to the *age* of the earth.

CLASSIFICATION OF MINERALS.

To arrange our examination of minerals with greater precision, as well as to facilitate the primary knowledge of them in general, mineralogists have divided minerals into certain classes, distinguishable from each other, by very obvious and permanent characters.

Mineralogy is chiefly employed in arranging similar bodies under the same, and dissimilar bodies under different denominations. It judges of similarity two ways, either from similarity of external appearances, or from the similarity of the internal composition.

The knowledge of the similarity of the internal constitution is acquired chiefly by regarding the changes produced in them by the chemical actions of other bodies; that of the internal characters, by regarding the figure, colour, texture, fracture, or other properties, which these bodies present to our senses, and which may be observed without causing them to undergo any material alteration whatever.

From the knowledge of the constituent parts of minerals is derived their economical application, their uses in agriculture, metallargy, and in the arts.

Most mineralogists have contented themselves with classing minerals according to their most obvious qualities, and have therefore classed together very heterogeneous substances. Sensible at last of this imperfection, others have availed themselves of the assistance of chemical knowledge, and have endeavoured to arrange minerals according to their internal component parts. This method is perfect in its kind, and usesul for common application. For instance, all earths and stones, which by certain additions form glass, and in which flint abounds, are called silicious stones, those which do not melt into glass, but become converted into brick, or become hard, and to which clay gives the character, are called argillaceous stones, those which burn into lime, calcareous stones, &c. To discriminate minerals therefore with accuracy and precision, the great outlines of the classification of mineral substances may most usefully be made from the chemical investigation of their constituent parts. Each individual mineral, however, has not, and cannot be analysed, this would be inpracticable, and were it not it would be without utility; but when the analysis of a mineral has been effected, we presume that a similarity of composition will exist in other specimens which agree with it closely in their internal and external characters.

SYSTEMATIC DISTRIBUTIONS OF MINERALS

TABULAR VIEW
OF
THE WERNERIAN SYSTEM OF MINERALOGY,
ADOPTED IN
THE GERMAN SCHOOL OF MINES.

CLASS I.

Earthy minerals, or minerals chiefly composed of earths.

1. Diamond Genus.

Diamond.

2. Zircon Genus.

Zircon family.

Zircon.
Hyacinth.
Cinnamon stone.

3. FLINT GENUS.

Chrysolite family.

- Chrysoberyl
- Chrysolite
- Olivine
- Coccolite
- Augite
- Vesuvian

Garnet family.

- Leucite
- Melanite
- Garnet
  - precious
- Staurolite or grenatite
- Pyrope
- Meïonite

Ruby family.

- Ceylanite
- Spinelle
- Sapphire
- Emery
- Corundum
- Diamond spar
- Automalite

Topaz family.

- Topaz
- Fibrolite
- Sommite

Shorl family.

- Euclase
- Emerald
- Beryl
  - precious
  - shorlaceous
- Shorl
  - tourmaline
- Pistacite
- Zoisite
- Axinite, or Tummerstone.

Quartz family.

- Quartz
  - Amethyst
    - thick fibrous
- Rock crystal
- Milky quartz
- Phrase

- Iron flint
- Horn stone
    - splintery
    - conchoidal
    - woodstone
- Flinty slate
    - lydian stone
- Flint
- Calcedony
- Cornelian
    - fibrous
- Hyalite
- Opal
    - precious
    - translucent
    - semi-opal
- Opal
    - wood-opal
- Menilite
- Jasper
    - Egyptian
    - red
    - brown
    - striped
    - conchoidal
    - earthy
    - opal
    - agate
- Heliotrope
- Chrysophrase
- Plasma
- Cat's eye

Pitchstone family.

- Obsidian
- Pitchstone
- Pearlstone
- Pumice
    - glassy
    - porphyritic

Zeolite family.

- Wavelite
- Phrenite
    - fibrous
    - foliated
    - needle stone
- Zeolite
    - mealy
    - fibrous
    - radiated
    - foliated
- Cubizite
- Crosstone
- Lomonite
- Dipyre
- Natrolite
- Azulite
- Azur stone

Feldspar family.

- Andaluzite
- Feldspar
    - Adularia
    - Labrador spar
        - glassy
        - variolite
        - hollow spar
        - compact feldspar
- Scapolite
- Wernerite or arctizite
- Spodumene
- Ichthyophthalmite

4. CLAY GENUS.

Clay family.

- Pure clay
- Porcellain earth
- Common clay
    - Loam
    - Potters clay
        - earthy
    - Variegated clay
    - Slaty clay
- Clay stone
- Adhesive slate
- Polishing slate
- Tripoli
- Float stone
- Alum stone

Clay slate family.

- Alum slate
    - glossy
- Bituminous shale
- Drawing slate
- Whet slate
- Clay slate

Mica family.

- Lepidolite
- Mica
- Pinite
- Potstone
- Clorite
    - chlorite earth
    - chlorite slate
    - foliated chlorite

Trap family.

- Diaspore
- Hornblende
    - labradore
    - basaltic
    - hornblende slate
- Smaragdite
- Basalt
- Wacke
- Clinkstone
- Iron clay
- Lava

Lithomarge family.

- Green earth
- Lithomarge
    - friable
    - indurated
- Rock soap
- Umber
- Yellow earth

5. MAGNESIA OR TALC GENUS.

- Native magnesia
- Bole
- Meerschaum
- Fullers earth
- Steatite
- Agalmatolite

Talc family.

- Nephrite
    - axe stone
- Serpentine
    - precious
    - conchoidel
    - splintery
- Schillerstone
- Talc
    - earthy
    - indurated
- Asbest
    - rock cork
    - amianth
    - rock wood

Actynolite family.

- Actynolite
    - asbestous
    - glassy
- Tremolite
    - asbestous
    - glassy
- Cyanite
- Sahlite

6. GADOLINITE GENUS.

Gadolinite.

7. CALCAREOUS. GENUS.

Lime family.

A. *Carbonate of lime.*
- Rock milk
- Chalk
- Lime stone
  - compact
  - roe stone
- Foliated lime stone
  - granular
  - calc spar
  - pea stone
- Calc tuff
- Foam earth
- Slate spar
- Brown spar
  - foliated
  - fibrous
- Schaal stone
- Dolomite
- Rhomboidal spar
- Swine or stink stone
- Marl
  - marl earth
  - indurated marl
- Bituminous marl slate
- Arragon

B. *Phosphate of lime.*
- Appatite
- Asparagus stone
- Phosphorite

C. *Fluate of lime.*
- Fluate of lime
  - compact
  - fibrous

D. *Sulphate of lime.*
- Sulphate of lime, or gypsum
  - gyps earth
  - compact gypsum
  - foliated gypsum
  - fibrous gypsum
- Selenite
- Cube spar

E. *Borate of lime.*
- Boracite
- Cryolite

8. BARYTIC GENUS.

- Carbonate of barytes
- Sulphate of barytes, or heavy spar
  - Compact

- Sulphate of barytes
  - Granular
  - Straight lamellar
    - fresh
    - disintegrated
  - Columnar heavy spar
  - Prismatic heavy spar
  - Bolognean heavy spar

9. STRONTIAN GENUS.

- Carbonate of strontian
  - fibrous
  - compact
- Sulphate of strontia, or celestine
  - foliated
  - prismatic

CLASS II.

NATIVE SALTS.

A. *Carbonates.*
- Carbonate of soda

B. *Nitrates.*
- Nitrate of soda

C. *Muriates.*
- Muriate of soda
- Stone or rock salt
  - foliated
  - fibrous
  - lake salt
- Muriate of ammonia

D. *Sulphates.*
- Sulphate of iron
- Sulphate of magnesia and sulphate of iron, or hair salt
- Native alum
- Sulphate of magnesia, or Epsom salt
- Sulphate of soda, or glauber salt

CLASS III.

INFLAMMABLE FOSSILS.

1. Sulphur Genus.

- Native sulphur
  - coherent
- Native sulphur
  - earthy
  - volcanic

2. Bitumen Genus.

- Mineral or fossil oil
- Mineral pitch
  - elastic
  - earthy
  - slaggy
- Brown coal
  - bituminous wood
  - earthy coal
  - alum earth
  - common brown coal
  - moor coal
- Black or pit coal
  - pitch coal
  - columnar coal
  - slate coal
  - cannel coal
  - foliated coal
  - coarse coal

3. Graphite Genus.

- Glance coal
  - conchoidal
  - slaty
- Graphite
  - scaly
  - compact
- Mineral charcoal

4. Amber, or Resin Genus.

- Amber
  - white
  - yellow
- Mellite, or honey stone

CLASS IV.

METALLIC MINERALS.

1. Platina Genus.

- Native platina

2. Iridium Genus.

- Ore of Iridium.

3. Gold Genus.

- Native gold
    - Gold yellow
    - Brass yellow
- Native gold
    - Greyish yellow

4. Mercury Genus.

- Native mercury
- Native amalgam
    - semifluid
    - solid
- Mercurial horn ore
- Mercurial liver ore
    - compact
    - slaty
- Cinnabar
    - dark red
    - light red

5. Silver Genus.

- Native silver
    - common
    - auriferous
- Antimoniated silver
- Arseniated silver
- Muriatic, or horn silver
- Silver black
    - friable
    - coherent
- Silver glance
- Brittle silver glance
- Indurated silver glance
- Red silver ore
    - dark
    - light
- White silver ore
- Black silver ore

6. COPPER ORES.

- Native copper
- Copper glance
  - compact
  - foliated
- Variegated copper ore
- Copper pyrites
- Grey copper ore
- Copper black
- Red copper ore
  - compact
  - foliated
  - capillary
- Tile ore
  - earthy
  - indurated
- Azure copper
  - earthy
  - radiated
- Malachite
  - fibrous
  - compact
- Copper green
- Ironshot copper green
  - earthy
- Copper emerald
- Copper mica
- Lenticular ore
- Oliven ore
- Muriate of copper

7. IRON GENUS.

- Native iron
- Iron pyrites
  - radiated
  - hepatic
  - capillary
- Magnetic iron
- Magnetic iron stone
  - iron sand
- Iron glance
  - compact
  - foliated
  - iron mica
- Red iron stone
  - frothy
  - ochrey
  - compact
  - red hematite
- Brown iron ore
  - brown iron froth
  - ochrey brown iron stone
- Iron ore
  - compact
  - brown hematite
- Sparry iron ore
- Black iron ore
  - compact
  - black hematite
- Clay iron ore
  - Reddle
  - Columnar clay iron ore
  - Lenticular clay iron ore
  - Jaspery clay iron ore
  - Common clay iron ore
  - Reniform clay iron ore
  - Pea ore, or pisiform iron ore

- Bog iron ore
  - Morass ore
  - Swampy iron ore
  - Meadow iron ore
- Pitchy iron ore
- Green iron earth
- Cube ore

8. LEAD GENUS.

- Sulphuret of lead, or lead glance
  - compact
- Blue lead ore, or galena
- Brown lead ore
- Black lead ore
- White lead ore
- Green lead ore
- Red lead ore
- Yellow lead ore
- Sulphate or vitriol of lead
- Earthy lead, or Lead earth
  - coherent
  - friable

9. TIN GENUS.

- Tin pyrites, or sulphuret of tin
- Tin stone, or oxid of tin
- Wood tin

10. BISMUTH GENUS.

- Native bismuth
- Sulphuret of bismuth, or bismuth glance
- Bismuth ochre, or oxid of bismuth

11. ZINC GENUS.

- Sulphuret of zinc, or blende
  - yellow
  - brown
- Sulphuret of zinc
  - black
- Calamine

12. ANTIMONY GENUS.

- Native antimony
- Grey antimonial ore
  - compact
  - foliated
  - radiated
- Antimony ore
  - plumose
- Black antimony ore
- Red antimony ore
- White antimony ore
- Antimonial ochre

13. TELLURIUM GENUS.

- Native tellurium
- Graphic ore
- Yellow tellurium
- Black tellurium

14. COBALT GENUS.

- White cobalt ore
- Grey cobalt ore
- Brown cobalt ore
- Red cobalt ore
  - cobalt crust
- Cobalt ore
  - cobalt bloom
- Cobalt glance
- Black cobalt ore
  - earthy
  - indurated

15. MANGANESE GENUS.

- Grey manganese ore
  - radiated
  - foliated
  - compact
- Grey manganese ore
  - earthy
- Black manganese ore
- Red manganese ore

16. NICKEL GENUS.

- Sulphuret, or copper nickel
- Nickel ochre

17. ARSENIC GENUS.

- Native arsenic
- Arsenical pyrites
  - argentiferous
- Orpiment
  - yellow
  - red
- Arsenic bloom

18. MOLYBDENA GENUS.

- Sulphuret of molybdena
- Molybdate of lead

19. TUNGSTEN GENUS.

- Wolfram, or tungstate of iron and manganese
- Tungsten

20. TITANITE GENUS.

Menachanite
Octahedrite
Rutilite
Nigrin
Iserine
Brown menachanite ochre
Yellow

21. URANITE GENUS.

Pitch blende
Uran mica
Uran ochre

22. CHROME GENUS.

Chromate of lead, or red lead ore
Chromate of iron

23. COLUMBIUM GENUS.

Columbate of iron

24. TANTALITE GENUS.

Tantalium

25. CEREUM GENUS.

Cerete.

TABULAR VIEW

OF

HAUY's METHODICAL DISTRIBUTION OF MINERALS,

Adopted in the French School of Mines.[*]

In this System of Mineralogy the arrangment of simple minerals is almost strictly chemical; but the classification and description of the rocks and lavas is founded on certain hypothesis respecting their formation. The species of the simple minerals is determined from one character, namely, the integrant molecule.

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[*] Copied from a Synopsis of the mineral kingdom.

DIVISION I.

MINERAL SUBSTANCES WHICH ADMIT OF SPECIFIC DISTINCTION.

CLASS I.

Acidiferous substances, composed of an acid united to an earth, or to an alcali, or to both.

ORDER I.

Combinations of earths with acids.

GENUS I.—LIME.

SPECIES.

Carbonate of lime
Phosphate of lime
Fluate of lime
Sulphate of lime
Nitrate of lime
Arseniate of lime

VARIETIES.

Carbonate of Lime united to different substances, so as to preserve its structure, or some of its principal characters.

Aluminiferous carbonate of lime
Ferriferous carbonate of lime
Siliceous carbonate of lime
Magnesian carbonate of lime
Hydro sulphurised, or fœtid carbonate of lime
Bituminous carbonate of lime

GENUS II.—BARYTES.

SPECIES.

Sulphate of barytes
Carbonate of barytes

GENUS III.—STRONTIA.

SPECIES.

Sulphate of strontia
Carbonate of strontia

GENUS IV.—MAGNESIA.

SPECIES.

Sulphate of magnesia
Borate of magnesia
Carbonate of magnesia

ORDER II.

Combinations of alcalies with acids.

GENUS I.—POTASH.

SPECIES.

Nitrate of Potash.

GENUS II.—SODA.

SPECIES.

Muriate of soda
Borate of soda
Carbonate of soda

GENUS III.—AMMONIA.

SPECIES.

Muriate of ammonia.

ORDER III.

Combinations of earths and alcalies with acids.

GENUS I.—ALUMINE.

SPECIES.

Sulphate of alumine and potash
Fluate of alumine and potash

CLASS II.

NON ACIDIFEROUS SUBSTANCES,

*Or Minerals exclusively composed of Earths, except when united sometimes to an alcali.**

SPECIES.

- Quartz
    - Hyaline
    - Agate
    - Resinite
    - Jasper
    - Pseudomorphic
- Zircon
- Telesia
- Cymophane
- Spinel ruby
- Topaz
- Emerald
- Euclase
- Amphigene
- Idocrase
- Meionite
- Feldspar
- Corundum
- Pleonaste
- Axinite
- Turmaline
- Amphibole
- Actinite
- Pyroxene

* *This Class has no orders nor genera, but is only a series of individual species.*

Staurotide
Epidote
Garnet
Sphène
Wernerite
Diallage
Anatase
Dioptase
Gadolinite
Lazulite
Mesotype
Stilbite
Phrenite
Chabasie
Analcime
Nèpheline
Harmotome
Pèridot
Mica
Disthène
Grammatite
Pycnite
Dypyre
Asbestus
Talc
Macle

CLASS III.

COMBUSTIBLE SUBSTANCES.

ORDER I.

Simple combustible substances.

SPECIES.

Sulphur
Diamond
Anthracite

ORDER II.

Compound combustible substances.

SPECIES.

Bitumen
Pit-coal
Jet
Amber
Mellite

CLASS IV.

METALLIC SUBSTANCES.

ORDER I.

Substances not immediately oxidable and reducible by heat.

GENUS I.—PLATINA.

Alloy of Platina

GENUS II.—GOLD.

Native Gold

GENUS III.—SILVER.

Native silver
Antimonio-sulphuret of silver
Sulphuret of silver
Antimonial silver
Muriate of silver

ORDER II.

Substances immediately oxidable and reducible by heat.

GENUS.—MERCURY.

Species.

Native mercury
Argentiferous mercury
Sulphuret of mercury
Muriate of mercury
Hydrosulphuret of mercury

ORDER III.

Substances which are oxidable, but not immediately reducible by heat.

I. SUBSTANCES CONTAINING DUCTILE AND MALLEABLE METALS.

GENUS I.—LEAD.

Species.

Native lead (volcanic)
Sulphuret of lead
Arseniate of lead
Chromate of lead
Carbonate of lead
Phosphate of lead
Sulphate of lead
Muriate of lead
Muria-sulphate of lead

GENUS II.—NICKEL.

Species.

Arseniate of nickel
Oxid of nickel

GENUS III.—COPPER.

Species.

Native copper
Sulphuret of copper
Grey oxid of copper
Red oxid of copper
Muriate of copper
Blue carbonate of copper
Green carbonate of copper
Arseniate of copper
Sulphate of copper

GENUS IV.—IRON.

Species.

Oxid of iron
Oligistous iron
Arseniate of iron
Sulphate of iron
Carbonate of iron
Chromate of iron

GENUS V.—TIN.

SPECIES.

Oxid of tin Sulphuret of tin

GENUS VI.—ZINC.

SPECIES.

Sulphuret of zinc Sulphate of zinc
Carbonate of zinc

II. SUBSTANCES CONTAINING METALS NOT POSSESSING DUCTILITY AND MALLEABILITY.

GENUS VII.—BISMUTH.

SPECIES.

Native bismuth Sulphuret of bismuth
Oxid of bismuth

GENUS VIII.—COBALT.

SPECIES.

Arseniate of cobalt Grey oxid of cobalt
Black oxid of cobalt

GENUS IX.—ARSENIC.

SPECIES.

Native arsenic Oxid of arsenic
Sulphuret of arsenic

GENUS X.—MANGANESE.

SPECIES.

Oxid of manganese

GENUS XI.—ANTIMONY.

Species.

Native antimony
Sulphuret of antimony
Oxid of antimony
Hydrosulphuret of antimony

GENUS XII.—URANIUM.

Species.

Oxid of uranium
Oxidulated uranium

GENUS XIII.—MOLYBDENA.

Species.

Sulphuret of molybdena.

GENUS XIV.—TITANIUM.

Species.

Oxid of titanium
Siliceo-calcareous titanium

GENUS XV.—TUNGSTEN.

Species.

Feruginated tungsten
Calcareous tungsten

GENUS XVI.—TELLURIUM.

Species.

Native tellurium, united to different metals.

GENUS XVII.—CHROMIUM.

Species.

Chrome.

DIVISION II.

SUBSTANCES WHICH DO NOT ADMIT OF SPECIFIC DISTINCTION.

I. DOUBTFUL MINERALS, OR SUBSTANCES NOT YET SUFFICIENTLY KNOWN TO HAVE A PLACE IN THE SYSTEM.

Amianthoide
Aplome
Arragonite
Coccolithe
Diaspore
Ecume de Terre
Emerald of France
Feldspar, apyrous
Jade
Koupholite
Lèpidolithe
Lime, sulphated anhydrous
Lime, sulphated quartziferous
Madrèporite
Malacolithe
Micarella
Petrosilex
Scapolithe
Radiant spar
Shistous spar
Spinthère
Tourmaline
Triphane
Zeolite, efflorescent
Zeolite, yellowish radiated
Zeolite, red

II. AGGREGATES OF DIFFERENT MINERAL SUBSTANCES USUALLY DENOMINATED COMPOUND ROCKS.

ORDER I.

Aggregates considered as of primitive formation, and which bear more particularly the name of rocks.

Feldsphathic rock
Quartzose rose
Amphibolic rock
Micaceous rock

Talcous rock
Calcareous rock
Jadean rock
Petrosiliceous rock
Cornean rock
Serpentinous rock
Argillaceous rock

ORDER II.

Aggregates generally considered secondary or tertiary in their formation, and which seem to owe their origin to sediments, and their hardness to desiccation.

Clay
Calcariferous clay or marle
Argillo-ferriferous polishable limestone, or secondary marble
Calcariferous sulphate of lime, commonly called plaister stone

VARIETIES.

Potter's clay
Fuller's clay
Lithomargic clay
Ochreous clay
Schistous clay

ORDER III.

Aggregates composed of fragments agglutinated posterior to the formation of the substances to which they have belonged.

Quartz-agate breccia
Calcareous breccia
Agglutinated arenaceous quartz, or grit
Tripolian aluminiferous quartz. *Tripoli*
Recomposed granite, commonly called grit of the coal mines

III. SUBSTANCES MODIFIED BY SUBTERRANEAN FIRE.

CLASS I.

I. VOLCANIC PRODUCTS.

LAVAS:

Substances which have undergone igneous fluidity.

ORDER I.

Lithoidal lavas, viz. having the appearance of stones.

GENUS.

Basaltic lithoidal lavas
Petrosiliceous lithoidal lavas
Feldspathic lithoidal lavas
Amphigenic lithoidal lavas

ORDER II.

Vitreous lavas, having more or less a vitrified appearance.

ORDER III.

Scoriated lavas, resembling more or less the scoria of forges.

VARIETIES.

Obsidian vitreous lava
Enamelled vitreous lava
Pearled vitreous lava
Pumiced vitreous lava
Capillary vitreous lava

CLASS II.

THERMANTIDES:

Substances which indicate only traces of the agency of subterranean heat.

VARIETIES.

Cementing thermantide
Tripolian thermantide
Pulverulent thermantide

CLASS III.

PRODUCT OF SUBLIMATION.

Sulphur	Sulphuret of arsenic
Muriate of ammonia	Oligistous iron, &c.

N. B. These admit of specific distinction, and have a place in the method: but considered with reference to volcanic products, are only various sublimates.

CLASS IV.

DECOMPOSED LAVAS,

Having suffered more or less decomposition by the attacks of acido-sulphureous vapours or by the action of the atmosphere.

VARIETIES.

Aluminiferous decomposed lava. The alum stone of Tolfa.

CLASS V.

VOLCANIC TUFAS.

Products of muddy eruptions, cementations, and agglutinations, by the humid process.

CLASS VI.

SUBSTANCES FORMED IN THE INTERIOR OF LAVAS POSTERIOR TO THEIR FLOWING.

VARIETIES.

Mèsotype
Analcime
Stilbite
Chabasia
Carbonate of lime
Sulphuret of iron

CLASS VII.

II. NOT VOLCANIC PRODUCTS,

Substances modified by subterranean fires.

VARIETIES.

Porcelain thermantide
Tripolian thermantide

Whatever arrangement of minerals we may adopt or frame, it is enough that the classification should be so made that minerals which possess some general, obvious, or physical properties should be placed together, in order to form a certain system or methodical arrangement, namely:

Class I. ORES.
II. EARTHS AND STONES
III. MINERAL OR NATIVE SALTS.
IV. INFLAMMABLE FOSSILS.

This is the general division of minerals adopted by men of science. But as some of these classes present to us a vast variety of individuals, mineralogists have been under the necessity of sub-dividing them into certain genera and species, in order to remove, or at least to facilitate the numberless difficulties which would otherwise oppose the acquisition of general scientific knowledge. This will become more conspicuous in the sequel of this essay.

PART II.

CLASS 1.

METALLIC MINERALS,

OR

ORES.

The name of ORES, or metallic ores, as they are frequently called, is given to all those minerals, which are either entirely composed of metals, or of which metallic substances constitute the most considerable part. It is from this class of bodies that metals are obtained. The number of metals hitherto known amount to 29. It is obvious therefore, that the same number of different orders of ores must exist. Each of which is distinguished by the name of the particular metal, which forms its most essential part; but as four metals have hitherto been found only in other ores, or combined with different metallic substances, the number of the orders of ores are reduced to 25, viz.

ORES OF

Platina,
Gold,
Silver,
Copper,
Lead,
Tin,
Iron,
Zinc,
Mercury,
Antimony,
Bismuth,
Nickel,
Cobalt,
Arsenic,
Tungsten,
Tellurium,
Uranium,
Molybdena,
Chrome,
Titanium,
Manganese,
Colubium,
Tantalium,
Iridium,
Osmium.

PHYSICAL PROPERTIES OF METALS.

All metals are combustible bodies. They possess a certain brilliancy, in consequence of the complete reflection of the light that falls upon them, which is termed *metallic lustre.*

They are the most dense and heavy substances in nature; the heaviest fossil, not metallic, having a specific gravity much below that of the lightest metal. They are the most opaque of all bodies. A stone of the greatest opacity, when divided into thin plates, has more or less transparency; whereas gold is the only metal which admits of being reduced to such a degree of thinness as to admit the smallest perceptible transmission of light. Gold leaf, which is about $\frac{1}{280000}$ part of an inch in thickness, transmits light of a lively green colour; but silver, copper, and all the rest of the metals, are perfectly opaque. Another property which belongs exclusively to metals (though they do not all possess it), is *malleability*; by which is meant a capacity of having their surface increased, either in length or breadth, without being liable to fracture. This capacity is not precisely the same in those metals which do possess it; for some, which admit of extension when struck with a hammer, cannot be drawn into wire, which is properly termed *ductility*. this property depends in some measure on another peculiar quality of metals, namely, *tenacity;* by which is meant the power which a metallic wire of a given diameter has of resisting the action of a weight suspended from its extremity. All metals are fusible, though the degree of temperature, at which this can be effected, differs very much. Mercury is always fluid at the ordinary temperature of our atmosphere, while platina can scarcely be melted by the most intense heat of our furnaces. Metals are perfectly opaque when in a state of fusion; and are crystalisable when suffered to cool slowly and undisturbed. The tetrahedron and the cube are their primitive figures, though they very often take the octahedral form. They can likewise be volatilised at very high temperatures. They are the best conductors of caloric and electricity. Their susceptibility of combination is very great: they unite with carbon, sulphur, and phosphorus. They do not combine with earths by fusion; but their oxids readily unite to acids, alcalies, and earths. They decompose water and several acids. Some effect this at common temperatures: some require a red heat, and others the interposition of another body. Water does not dissolve any of the metals, though it is a solvent of some of their oxids. They are insoluble in ardent spirit, ether, or oils. They are all capable of combining with oxigen, though many of them require very high temperatures to effect this union, and others cannot be united to it but in an indirect manner. Most of the metals can be combined with each other; they then form alloys, many of which are of the greatest utility in the arts.

NATURAL HISTORY OF ORES.

Ores may be either native, that is to say, metals in a state more or less pure, or uncombined with any other substance, or in the state of an oxid, or sulphuret, or carburet, or metallic salt. They are found in the bowels of the earth, sometimes indeed at the surface, and more generally in mountains than in plain or level districts.

Ores are usually met with in crevices, or clefts of rocks, and are then called *veins*. These veins are frequently deposited *upon*, mixt, or surrounded by some stony substance, which is of a different nature from that of which the rock itself is composed. This substance whatever it may be, is called the matrix of the ore, which however must not be confounded with the mineralizing substance, with which the metal is combined, such as sulphur, arsenic, oxigen, &c. for this latter is chemically combined with the metal, so as not to be separable but by chemical means, whereas the matrix may be separated by mechanical efforts.

The veins of ores are always more or less inclined to the horizon, and hence they are distinguished by the names of direct, oblique, or inclined veins, according to the angle they make with the horizon. Thus placed by the hand of nature, they are more easily discovered, than if situated on a level, or in plains. For a more circumstantial account of the general nature and characters of mineral veins, beds of ores, their formation, relative age, modes of working, and modes of discovering them, the reader is referred to a System of Mineralogy and Mineralogical Chemistry now in the press, which will be published shortly.

CHARACTERISTIC PROPERTIES OF ORES.

Ores of metals may be distinguished from other minerals, by their greater specific gravity. They are at least five or six times heavier than water when perfectly free from foreign matters. All that is necessary to be done to distinguish metallic ores from other mineral substances is, to find their specific gravity, or in other words, to weigh them hydrostatically. This may be done as stated already, page 21.

ANALYSIS OF ORES.

The variety of metallic ores being very great, no general method of analysing them can be given, which might possibly prove useful to those who are not skilled in chemical pursuits. The best method of acquiring that knowledge consists in examining the different orders and genera of ores, one by one, so as to acquire a knowledge of those generalities which have been deduced from the analytical labours of former philosophers, and to become familiar with certain general principles, and manipulations, which characterize, and are requisite for the analysis of each individual.

ORDER I.

ORE OF PLATINA.

Genus I.—*Native Platina.*

This ore has hitherto been met with only in the state of an *alloy*, containing, either mechanically mixed or chemically combined with it, nine or ten other metallic substances, of which not less than four are distinct metals, besides the metal to which the name of platina properly belongs.

ANALYSIS OF NATIVE PLATINA.

The grains of platina met with in commerce, which were, until lately, considered as a homogeneous substance, are now known to contain not less than eight metals, and sometimes even nine or ten: these are, mercury, gold, platina, iron, palladium, rhodium, osmium, iridium, copper, and lead.

Process I.—To separate the mercury, introduce the ore into a barometer tube ten or twelve inches long, closed at one end: place the closed end in a crucible filled with sand, surround the crucible with fire in the furnace, till it is of a dull red heat. The mercury will thus become sublimed in the colder part of the tube, it may be collected by cutting the tube with a file, and removing the sublimed quicksilver by a feather or wire.

II.—The separation of the iron requires less trouble. This metal is present chiefly in the state of iron sand; the greatest portion of which may be separated by the magnet, the remainder will be best obtained by a process to be detailed immediately.

III.—To separate the gold which was alloyed with the mercury, let the ore be digested in dilute nitro muriatic acid, without the assistance of heat. Repeat this operation till all the gold is dissolved, which may be known by a solution of sulphate of iron, not occasioning a precipitate when added to the muriatic solution.

IV.—To obtain the gold from this fluid, add to it a solution of green sulphate of iron, or sulphureous acid, till no more cloudiness ensues; the precipitate which falls down is metallic gold, it may be collected on a filter, and fused into a button.

V.—The solution from which the gold has been separated, should next be examined for platina, portions of which may probably have been dissolved by the nitro-muriatic acid. (Experiment III.) To detect this metal, add to it a solution of muriate of ammonia; if a buff, or orange-coloured precipitate ensues, platina is present; the precipitate which falls down is muriate of ammonia and platina: let it be put aside for farther use.

VI.—The ore left and thus freed from the gold it may contain, should be digested in sixteen times its quantity of nitro-muriatic acid, composed of two parts of muriatic, and one of nitric acid, diluted with one-fourth part of water, assisting the action by a gentle heat. This operation is to be repeated until all the platina that was present in the ore is dissolved, which may be known by muriate of ammonia, not occasioning a precipitate when added to the acid that has been made to act on the ore. The insoluble substance left, may be washed, dried, and preserved for further use. It contains the two new metals iridium and osmium.

VII.—The muriatic solution contains platina, palladium, rhodium, copper, iron, and lead, if the latter 3 metals are present, to separate the platina add to it a solution of muriate of ammonia, dry the precipitate, and reduce it to the metallic state by heat, together with that obtained before. (Experiment V.)

VIII.—Into the fluid from which the platina is separated, a polished plate of zinc may then be suspended, and suffered to be immersed in it till it cease to produce any farther precipitate; this obtained product consists of all the metals (iron excepted) that were contained in the solution, namely, rhodium, palladium, copper, lead, and perhaps a small portion of platina.

IX.—Digest the precipitate obtained in dilute nitric acid repeatedly, until a chrystal of sulphate of potash, when added to the solution, occasions no further cloudiness; the precipitate is muriate of lead, which may be reduced by fusing it with carbonate of soda.

X.—To this fluid from which the lead has been separated, after having been concentrated by evaporation, add liquid ammonia in excess, a brown precipitate perhaps falls down which is iron; this precipitate after being ignited with a little wax, gives the quantity of metallic iron that was contained in the ore.

XI.—To obtain the copper, neutralize the ammoniacal solution, from which the iron has been separated, by sulphuric acid, and suspend in it a cylinder of polished zinc or iron, the copper will become precipitated in a metallic state upon the cylinder of zinc.

XII.—To separate the rhodium, palladium, aud platina, from the insoluble residue left, (in process IX.) digest it in dilute nitro-muriatic acid, and effect a solution; to which muriate of soda, equal in weight to about $\frac{1}{50}$th part of the ore of platina employed, should be added, then evaporate the whole to a dry mass by a gentle heat: the dry mass consists of the triple salts of muriate of platina and soda, palladium, and rhodium. To separate these salts, wash the dry mass repeatedly in small quantities of alcohol; the muriate of platina and soda, as well as the palladium become separated, and the salt of rhodium remains behind in a state of purity, being insoluble in alcohol.

XIII.—To separate the palladium, add to the alcoholic solution prussiate of potash, the precipitate which falls down is prussiate of palladium. On heating it to redness the palladium will be obtained in a metallic state.

XIV.—To ascertain the presence of platina, if any is contained in the solution, add muriate of ammonia, collect the precipitate, and proceed as directed before, process VI.

XV.—To obtain the rhodium, take the salt which was not acted on by alcohol, (process XII.) which consists of the oxid of rhodium, united to common salt; re-dissolve it in boiling water, and suspend in it a cylinder of polished zinc; the black powder which falls down is rhodium: on heating it strongly with borax, it assumes a metallic lustre; it may be rendered fusible by arsenic, and also by sulphur, both of which may again be separated by a continued heat. For the analysis of the black powder, left behind in process VI. containing the two new metals called iridium and osmium, the reader is referred to the article iridium.

ORDER II.

ORES OF GOLD.

Division of Ores of Gold.

Gold, the most precious of all metals, is hitherto found only in the state of an alloy, combined with silver, copper, tellurium, &c. Ores of gold are generally divided into four sub-species, viz.

Sub-species 1.—*Pure gold.*
2.—*Brass yellow native gold.*
3.—*Greyish yellow native gold.*
4.—*Gold dust.*

Gold is also met with in some species of pyrites, called auriferous pyrites; and in some lead ores, viz. auriferous sulphuret of lead. Of the different sub-species of gold ores, several varieties are distinguished from each other, according to the different shapes in which the gold is found to exist in them, hence the denominations of *gold in filaments*, or *filamentous gold ore, dendritical gold, lamellated, arborescent, wire-shaped gold, &c.*

ANALYSIS OF ORES OF GOLD.

1. *Analysis of Native Gold.*

The analysis of gold ores is very simple, the chief difficulty arising from the minute portion of this metal contained in the greater part of the ore, even of these which are called very rich.

Process I.—Take one part of the ore, freed as much as possible from its matrix, reduce it to a fine powder, mix it with four times its weight of sub-carbonate of potash and one of glass of borax, melt the mixture in an earthen crucible, and after having fused it for half an hour, pour it out on a stone slab, suffer it to cool, and reduce it to powder.

II. Transfer the mass into a Florence flask, cover it with nitro-muriatic acid and digest it in a gentle heat for a few hours. Decant the fluid and repeat the digestions until the residue is of a pure white colour. Let it be washed, and add the washings to the muriatic solution.

III.—Transfer the fluid obtained in the foregoing processes into a Wedgwood's bason, and evaporate it slowly, over a lamp, to dryness.

IV.—Pour upon the residue, obtained in the last process, so much boiling distilled water as is sufficient to dissolve it, and filter the solution through paper placed in a funnel.

V.—Having done this, prepare a solution of green sulphate of iron, by dissolving one part of that salt in eight or ten of boiling water, and add so much of the solution to that obtained in process IV. till no farther change of color ensues, then suffer the whole to stand undisturbed for some days; the gold which was contained in the fluid will now be precipitated, and found at the bottom of the vessel, in the state of a brown powder.

VI.--Decant the fluid from this powder carefully, collect the latter, which is metallic gold, by putting it upon a filter, and when perfectly dry, introduce it into a crucible, and fuse it into a button or mass, with a small portion of nitre.

Remark—If the gold exists in the ore alloyed with a small portion of silver, as in the ores, called yellow native gold, a white powder will be seen floating in the nitro-muriatic solution: 100 parts of this powder when separated by the filter, and perfectly dried, contain 75 parts of silver, which may be obtained from it, as shall be noticed more fully under the article of silver ores.

The presence of silver may also be detected by exposing the insoluble residue (process II.) to the rays of the sun, the mass will acquire a purplish tint if it contains silver. If this be the case, let it be mixed with three times its weight of sub-carbonate of potash, and fuse it for a quarter of an hour. The silver will be thus reduced to the metallic state.

If the ore contained copper, a polished cylinder of iron or zinc, after having been immersed in the nitro-muriatic solution, will be covered with a crust of copper, the increase of weight of the cylinder gives the quantity of copper. In this case the solution should have no excess of acid.

When gold is found interspersed amongst sand, or earthy substances, in the state of so minute particles, that it cannot be distinguished by the mere eye, we may examine such substances, in the following manner:

2. *Analysis of gold dust.*

Process I.—Diffuse the sand or earth through a large quantity of water in a convenient vessel, and frequently decant the fluid immediately after stirring it each time, by that means, the lighter particles of sand, or earth, as well as other substances, remaining longer suspended, may thus be washed away by the water employed, whilst the more ponderable particles of gold, fall to the bottom with greater rapidity.

II.—But as it would be difficult to separate the gold thus completely, by mere mechanical ablution with water, let the last portion of sand which has been repeatedly washed, be reduced to a very subtile powder, put it into a flask, cover it with nitro-muriatic acid, and digest it by heat for at least one hour, dilute the fluid with water, and separate the gold, by adding to it a solution of sulphate of iron, as directed, page 106, process V.

The presence of gold may be detected in any ore by effecting a solution of it in nitro-muriatic acid, and then mingling it with a solution of green sulphate of iron. If the minutest quantity of gold be present, a purple brown precipitate will gradually appear.

When a mineral is examined merely for gold and silver, which it contains, it is a usual practice to pulverise it very finely, and digest it first in moderately strong nitric acid, and then in nitro-muriatic acid. The first solution contains the silver, the second the gold. This, however, is a very inaccurate way of proceeding, especially for the silver, because whenever this does not greatly exceed the gold, it will be more or less covered by it, from the action of the nitric acid, and, on the subsequent digestion with nitro-muriatic acid, will be converted into muriate of silver, and thus rendered insoluble.

There are several ways mentioned by authors of analysing in the dry way, or rather of assaying ores of gold; none of them, however, are equal in accuracy to the modes of analysis in the humid way, which we have mentioned.

ORDER III.

SILVER ORES.

Division of Silver Ores.

The ores of silver are more numerous than those of gold, mineralogists have divided them into different genera, according to their mineralising substance, which with the metal forms the ore; namely,

GENUS I.—*Alloys of Silver.*

Species 1.—Native Silver.
2.—Plumbiferous Silver.
3.—Auriferous Silver.
4.—Antimonial Silver.
5.—Arsenical Silver.

GENUS II.—*Sulphurets of Silver.*

Species 1.—Common Sulphuret of Silver; or, Vitreous Silver Ore.
2.—Antimonial Sulphuret of Silver; or, Brittle, Vitreous Silver Ore.
3.—White Silver Ore.
4.—Grey Silver Ore.

5.—Black Silver Ore.
6.—Bismuthic Silver Ore.

GENUS III.—*Oxides of Silver.*

Species 1.—Dark red, or ruby, Silver Ore.
2.—Light red Silver Ore.

GENUS IV.—*Salts of Silver.*

Species 1.—Muriate of Silver.
2.—Carbonate of Silver.
3.—Argillaceous muriate of Silver.

As each of these different genera of ores require different treatment, we shall consider them one by one, in order to give an example of all of them.

ANALYSIS OF ALLOYS OF SILVER.

Species I. *Analysis of Native Silver.*

Process I.—Take one part of the ore previously comminuted, affuse upon it in a Florence flask three or four parts of nitric acid, and apply a gentle heat; repeat this operation till a new addition of nitric acid does not produce any further action upon the residue, from which the acid has been decanted; having done this, mix the different nitric solutions, pour over the insoluble residue a small quantity of water at a time, till this fluid runs off tasteless, then mix the water used for washing, with the first obtained solutions.

II.—Add to the fluid obtained in the first process, common salt, dissolved in water, in small quanties at a time, till no farther precipitate ensues; collect this precipitate, pour water over it so as to wash it thoroughly, then suffer it to dry. When perfectly dry, 100 parts contain 75 of silver, which may be obtained from it in the following manner:

III.—Mix one part of the dry precipitate (muriate of silver) with three of carbonate of soda, freed from its water of crystallisation, introduce this mixture into a crucible in the bottom of which a portion of the same salt has been put and pressed down; expose the mixture to a red heat for half an hour, or till it fuses quietly. Then suffer the crucible to cool, and upon breaking it, a button of pure silver will be found at the bottom.

Species II.—*Analysis of Plumbiferous Native Silver.*

In this ore the silver exists alloyed with lead, and sometimes also with iron. The analysis of it may be accomplished in the following manner:

Process I.—Proceed as in the former process I, page 111, and immerse into the solution of the ore in nitric acid, a polished cylinder of copper: let it continue in the solution for at least 24 hours. The silver will now be precipitated in a metallic state. It may be fused into a button, without any addition, and its weight ascertained. It is essential however in this case that the solution of the ore should have not much excess of acid.

II.—To the fluid from which the silver has been obtained, add a solution of sulphate of soda in water. If a white precipitate ensues it is a proof that lead was present in the ore. Its quantity may be determined by the weight of this precipitate; 100 parts of it when perfectly dry, indicate 30 of metallic lead.

III.—The presence of iron may be investigated by dropping into the solution, prussiate of potash, which in that case occasions a blue precipitate; or by ammonia, occasioning a brown powder to fall down.

Species III.—*Analysis of Auriferous Native Silver.*

In this ore silver exists alloyed with gold. The analysis may be conducted thus:

Process I.—Let one part of the ore reduced to a fine powder be repeatedly digested in three of nitric acid, until the portion of the acid last decanted from the ore, does not yield any white precipitate, by dropping into it muriatic acid.

II.—Digest the insoluble residue in nitro-muriatic acid, till a new addition of that fluid extracts no more gold, which may be known by not becoming turbid by the addition of sulphate of iron, or by adding to it a few drops of muriate of tin.

III.—To recover the gold contained in the nitro-muriatic solution, proceed as mentioned before, page 105, process III, IV, V, &c.

IV.—The silver that was contained in the ore, and which is extracted in the first process by means of nitric acid, may be separated by precipitating it with muriatic acid, and subsequent reduction. See page 112.

Remark.—If the ore contains copper, as is the case in the *cupriferous native silver ore*, the presence of this metal may be detected by dropping into the nitric solution liquid ammonia, the fluid will instantly acquire a blue colour.

Species IV.—*Analysis of Antimonial Silver.*

In this ore silver is alloyed with antimony.—Its analysis may be effected in the following manner:

Process I.—Digest one part of the ore repeatedly in muriatic nitric acid, till all the silver is removed.

II.—Separate the silver from this solution by a cylinder of copper, as stated, page 113.

III.—Digest the residue of process I. repeatedly in muriatic acid, assisted by heat, and decompose this solution by immersing in it a cylinder of iron: the precipitate which falls down is metallic antimony.

Species V.—*Analysis of Arsenical Silver.*

This ore consists of silver, arsenic, iron, and antimony.

Process I.—Digest the ore repeatedly in nitric acid, until all the silver is extracted.

II.—Separate the silver from the obtained solution by muriatic acid, or common salt, and reduce it to the metallic state, by fusing it with carbonate of soda. See process III. page 112.

III.—The silver being separated, let the solution be rendered neutral by the admixture of carbonate of potash: a precipitate falls down which is arseniate of iron.

IV.—To decompose the arseniate of iron let it be dissolved in nitric acid, and decompose the solution by the addition of nitrate of lead: 100 parts of the dried precipitate indicate about 22 of arsenic. Or the decomposition of the arseniate of iron may be effected by heating it repeatedly, in contact with ignited charcoal, till no arsenical smell is observable. The arsenic will be volatilized, and the oxid of iron left behind.

V. To separate the antimony let the insoluble residue of process I. be repeatedly digested in muriatic acid, and separate the antimony, by immersing in it a cylinder of iron.

ANALYSIS OF SULPHURET OF SILVER.

Species I.—*Analysis of common Sulphuret of Silver.*

The analysis of this ore, which consists of silver and sulphur only, may be accomplished thus:

Process I.—Let one part of the ore be digested in eight times its weight of nitric acid, of about

13.5, specific gravity, diluted with half its quantity of water, and repeat this operation till a new portion of acid (after being suffered to act upon the ore for some time) does not become cloudy by the addition of a few drops of muriatic acid; then wash the residue, and add the water thus employed to the nitric solution of the ore.

II.—In order to separate the silver from this solution, proceed as directed in the analysis of native silver ore, page 111.

III.—To ascertain the quantity of sulphur, which existed in the ore, take the insoluble residue of the first process dried thoroughly, put it into a crucible, and expose it to a red heat; the sulphur will take fire, and burn off. The loss of weight indicates the greater part of the sulphur. But in order to be more correct, pour water upon the residue left in the crucible, filter the fluid and drop it into a solution of nitrate of barytes, a white precipitate will fall down, collect it on a filter and dry it perfectly, 100 parts of this precipitate indicate 14. 5 of sulphur, which added to the loss of the weight which the residue of the first process suffered, gives the real quantity of sulphur contained in the ore.

Remark.—The fluid obtained in process II. by decomposing the nitric solution of silver, by means of muriatic acid, should also be assayed for sulphuric acid, which perhaps may have been formed during the repeated action of the nitric acid upon the sulphur contained in the ore. If therefore a precipitate takes place on dropping into the above fluid nitrate of barytes, sulphuric acid has been produced; the precipitate must be collected and weighed, and the quantity of sulphur calculated as stated above, and this should be added to that already noticed.

Species II.—*Analysis of Antimonial Sulphuret of Silver.*

The analysis of this ore was effected by Klaproth, in the following manner:

Process I.—One hundred grains of the ore were repeatedly boiled in nitric acid, till the original black colour became changed to a greyish yellow.

II.—To this nitric solution muriate of soda was added, by which a precipitate of 84.75 grains of muriate of silver was obtained.

III.—The filtered solution was examined by sulphate of soda, but no precipitate took place; thus shewing the absence of lead. An excess of liquid ammonia was then added, which threw down a grey precipitate, weighing five grains. This, when heated, exhaled a slight arsenical odour; and being dissolved in nitric acid, afforded a deep blue precipitate with prussiate of potash: thus showing it to be oxyd of iron, with a little arsenic.

IV.—The ammoniacal solution, which had a light blue colour, was slightly supersaturated with sulphuric acid; a polished iron cylinder being then immersed, became tinged with copper, but in so small a quantity as not to be appreciable.

V.—The ore left, and which was insoluble in nitric acid, process I. was digested in nitro-muriatic acid, and the part not taken up by this fluid amounted to 13 grains, of which 12 were burnt off on a scorifying test, and were sulphur; the remainder was silex.

VI.—The nitro-muriatic solution, being poured into water, deposited 13 grains of oxyd of antimony.

Species 3.—*Analysis of White Silver Ore.*

The analysis of this ore was accomplished by the same chymist, in the following manner:

Process I.—Four hundred grains of this ore, being pulverized, were mixed with four ounces of strong nitric acid, and two ounces of water. After the acid had ceased to act it was poured off, and replaced by two ounces of nitric acid, to which, being made to act upon it for some time, was mingled with eight ounces of water, and the whole made to boil. The undissolved residue weighed 326 grains.

II.—To the nitric solution was added common salt, by which muriate of silver was immediately precipitated, and after a few hours were also deposited crystals of muriate of lead. The mixed precipitate was boiled with much water, by which the muriate of lead was dissolved, and the muriate of silver obtained pure. From this, by fusion with soda, as stated before, page 112, were obtained 81.5 grains of silver.

III.—Into the two solutions, mingled together, ammonia was added to saturation, which threw down a light brown precipitate, weighing 40 grains. This was re-dissolved in nitric acid, and by the addition first of prussiate of potash, and then of soda, was separated into 12 grains oxyd of iron, and 28 alumine.

IV.—The undissolved residue was boiled in repeated portions of muriatic acid, and at length there remained only 51 grains, which, when ignited, proved to be 49 grains of sulphur, and two grains of a residue, half of which consisted of silex, and the rest being soluble in muriatic acid, was added to the other muriatic solution.

V.—The muriatic solution was evaporated till it ceased to deposit crystals. These being collected, and mixed with twice their weight of black flux, and reduced in a lined crucible, afforded $16\frac{1}{8}$ grains of lead, which, being cupelled, emitted a few antimonial vapours, and left behind $\frac{1}{8}$ of a grain of silver.

VI.—The muriatic solution, from which the muriate of lead had been separated, being poured into water, deposited oxid of antimony, which, mixed with soap and black flux, was reduced by fusion to the metallic state. In this process, however, a slight portion of the antimony was volatilized; what remained weighed 31.5 grains.

Species IV.—*Analysis of Grey Silver Ore.*

The analysis of this ore was conducted by Klaproth, thus:

Process I.—Three hundred grains of this ore were pulverized and digested with four times their weight of nitric acid. When this had ceased to act, it was poured off, and replaced by another equal quantity of the same acid. The undissolved residue was of a greyish yellow colour, and weighed 188 grains.

II.—The nitric solution was decomposed by muriated soda. The precipitate obtained afforded, by fusion with soda, 31.5 grains of silver.

III.—The silver being thus separated, sulphate of soda was added to the solution, but without occasioning any precipitate, therefore the liquor contained no lead.

IV.—Ammonia was then added to the fluid in excess, which occasioned a brownish red precipitate, which, after being ignited, weighed 9.25 grains. By digestion in nitric acid it dissolved, with the exception of 0.5 grains of silex. Prussiate of potash threw down from the solution a deep blue precipitate, and 1.5 grains of alumine was obtained, by means of soda. —Hence the oxyd of iron amounted to 7.25 grains.

V.—The blue ammoniacal solution was now supersaturated with sulphuric acid, and a cylinder of polished iron precipitated 69 grains of copper.

VI.—The insoluble portion was boiled with six times its weight of muriatic acid, which, being poured off when its action had ceased, left 105.5 grains still undissolved.

VII.—The muriatic solution having been concentrated by evaporation, deposited a little muriate of silver, from which 0.25 grains of metal was obtained. The fluid being then poured into water afforded 97.25 grains of oxid of antimony, equivalent to 75 of metal.

VIII.—The residue left in Experiment VI, which resisted the action of muriatic acid, weighing 105.5 grains, was ignited, and 25.25 grains of sulphur were burnt off. The remainder, being silex, was fused with black flux, and afterwards dissolved in water, leaving behind 0.75 grains of silver. Hence the amount of silex was 79.5 grains.

The analysis of the black silver ore may be effected in a similar manner.

Species V.—*Analysis of Bismuthic Silver Ore.*

Process I.—Digest the ore repeatedly in nitric acid, till this fluid exercises no further action on the ore.

II.—Pour the nitric solution into a large quantity of water, a precipitate falls down, which is oxid of bismuth; 123 parts of it, when dry, are equivalent to 100 of bismuth.

III.—Evaporate the fluid to at least one-third of the original bulk, and drop into it muriatic acid. Collect the precipitate which falls down; wash and dry it.

IV.—The precipitate now left is muriate of silver: let it be digested in nitric acid, decant the fluid, and mingle it with a large quantity of water. If any precipitate should ensue, it is a portion of oxid of bismuth which escaped the action of the water in process II. Let it be dried and added to that obtained before.

V.—The remaining fluid may next be assayed for lead: let it therefore be concentrated to dryness; dissolve the residue in a sufficient quantity of water, and drop into it sulphuric acid. A precipitate will appear if lead be present: let it be collected and dried, and the quantity of lead determined, as stated, page 113, process II.

VI.—The solution from which the lead is separated may then be examined for iron; for that purpose add to it liquid ammonia, till the odour of the latter considerably predominates. A brown precipitate falls down, if iron was contained in the ore: this precipitate must be heated to redness, and weighed: 100 parts of it are equal to 53 of iron.

VII.—If the ore contained copper, the fluid has now a blue colour. It may be saturated with sulphuric acid, in excess: a cylinder of iron will precipitate the copper.

VIII.—The insoluble residue left in process I. may be examined for sulphur; for that purpose let it be ignited in a crucible, and proceed according to the rules mentioned, page 117.

IX.—The residue may again be digested repeatedly in muriatic acid, and assayed for lead by sulphuric acid. If a precipitate ensues, it is sulphate of lead, which is to be added to that obtained before. The residue now left, if any, is merely the matrix of the ore.

ANALYSIS OF OXIDS OF SILVER.

Species 1.—*Analysis of Dark-Red, or Ruby, Silver Ore.*

In this ore silver exists, in the state of an oxid, combined with sulphur and oxid of antimony, and sometimes sulphuric acid. Its analysis was effected by Klaproth in the following manner:

Process I.—Five hundred grains, being very finely pulverized, were digested for several hours in a gentle heat, with six times their weight of strong nitric acid and water: a further quantity of water was then added, and the liquor made to boil. The nitric solution was decanted off, and the undissolved residue digested with a like portion of acid as at first, repeatedly; and lastly it was poured on a filter, and the residue washed in water.

II.—The nitric solutions, together with the washings, being mingled together, were evaporated to one-eighth of their bulk, and the remaining fluid deposited, by cooling a considerable quantity of greyish-white crystals of sulphate of silver. The nature of these crystals being ascertained, water was added to the supernatant liquor, and by a gentle heat the whole was re-dissolved. To the solution muriatic acid was added, as long as any precipitate fell down. The muriate of silver weighed 391.5 grains, when dried.

III.—The fluid from which the above precipitate had been obtained was reduced to a small bulk by evaporation, in consequence of which it became turbid, and deposited one grain more of muriate of silver. Nothing now remained in the fluid, except sulphuric acid.

IV.—The insoluble residue which resisted the action of nitric acid weighed 202 grains, it was digested in nitro-muriatic acid, consisting of five parts muriatic, and one of nitric acid, which left 65 grains undissolved. This residue, being washed and dried, was exposed to a gentle heat, in which the sulphur was volatilized, leaving six grains and half of muriate of silver.

V.—The nitro-muriatic solution, after having been concentrated by evaporation, was poured into a large quantity of water, which occasioned a white pulverulent precipitate, weighing, when dried, 132 grains, which was oxyd of antimony, entirely unmixed with the smallest portion of arsenic. When fused, in a covered crucible, with tartrate of potash, a button of reguline antimony was produced; and this, when heated on a scorifying test, became volatilized, leaving behind 0.5 grains of silver.

VI.—The residues of the nitro-muriatic solution (IV.) and of the nitric solution (III.) were mixed and distilled till dense white vapours appeared. The concentrated fluid was diluted with water, and muriate of barytes added, as long as a cloudiness appeared. The sulphate of barytes obtained weighed 194 grains.

In this analysis, the muriate of silver obtained amounted to 399 grains, which, being reduced to the metallic state furnished, together with the half grain of silver contained in the antimony (process V.) exactly 300 grains of pure silver; a result which was confirmed by two assays of this ore on the cupel, each of which yielded 30 *per cent.* of silver.

In order to ascertain the quantity of antimony contained in the 132 grains of white oxid (process V.) 100 grains of reguline antimony were digested by heat in muriatic acid, to which nitric acid was added, drop by drop, till the whole of the metal was dissolved. This solution being concentrated by evaporation, and then poured into water, afforded 130 grains of white oxid. Hence the above 132 grains of oxid indicate 101.5 of metallic antimony.

With respect to the sulphuric acid which made its appearance in this analysis, it is affirmed by Klaproth to have pre-existed, at least for the most part, in the ore, and not to have been produced by the action of the nitric acid upon the sulphur, for the following reasons:

In the first place, the quantity of nitrous gas disengaged during the action of the nitric acid on the ore, appeared by no means sufficient to account for the production of so large a quantity of sulphuric acid.

Secondly, some finely pulverized red silver ore, being digested with strong muriatic acid, the solution was found to contain not only antimony and silver, but also sulphuric acid.

Now, as muriatic acid is incapable of acidifying sulphur, it follows, that the abovementioned acid must have pre-existed in the ore.

This is further confirmed by an observation of Henkel's, that the silver may be extracted from the red ore merely by successive digestions in muriatic acid, which could not have happened without the presence of sulphuric acid likewise. —We shall return to the consideration of this question presently.

The analysis of this ore by Vauquelin was thus conducted:

Process I.—One hundred parts of the ore, finely pulverized, were digested in 400 parts of nitric acid, and 200 of water: the colour of the ore became grey, and lastly white. During the whole of this change there was no perceptible disengagement of nitrous gas; whence it may be concluded, says the author, that the ingredients of the ore were already sufficiently oxygenated to dissolve in nitric acid. After a gentle ebullition, the whole was poured on the filter, and the insoluble portion, after ablution with water, weighed 42.06.

II.—The insoluble portion of process I. was digested in strong muriatic acid, by which its colour became yellow, and its amount was reduced to 14.66. Being then laid on a hot coal, it burnt entirely away with a blue flame, and all the other characters of sulphur. The sulphur of the ore, therefore, may be reckoned at 14.66.

III—The muriatic solution, being mingled with a large quantity of water, deposited a white precipitate of oxyd of antimony, weighing 28.25, which, according to Vauquelin, are composed of 16.13 antimony, and 12.12 oxygen.

IV—The nitric solution was mixed with muriatic acid, and furnished 72.66 of muriate of silver, which he estimated, according to Bergman, at 56.67 of metal.

Remarks.—In this analysis by Vauquelin there is no mention made of sulphuric acid, which was found so abundantly by Klaproth; and in order to bring this matter more completely to an issue, 100 parts of the ore were digested with a solution of potash. As soon as the two substances came into contact, the colour of the ore changed first to grey, and presently to a deep black, 66 parts remaining undissolved. These were treated with dilute nitric acid, at a gentle heat, upon which a disengagement of nitrous gas took place, and the undissolved matter amounted only to eight parts, and was sulphur. The nitric solution, on the addition of muriatic acid, afforded 70 of muriate of silver. The alkaline solution, which was perfectly clear and colourless, gave, when treated with muriatic acid, 32 of sulphuretted oxid of antimony. After the separation of this, the remaining fluid was mixed with muriate of barytes, without any precipitate being formed: hence it contained no sulphuric acid. Indeed, Klaproth himself, at the conclusion of his dissertation on this subject, appears to be disposed to think that the sulphuric acid does not exist in the ore, but that the whole of the sulphur is in the state of an oxid: on account of the action of the acid employed in the decomposition of the ore, the whole of the oxigen unites with part of the sulphur, converting it into sulphuric acid, and leaving the remainder of the sulphur completely deoxygenated. But we do not see how this can be the case: besides, it is obvious that the silver at least must be in the state of oxid, since it dissolves in nitric acid, without producing any nitrous gas. If it were not, therefore, for the circumstance, that the ore, when treated with simple muriatic acid, gives out sulphuric acid, we should be disposed to believe, that the ore contains no sulphuric acid, and that the oxigen is combined, not with the sulphur, but with the metal.

The light red silver ore may be analysed in a similar manner.

ANALYSIS OF NATIVE SALTS OF SILVER.

Species 1.—*Analysis of Muriate of Silver.*

The analysis of this ore was conducted by Klaproth thus:

Process I.—Two hundred grains of a massive variety of muriate of silver were treated with thrice their weight of nitric acid, but no perceptible action took place, either in the cold or at a boiling heat, except that a little oxid of iron was separated. The solution being decanted, and mixed with ammonia, an additional portion of oxid of iron was thrown down. The supernatant liquor became opalescent on being mixt with muriatic acid, but no precipitate was deposited:

hence it was manifest, that the muriate of silver in the ore was not mixed with any in the metallic or sulphuretted state, otherwise it would have been taken up by the nitric acid, and have afforded a precipitate with muriatic acid.

II.—The insoluble part of the ore was then fused with twice its weight of subcarbonate of potash, and yielded 133 grains of metallic silver.

On these preliminary experiments the following analysis was founded.

III.—Two hundred grains of the ore were mixed with 600 grains of potash, freed from carbonic acid, and fused in a glass retort. After cooling, the neck of the retort being broken off, the fused mass was softened with hot water, to effect a solution, and the fluid was rendered clear by filtration.

IV.—The insoluble portion was next digested in nitric acid, by which the greater part of it was dissolved.

V.—The insoluble part now left was digested in nitro-muriatic acid, which left undissolved a few grains of residue, of a white colour, which proved to be muriate of silver, with a little of the matrix of the ore. This muriate of silver afforded two grains of silver. The nitro-muriatic solu tion, being decomposed by liquid ammonia, yielded seven grains of oxyd of iron.

VI.—To the nitric solution (IV.) was added common salt dissolved in water, and the muriate of silver thus obtained afforded, by fusion with soda, 134½ grains of silver. The remaining fluid gave, by saturation with ammonia, five grains of oxyd of iron.

VII.—The alkaline solution (III.) being saturated with acetous acid, yielded three and half grains of alumine, which after being separated, the fluid was evaporated to dryness, and the product digested in alcohol; by which means the acetite of potash formed was removed, and the muriate of potash left behind: this latter, by solution in water, and subsequent evaporation, yielded 117½ grains of muriate of potash.

VIII.—The muriate of potash being again dissolved in water, muriate of barytes was added, by which means about three grains of sulphate of barytes was obtained, which, according to Klaproth, indicate one and half grains of sulphate of potash, and this reduces the amount of muriate of potash to 116 grains, in which the muriatic acid amounts to 42 grains.

From these results the contents of the ore are stated as before.

Remark.—The analysis here adopted appears to be perfectly satisfactory, but there seems to be a few oversights in stating the results.

The silver is a little under-rated; its amount, according to processes V. and VI. being 136.5 or 68.25 *per cent.* There is no notice taken of the oxigen, which forms an essential part of muriate of silver; and in consequence of this omission, the muriatic acid is probably estimated much too high. The amount of the silver may be considered as ascertained with the most exactness, as it was actually reduced to the reguline state. Assuming this, therefore, as the basis of our calculations, and that 100 parts of muriate of silver consist of 75.24 silver, 8.16 oxigen, and 16.6 acid, it follows, that 136.5 of silver require, in order to be converted into muriate of silver, 14.72 of oxigen, and 30.04 of acid. But 30.04 of muriatic acid, when saturated with potash, would afford only about 84 of muriate of potash, instead of 116, as obtained by process VIII. It may be added, as a further proof of the amount of this salt being erroneously stated, that 42 grains of muriatic acid (contained in 116 grains of muriated potash) indicate 253 grains of muriate of silver, which is impossible, the whole amount of the ore being only 200 grains. It is probable, therefore, that the following corrected statement of the contents of this ore is nearer the truth than that quoted above, viz.

68.25	Silver
7.36	Oxygen
15.02	Muriatic acid
6.00	Oxyd of Iron
1.75	Alumine
0.5	Sulphuric acid
98.88	

Species 2.—*Analysis of Argillaceous Muriate of Silver.*

The analysis of this ore may be conducted like the preceding.—Klaproth states his analysis as follows:

Upon 35 grains of pulverised ore nitric acid was poured, and the mixture made to boil: neither effervescence, nor red vapours appeared; the acid seemed to attack the ore but weakly; the residuum assumed the form of a precipitate, resembling a cheesy coagulum. The acid, which was tinged of a faint blue, being separated through a filter, admitted of combination with common salt, without being rendered turbid. By the addition of carbonate of ammoniac to excess, alumine was thrown down, and the fluid appeared of a deep blue; but after it had been supersaturated with sulphuric acid, and an iron cylinder immersed into it, it deposited a thin coppery crust. The dried residue weighed 30 grains; it was extracted by repeatedly pouring upon it liquid ammonia, agitating it frequently. Nitric acid being added to a few drops of it, some muriate of silver immediately precipitated. The whole of this solution, when evaporated by a gentle heat, became converted into flexible membranes, of a pearl grey, which tarnished into blue by exposure to air; and when gently melted in a small silver cup, ran into a waxy substance. The weight of this fused muriate of silver amounted to 10½ grains. When the alumine that was left behind, after the extraction of the muriate of silver by ammoniac, was melted with soda, it still afforded a bead of silver, of three-quarters of a grain. As this is equal to one grain of muriate of silver, the above 36 grains of this ore contained 11$\frac{1}{2}$ grains of muriated, or 8$\frac{5}{8}$ths. of metallic silver, and 2$\frac{7}{8}$th grains of concentrated muriatic acid.

Klaproth says, it is owing to the alumine contained in this ore that it does not assume the same appearance, when heated on charcoal, as the common muriate, but that the metal transudes in the metallic state, in small globules; for as that earth deprives the muriate of silver of its acid, when heated, the silver is enabled to assume the metallic form.

As silver, notwithstanding its great affinity with muriatic acid, cannot enter into combination with it in the reguline state; and since that metal, as far as we know, is never found in the bowels of the earth, in an oxidated state, it is difficult to ascertain the operation of Nature in producing the corneous ore. Bergmann* was of opinion, that Woulfe had solved that doubt by asserting, that in the above-mentioned ore he had traced the sulphuric acid, besides the muriatic, for silver unites readily with sulphur; and since sulphurated silver not unfrequently under-

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* Torb. Bergmann, on the Generation of Natural Corneous or Muriated Metals.

Crett's Chemistre Annalen, 1784; No. IV page 377.

goes a decomposition, more especially when, as in this case may be conjectured, from the presence of oxyd of iron, some sulphuret of iron, disposed to disintegration, intervenes, the sulphur passes over into the state of sulphureous acid, and forms sulphate of silver. If now muriatic acid interferes, it will, by virtue of its greater affinity to silver, decompose the sulphate, and instead of it form muriate of silver—of that species of muriate of silver which is found in regular cubic chrystals, Bergman had already conjectured, that it might be considered as pure, and free from sulphuric acid. He also wished to convert this conjecture of his into an established truth, by duly examining that fossil; for, as he very justly says, it is better to sacrifice such a specimen, scarce as it yet is, to investigation, than to deprive the science of a means of enlarging our knowledge, by preserving it. The wish of this chemist is in some degree accomplished, and his conjecture for the most part confirmed, by the inquiry of Klaproth, with the unimportant difference, however, that instead of chrystallized muriate of silver, the chemist of Berlin has employed a specimen of that which occurs in lumps, or massive.

Mr. Klaproth thinks that, in order to comprehend how Nature can produce the muriate of silver, without the interposition of sulphur, or sulphuric acid, we may receive some light from the following intelligence, taken from a letter of Proust, in Rozier's Journal de Physique.—It is there stated, that the coined silver of the Spanish ship San Pedro d'Alcantaro, that was wrecked on the coast of Portugal, became coated with a blackish crust, of $\frac{1}{48}$th of an inch thickness, during the short time before it was recovered from the sea. This crust broke off in scales, and was a true muriate of silver. Moreover, Pallas[*] relates, that he has found, on the Jaik in Siberia, several old Tartarian silver coins, which in that tract of saline land were converted into true muriate of silver, some throughout their whole mass, and others on the surface only.

From this knowledge of the constituent parts of the native muriate of silver, art is enabled to imitate nature pretty nearly. If muriate of silver be made to fuse uniformly, at a moderate heat, an artificial muriate of silver ore is produced (according to Klaproth) which may be

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[*] Nordische Beytraege, III. Vol.

made more similar to the natural one, by adding, before the fusion, a proportional quantity of oxid of iron. And if muriate of silver be dissolved in ammonia, and the fluid evaporated in a gentle warmth, the muriate of silver appears, in small glittering scales, resembling those with which the native ore is found partly covered. But if this solution be left to spontaneous evaporation, the muriate of silver will sometimes crystallize into solid regular crystals, of the same appearance with the cubic crystals of the native ore.*

Species 3.—*Analysis of Carbonate Silver.*

This ore may be analysed in the following manner:

Process I.—Introduce into a tubulated retort, connected with a graduated cylinder, filled with mercury, and standing in the mercurial trough, a determinate portion of the ore, and pour over it, as expeditiously as possible, eight of nitric acid; the carbonic acid contained in the ore will be extricated, and pass into the cylinder.

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* Analytical Essays, VI. p. 124.

II.—To ascertain its bulk, pass up into the cylinder barytic water; the loss of the bulk of the gas gives the volume of the carbonic acid.

III.—To ascertain the quantity of silver, filter the contents of the retort, and add muriatic acid; the muriate of silver produced gives the quantity of silver contained in the ore, according to the rule so often stated before.

ORDER IV.

COPPER ORES.

Division of Copper Ores.

The ores of copper are very numerous.—They are arranged in the following manner:

GENUS I.—*Alloys of Copper.*

Species 1.—Native Copper.

GENUS II.—*Sulphurets of Copper.*

Species I.—Vitreous, or Common Sulphuret of Copper.
2.—Purple, or Variegated, Copper Ore.
3.—Yellow Copper Ore, or Copper Pyrites.
4.—Black Copper Ore.
5.—Grey Copper Ore.

GENUS III.—*Oxides of Copper.*

Species 1.—Ruby Copper, or Red Copper Ore.

2.—Capillary Ruby Copper, or Hair Copper Ore.
3.—Compact Ruby Copper.
4.—Tile Copper, or Brick-red Copper.
  Subspecies 1.—Indurated Tile Red Copper Ore.
    2.—Earthy Tile Red Copper.
Species 5.—Dioptase, or Emerald Copper.
6.—Bituminous Copper Ore.

GENUS IV.—*Salts of Copper.*

Species 1.—Blue Carbonate of Copper, Azure Copper Ore, or Mountain Blue.
  Subspecies 1.—Radiated Azure Copper.
    2.—Earthy Azure Copper.
Species 2.—Green Carbonate of Copper, Malachite, or Mountain Green.
  Subspecies 1.—Fibrous Malachite.
    2.—Compact Malachite.
    3.—Earthy Malachite.
    4.—Ferrugenous Malachite.
Species 3.—Arseniate of Copper, Olive Ore, or Octahedral Copper Ore.
  Subspecies 1.—Lamellar, or Hexeadral Arseniate of Copper.

Subspecies 2.--Prismatic Arseniate of Copper.
3. Trihedral Arseniate of Copper.
4.—Capillary Arseniate of Copper.
5.—Ferriferous, or Martial Arseniate of Copper.

Species 4.—Phosphate of Copper.

Species 5.—Muriate of Copper, or Green Copper Sand.

Subspecies 1.—Compact Muriate of Copper.
2.—Pulverulent Muriate of Copper.

Species 6.—Sulphate of Copper.

ANALYSIS OF ORES OF COPPER.

Species 1.—*Analysis of Native Copper.*

Process I.—Let one part of the ore be dissolved in four or five times its weight of nitric acid, and evaporate the solution to dryness.

II.—Upon the dry mass affuse about eight times its quantity of water; boil the mixture for a quarter of an hour, and filter the fluid.

III.—Immerse into this solution a polished cylinder of iron or zinc; the copper will be precipitated in a metallic state.

Remark.—If the ore contains gold, silver, and iron, it must be repeatedly digested in dilute nitric acid. The silver may be precipitated from this solution by a cylinder of zinc. The iron may be separated by evaporating the solution to dryness, dissolving it again in concentrated nitric acid, evaporating the acid as before, and repeating this operation several times successively: this being done, let water be poured on the mass, and filter the solution; the iron will now remain upon the filter in the form of a brown powder, and the nitrate of copper becomes dissolved in the watery fluid. This fluid may be decomposed by boiling it with potash; a precipitate is produced which is black oxid of copper; 100 parts of it, after being dried in a red heat, contain 80 of copper.

ANALYSIS OF SULPHURET OF COPPER.

Species 1.—*Analysis of Vitreous, or Common Sulphuret of Copper.*

Process I.—Digest one part of the pulverized ore repeatedly in three times its weight of dilute nitric acid, till it extracts no more copper, which may be known by dropping into the obtained solution liquid ammonia in excess; if the fluid acquires no blue colour it contains no copper.

II.—Evaporate this solution to dryness, redissolve it in concentrated nitric acid, and again evaporate the solution to dryness: repeat this process for several times successively.

III.—Boil the dry mass in eight times its weight of water, a brown powder becomes separated, which is the iron that was contained in the ore; collect it on a filter, wash, dry, and ignite it.

IV.—Mingle the fluid from which the iron has been separated with a solution of potash, till no further precipitate ensues, and boil it for a few minutes; collect the precipitate, and dry it in a red heat: 100 parts contain 80 of copper.

V. To ascertain the quantity of sulphur contained in the ore, heat the residue of process I. and proceed as directed before; but as part of the sulphur is generally acidified during the digestion of the nitric acid upon the ore, the solution, after the metal is separated, may be assayed for sulphuric acid by nitrate of barytes, and the real quantity ascertained, according to the rule laid down, page 117. The ores called purple, yellow, and black copper ores may be analysed in a similar manner.

Grey copper ore contains, besides copper, sulphur and iron; also, silver, lead, and antimony: it may be analysed in a like manner; the silver may be separated by common salt (see page 112); but as lead is also separated by this substance, the precipitate must be digested in liquid ammonia; this dissolves the muriate of silver, and leaves the lead; by subtracting the weight which the precipitate has lost by this treatment the quantity of both the metals may be found. If antimony was present, it will be separated from the remaining solution by a copious affusion of water: the precipitate remains insoluble in that fluid.

ANALYSIS OF OXIDS OF COPPER.

Species 1.—*Analysis of Ruby, or Red Copper Ore.*

Oxid of Copper, or Ruby Copper Ore, may be analysed by merely dissolving it in muriatic acid, and precipitating the copper by a cylinder of iron or zinc.

The following method was employed by Mr.

Chenevix* to examine the native red oxid of copper from Cornwall.

Process I.—One hundred parts of the ore, being submitted to the action of nitric acid, became totally dissolved by digestion.

II.—The obtained solution being evaporated to dryness was covered with muriatic acid, to convert it into a muriatic acid, and again evaporated to dryness.

III.—Upon the dry mass water was poured, till all the muriate of copper was extracted.

IV.—On immersing into the obtained solution a cylinder of iron, 88.5 of copper were obtained.

The species of copper ores called capillary, compact, or tile ruby copper ore, may be analysed in a like manner.

ANALYSIS OF SALTS OF COPPER.

Species 1.—*Analysis of Blue Carbonate of Copper, or Mountain Blue.*

Process I.—In order to ascertain the quantity of carbonic acid which exists in the ore, united to the oxid of copper, let a portion of it be

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* Philos. Trans. 1801.

heated in a retort to a dull redness; collect the gas in the usual manner over mercury, and let it be absorbed by lime-water, in order to measure its quantity; or, if this should be deemed too troublesome, let one part of the ore be introduced into a bottle, containing three parts of sulphuric acid, diluted with four of water; close the bottle with a cork, into which is fixed a capillary tube, and weigh the whole accurately. When no more effervescence ensues, weigh the bottle and its contents again; and the loss of weight will indicate, with tolerable accuracy, the quantity of carbonic acid which escaped.

II.—To ascertain the quantity of copper, digest one part of the ore repeatedly in sulphuric acid, diluted with an equal bulk of water, till this acid extracts no more copper (see page 147, process I.) and filter the solution.

III.—Immerse into the sulphuric solution a cylinder of zinc or iron, and the copper will be precipitated.

The analysis of carbonate of copper may likewise be effected, and perhaps more easily, in the following manner:

Process I.—Take one part of the ore, expose it to a red heat in a crucible for about half an hour.

II.—Let one part of this previously ignited ore be mixed with three times its weight of black flux, and one-fifth of charcoal powder, or resin; put the mixture into a crucible, cover it with a stratum of muriate of soda, and fuse it for about half an hour; a button of copper will then be found when the crucible is broken.

The ore called green carbonate of copper, and all its subspecies, may be examined in a like manner.

Dr. Fordyce has given the following general process for analysing all copper ores, with a view to ascertain the quantity of copper.

Process I.—Take 100 grains of the pulverised ore, digest it repeatedly in one ounce of nitro-muriatic acid, composed of equal parts of nitrous and muriatic acid, till all the copper is extricated, which may be known as directed already, page 147.

II.—The different solutions are then to be mingled, precipitated by the addition of carbonate of potash, and the precipitate collected on a filter.

III.—This precipitate is to be re-dissolved in a sufficient quantity of sulphuric acid, and the solution precipitated by a polished cylinder of zinc or iron.

Species 2.—*Analysis of Arseniate Copper.*

In this ore and its subspecies copper exists, united to arsenic acid, without any other metallic substance; or at least very rarely it contains other bodies. The analysis may be conducted thus:

Process I.—Let one part of the ore, reduced to a fine powder, be repeatedly digested in nitric acid, until all the copper is extracted.

II.—To the obtained solution add carbonate of potash, in such a quantity only, as to remove the excess of acid, if any, or so as to obtain a neutral solution.

III.—To the fluid obtained add a solution of acetate or nitrate of lead, until no more cloudiness ensues.

IV.—Collect the white precipitate, which is arseniate of lead; wash and dry it: 100 grains contain 33.66 of arsenic acid.

V.—To ascertain the quantity of copper, add to the solution from which the arseniate of lead has been separated, sulphuric acid, and immerse in it a cylinder of iron. The copper will then be obtained in the metallic state. But as the copper does not exist in the ore in a metallic state, but in the oxidised state, therefore one-quarter of the weight of the obtained copper must be added for oxigen, in stating the result of the analysis.

Remark.—The object of rendering the nitric solution neutral by an alkali (process II.) is merely to prevent the arseniate of lead formed in the next process from being dissolved in the excess of acid which may be present. Where iron is suspected, the solution, instead of being precipitated by a cylinder of iron (process V.) may be decomposed by ammonia, which in that case will dissolve the copper and precipitate the iron. To collect the copper, the ammoniacal solution may be neutralized by sulphuric acid, and then decomposed by a cylinder of iron. To prove that the white precipitate obtained in process IV. is arseniate of lead, it may be digested with sulphuric acid; the arsenic acid will be disengaged, and its characters manifested by the usual tests.

The following method was employed by Mr. Chenevix, for analysing the arseniates of copper of Cornwall: *

The ore being previously heated moderately, to expel and estimate the water it contained, was dissolved in dilute nitric acid, and then decom-

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* Philos. Trans. 1801; p. 198.

posed by nitrate of lead. The solution being evaporated nearly to dryness, was mingled with alcohol, to promote the separation of the arseniate of lead, in case an excess of nitric acid should have dissolved a portion of it. The solution was then boiled with potash, and the brown oxid of copper (100 parts of which are equal to 80 of copper) separated by the filter.

All the remaining species of arseniates of copper may be examined in this manner.

Species 3.—*Analysis of Phosphate of Copper.*

Process I.—Let one part of the ore be repeatedly digested in dilute nitrc acid, till all the copper is extracted.

II.—To this solution add, gradually, carbonate of potash, to remove the excess of acid as accurately as possible, and then let fall into it a solution of sub-acetate of lead, till no further precipitate ensues. Wash the obtained precipitate, and dry it in a dull red heat; 138 parts of phosphate of lead indicate 30.95 of phosphoric acid.

III.—To ascertain the quantity of copper, suspend in the fluid left in the last process a cylinder of iron, the copper will become precipitated. But as the metal is contained in the ore in the state of an oxid, 25 per cent. should be added to the copper, to learn the quantity of oxid of copper contained in the ore.*

Species 4.—*Analysis of Muriate of Copper.*

Process I.—Digest one part of the ore repeatedly in three of dilute nitric acid, until all the copper is removed, which may be known by liquid ammonia not rendering the solution blue, when added to it in excess. If iron is combined with the ore a brown precipitate will ensue by ammonia. (See page 153).

II.—To ascertain the quantity of muriatic acid, add nitrate of silver, collect the precipitate, and dry it at a dull red heat: 100 parts of the precipitate are equal to 25 of muriatic acid.

III.—To ascertain the quantity of copper, immerse into the solution a cylinder of iron or zinc; the copper will be precipitated in a metallic state. But as the copper exists in the ore, in the state of an oxid, the weight of the copper ought to be increased 25 per cent. which gives the quantity of oxid of copper contained in the ore.

Such are the modes of analysing the ores of copper.—On considering the different pro-

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* Klaproth's Essays, Vol. I. p. 164.

ceedings, it will be found that the totallity of the examination of this class of ores is exceedingly simple, and may be shortly stated, thus:

The ore being repeatedly digested in nitric acid, till all the copper and other metals are extracted, and then precipitating from this solution the copper, either in the metallic form, or in the state of an oxid, from which the quantity of the metal may be inferred.

The presence of silver is detected by muriate of soda, or muriatic acid, which separates the silver in the state of a muriate (see page 112) and leaves the copper. The presence of lead may be detected by adding to the obtained solution sulphate of soda, which precipitates the lead, in the form of a sulphate of lead, 100 parts of which are equal to 30 of lead. The presence of antimony may be detected by decomposing the solution of the ore by an alkali, and then digesting the oxid with concentrated nitric acid, which dissolves the oxid of copper, and leaves the oxid of antimony. Iron is separated by supersaturating the solution with ammonia, which dissolves the copper, and leaves the oxid of iron; or else, by immersing a polished cylinder of iron or zinc, which separates the copper, and leaves the iron in solution. Tin, if any be present, may be separated, by immersing into the solution a cylinder of tin, which separates the copper only. Arsenic is separated by acetate or nitrate of lead, which separates the arsenic in the form of arseniate of lead, and leaves the copper, 100 parts of which are equal to 33.66 of arsenic acid: to get rid of the excess of lead, if any should remain, let sulphate of soda be added, which will separate this metal. If nickel should be present, it is always in combination with iron: let liquid ammonia be added to the solution, the copper and the iron, and likewise the nickel, will be separated. To separate the copper add muriatic acid in excess, and then immerse into the solution a cylinder of zinc or iron; the copper will then be precipitated, and the nickel left in solution.*

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* For a more circumstantial detail of the practical proceedings, as well as for the modes of assaying and smelting ores of copper, in the dry way, see the article Analysis of Copper Ores, in the Author's System of Mineralogy and Mineralogical Chemistry.

ORDER V.

ORES OF LEAD.

There are a vast variety of lead ores, which are classed by mineralogists in the following manner:

Division of Ores of Lead.

GENUS I.—*Sulphurets of Lead.*

Species 1.—Common Sulphuret of Lead, or Galena.
    Subspecies 1.—Blue Sulphuret of Lead, or Blue Lead Ore.
Species 2.—Antimonial Sulphuret of Lead.

GENUS II.—*Salts of Lead.*

Species 1.—Carbonate of Lead.
    Subspecies 1.—Black Carbonate of Lead.
Species 2.—Murio-Carbonate of Lead.
    3.—Sulphate of Lead.
    4.—Phosphate of Lead.
    5.—Arseniate of Lead.
    Subspecies 1.—Green Arseniate of Lead.
Species 6.—Molybdate of Lead.
    7.—Chromate of Lead.

GENUS III.—*Oxids of Lead.*

Species 1.—Lead Ochre, or Earthy Lead Ore.

Subspecies 1.—Earthy Lead Ochre.

2.—Friable Lead Ochre.

ANALYSIS OF ORES OF LEAD.

Species 1.—*Analysis of Common Sulphuret of Lead, or Galena.*

Process I.—Let one part of the ore, finely powdered, be digested in a flask, with six of nitric acid, diluted with three or four of water, and repeat this process for several times successively. During this process a great part of the sulphur contained in the ore will become separated, in the form of a light powder, floating on the top of the fluid, or subside to the bottom.

II.—Add to the obtained solution, previously evaporated to a small compass, muriatic acid, till no further cloudiness appears; suffer the mixture to stand undisturbed, till the precipitate is fairly deposited, then decant the fluid, separate the precipitate, and wash it repeatedly, by pouring alcohol over it.

III.—The obtained precipitate consists of muriate of lead, and muriate of silver, if the latter was contained in the ore.

IV.—In order to separate these two metals, digest the precipitate in liquid ammonia, for at least six hours; the muriate of silver will be dissolved, and the muriate of lead left behind: or the muriate of lead may be separated by boiling the precipitate in 24 parts of water, which dissolves the muriate of lead, and leaves the muriate of silver: or the solution of the muriate of lead may still more easily be effected by digesting it in dilute nitric acid, which dissolves it readily, but does not touch the muriate of silver.

V.—Mingle the ammoniacal solution of silver with nitric acid, heat it for a few minutes, and precipitate the silver by a cylinder of copper.

VI.—To ascertain the quantity of lead obtained in process IV. mix the muriate of lead with half its weight of black flux; introduce the mixture into a crucible, and expose it to a red heat for half an hour; the lead will be reduced to a metallic state. Or this process may be omitted, and the quantity of lead ascertained, by merely weighing the precipitate, dried at a dull red heat: 100 parts of it contain 75.2 of metallic lead.

The muriate of lead may also be reduced, by immersing into the aqueous solution of it, obtained in experiment IV. a cylinder of iron, which precipitates the lead in a metallic state.

VII.—To find the quantity of silver, proceed as directed, analysis of silver ores.

To assay the ore for iron and copper, let the solutions from which the lead and silver have been separated, be mingled with liquid ammonia in excess, a brown precipitate falls down, which is oxid of iron. The presence of copper may be known by the solution acquiring a blue colour, by the addition of ammonia, it may be separated by immersing into the fluid, after having been neutralized by sulphuric acid, a cylinder of zinc; or by boiling it with potash (See page 147).

All the different varieties of lead ores of this class may be analysed in a like manner.

The proportion of silver in common sulphuret of lead, or galena, varies greatly, from $\frac{1}{300}$th part to $\frac{1}{25}$th. It is observable that the presence of this metal considerably impairs the lustre of the ore, and that it is much more frequently found in the octahedral than in the cubical varieties of this mineral. The presence of antimony may be suspected from its tendency to a radiated texture.

Galena consists chiefly of lead and sulphur, in the proportion of about 100 of the former to 15 of the latter.

Species 3.—*Analysis of Antimonial Sulphuret of Lead.*

This ore is a triple compound, containing lead, antimony, copper, with a minute portion of iron. It was thus analysed by Mr. Hatchett:

Process I.—Two hundred grains of the ore, finely pulverised, were put into a matrass, with two ounces of muriatic acid, heated, and nitric acid added to it, drop by drop, till the whole moderately effervesced. It was then gently heated for an hour, and a green solution was obtained, on the surface of which floated a quantity of sulphur, which was collected and digested with muriatic acid, and lastly washed and dried. It weighed 34 grains, and burned away in a red hot crucible, without residue.

II.—The nitric solution, together with the muriatic acid in which the sulphur had been digested, was evaporated, and mixed with six pints of boiling distilled water, which it rendered instantly milky, after which it was filtered.

The white precipitate obtained, when dried, weighed 63 grains, and was oxid of antimony.

III.—The liquor, with the washings, was found to deposit, on cooling, crystallized muriate of lead: it was therefore evaporated nearly to dryness, and a few drops of sulphuric acid added, to separate in the form of a sulphate of lead what little of that metal remained in solution.

IV.—The residue was then re-dissolved in boiling water, and decomposed by sulphate of soda. The sulphate of lead produced being added to that obtained before, process III. when dried it weighed 120.2 grains.

V.—The fluid, which was now bluish-green, acquired a deep blue colour by ammonia, and a small quantity of oxid of iron was separated, which when dried and heated with wax became magnetic, and weighed 2.4 grains.

VI.—The fluid was next evaporated nearly to dryness, boiled with a strong solution of potash till nearly dry, and on washing it with water, the oxid of copper obtained weighed 32 grains.

In this analysis the metals are estimated as in their metallic state, this being the form in which they exist in the sulphurets, and hence, for the

63 grains of oxid of antimony, 48.46 of metallic antimony are to be put down, and for 120.2 of ulphate of lead, Mr. Hatchett estimates 85.24 of metallic lead, which is in the proportion of 70.9 in 100.

ANALYSIS OF SALTS OF LEAD.

Species 1.—*Analysis of Carbonate of Lead.*

This ore may be analysed in the following manner:

Process I.—Let 100 grains of the ore be dissolved in a weighed quantity of dilute nitric acid, and note down the loss of weight, which gives the quantity or carbonic acid.

II.—Into the obtained solution immerse a cylinder of zinc, which precipitates the lead in a metallic state. The remaining fluid may be examined for iron and copper, as stated before.

A specimen of carbonate of lead was analysed by Klaproth in the following way:

One hundred grains of finely pulverized ore were dissolved in 200 grains of nitric acid, diluted with 300 of water, and the loss of weight by the effervescence noted, which amounted to 16 grains: it was carbonic acid. The nitric solution was then diluted, and a cylinder of zinc immersed in it, which precipitated the lead in the metallic state. When dried it weighed 77 grains, which are equal to 82 of oxid, as it is in this state that the lead exists in the ore. This proportion, however, would give an increase of only 6.5 of oxigen upon 100 of lead.

The black carbonate of lead may be analysed in a like manner.

Species 3.—*Murio-Carbonate of Lead.*

This rare variety of lead ore has been analysed by Klaproth in the following manner:

Process I.—Fifty grains of the ore were triturated with 150 of carbonate of potash, and heated in a platina crucible to a moderate redness, then softened with water, lixiviated, and filtered: an oxid of lead was left behind.

II.—The obtained solution was next supersaturated with nitric acid, and precipitated with nitrate of silver. The muriate of silver obtained weighed 27 grains.

III.—Another quantity of the ore of 100 grains was powdered, and nitric acid affused, which produced an effervescence of carbonic acid. This solution gave, with nitrate of silver, 55 grains of muriate of silver, corresponding very closely in proportion with the former experiment, the acid of which amounted to 8.5 grains.

IV.—The lead was then precipitated by potash, and the oxid thus procured weighed, after thorough drying, 85½ grains, which is the state of oxidisement in which it is supposed to exist in the ore. In this case, therefore, 85.5 grains of oxid of lead were combined with only 8.5 of muriatic acid, which is far short of the saturating quantity, since, in the artificial crystallized muriate of lead, the proportion of acid amounts to 13 or 14 per cent.. This deficient saturation therefore allows the presence of carbonic acid, which amounts to six grains, and completes the saturation of the oxid.

A similar ore was analysed by Mr. Chenevix, nearly in the same way, and with the same result.

Process I.—The ore was first dissolved in nitric acid, and the quantity of carbonic acid, amounting to six grains, estimated by the loss after effervescence.

II.—The solution was then neutralized by ammonia, and assayed by different tests. As nitrate of lime gave no precipitate, the solution could not contain either arsenic, molybdic, or phosphoric acids; and as nitrate of barytes gave none, the absence of sulphuric acid was proved.

III.—Nitrate of silver was then added, and a copious precipitate ensued, the muriate of silver weighed, after drying, 48 grains, which Mr. C. estimates as equivalent to eight of muriatic acid. The composition of the ore is thus stated: six grains of carbonic acid saturate 34 of oxid of lead, and eight of muriatic acid saturate 51 of oxid of lead, and the acids may be supposed to be in the state of perfect saturation; consequently, the ore is composed of 59 parts of muriate of lead, and 40 of carbonate of lead, or of 14 of acid and 85 of oxid.

Species 4.—*Analysis of Sulphate of Lead.*

The Anglesea sulphate of lead was thus analysed by Klaproth:

Process I.—One hundred grains were first ignited moderately, and lost two grains, which were water of crystallization. The remainder was mixed with 400 grains of carbonate of potash, and kept for some time in a red heat, in a platina crucible, it yielded a reddish-yellow hardened mass.

II.—This, digested with water, was all dissolved, except the oxid of lead separated in the previous process, amounting to 72 grains, after strong drying.

III.—This oxid was re-dissolved in nitric acid, and deposited thereby one grain of oxid of iron.

IV.—The solution was then decomposed by zinc, and yielded 66.5 grains of metallic lead.

V.—The alkaline fluid formed by the washing of the contents of the crucible, after ignition, was saturated with nitric acid, and acetate of barytes added as long as any sulphate of barytes became precipitated. This amounted to 73 grains, equal to 24.8 of concrete sulphuric acid, on the estimation that 100 parts (after ignition) contain 34 of acid. The iron in this ore appears merely casual.

Species 5.—*Analysis of Green Phosphate of Lead.*

In this ore lead exists in combination with phosphoric and muriatic acids. The green phosphate was thus analysed by Klaproth, after some imperfect attempts of reduction in the dry way, in the following manner:

Process I.—One hundred grains of the ore were dissolved in hot nitric acid, leaving no residue; and nitrate of silver being added gave a precipitate of 11 grains of muriate of silver; the muriatic acid of which amounted to 1.7 grains.

II.—Sulphuric acid was then added to the warmed solution, by which sulphate of lead was precipitated, weighing after ignition 106 grains, equal to 73.61 of metallic lead, or 78.4 of the oxid.

III.—The fluid was freed from sulphuric acid by nitrate of barytes, and was then nearly saturated with ammonia, and acetite of lead added. The phosphoric acid in the solution was thus precipitated in the form of phosphate of lead, weighing, after ignition, 82 grains, of which the mere acid amounts to 18.37 grains.

IV.—The rest of the solution was mixed with a little muriatic acid, concentrated by evaporation, and then mingled with alcohol, to redissolve the muriate of iron formed, if any; from which, by the addition of prussiate of potash, there was obtained an extremely small quantity of blue precipitate, indicating no more than about one part of a grain of oxid of iron.

Species 6.—*Analysis of Arseniate of Lead.*

This lead ore is a compound of lead, arsenic, and iron. It was thus examined by Vauquelin:

Process I.—One hundred grains of the ore, being roasted in a scorifying test for half an hour, with a little suet added occasionally, to facilitate the reduction and volatilization of the arsenic, lost 38 grains; it acquired a black colour and became magnetic.

II.—Upon the roasted ore muriatic acid was made to act by heat, till no further action took place.

III.—The muriatic solution being evaporated to dryness, re-dissolved in water, and decomposed by sulphate of soda, the precipitate obtained weighed 25 grains, equal to 20.2 of lead, or 22 of oxid of lead.

IV.—The remaining fluid, being mingled with ammonia in excess, afforded 39 grains of oxid of iron.

The rest of the species of arseniate of lead may be analysed in a like manner.

With regard to the analysis of the molybdate of lead, the reader is referred to the article molybdate, and for the chromate of lead to chrome.

ANALYSIS OF OXIDS OF LEAD, OR LEAD OCHRES.

All these ores may be analysed by dissolving them in nitric acid, and precipitating the lead, as directed before.

ORDER VI.

ORES OF TIN.

No metal exhibits a smaller variety of ores than tin; it has hitherto been met with in two states only, and hence the following

Division of Ores of Tin.

GENUS I.—*Oxids of Tin.*

Species 1.—Native Oxid of Tin, or Tin Stone.
2.—Wood Tin.

GENUS II.—*Sulphuret of Tin.*

Species 1.—Sulphuret of Tin, or Tin Pyrites.

ANALYSIS OF ORES OF TIN.

Species 1.—*Analysis of Native Oxid of Tin.*

Process I.—Take one part of the ore, freed carefully from all its matrix, reduce it to an impalpable powder, triturate it with four times its weight of potash, moistened with water, and lastly, boil the mass in a silver vessel in eight parts of water, evaporate the whole to dryness, and moderately ignite it for at least half an hour.

II.—Pour water upon the mass, boil the mixture for about a quarter of an hour, and filter the fluid.

III.—Take the residue left on the filter, if any, mix it again with a like quantity of potash, dissolved in a sufficient quantity of water, evaporate to dryness, and proceed as above.

IV.—Let the solutions thus obtained be mingled, and add to it muriatic acid till no more precipitate falls down, adding the acid rather in excess; suffer the mixture to stand undisturbed till the precipitate is subsided, in order to collect it on a filter.

V.—Dissolve this precipitate in muriatic acid, in excess, precipitate it again by the addition of carbonate of soda, collect the precipitate on a filter, wash it by pouring water over it repeatedly, and suffer it to dry.

VI.—Let the precipitate be again dissolved in muriatic acid, assisted by a gentle heat (the insoluble part, if any, consists of silex), dilute the solution with two or three parts of water, immerse into it a cylinder of zinc: leave the whole undisturbed for some days, and all the tin that was contained in the ore will now be deposited round the cylinder of zinc, in a metallic state. It may be formed into a button, by melting it in a crucible, taking care to cover it with charcoal powder.

Species 1.—*Analysis of Sulphuret of Tin.*

In this ore tin exists, mineralized by sulphur, and frequently associated with copper; its analysis may be accomplished in the following manner:

Process I.—Let one part of finely pulverised ore be repeatedly digested in six of nitro-muriatic acid, composed of two parts of muriatic acid, and one of nitric acid, till it dissolves no more, and decant the fluid.

II.—Add to this solution carbonate of potash till no further precipitate ensues, collect the precipitate on a filter.

III.—Re-dissolve this precipitate in muriatic acid, diluted with three or four parts of water, and suspend in this solution a cylinder of tin whose weight is known. If copper was contained in the ore it will be precipitated in a metallic state on the tin cylinder, but in order to be certain that it is not contaminated with tin, let the precipitated metal be re-dissolved by heat, in concentrated nitric acid; if a white powder remains it is a portion of oxid of tin.

IV.—As in the foregoing process, the tin employed for precipitating the copper is acted upon by the muriatic acid, immerse into the solution from which the copper has been separated a cylinder of zinc, the whole of the tin will be again precipitated on the cylinder of zinc; let it be dried and its weight ascertained, when melted into a mass. From this quantity of tin subtract now that portion which proceeds from the cylinder of tin employed for precipitating the copper, the remainder will give the true quantity of metal contained in the ore.

V.—Having thus far proceeded, expose the insoluble residue left in process I. to a low red heat in a crucible, pour water into it, filter the fluid, and ascertain the quantity of sulphur, as stated in page 117, what remains will be the matrix of the ore. It consists in general of alumine and silex.

ORDER VII.

IRON ORES.

There are a vast variety of ores of iron scattered over the surface of the earth, which are divided by mineralogists in the following manner:

Division of Ores of Iron

GENUS I.—*Alloys of Iron.*

Species 1—Native Iron.

GENUS II.—*Sulphuret of Iron.*

Species 1.—Common Sulphuret of Iron, or Unmagnetical Iron Pyrites.
  Subspecies 1.—Common Iron Pyrites.
    2.—Radiated Pyrites.
    3.—Capillary Pyrites.
    4.—Cellular Pyrites.
    5.—Hepatic Pyrites.
Species 2.—Magnetical Pyrites.

GENUS III.—*Oxids of Iron.*

Species 1.—Magnetic Oxid of Iron, or Common Magnetic Iron Ore.

Subspecies 1.—Magnetic Iron Sand.

Species 2.—Specular Iron Ore.
    Subspecies 1.—Common Specular Iron Ore.
        2.—Micaceous Iron Ore.

Species 3.—Red Iron Stone.
    Subspecies 1.—Red Scaly Iron Ore.
        2.—Red Ochre.
        3.—Compact Red Iron Stone.
        4.—Red Hematite.

Species 4.—Black Iron Ore.
    Subspecies 1.—Compact Black Iron Ore.
        2.—Black Hematite.

Species 5.—Brown Iron Ore.
    Subspecies 1.—Compact Brown Iron Stone.
        2.—Fibrous Brown Iron Stone.
        3.—Scaly Brown Iron Ore.
        4.—Brown Hematite.

Species 6.—Sparry or Spathose Iron Ore.

Species 7.—Argillaceous Iron Ore.
    Subspecies 1.—Common Argillaceous Iron Ore.

Subspecies 2.—Graphic Red Argillaceous Iron Ore, Reddle, or Red Chalk.
3.—Columnar Argillaceous Iron Ore.
4.—Lenticular Argillaceous Iron Ore.
5.—Jaspery Argillaceous Iron Ore.
6.—Nodular or Reniform Iron Ore.
7.—Pisiform Iron Ore.

Species 8.—Bog or Morassy Iron Ore.
Subspecies 1.—Morassy Iron Ore.
2.—Swampy, or Lowland Iron Ore.
3.—Meadow Iron Ore.

GENUS IV.—*Salts of Iron.*

Species 1.—Arseniate of Iron.
2.—Carbonate of Iron.
3.—Phosphate of Iron.
4.—Phosphate of Iron and Manganese.
5.—Prussiate of Iron.
6:—Arseniate of Iron and Copper,

Species 7.—Green Iron Earth.
8.—Sulphate of Iron.

ANALYSIS OF ALLOYS OF IRON.

Species 1.—*Analysis of Native Iron.*

Although the mineral called native iron is exceedingly rare, it is nevertheless certain that it has been found in different parts of the world. A specimen, weighing about four pounds, was found in the mine of Hackenberg. The masses of native iron observed by Pallas in Siberia, by Rubin de Cellis in South America, &c. are now considered as masses of native iron and nickel which have descended from the atmosphere.* The presence of nickel distinguishes them from the true native iron, which is destitute of this metal.

A specimen of native iron, from the mine Johannes, near Kamsdorff in Saxony, analysed by Klaproth, consisted of iron, lead, and copper.— The analysis may be performed in the following manner:

Process I.—Endeavour to effect a solution of the ore by the repeated application of dilute nitric acid, assisted by a gentle heat.

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* Cramer Philos. Mag. XIII. 32.

II.—Into the obtained solution let fall sulphate of soda, till no farther cloudiness ensues: 100 parts of the sulphate of lead are equal, according to Klaproth, to 69.44 metallic lead, or, according to Hatchett, to 70.9.

III.—To the fluid from which the lead has been separated, add a solution of soda in excess. Heat the mixture, and separate the precipitate, which consists of oxids of iron and copper.

IV.—To separate the copper, digest the precipitate repeatedly in liquid ammonia, as long as this fluid acquires a blue colour. The copper will thus be removed, and the oxid of iron left behind.

V.—To obtain the copper from the ammoniacal solution, supersaturate it slightly with sulphuric acid, and immerse in it a cylinder of iron, which will separate the copper.

VI.—To ascertain the quantity of iron, let the oxid of that metal obtained in process IV. be heated with a little wax, in a covered crucible, in order to become reduced to the state of a magnetic oxid, 100 parts of which indicate 73 of metallic iron. Or it may be mixed with a few grains of hyper oxi-muriate of potash, in contact with a little nitric acid, evaporated to dryness, and lastly heated for a few minutes in a crucible: it will thus be changed to the red oxid of iron; 100 parts of which are equal to 52 of iron.

ANALYSIS OF SULPHURETS OF IRON.

Species 1.—*Analysis of Common Sulphuret of Iron, or Unmagnetical Pyrites.*

None of the ores of iron belonging to this species can be wrought to extract the metal; they are more frequently employed for obtaining from them sulphate of iron. They may be analysed in the following manner:

Process I.—Put into a florence flask one part of the ore, reduced to a fine powder; pour over it eight of nitric aid; digest the mixture till no farther action takes place; and lastly, evaporate the whole almost to dryness.

II.—Pour three or four parts of water on the obtained mass, separate the fluid by filtration, and wash the residue in a small portion of water, which may be added to the filtered solution.

III.—Upon the insoluble residue left in process I. pour again a like portion of nitric acid, digest and evaporate it, and repeat this operation successively, until the nitric solution, when diluted with water, does not become turbid, by dropping into it nitrate of barytes; and, lastly, separate the insoluble residue.

IV.—Let the solutions, together with the water employed for washing the insoluble residue, be mingled together; add to it carbonate of potash or soda in excess, and separate the precipitate by the filter, if any.

V.—To the fluid left in the last process add nitric acid, so as to neutralize the excess of alkali added before; or better add nitric acid rather in excess, and then drop into it nitrate of barytes: the precipitate obtained is sulphate of barytes, of which 100 are equal to 14.5 sulphur.

VI.—The insoluble residue left in experiment III. together with the precipitate obtained in process IV. should next be mixed with about twice its weight of soda or potash, fused for about 20 minutes in a silver crucible, dissolved in muriatic acid, and evaporated nearly to dryness.

VII.—The dry mass must be softened by water, digested in that fluid, and the insoluble part which is silex, separated by the filter.

VIII.—If to the muriatic solution liquid ammonia be added in excess, the oxid of iron, and alumine, if any was present, will be precipitated, and lime, if it should be present, will be left in solution.

IX.—To separate the oxid of iron from the alumine, let the obtained precipitate be digested in concentrated nitric acid, which will dissolve the alumine, and leave the oxid of iron; 100 parts of which, after having been heated, are equal to 52 of iron.

X.—If lime was present, it may be detected by adding to the solution from which the oxid of iron and alumine are separated (process VIII.) a solution of carbonate of potash; the precipitate which falls down is carbonate of lime, which may be decomposed by exposure to a red heat.

The ores called radiated, capillary, cellular, hepatic pyrites may be examined in a like manner.

ANALYSIS OF OXIDS OF IRON.

Species 1.—*Analysis of Magnetic Iron Ore, or Common Magnetic Oxid of Iron.*

This ore contains, besides oxid of iron, a small portion of silex and alumine. It is not only attracted by the magnet, but it possesses itself polarity; hence it attracts iron filing. It affords cast iron of but indifferent quality, but very excellent bar iron.

Process I.—Take one part of the ore levigated as fine as possible, add to it six parts of potash or soda, and 18 of water, boil the mixture in a silver bason or crucible, for at least two hours, taking care to supply the water as it evaporates; lastly, evaporate the mixture to dryness; and raise the heat, so as just to fuse the whole, and suffer it to remain fused, at a dull red heat, for about half an hour.

II.—Soften the fused alkaline mass with water, transfer it into a flask, pour over it muriatic acid, previously diluted with two of water, digest it for a few minutes, and then evaporate it to dryness.

III.—Upon the dry mass obtained pour about 10 parts of boiling water, and separate the insoluble part, which is silex, by the filter.

IV.—To the fluid from which the silex has been separated, after having been previously concentrated, add potash or soda, in excess, boil the whole for a few minutes, dilute it with water, suffer the precipitate to subside, or separate it by the filter, dry and wash it. The precipitate thus obtained may be mixed with a little nitric acid, and kept for a few minutes in an open crucible, at a dull red heat, it will become changed into the perfect red oxid of iron, 100 parts of it indicate 52 of iron.

V.—If to the alkaline fluid from which this oxid has been separated nitric acid be added just sufficient to render the solution neutral, the alumine may be separated, by adding to it benzoate of ammonia till no farther cloudiness ensues. This precipitate, after having been heated to redness for half an hour, gives the quantity of alumine that was present in the ore.

Magnetic iron sand, specular iron ore, micaceous iron ore, red iron stone, and all its subspecies, may be analysed in a like manner.

Species 4.—*Analysis of Black Iron Ore.*

This ore differs from the latter, by containing a small portion of manganese.

Process I.—Treat the ore with potash or soda, as directed in the opposite page, process I. separate the silex according to process II. and III. decompose the muriatic solution as stated process IV. and collect the precipitate. It consists of oxid of iron and oxid of manganese, which may be separated best and most expeditiously in the following manner:

II.—Transfer the precipitate into a florence flask, and effect a solution of it, by means of muriatic acid, assisted by a gentle heat.

III.—To the obtained solution add succinate of soda, whilst boiling hot, till no farther cloudiness ensues. The precipitate thus obtained is succinate of iron: 100 parts of it, after having been heated with a little wax, in a low red heat, are equal to 70 of metalic iron.

IV.—Or the two metals may be separated by dissolving the compound precipitate of oxid of iron, and oxid of manganese, in muriatic acid, by a gentle heat, and adding to it when boiling hot a solution of soda, in small quantities at a time, till the fluid becomes colourless, or till the precipitate that is thrown down by each addition of soda begins to assume a white colour. Collect this precipitate, and heat it with nitric acid: it gives the quantity of iron as stated, page 183, process IX.

V.—To the remaining fluid now add soda till no further precipitate ensues: the precipitate obtained is oxid of manganese.

The ores called black hematite, brown iron ore, and all its subspecies, may be analysed in a like manner.

Species 6.—*Analysis of Sparry or Spathose Iron Ore.*

The composition of this ore is far more complicated than any of the former. It usually contains besides oxid of iron, silex, and alumine, a considerable portion of oxid of manganese, and carbonate of lime, and sometimes, also, a small portion of carbonate of magnesia and barytes.

The iron obtained from this ore is particularly valuable, as it may be converted into fine steel immediately from the state of cast iron. The bar iron which it yields possesses both hardness and tenacity in a high degree. The ore may be analysed in the following manner:

Process I.—Take one part of the ore, finely levigated, put it into a bottle furnished with a spiral glass tube, and pour over it twice its weight of nitro-muriatic acid, and ascertain the quantity of carbonic acid by the loss of weight it sustains. (See apparatus for ascertaining the quantity of carbonic acid, in the description of the plates.)

II.—Upon the ore thus freed from carbonic acid pour four times its weight of muriatic acid, and digest it in a flask with like portions of muriatic acid, till no further action ensues, or till tincture of galls does not change the acid that has acted upon it, and when rendered neutral by an alcali, blue or black.

III.—Mingle the obtained solutions, and having concentrated the whole by evaporation, decompose it whilst boiling hot, by soda, adding this alkali rather in excess, and boil the whole for about a quarter of an hour. The alumine will by this means become dissolved in the excess of the alkali. Separate the insoluble residue by the filter.

IV.—To separate from the insoluble residue of the last obtained process, the lime, barytes, and magnesia it may contain, let it be digested in dilute nitric acid. The former earths will become dissolved, and the oxid of iron and manganese will be left untouched, which may be separated by filtration.

V.—Into the solution of process IV. previously diluted with 20 parts of water, let fall sulphuric acid, till no further cloudiness ensues; the barytes which was present will be separated in the form of an insoluble white powder, being sulphate of barytes, and the other earths which were present in the solution will remain undisturbed.

VI.—To separate these earths, again concentrate the fluid from which the barytes has been removed, and decompose it by the addition of sub-carbonate of potash. The obtained precipitate consists of carbonate of lime and carbonate of magnesia.

VII.—To separate these earths, cover them with sulphuric acid, and evaporate the mixture to dryness, till no more fumes are visible; and lastly pour over it a small portion of water, which will dissolve the sulphate of magnesia and leave the sulphate of lime.

VIII.—To the obtained solution of sulphate of magnesia add sub-carbonate of potash. The precipitate obtained is sub-carbonate of magnesia, which, after having been freed from its carbonic acid, by exposure to a red heat, gives the quantity of magnesia that was present in the ore.

IX.—To ascertain the quantity of lime, take the sulphate of lime obtained in process VII. boil it with three times its weight of sub-carbonate of potash, and ten of water, repeatedly, until it is found to be completely soluble in nitric acid; evaporate the nitric solution to dryness, and decompose it at a red heat. The lime that was present will thus become evident.

X.—To separate the oxids of iron and manganese obtained in process IV. let the mass be digested at a gentle heat with dilute nitric acid, and a small piece of sugar; the manganese will be dissolved, and the oxid of iron will be left behind; from which the quantity of iron may be inferred, according to the rules laid down, page 186.

XI.—To ascertain the quantity of manganese, add to the nitric solution from which the iron has been separated carbonate of soda, till no farther cloudiness ensues. This precipitate, after being washed and dried at a low red heat, is carbonate of manganese, 100 parts of it are equal to 55 of metallic manganese.

Species 7.—*Analysis of Common Argillaceous Iron Ore.*

This ore is chiefly composed of oxid of iron, alumine, and a small portion of silex, and hence its analysis may be effected according to the rules already pointed out, for separating these bodies: it usually yields from 30 to 40 per cent. of iron.

The ore called Reddle or red chalk, which is chiefly used for what are commonly called red lead pencils, is, we believe, never smelted for iron, it differs from the former, by containing the iron in the state of a red oxid.

The other subspecies of argillaceous iron ores sometimes contain, besides the ingredients already stated, variable portions of oxid of manganese, phosphate of iron, and silex; they may therefore be analysed thus:

Process I.—Digest one part of the ore repeatedly in nitric acid, until all the iron is extracted by the acid.

II.—Evaporate the nitric solution almost to dryness, and suffer to digest the residue in a closed phial, with cold water. The phosphate of iron, if any was present, will become precipitated.

III.—Fuse the insoluble residue left in experiment I. with four times its weight of soda for one hour; dissolve the mass in water, filter it, and separate the silex from the alkaline solution, by the admixture of muriatic acid; collect and dry it.

IV.—To the fluid from which the silex has been obtained, add the solution from which the phosphate of iron has been separated, experiment II. supersaturate the whole with soda, and boil the mixture for about half an hour. The alumine, if any, will be dissolved in the excess of soda added, and the metallic oxids, together with the lime, will remain unacted on: separate the insoluble part by the filter.

V.—Digest the mass obtained in process IV. in concentrated nitric acid; evaporate the solution to dryness. Repeat this operation for several times successively, and lastly again digest it in dilute nitric acid, and separate the fluid by the filter.

VI.—Decompose the obtained nitric solution by carbonate of potash, and expose the precipitate to a red heat for half an hour: the lime which was present in the ore will thus be obtained.

VII.—To separate the metallic oxids, namely, the oxid of iron and oxid of manganese, left undissolved in process V. proceed as directed before.

ANALYSIS OF SALTS OF IRON.

Species 1.—*Analysis of Arseniate of Iron.*

In this ore iron is united to arsenic acid; sometimes it contains likewise a small quantity of copper. The mode of analysis recommended by Chenevix succeeds best.*

Process I.—Expose a weighed quantity of the ore for about ten minutes, to a low red heat: the

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* Philos. Trans. 1801; p. 220.

loss gives the quantity of water of crystallization that was present.

II.—Let the ore next be boiled in a silver basin, with three of potash and six of water, to dryness; re-dissolve the mass in water, and separate the insoluble part by the filter.

III.—To the obtained alkaline solution add nitric acid sufficient to render it neutral, and then drop into it a solution of nitrate of lead till no more precipitate ensues; collect the precipitate and dry it: 100 parts of it are equal to 33 of arsenic acid.

IV.—To learn the quantity of iron, take the residue which was insoluble in potash (process II.) and digest it repeatedly in muriatic acid; the metallic matter will be removed, and what is left behind consists of silex.

V.—To the muriatic solution add liquid ammonia in excess, the oxid of iron becomes precipitated, and the oxid of copper remains in the supernatant ammoniacal solution: 100 parts of the oxid of iron, after having been heated in a crucible for a few minutes with a little nitric acid, is equal to 52 of iron. The quantity of copper may be learned by boiling down the ammoniacal solution to dryness; 100 parts of the oxid of copper thus obtained, after being ignited, are equal to 80 of copper.

For the modern processes of smelting iron ores in the large way, the reader is referred to the article iron, in the author's System of Mineralogy and Mineralogical Chemistry.

ORDER VIII.

ORES OF ZINC.

Division of Ores of Zinc.

The ores containing zinc are the following:

GENUS I.—*Sulphurets of Zinc, or Blende.*

Species 1.—Yellow Sulphuret of Zinc, or Yellow Blende.
  2.—Brown Sulphuret of Zinc, or Brown Blende.
    Subspecies 1.—Foliated Brown Blende.
      2.—Fibrous Brown Blende.
Species 3.—Black Sulphuret of Zinc, or Black Blende.

GENUS II.—*Native Oxids of Zinc.*

Species 1.—Silicated Oxid of Zinc, or Electric Calamine.

GENUS III.—*Native Salts of Zinc, or Common Calamine.*

Species 1.—Common Calamine, or Carbonate of Zinc.

Subspecies 1.—Crystallized Calamine.
2.—Compact Calamine.
Species 2.—Hydrous Carbonate of Zinc, or Earthy Calamine.
3.—Sulphate of Zinc.

ANALYSIS OF SULPHURET OF ZINC.

Species 1.—*Analysis of Yellow Sulphuret of Zinc, or Yellow Blende.*

This ore usually contains, besides zinc and sulphur, also iron, lead, copper, arsenic, alumine, silex, and sometimes water.—Let us suppose they should all be present.—

Process I.—To ascertain the quantity of water, introduce a given weight of the ore into a retort, to which a receiver has been joined, and heat the vessel dull red hot for about ten minutes, to collect the water in the usual manner in the receiver.

II.—To learn the quantity of sulphur, take a fresh portion of the ore, digest it repeatedly in very dilute nitric acid, till no farther action takes place, collect the insoluble residue, weigh it, and ignite it, the sulphur will burn off, and its amount may be estimated by the loss of weight, with tolerable accuracy.

III.—Upon the mass left in the preceding process pour nitro-muriatic acid, and digest it till the insoluble part becomes white; it is then pure silex.

IV.—To the nitric solution (process II.) add a few drops of a solution of sulphate of soda, from time to time, till no farther precipitate ensues, and when the whole is brought nearly to dryness cover it with very dilute muriatic acid, which will dissolve every thing and leave the sulphate of lead.

V.—Mingle the nitro-muriatic solutions (process III. and IV.) decompose the whole by carbonate of soda, and collect the precipitate.

VI.—Pour over the precipitate liquid ammonia, and suffer it to stand for a few days. The oxid of zinc and oxid of copper will become dissolved in the ammonia.

VII.—To separate the two oxids, mingle the ammoniacal solution with muriatic acid in excess, and boil it, adding a solution of caustic soda, till no more precipitate ensues: the obtained precipitate is brown oxid of copper; 100 parts are equal to 80 of copper.

VIII.—To obtain the oxid of zinc, saturate the alkaline soluton, from which the copper has been separated, with muriatic acid, and then decompose it by carbonate of soda. The obtained precipitate, after being ignited, is oxid of zinc. To learn the quantity of metallic zinc it is capable of yielding proceed as directed, p. 201, process X.

IX.—The residue left in process VI. may be abstracted repeatedly with nitric acid, and lastly digested in a solution of soda. What remains is oxid of iron, perhaps slightly contaminated with a minute portion of arsenic.

X.—Into the alkaline solution thus obtained let fall nitric acid sufficient to neutralize it, and then decompose it by the admixture of nitrate of lead. The precipitate is arseniate of lead; 100 parts are equal to 33 of lead.

XI.—The fluid from which the arseniate of lead has been separated, may be assayed by means of sulphate of soda, to free it from nitrate of lead, if any should be present, and then add carbonate of ammonia. The precipitate produced, after being washed and ignited, is alumine.

The rest of the species of sulphurets of zinc may be analysed in a like manner.

ANALYSIS OF NATIVE OXIDS OF ZINC.

Species 1.—*Analysis of the Electric Calamine, or Silicated Oxid of Zinc.*

In this ore oxid of zinc exists, combined with a considerable portion of silex and water.

Process I.—Digest the finely pulverized ore repeatedly in dilute nitric acid, evaporate the solution to dryness.

II.—Pour water on the mass, and separate the insoluble part, which is silex, by the filter.

III.—If the silex is not perfectly white, let it be digested in muriatic acid, to free it from iron.

IV.—Decompose this muriatic solution by sub-carbonate of potash, and transfer the precipitate into the nitric solution obtained process II. and conduct the remaining operations as stated in the opposite pages.

Remark.— To determine the quantity of water, take a weighed quantity of the ore, heat it moderately for half an hour; note down the loss of weight, and transfer the residue into muriatic acid. If it emits any gas, let the loss of the weight be noted; then add together the losses by ignition and solution, and deduct from the sum total the known weight of the gas (viz.

carbonic acid,) the remainder gives the weight of the water.

ANALYSIS OF NATIVE SALTS OF ZINC.

Species 1.—*Analysis of Carbonate of Zinc, or Common Calamine.*

This ore usually contains, besides oxid of zinc, and water, carbonates of lead, iron, and lime.

Process I.—Digest one part of the finely pulverised ore in the cold, with six of nitric acid, in a bottle furnished with a capillary tube.* The loss of weight after digestion gives the quantity of carbonic acid with tolerable accuracy.

II.—Heat the mixture, and keep it gently boiling for about half an hour, and filter it.

III.—Neutralize the obtained solution by means of soda, and evaporate it, gradually adding, from time to time, a few drops of sulphate of soda, till no further cloudiness takes place, and lastly evaporate it to dryness.

IV.—Digest the dry mass first in alcohol, and next wash it in a small quantity of cold water, to free it from every saline combination, except sulphate of lime and sulphate of lead.

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* See description of the plates: apparatus for ascertaining the quantity of carbonic acid of minerals.

V.—To separate these two salts digest the residue in very dilute sulphuric acid, which will dissolve the sulphate of lime, and leave the sulphate of lead, and filter the fluid.

VI.—Neutralize the solution by soda, and evaporate it nearly to dryness, and then add to it, when still hot, alcohol. The crystalline precipitate obtained consists chiefly of sulphate of lime, with a small portion of sulphate of soda; the latter may be removed by washing the precipitate in small portions of water.

VII.—Evaporate the alcoholic solution (process IV.) to dryness, and digest it in a concentrated solution of potash, the oxid of zinc will become dissolved in the alkali, and the oxid of iron left behind.

VIII.—To ascertain the quantity of zinc, neutralize the alkaline solution obtained in process VII. by muriatic acid, and add the acid a little in excess.

IX.—Decompose the obtained muriatic solution by super-carbonate of potash, and collect the precipitate on a filter.

X.—Dissolve the carbonate of zinc thus obtained in dilute sulphuric acid, evaporate the solution to dryness ignite the sulphate of zinc in a platina crucible, and ascertain its weight: 100 parts of it are equal to 50 of oxid of zinc; and 50 parts of oxid of zinc are equal to 40 of metallic zinc. The quantity of water the ore contains may be learnt as stated page 199.

The rest of the ores belonging to this genus may be analysed in like manner.

ORDER IX.

ORES OF MERCURY.

Division of Ores of Quicksilver.

GENUS I.—*Native Alloys of Mercury.*

Species 1.—Native Mercury.
2.—Native Amalgam.

GENUS II.—*Sulphurets of Mercury, or Cinnabar.*

Species 1.—Compact, Common, or Dark Red Cinnabar.
2.—Fibrous or Bright Red Cinnabar.
3.—Liver-Coloured, or Hepatic Quicksilver Ore.
  Subspecies 1.—Compact Hepatic Quicksilver Ore.
  2.—Slaty Hepatic Quicksilver Ore.
  3.—Bituminous Hepatic Quicksilver Ore.

GENUS III.—*Native Salts of Mercury.*

Species 1.—Native Muriate, or Horn Quicksilver Ore.

2.—Hydro-sulphuret, or Fœtid Hepatic Quicksilver Ore.

ANALYSIS OF ORES OF MERCURY.

Species 2.——*Analysis of Native Amalgam.*

The constituent parts of this ore are silver and mercury.

Process I.—Introduce the amalgam into a glass tube, about half an inch in the bore, and eight or ten inches long, and place it in a sand bath, or crucible filled with sand.

II.—Apply heat, and increase it gradually, till the bottom of the tube is of a dull red heat. The quicksilver will thus be volatilized, and become sublimed in the colder part of the tube, and the silver will be left behind in a pure state, if no other metal was present. But as the native amalgam contains sometimes a portion of bismuth, and even gold, the following mode may be pursued :

Process I.—Dissolve the ore in nitric acid, assisted by a gentle heat. If any gold should be present, it will be left behind, in the form of a brown powder. Let it be examined as directed under the article Ores of Gold.

II.—Evaporate the nitric solution till a pellicle appears, and then pour it into a large quantity of distilled water. If the amalgam contained bismuth, the water will become milky, and a white powder will subside, which collect by the filter.

III.—Having thus separated the greatest portion of the bismuth, concentrate the fluid from which the oxid of bismuth has been obtained to a small compass, (separate the precipitate, if any should appear during this process, and add it to that obtained before,) and mingle with the concentrated fluid a solution of common salt, or muriatic acid, till no further cloudiness ensues. Suffer the precipitate to subside, and decant or filter the fluid. The obtained precipitate consists of muriate of silver and muriate of mercury.

IV.—Into the fluid left in process III. drop a solution of carbonate of potash, till no further cloudiness ensues, then boil the mixture, separate the produced precipitate, and put it aside for further use.

V.—Upon the precipitate, consisting of muriate of silver and muriate of mercury, obtained in process III. pour nitro-muriatic acid, of a moderate strength, and digest; the muriate of lead will thus be dissolved, and the muriate of silver left behind, 100 parts of it indicate 75 of silver.

VI.—Let the fluid from which the muriate of silver has been obtained, be made boiling hot, and then decompose it by a solution of carbonate of potash; collect the precipitate, and add it to that obtained in process IV. Mix the whole with a little sugar, introduce the mixture into an earthen-ware or coated glass retort, and proceed to distillation, taking care to keep the bottom part of the retort of an obscure red heat, for about half an hour, or till no more quicksilver falls into the receiver, loosely adapted to the beak of the retort. The receiver should of course be filled with water, and the neck of the retort dipt into it for about half an inch or one inch. What remains in the retort is charcoal, and perhaps a little metallic bismuth, which escaped the process of separation employed.

ANALYSIS OF SULPHURET OF MERCURY.

Species 1.—*Analysis of Native Cinnabar.*

Process I.—Digest one part of the ore, levigated as fine as possible, in four of nitro-muriatic acid, composed of three parts of muriatic, and one of nitric acid, repeatedly, until it dissolves no more.

II.—Ignite the insoluble residue, which consists chiefly of sulphur and silex, and note the loss of weight, which gives the weight of the sulphur it contained, provided no portion of the sulphur has been acidified in process I. which may be known by nitrate of barytes not producing a precipitate when added to the solution. Should a precipitate take place, 100 parts of it are equal to 14.5 of sulphur.

III.—Mingle the nitro-muriatic solution with carbonate of potash, at a boiling heat; collect the precipitate, and dry it thoroughly.

IV.—To the obtained precipitate add one-eighth part of lamp-black, introduce the mixture into an earthen-ware retort, to which a receiver, previously filled with water, has been adapted, and distill till no more drops of quicksilver fall from the neck of the retort.

The residuary mass in the retort consists chiefly of charcoal and oxid of iron.

ANALYSIS OF SALTS OF MERCURY.

Species 1.—*Analysis of Muriate of Mercury.*

In this ore oxid of mercury exists with muriatic and sulphuric acid.

Process I.—Take one part of the ore, reduced to a fine powder, and digest it repeatedly in acetous acid; by this means the metallic mercury, if it contains any, will be left behind, and the sulphate and muriate will become dissolved.

II.—Decompose the obtained solution by acetate of barytes, and collect the precipitate, to learn the quantity of sulphuric acid which is always present in the ore, 100 parts of the precipitate indicate 186 of sulphate of mercury.

III.—Into the remaining fluid, let fall a solution of nitrate of silver, to ascertain the quantity of muriatic acid.

IV.—To learn the quantity of mercury, immerse into the solution obtained in process III. a cylinder of iron which throws down the quicksilver in a metallic state.

The analysis of this ore may likewise be effected by boiling it repeatedly with sub-carbonate of potash in a sufficient quantity of water, by this means muriate of potash and sulphate of potash will be obtained in solution, and carbonate of mercury will be left behind. The latter may be dissolved in nitric acid, and the mercury precipitated by a cylinder of copper. The quantity of sulphuric acid may be learnt by the addition of nitrate of barytes, and that of the muriatic acid by nitrate of silver, in the manner so often mentioned already.

Species 2.—*Analysis of Hepatic Mercury.*

The analysis of this ore was conducted by Klaproth in the following manner.

Process I.—One hundred grains of the ore being reduced to a fine powder, were heated with 500 grains of muriatic acid to ebullition, to which was added, by a little at a time, 100 grains of nitric acid, in order to effect a solution: a black residue remained weighing 10 grains. This residue was heated in a crucible carefully, in order that the sulphur it might contain, should be volatilized. There remained three grains of a light coaly powder, which became ignited and burned away by a stronger heat, leaving one grain of reddish ashes.

II.—The solution being precipitated by muriate of barytes, 46,5 grains of sulphate of barytes fell down, so that 6,5 grains of sulphur had been converted into sulphuric acid by the action of the nitric acid. Mr. Klaproth estimates the quantity of sulphur contained in the sulphurated hidrogenous gas, given out during the solution of the ore, at 0,25 grains, which he estimates to be equal to 13,75 parts of sulphur in 100 of the mineral.

III.—Having so far proceeded, one thousand grains of hepatic mercury in powder were put into a retort joined to the pneumatic apparatus; the heat was gradually raised till the bottom of the retort became red hot. After the heat had driven out the atmospheric air from the retort, sulphurated hidrogen gas was evolved; its volume measured 24 cubic in. without reckoning that portion which had been absorbed by the water put into the intermediate receiver, which water was strongly impregnated with the gas. A few globules of mercury were collected in the receiver. The neck of the retort contained a mixture of black hydro-sulphuret of mercury, of a greasy consistence, some small metallic globules of quicksilver, and a few small needles of cinnabar. The mercury which was mechannically extracted from this mixture weighed 3,17 grains. The roof of the neck of the retort was alone covered with a solid sublimate of pure cinnabar which weighed 2,56 grains. The residue in the retort was a powder resembling soot, it weighed 39 grains. Burned in the open air it left 16 grains of ashes; so that the coal consumed amounted to 23 grains.

IV.—The earthy residue being digested with muriatic acid, left 6,5 grains of silex.

V.—The muriatic solution was supersaturated with ammonia, a brown precipitate fell down, and the fluid assumed a light blue tinge. The precipitate being dissolved in a hot alkaline solution left oxid of iron, which was attracted by the magnet. After having been ignited, it weighed 2 grains.

VI.—Muriate of ammonia was then poured into the alkaline fluid; this threw down alumine, which after ignition weighed 5½ grains.

VII.—The other ammoniacal fluid was supersaturated with muriatic acid. A cylinder of zinc being immersed therein separated 0,20 grains of metallic copper.

On collecting the results of this analysis of the ore we find that 1000 parts consist of

Mercury	818	
Sulphur	137	50
Charcoal	23	
Silex	6	50
Alumine	5	50
Oxid of Copper	2	
Copper	0	20
Water which served to form sulphurated hidrogen gas, and other loss	7	30
	1000	

Remark.—This analysis may serve to rectify the false notions which have been adopted concerning the composition of this mixed mineral. By shewing that the sulphur is combined with the metal in the same proportion as in cinnabar, namely as 1 to 6 in round numbers, we are taught how little foundation there is for the opinion of those who think that a part only of the mercury is in the state of sulphuret of mercury, and that the other is a simple oxid. If that were the case, the non-sulphurated part would certainly be soluble in nitric acid. Experiment shews that this is not the case, because the acid cannot dissolve any portion, even when boiling hot, the mineral remains unchanged at the bottom of the vessel. The above opinion has arisen from observing that in sublimation part only of the mineral rises in the state of cinnabar, while the other is volatilized in the form of fluid mercury. But this no doubt arises from the presence of charcoal among its ingredients, which decomposes part of the cinnabar at an elevated temperature: whether it be that the charcoal takes from the mercury the minimum of oxigen necessary to the formation of cinnabar, or whether it be that the sulphur which combines at a high temperature with the carbon, and forms carburetted sulphur, is put into a state in which it cannot combine with mercury. The facts shew that it is really so; for having, says Mr. Klaproth, as a direct proof sublimed artificial cinnabar with lamp black, the greatest part of the cinnabar was decomposed in the same manner as the hepatic mercury, and the result was a mixture of Ethiops mineral or hydro-sulphuret of mercury and globules of metallic quicksilver

ORDER X.

ORES OF ANTIMONY.

Division of Ores of Antimony:

GENUS I.—*Alloys of Antimony.*

Species 1.—Native Antimony.

GENUS II.—*Sulphurets of Antimony.*

Species 1.—Grey Sulphuret of Antimony.
  Subspecies 1.—Compact Grey Sulphuret of Antimony.
    2.—Foliated Grey Sulphuret of Antimony.
    3.—Radiated Grey Sulphuret of Antimony.

GENUS III.—*Oxids of Antimony.*

Species 1.—Red Ore of Antimony.
  2.—White Ore of Antimony.
  3.—Yellow Ore of Antimony.
  4.—Antimonial Oxid.

ANALYSIS OF ORES OF ANTIMONY.

Species 1.—*Analysis of Native Antimony.*

This ore is chiefly composed of antimony and iron, sometimes it contains a minute portion of silver and arsenic.

The analysis of it was effected by Klaproth, thus:

Process I.—One hundred grains of finely pulverised ore were digested in concentrated nitric acid till the whole was converted into a white powder, or till no further action took place, which was known by a fresh portion of the acid emitting no nitrous gas when suffered to act on the ore assisted by heat.

II.—The obtained mass, after being diluted with water, was thrown on a filter, the insoluble white oxid separated, washed, and dried.

III.—Into the fluid obtained by filtration, muriatic acid was dropt, a white curdly precipitate fell down, which being weighed indicated one grain of silver.

IV.—The fluid, from which the silver was obtained, yielded a blue precipitate, by the addition of prussiate of potash· This precipitate, after being treated in the usual manner, namely, being ignited, yielded one quarter of a grain of iron.

V.—The insoluble oxid obtained in process II. was dissolved in muriatic acid assisted by heat. The solution was diluted with six times its weight of water, and the precipitate thus produced re-dissolved by the admixture of muriatic acid.

VI.—Into this muriatic solution a cylinder of zinc being immersed, 98 grains of metallic antimony were separated. Thus 100 grains of the ore contained,—antimony 98 grains, silver 1 grain, iron 0,25 grain.

If the ore contains arsenic and no silver, the analysis may be made by digesting it repeatedly in nitro-muriatic acid, composed of nitric acid, specific gravity 1,25 one part, and concentrated muriatic acid three parts. Both the arsenic and antimony become dissolved; the latter may be separated by the mere admixture of water, and the arsenic may be disengaged by nitrate of lead; 100 parts of arseniate of lead indicate 33 of arsenic acid or 22 of metal; or, the ore may be repeatedly digested in concentratad nitric acid assisted by heat; the arsenic becomes acidified and dissolved, and the oxid of antimony is left behind: the oxid of antimony may be re-dissolved in muriatic acid, and treated as stated before; the quantity of arsenic may be ascertained by nitrate of lead as stated above.

ANALYSIS OF SULPHURETS OF ANTIMONY.

The sulphurets of antimony usually contain, besides antimony, a portion of lead, copper, iron, and silver; to which must be added the earths composing the stony matrix, from which they cannot be perfectly separated previously to analysis. With these compound ores the best method of proceeding is as follows:

Process I.—Take 500 grains of ore, finely pulverized, digest it with 1500 grains of pure nitric acid, specific gravity 1.25 and 1000 grains of water for about half an hour, at the temperature of 150° Fahr. and repeat this process for several times.

II.—Mingle the solution with a quantity of water equal to the rest of the fluid, and pour off the liquor as soon as it becomes clear; it may consist of the nitrates of silver, lead, and copper, with probably a little iron, dissolved in an excess of acid.

III.—To separate the iron, boil the fluid, and the iron will be separated in the state of red oxid, by subsequent filtration.

IV.—Drop muriate of soda into the solution, as long as a precipitate takes place, and allow the whole to stand till the supernatant fluid becomes perfectly clear; the precipitate is muriate of silver, which, being separated and washed, may be mixed with two or three times its weight of dry carbonate of soda, and reduced by fusion to the metallic state.

V.—The solution obtained in process IV. must now be saturated by potash or soda, and concentrated by evaporation to about one-third of its bulk; and then mingled with ammonia in excess, the lead will be precipitated as white oxid, and the copper remains in solution. The former, by fusion with black flux, may be reduced to the metallic state.

VI.—The solution freed from lead may then be slightly acidulated with nitrous acid, and carbonate of potash added to it, which will throw down the oxid of copper; and this after being exposed to a low red heat becomes converted to the state of brown oxid, 100 parts of which denote 85 of metal.

VII.—The insoluble portion of the ore left in process I. is to be digested, at a temperature somewhat inferior to boiling with successive portions of nitro-muriatic acid (consisting of nitric acid specific gravity 1,25 one part, strong muriatic acid three parts) as long as any action takes place; the solutions being then mixed and concentrated by evaporation, are to be poured into a considerable quantity of pure water; an immediate precipitate or white oxid of antimony takes place, which, being separated, washed, and mixed with twice its weight of black flux, and a little nitre, is easily reduced to the metallic button by a full red heat continued for a few minutes.

VIII.—The solution obtained in process VI. now contains only a little sulphuric acid and perhaps iron, with some earthy matter. The addition of nitrate of barytes, as long as any precipitate falls down, indicates the quantity of sulphur; after which, an excess of caustic potash, assisted by a boiling heat, will throw down the iron, and retain the alumine and silex, according to rules given repeatedly already.

IX.—The insoluble residue of process VII. containing only sulphur and earth, is decomposed by ignition, the sulphur flying off, and the earth remaining.

Thus the quantity of antimony is obtained by
process VII.
of sulphur and earth by VIII. and IX.
of iron by II. and VII.
of silver by IV.
of lead by V.
of copper by VI.

The rest of the species of sulphurets of antimony may be analysed in a like manner.

ANALYSIS OF OXIDS OF ANTIMONY.

Species 1.—*Analysis of Red Ore of Antimony.*

The analysis of this ore was conducted by Klaproth, thus:

Process I.—Upon 100 grains of the ore introduced into a retort, lodged in a sand-bath, and connected with the pneumatic apparatus, was poured muriatic acid. As soon as the ore was acted on by the acid, assisted by heat, sulphureted hidrogen gas was disengaged, which towards the middle of the process deposited in the neck of the retort, and in the hot water of the trough, a portion of sulphuret of antimony of an orange-red colour, which amounted to several grains.

II.—The obtained sulphureted hidrogen gas being measured and having deducted the common air of the retort, amounted to 37 cubic inches.*

III.—These preliminary experiments being made, 100 grains of the same ore, of select pure specimens, were again digested with muriatic acid in a long-necked mattrass. In this case, likewise, sulphuret of antimony was deposited in the neck of the vessel. When the solution was effected, there remained 1½ grain of a grey residue, which, on being heated, burnt with the character of sulphur,

IV.—The antimony contained in the muriatic solution, was next precipitated, in the state of a white oxid, by diluting it with water, and the small portion of the metal that might still remain in that fluid was afterwards thrown down by the addition of potash.

V.—The oxid thus procured, was re-dissolved in muriatic acid, the solution diluted with six times its quantity of water, and once more combined with such a proportion of the same acid,

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* From this Klaproth infers that the ore contains 19,70 of sulphur.

as was necessary to re-dissolve the oxid precipitated. After the dilute solution had in this manner again been rendered clear, the antimony was separated in a metallic state by a polished cylinder of iron. It weighed 67½ grains.

Hence the products obtained, were

Antimony.............	67,50
Oxigen...............	10,80
Sulphur..............	19,70
	98

Species 2.—*Analysis of the White Ore of Antimony.*

The analysis of this ore was performed by Klaproth in the following manner:

Process I.—Twenty-five grains of the ore were mixed with 200 grains of carbonate of potash, and heated to redness in a platina-crucible. It melted and acquired a yellow colour.

II.—The mass was softened with water, and the oxid of antimony separated by the filter.

III.—The clear fluid was then supersaturated with nitric acid; upon which the mixture became turbid, depositing a small quantity of oxid of antimony; which, being separated, nitrate of silver when dropped into the clear fluid, produced no change. This mineral is therefore a pure oxid of antimony; which, as may be judged from its solubility in nitro-muriatic acid, is but imperfectly saturated with oxigen, and bears the greatest resemblance to the artificial oxid of that metal.

ORDER XI.

ORES OF BISMUTH.

Division of Ores of Bismuth.

GENUS I.—*Alloys of Bismuth.*
Species 1.—Native Bismuth.

GENUS II.—*Sulphurets of Bismuth.*
Species 1.—Common Sulphuret of Bismuth.
2.—Cupreous Sulphuret of Bismuth:

GENUS III.—*Oxids of Bismuth.*
Species 1.—Bismuth ochre.

ANALYSIS OF ORES OF BISMUTH.

Species 1.—*Analysis of Native Bismuth.*

Process I.—Digest a determinate quantity of finely pulverised ore repeatedly in dilute nitric acid, assisted by a very gentle heat, till the fluid dissolves no more, which may be known by the last portion of acid occasioning no precipitate, when poured into water.

II.—To separate the bismuth from the solution, mingle it with a large portion of water, a white precipitate falls down, which is oxid, or more properly, nitrate of bismuth. But as the whole cannot be separated by one process, let the solution be concentrated again by evaporation, a second affusion of water will then precipitate another portion of the oxid, which escaped the action of the water. The same process may be repeated for several times successively. If lead, silver, copper, or iron, should be present, they will remain in the fluid, which is decanted from the precipitate.

III.—To effect the separation of the oxid of bismuth in the most perfect manner, let the remaining fluid, from which water separates no precipitate, be again concentrated to as small a bulk as possible; that is to say, so as just to hold all substances it may contain in solution, without crystallizing; or if part of nitrate of lead should be deposited in a crystalline form, add again a few drops of water, to effect a solution, and then add to this concentrated fluid, muriatic acid, drop by drop, as long as a precipitate ensues; this precipitate consists of the remaining portion of oxid of bismuth, and perhaps of muriate of silver, or muriate of lead, if these metals were present.

IV.—To separate these precipitates, add a few drops of concentrated nitric acid, which will dissolve the bismuth and leave the silver, and then drenching again the fluid with water, which will now separate the whole: 100 parts of the oxid contain, according to Klaproth, 81,3 of bismuth.

V.—The bismuth and silver being thus separated the fluid may be examined for iron by ammonia, in the manner stated under the article iron ores.

Sulphurets and oxids of bismuth may be analysed in a similar manner, the quantity of sulphur may be found by means of nitrate of barytes, according to the rules described already, page 117.

ORDER XII.

ORES OF NICKEL.

Divison of Ores of Nickel.

The ores of nickel are not numerous; they are the following:

GENUS I.—*Sulphurets of Nickel.*

Species 1.—Sulphuret of nickel, or copper nickel.

GENUS II.—*Oxid of Nickel.*

Species 1.—Nickel ochre.

ANALYSIS OF ORES OF NICKEL.

Species 1.—*Analysis of Sulphuret of Nickel.*

This ore, when pure, is composed of nickel, sulphur, and arsenic, but it is often found contaminated with cobalt, iron, and bismuth.—Besides these metals it may contain copper and silver; the matrix, which is usually quartz and alumine, cannot be separated completely. Let us suppose that all these substances were contained in the ore, the mode of analysis might then be conducted thus:

Process I.—Take one part of the finely pulverised ore, pour over it four of nitric acid diluted with an equal bulk of water; digest the mixture by a gentle heat till no further action ensues; and repeat this operation, with fresh quantities of acid, for several times successively, until no farther action takes place; and lastly, separate the insoluble part by the filter.

II.—Let the insoluble part, which consists chiefly of sulphur and the silex of the ore, be weighed; when dry ignite it in a crucible, and ascertain the loss which gives the weight of the sulphur with tolerable accuracy.

III.—Boil the remaining part in concentrated nitric acid repeatedly, wash, dry, and ignite it; it is silex.

IV.—Mingle the before-obtained nitric solution, and add to it a solution of soda so as to render it neutral, or nearly so; then concentrate it by evaporation and pour it into water. If a white precipitate falls down it is oxid of bismuth. Separate it by the filter; dry and weigh it, 100 parts are equal to 81.3 of metallic bismuth.

V.—To the fluid, from which the oxid of

bismuth has been separated, add muriate of soda till no further precipitate falls down. The precipitate is muriate of silver, 100 parts are equal to 75 of silver.

VI.—To learn whether iron was present in the ore, evaporate the solution to dryness, and boil it repeatedly to dryness with concentrated nitric acid; lastly, diffuse it through water, and collect the oxid of iron by the filter, 100 parts = 53 of metallic iron.

VII.—To the fluid from which the iron has been separated add a solution of soda to render it neutral, and then drop into it a solution of nitrate of lead. The precipitate is arseniate of lead, 100 parts = 33 arsenic acid, or to 22 of metallic arsenic.

VIII.—If to the nitric solution carbonate of soda is now added, a precipitate falls down, which, after being washed in liquid ammonia, consists of oxid of iron and alumine.

IX.—To separate these two substances boil the precipitate in a concentrated solution of potash, the alumine will be dissolved, and the oxid of iron left behind; deducting the weight of the latter, from the weight of the whole, the quantities of each may be found.

X.—To separate the copper supersaturate the ammoniacal solution, process VII. slightly with nitric acid, and immerse into it a cylinder of iron, to get again rid of the iron used for separating the copper, again decompose the solution by carbonate of soda, and again digest the precipitate in ammonia.

XI.—The solution being now freed from all metals, and containing nothing but nickel and cobalt, should be treated according to Mr. Phillips, in the following manner:

XII.—Evaporate the fluid till the excess of ammonia is volatilized, which may be known by the vapours ceasing to discolour moist turmeric paper, then dilute it copiously with water, and decompose it by a solution of potash or soda, the precipitate is oxid of nickel.

XIII.—The solution now contains only cobalt, which may be separated by carefully saturating it with nitric acid, and adding carbonate of soda.

The oxids of nickel are best analysed in a like manner.

ORDER XIII.

ORES OF COBALT.

Few of the ores of cobalt have hitherto been examined with accuracy, hence much confusion exists with regard to them. The following is the general division of ores of cobalt adopted.

Division of Ores of Cobalt.

GENUS I.—*Alloys of Cobalt.*

Species 1.—White Cobalt Ore.
2.—Bright White, or Glanz Cobalt Ore.
3.—Dull grey Cobalt Ore.

GENUS II.—*Oxids of Cobalt, or Earthy Cobalt Ores.*

Species 1.—Friable black Cobalt ochre
2.—Indurated Black Cobalt Ochre.
3.—Yellow Cobalt Ore.
4.—Brown Cobalt Ore.

GENUS III.—*Salts of Cobalt.*

Species 1.—Red Cobalt Ore, or Arseniate of Cobalt.
2.—Earthy Red Cobalt Ore.
3.—Cobalt Bloom, or Radiated Red Cobalt Ore.
4.—Sulphate of Cobalt.

ANALYSIS OF ORES OF COBALT.

The native alloys of cobalt often contain a considerable portion of arsenic in the metallic state, and nickel and iron; sometimes even a small portion of manganese and copper has been detected in them; hence the analysis of these ores, is rather difficult.

ANALYSIS OF ALLOYS OF COBALT.

It having been stated that arsenic in the metallic state is usually contained in cobalt ores, it should be remembered that when we apply nitric acid to effect a solution of these ores, the arsenic becomes changed either into arsenious or arsenic acid, according to the mode in which the nitric acid is applied. If, namely, a small portion of nitric acid, and in a diluted state, is applied to the ore of cobalt, containing metallic arsenic, the latter metal becomes converted into arsenious acid, which is insoluble, and therefore becomes precipitated by simply evaporating or concentrating the nitric solution; whereas, on the contrary, if a concentrated, or a large quantity of nitric acid is applied to the ore, the arsenic is compleatly acidified at the expense of the nitric acid, and becomes converted into arsenic acid, which is not precipitated, but being soluble is held in solution. This arsenic acid thus formed, unites as arsenic acid with part of the cobalt, as well as with the other metals, and forms arseniates of those metals which are decomposable by alcalies, and thus render the analysis exceedingly difficult. Let it be understood, however, that oxid of cobalt is soluble in liquid ammonia, but oxid of iron is not, and that nitrate of iron deposits much of its oxid by mere exposure to air, but the solution of nitrate of cobalt is permanent.

This being premised, the following analysis of Tassaert will be easily understood.

Process I.—To estimate the quantity of arsenic separately M. Tassaert digested one hundred parts of the cobalt ore with dilute nitric acid, and in some hours the whole was dissolved;

but by cooling, a quantity of white crystalline grains were deposited. On evaporation more of them were deposited, and when all had thus separated, they were collected and dried, and weighed 56 parts, all of which was sublimed by heat except 3 parts, probably a mixture of arsenic and cobalt. Hence the oxid of arsenic from this ore may be reckoned at about 53 parts, indicating 49 per cent. of metallic arsenic in the ore.

II.—Three hundred parts of the ore were then digested with four times as much nitric acid, which made a rose-coloured solution. By partial evaporation, and subsequent addition of water, and heating, a rose-white precipitate fell down, leaving a rose-coloured solution.

III.—This solution, boiled with an excess of potash, gave an oxid of cobalt at first rose-coloured, then passing to green, and when dried in a red heat, it became black. It weighed 85 parts.

IV.—The 85 parts of the last experiment were then examined for iron. When re-dissolved in nitro-muriatic acid, liquid ammonia was added, which gave a black precipitate, which became re-dissolved by an excess of the alkali except a small portion. This being again treated with nitro-muriatic acid and ammonia, was reduced to 4 parts, and appeared to be oxid of iron.

V.—The rose-coloured precipitate of experiment III. which proved to be a mixed arseniate of cobalt and iron, was decomposed by potash in excess, and gave a precipitate weighing 100 parts when dried.

VI.—The precipitate obtained in the last experiment was re-dissolved in nitric acid, the solution concentrated, and diluted with water. A precipitate of oxid of iron weighing 27 parts separated, and a clear solution of cobalt was left behind.

VII.—The nitric solution of cobalt of experiment VI. was decomposed by ammonia, the precipitate became re-dissolved by an excess of the alkali, except 15 parts which were oxid of iron. The solution was added to the ammoniacal solution of cobalt of experiment IV.

VIII.—The insoluble precipitates of oxid of iron obtained in experiments IV. VI. VII. were then mixed and examined. They still gave a blue glass when fused with borax, and therefore contained a portion of cobalt. Acetic acid was found a good method of separating them.

IX.—For this purpose they were re-dissolved in nitro-muriatic acid, precipitated by a sufficient quantity of ammonia, and the precipitate whilst still wet was put into acetic acid. This dissolved the whole at first, but on boiling and evaporating the solution nearly to dryness, most of the iron separated, and by re-dissolving the mass in water and evaporating it nearly to dryness successively, nearly all the oxid of iron was rendered insoluble, whilst the cobalt remained in the solution, and this acetate of cobalt in proportion as it was freed from iron became more and more of a fine rose colour.

X.—The solution was then supersaturated with ammonia, and this solution was added to the different portions of the same fluid obtained in the former experiments. The whole was then boiled to expel the excess of ammonia, and by adding potash the oxid of cobalt was precipitated, which after being washed and dried, weighed 133 parts. This oxid reduced in a crucible lined with charcoal, gave regulus of cobalt in its purest form, of the specific gravity of 8,538, totally free from arsenic and iron.

XI.—Lastly, to estimate the quantity of sulphur, 100 parts of the ore were separately boiled with 500 of nitric acid, and diluted with water to separate all the oxid of arsenic or arsenious acid, that would be deposited spontaneously. All the sulphur being now converted into sulphuric acid by the action of the nitric acid, nitrate of barytes was added, and from the precipitated sulphate of barytes the quantity of sulphuric acid, and of course, of sulphur, was estimated according to the rules stated, p. 117.

Remarks.—Some improvements may be suggested in this ingenious analysis. To separate arsenic compleatly from the cobalt to which it adheres so obstinately, Mr. Chenevix's method may be advantageously adopted of adding nitrate of lead to the solution of the ore containing the arsenic fully acidified and partly united to the cobalt. The nitrate of lead engages all the arsenic acid, and decomposes the arseniate of cobalt. The arseniate of lead, being insoluble, remains at the bottom, the clear solution may then be decomposed by carbonate of potash, which separates the metallic contents, after which ammonia will dissolve the cobalt, and also any nickel that may be present, leaving the iron and any excess of lead that may remain. The ammoniacal solution of nickel and cobalt may be separated, according to Mr. R. Phillips, viz. Let the solution be evaporated till the excess of ammonia is driven off (which is known by a paper dipped in tincture of turmeric no longer turning brown) in this state, if potash is added, and diluted with much water, the whole of the nickel is precipitated very speedily, but the cobalt remains suspended for a considerable time.

If copper be present, after the arseniate of lead is precipitated, let the copper be separated by a cylinder of iron before the nitric solution is decomposed by alkalies.

The ore called bright white cobalt ore, may be examined in a like manner.

Species 3.—*Analysis of the Dull Grey Cobalt Ore.*

The analysis of this ore (which may be effected like the former) was conducted by Klaproth, in the following manner:

Process I.—One hundred grains of the ore, when gently digested with nitric acid, dissolved in it gradually, leaving behind 16½ grains and a half of minute white-grey resplendent globules, which consisted of arsenic, with a little sulphur. By boiling with water, this arsenical ingredient was dissolved, and there remained 1½ grain: of which ½ grain of sulphur deflagrated on a small scorifying test. The remaining 1 grain was oxid of cobalt.

II.—The nitric solution which was brownish red was evaporated partly in a sand-bath. In this process there still became separated some oxid of arsenic, in the form of a white crystalline crust; which, collected after cooling, and being by degrees lixiviated with a little water, weighed 30 grains when dry. It again entirely dissolved in the water with which it was boiled.

III.—Both the solutions of the arsenical oxid in water shewed exactly the same appearances which are exhibited by any other aqueous solution of oxid of arsenic. By combination with lime-water, they yielded arseniate of lime; with sulphuret of ammoniac they produced yellow sulphuret of arsenic (orpiment), and the green pigment of Scheele with ammoniacal oxid of copper.

IV.—When the nitric solution of cobalt did no longer deposit arsenic, it was diluted with water, and precipitated by carbonate of potash; the oxid of cobalt, thus obtained, had a peach-flower colour. On dissolving it in muriatic acid, and diluting the solution with water, the fluid acquired a rose-red colour.—Therefore the constituent parts of the crystallized, white cobalt-ore, separately produced in this analysis, consist, according to Klaproth, in the hundred, besides the portion of cobalt itself, of 45 grains of oxid of arsenic, and ½ grain of sulphur: no traces of iron was found.

ANALYSIS OF OXIDS OF COBALT.

The analysis of the native oxids of cobalt may be conducted in the manner stated already; but, as sometimes a portion of manganese and copper is present in these ores, we shall give the analysis of a native oxid of cobalt containing both these metals, as conducted by Klaproth.

Process I.—Five hundred grains of a magnesian ore of cobalt were digested in moderately strong muriatic acid. The solution was effected with the extrication of oxy-muriatic gas. By continuing the digestion at the degree of ebullition, the mixture lost its brown colour, and the fluid became green, leaving a white earthy residue. On diluting the solution with water, its green colour disappeared, and the filtered fluid acquired a brownish red colour. The residue, separated by filtration, weighed 206 grains, after ignition.

II.—The obtained solution being concentrated by evaporation a precipitate became deposited, which was silex; it being collected on the filter and ignited, weighed 10 grains. After this the solution was saturated or mingled with potash in excess, and the mixture digested for some time and filtered. A muddy residue remained on the paper of a dirty light brown colour, which rapidly turned black on exposure to air.

III.—The fluid separated from this residue was neutralized with muriatic acid, and then combined with carbonate of potash. It deposited alumine, the quantity of which, after ignition, amounted to 12 grains.

IV.—The black residue (process II.) was again dissolved in muriatic acid, and precipitated by carbonate of potash; the precipitate was of a pale red colour. When washed and dried it was subjected to a strong red heat for one hour, it acquired a greyish brown hue, it weighed 178 grains.

V.—These 178 grains were digested for some time in a boiling heat, with nitric acid, and the solution afterwards diluted with water, and filtered. There remained a black residue, which, being washed, dryed, ignited, weighed 80 grains, it was oxid of manganese. In order to examine it for iron, it was again digested in nitric acid; in which, on the addition of a little sugar, it immediately dissolved, without leaving iron, or any other residue. When precipitated by carbonated potash, it yielded a carbonate of manganese, of a white colour.

VI.—Hence the nitric solution still contained 98 grains of the mentioned 178; but from the first there must be subtracted one grain for copper, discovered in the sequel. By carbonate of potash, this re-dissolved portion was again precipitated, of a pale peach-flower colour; and this precipitate, as the following examination of it has shewn, consisted of a mixture of oxid of cobalt and oxid of manganese.

VII.—The 206 grains, which remained on dissolving the ore, process I. were mixed with twice their weight of carbonate of potash, and moderately ignited for two hours; they were then covered with water, supersaturated with muriatic acid, and evaporated to a gelatinous constistence: when the siliceous earth had been separated, washed, and ignited, it weighed 114 grains.

VIII.—The remaining muriatic solution being neutralized with carbonate of potash, and then combined with oxalate of potash, did not yield a precipitate. It was therefore combined with liquid ammonia, which threw down alumine, the quantity of which, after ignition, weighed 90 grains. The still remaining portion of the fluid continued clear on the addition of carbonate of soda.

IX.—To ascertain the proportion of copper, the presence of which has already been observed in the previous experiments, sulphuric acid was affused upon 500 grains of the ore, the solution being evaporated, the inspissated mass was dissolved in water, and a polished cylinder of iron was immersed into the clear solution, which acquired a pale rose colour. The iron became gradually incrusted with a cupreous pellicle; which, when carefully collected, weighed $\frac{1}{2}$ grain; and thus one grain of oxid of copper must be put in the computation.

X.—One hundred grains of the ore lost on exposure to heat 17 grains. Therefore, the five hundred grains of the mineral here examined have been decomposed into

Oxid of cobalt, mixed with oxid of magnesia, process	VI.		97
Oxid of manganese	V.		80
Oxid of Copper	IX.		1
Silex	II.	10	124
——	VII.	114	
Alumine	III.	12	102
——	VIII.	90	
Water	X.		85
			489

The analysis of the salts of cobalt may be easily accomplished, according to what has been stated in the preceding analysis.

ORDER XIV.

ORES OF ARSENIC.

The ores of arsenic are very abundantly diffused through the mineral kingdom, and accompany almost every other ore. They may be divided in the following manner:

Division of Ores of Arsenic:

GENUS I.—*Alloys of Arsenic.*

Species 1.—Native Arsenic.

GENUS II.—*Sulphurets of Arsenic.*

Species 1.—Arsenical Pyrites, Mispickel, or Marcasite.
2.—Sulphuret of Arsenic, or Realgar.

Subspecies 1.—Yellow Sulphuret of Arsenic, or Orpiment.

GENUS III.—*Oxids of Arsenic.*

Species 1.—Native White Oxid of Arsenic.

GENUS IV.—*Salts of Arsenic.*

Species 1.—Arseniate of Lime, or Pharmacolite.

ANALYSIS OF ORES OF ARSENIC.

Species 1.—*Analysis of Native Arsenic.*

This ore usually contains a portion of iron, and sometimes, though very rarely, a portion of gold and silver. Its analysis may be effected thus:

Process I.—Take one part of the finely pulverized ore, digest it repeatedly, assisted by a gentle heat, in three of nitro-muriatic acid, composed of one part of nitric and one and a half of muriatic acid, and repeat this operation till a complete solution is obtained, or till a new portion of acid produces no further action upon the residue; then decant the fluid, and let it subside. If a white precipitate be observed in the solution, the ore contained silver: let the precipitate be therefore collected. It is muriate of silver.

II.—Evaporate the muriatic solution, from which the silver has been separated, to about $\frac{1}{4}$, or till it becomes turbid, and add to it water, till this fluid occasions no further turbidness, which may be known by filtering from time to time a small quantity of the mixture, and assaying the filtered solution by a new addition of water. The white precipitate obtained is oxid of arsenic. The water which has been employed for precipitating the oxid of arsenic should again be evaporated to as small a compass as possible, and again assayed for arsenic by water, and this process must be repeated till no more precipitate takes place by adding water to the concentrated solution; and lastly the solution should be evaporated to compleat dryness, and then diffused through water, to separate the last portion of arsenic, if any.

III.—Re-dissolve this precipitate in muriatic acid, and precipitate it, by immersing into its solution a cylinder of zinc, mixing with it at the same time $\frac{1}{10}$ part of alcohol; this precipitate after being dried, may be fused. It is metallic arsenic.

IV.—The solution from which the arsenic has been separated, may be assayed for iron: for that purpose, let it be concentrated, and mix it with liquid ammonia in excess; if a brown precipitate ensues, it is iron.

Remark.—If the ore contain gold, nitric acid should be made use of in the first process. The residue may then be treated in a similar manner with nitro-muriatic acid, and the solution precipitated by sulphate of iron, to obtain the gold.

Remark.—As a general rule in attempting the analysis of the ores of arsenic, as usual by the application of nitro-muriatic or nitric acid, it should be observed that whenever the object is to obtain merely a solution of the ore, with a view to obtain, in the manner stated by water, or by an alcali, the arsenical oxid, no more acid should be used than is absolutely necessary to effect the solution of the ore. For if a larger portion of nitric or nitro-muriatic acid be applied, the arsenic, or a portion of it, is converted into arsenic acid, which is no longer precipitable by water or by an alcali, and which combining with the iron or other metallic oxid, or earth, that may be present, renders the analysis unnecessarily complicated and difficult.

But as in every application of nitric or nitro-muriatic acid to arsenic, some arsenic acid will probably be generated, another mode of analysis may be pursued, which is by far the most accurate: it consists in the compleat acidification of arsenic in the first instance, and afterwards transferring the arsenic acid to lead, with which it forms an insoluble compound, the proportions of which are invariable. The following may serve as an illustration of what has been stated.

ANALYSIS OF SULPHURETS OF ARSENIC.

Species 1.—*Analysis of Arsenical Pyrites.*

Process I.—Reduce the ore to as fine a pow-as possible, pour over it in a Florence flask four parts of nitro-muriatic acid, assist the action by a gentle heat, and repeat this operation for several times successively, and lastly, filter the fluid. The whole of the arsenic that was present in the ore will thus be acidified or converted into arsenic acid.

II.—Saturate the obtained solution with carbonate of potash accurately, and decompose it by dropping into it a solution of nitrate of lead till no farther precipitate ensues. One hundred parts of the obtained arseniate of lead, when dried at a low red heat, contain 33 of arsenic acid, of which the metallic contents may be reckoned at 22 parts.

III.—But as the ore contains sulphur, sulphuric acid must have been formed by the application of the nitro-muriatic acid, and the precipitate obtained by nitrate of lead, must contain sulphate of lead. To get rid of this let it be digested in very dilute nitric acid or in acetous acid, the arseniate of lead will become dissolved, and the sulphate of lead will be left behind. Hence the difference of weight between the precipitate before and after treatment with the latter acid will show the proportion of the arseniate and sulphate of lead.

In this manner all the rest of the sulphurets and oxids of arsenic may be examined.

ANALYSIS OF SALTS OF ARSENIC.

Species 1.—*Analysis of Arseniate of Lime.*

In this ore arsenic exists in the state of arsenic acid combined with lime and water. Its analysis was conducted by Klaproth thus:

Process I.—One hundred grains of the ore being moderately heated lost 22½ grains. As in this operation neither by the smell nor by the sight any other volatile matter, the water, could be observed, Mr. Klaproth considers the loss of weight as water of crystallization.

II.—Those 77 grains and a half which remained after the ignition, dissolved in nitric acid, left a grey residue of 6 grains of silex mixed with alumine.

III.—The filtered solution had a reddish hue, it was evaporated to a small volume, and mixed with a solution of acetate of lead as long as a precipitation ensued. The precipitate, when collected, washed, dried, and ignited, weighed 138 grains. It consisted of arseniate of lead. Agreeably to a counter experiment, in which 100 grains of dry acid of arsenic, dissolved in water and combined with the quantity of acetated lead requisite to effect a saturation, yielded 297 parts of arseniate of lead, those 138 grains mentioned before, indicate, according to Klaproth, 46½ grains of concrete acid of arsenic.

IV.—What remained of the fluid after the separation of the precipitate, together with the washings, was concentrated, during which operation green coloured borders appeared on the inner surface of the vessel. To separate the small quantity of undecomposed acetate of lead, it might yet have contained, muriatic acid was added. When upon farther evaporation no muriate of lead appeared, it was mixed with sulphuric acid. This produced a copious precipitate of sulphate of lime, which being collected on the filter, washed with weak spirit wine, and heated to redness, weighed 54 grains Therefore, since in 100 parts of ignited sulphate of lime, the lime amounts to 42½ parts, the mentioned 54 grains determine the portion of lime contained in the fossil examined at 23 grains.

V.—The remainder of the fluid was neutralized with carbonate of soda, and evaporated to dryness. On re-dissolving in water the dry saline mass, there remained a powder weighing ½ grain, which tinged glass of borax with a fine deep blue, and thus proved to be oxid of cobalt.

Thus hundred grains of pharmacolite, submitted to this analysis, have been decomposed by Klaproth, into

Arsenic Acid	46,5
Lime	23,
Oxid of Cobalt	0,5
Alumine and Silex	6,
Water	22,5
	98,5

But since the oxid of cobalt is here but casually admixed, and as the silex originates merely from the granitic matrix of the ore, it follows, that after subtracting these, the proportions of the constituent parts of the pharmacolite, are,

Arsenic Acid	50,54
Lime	25,
Water	24,46
	100*

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[*] Analytical Essays, vol. I. p. 224:

ORDER XV.

ORES OF TUNGSTEN.

There are only two ores of Tungsten hitherto known.

Division of Ores of Tungsten.

GENUS I.—*Oxid of Tungsten.*

Species 1.—Tungstate of Iron and Manganese, or Wolfram.

Species 2.—Tungstate of Lime.

ANALYSIS OF ORES OF TUNGSTEN.

Species 1.—*Analysis of Tungstate of Iron and Manganese, or Wolfram.*

In this ore oxid of tungsten exists in combination with a considerable portion of iron, and oxid of manganese. Its analysis may be accomplished in the following manner:

Process I.—Take one part of the ore levigated as finely as possible, digest it in a very gentle heat for at least four hours with 3 parts of muriatic acid; suffer it to cool, decant the solution, and wash the residue repeatedly in water, and dry it.

II.—Pour over the residue two parts of liquid ammonia, suffer it to stand 4 or 5 days, and agitate it frequently; decant the ammoniacal solution, wash the residue, dry it, and digest it alternately in muriatic acid and in liquid ammonia, till it experiences no farther diminution, or till the whole is nearly, or totally dissolved. What remains is silex.

III.—Mingle the ammoniacal solutions, and evaporate it in a retort or bason, to dryness; transfer the mass into a platina crucible, and heat it thoroughly, or till it acquires a yellow colour. This product is oxid, or acid of tungsten.

IV.—Having done this, mix all the muriatic solutions which contain the iron and manganese, with $\frac{1}{6}$ part of sulphuric acid, and evaporate the whole to dryness.

V.—Re-dissolve the before obtained mass in water, and add to it liquid ammonia, the precipitate which falls down consists of the oxids of iron and manganese, contained in the ore; collect, wash, and dry it.

VI.—To separate these metals, digest the precipitate by heat repeatedly in concentrated nitric acid, and evaporate it to dryness.

VII.—Transfer the mass into acetic acid, and digest it with heat; the manganese will become dissolved, and the iron remain behind, deducting the weight of this, from the weight of the whole precipitate, the respective proportions of each may be found; or if a solution of an alkali be added, the fluid will assume a brown colour, and a precipitate will be obtained after boiling for a few minutes. This is the oxid of manganese contained in the ore.

Species 2.—*Analysis of Tungstate of Lime.*

In this ore oxid of tungsten exists combined with lime.

Process I.—Digest one part of the ore repeatedly in three of nitric or nitro-muriatic acid, till a new addition of acid dissolves no more; the earth will be dissolved, and the tungsten remain behind in the form of a yellow oxid, if pure: it is soluble in liquid ammonia, from which it may be recovered, as directed in the preceding analysis.

II.—The nitric or muriatic solution contains the lime, and sometimes a little iron; on adding to it at a boiling heat, carbonate of potash, the lime will be precipitated, as carbonate of lime, 32 parts of which = 17,6 of lime: if it contains iron, dissolve the precipitate in muriatic acid, and add liquid ammonia, the iron will thus become separated.

ORDER XVI.

ORES OF TELLURIUM.

Division of Ores of Tellurium.

There is but one genus of the ore of Tellurium, which is an alloy of the metal called Tellurium. As this metal, however, is met with in combination, or at least mixed with gold, silver, or lead, in various proportions, the ores of tellurium have been divided in the following manner:

GENUS I.—*Alloys of Tellurium.*

Species 1.—Native Tellurium, or Aurum Paradoxum; Sylvanite, or White Native Tellurium.
2.—Graphic Ore, Aurum Graphicum, or Grey Native Tellurium.
3.—Yellow Native Tellurium, or Yellow Ores of Naggag.
4.—Foliated, or Black Ore of Tellurium.

ANALYSIS OF ORES OF TELLURIUM.

Species 1.—*Analysis of Native Tellurium.*

Process I.—Let one part of the finely pulverised ore be gently digested with six parts of muriatic acid, and add three parts of nitric acid gradually. Repeat this operation till the acid exercises no farther action upon the ore, and filter the solution.

II.—Dilute it with so much water as it can bear, without becoming turbid, and add to the solution potash, dissolved in water, in excess, or until the white precipitate which is first formed, is again dissolved, and nothing remains but a brown flaky sediment, which is a mixture of gold and iron contained in the ore.

III.—To separate these two metals, let it be re-dissolved in nitro-muriatic acid, precipitate the gold from this fluid by a solution of cold prepared nitrate of mercury added drop by drop till no further brown precipitate ensues. This product consists of gold and muriate of mercury. The gold may be separated by exposing it to heat, which will volatilize the muriate of mercury.

IV.—To obtain the iron add to the nitro-muriatic solution liquid ammonia, the brown precipitate is oxid of iron.

V.—To the alcaline fluid of process II. add muriatic acid, taking care to avoid an excess of acid. The oxid of tellurium is thus precipitated in the form of a white oxid, 178 parts = to 148 of the metal.

VI.—To reduce this oxid to the metallic state, form it into a paste with a small quantity of oil, put it into a retort or crucible, and apply heat; as the oil becomes decomposed, brilliant metallic drops are observed in the upper part of the vessel, which increase in number until the oxid is reduced.

Species 2.—*Analysis of Aurum Graphicum, or Grey Native Tellurium.*

In this ore tellurium is alloyed with gold and silver.

Process I.—Digest the finely pulverised ore repeatedly in small portions of nitro-muriatic acid, till no farther action ensues. The insoluble residue contains muriate of silver formed during this operation, together with the stony matters or matrix of the ore, which is usually quartz.

II.—To recover the silver, fuse the muriate of silver with carbonate of soda, as directed before, page 112.

III.—To obtain the oxid of tellurium concentrate the nitro-muriatic solution, and pour it into water; the powder which falls down is oxid of tellurium.

IV.—Re-dissolve the obtained oxid of tellurium in muriatic acid, and immerse in the solution a cylinder of iron, brown or black flakes will fall down, which consists of metallic tellurium.

V.—The gold which is present in the ore may be obtained by mingling the fluid from which the tellurium is separated with a solution of sulphate of iron. See ores of gold.

Species 3.—*Analysis of Yellow Native Tellurium.*

This ore contains, besides tellurium, gold, silver, lead, and sulphur, hence its analysis is more complicated than the former. It was analysed by Klaproth thus:

Process I.—Four hundred grains of the pulverized ore were digested with nitric acid, till every substance soluble in this fluid had been extracted.

II.—The nitric solution was combined with muriatic acid, till no further precipitate took place; by this there was obtained 51 grains of a white powder, of which 43 grains were again dissolved in boiling water. The insoluble part amounted to 8 grains: it was muriate of silver.

III.—The solution containing the 43 grains above mentioned, being concentrated by evaporation, yielded delicate crystals of muriate of lead.

IV.—The residue of process I. which was insoluble in nitric acid, was digested with nitro-muriatic acid, as long as any substance was taken up: the solution was mixed with the nitro-muriatic solution obtained before, and reduced by evaporation till it ceased to deposit muriate of lead: 11 grains were thus obtained.

V.—To the concentrated solution, process IV. was added potash in excess, which threw down a copious blackish-brown precipitate; this being separated, the alkaline fluid was saturated with muriatic acid, and the white precipitate obtained being again dissolved in muriatic acid, and then precipitated by means of a cylinder of zinc, afforded 85 grains of metallic tellurium.

VI.—The blackish-brown precipitate of process V. was dissolved in nitro-muriatic acid, and the fluid nearly saturated with potash; nitrate of mercury was then added, till the precipitate began to be white. This precipitate being separated by the filter, and washed, the filter, with its contents, was ignited in a crucible, and a little nitre being added, the fire was increased, and a button of pure gold was obtained, weighing 50,75 grains.

VII.—The remainder of the nitro-muriatic solution was saturated with carbonate of potash, and a precipitate was obtained, consisting of oxid of manganese, mixed with carbonate of lime and a little alumine and oxid of iron.

VIII.—The insoluble residue of process IV, weighing 120,5 grains, and consisting chiefly of quartz, was heated, by which it lost about 1 grain, which was sulphur: being then mixed with four times its weight of carbonate of potash, and fused, there was obtained a button of silver, weighing 10,125 grains.

Species IV.—*Analysis of the Foliated, or Black Native Tellurium.*

This ore differs from the latter, by containing, besides the metals, tellurium, gold, silver, and lead, also a portion of copper, &c.

It was analysed by Klaproth in the following manner:

Process I.—One thousand grains of the pulverized ore were digested with ten ounces of muriatic acid, to which was added, by degrees, a little nitric acid: this being poured off, five ounces more of muriatic acid were added, by which every thing soluble in this fluid was dissolved. To the filtered solution boiling water was added, to re-dissolve the muriate of lead which had begun to make its appearance.

II.—The insoluble residue consisted for the most part of sulphur, weighing 17,5 grains: This being gently ignited, left 3,5 grains of a blackish matter which was dissolved in muriatic acid, and added to the foregoing solution. Hence the sulphur of the ore amounted to 14 grains.

III.—The remainder of the insoluble residue consisted chiefly of quartz, and weighed 440,5 grains. Being melted with four times its weight of carbonate of potash, there appeared, on breaking the mass, a few globules of silver, amounting to about 2,5 grains equivalent to 3,5 grains of muriated silver; so that the quartz matrix of the ore was equal to 437 grains.

IV.—The solution, process I. being concentrated by evaporation, crystals of muriate of lead were deposited, to the amount of 330 grains, which Klaproth considers as equal to 248 of metallic lead.

V.—Having thus separated the lead, the remainder of the solution was copiously diluted with alcohol, by which a white oxid of tellurium was thrown down. This oxid, being redissolved in muriatic acid, and again precipitated by soda, afforded 178 grains of oxid, equivalent to 148 grains of metallic tellurium.

VI.—The alcoholic solution was next distilled, by which the alcohol was separated; the remaining fluid being diluted with water, was treated with nitrate of mercury, in the way already described, page 263, by which a button of gold, weighing 41,5 grains was obtained.

VII.—The fluid left in process VI. was saturated with carbonate of soda and boiled, by which a bluish-grey precipitate was obtained: by digestion in muriatic acid it dissolved, and oxy-muriatic acid gas was produced: the muriatic solution being then super-saturated with carbonate of ammonia, there was deposited carbonate of manganese, mixed with iron, to the amount of 92 grains.

VIII.—The ammoniacal solution being of a blue colour, it was super-saturated with sulphuric acid, and a cylinder of iron being immersed in it, 6 grains of copper were deposited.

ORDER XVII.

ORES OF URANIUM.

The ores of this metal consist all of native oxids: they are the following:

Division of Ores of Uranium.

GENUS I.—*Oxids of Uranium.*

Species 1.—Black Oxid of Uranium, Pitch Ore, or Pitch Blende.
- 2.—Micaceous Oxid of Uranium, or Green Uranite, or Chalcolite.
- 3.—Uran Ochre, or Ochery Uranium.

ANALYSIS OF ORES OF URANIUM.

Species 1.—*Analysis of Black Oxid of Uranium.*

In this ore uranium exists in combination with oxid of iron and sulphuret of lead.

Process I.—Let one part of the ore finely pulverized, be digested repeatedly in four of dilute nitric acid, till the whole of the ore is dissolved, or till a new portion of acid occasions no farther action upon the residue; the black colour of the ore shows that its decomposition is complete.

II.—Evaporate the solution to at least one-third of its original bulk, and leave it to cool, a precipitate will become deposited, which is nitrate of lead, collect it by filtration. To ascertain the quantity of lead, add sulphuric acid, and proceed as directed, page 169.

To separate a small portion of iron which is generally dissolved by the acid, immerse a cylinder of zinc into the solution, the iron will become precipitated, if any was present.

III.—Into the nitric solution from which the lead has been separated, let fall a solution of potash, at a boiling heat, the precipitate which is formed consists of oxid of uranium and oxid of copper.

IV.—To separate these two metallic oxids, transfer the precipitate into a phial containing liquid ammonia, and digest for some days, the oxid of copper will become dissolved in the ammonia, and the oxid of uranium left behind:

transfer it on a filter, wash it, and when dry, weigh it; the loss indicates the quantity of oxid of copper contained in the solution; or better supersaturate the ammoniacal solution with sulphuric acid, and separate the copper in a metallic state by a cylinder of zinc. The oxid of uranium, then freed from copper, may be abstracted repeatedly with nitric acid, and lastly digested in dilute nitric acid, which will dissolve the uranium, and leave oxid of iron, if any was present.

V.—To the nitric solution of the oxid of uranium add potash, and boil the whole for a few minutes, pure yellow oxid of uranium will thus be obtained.

The undissolved residue of process I. is a mixture of silex, sulphur, and perhaps iron, which was contained in the ore: the sulphur may be separated as stated before, page 117. The iron may be separated by liquid ammonia, the remainder is silex.

The rest of the ores of uranium may be analysed in a similar manner.

ORDER XVIII.

ORES OF MOLYBDENA.

Division of Ores of Molybdena.

GENUS I.—*Sulphuret of Molybdena.*

Species 1.—Common Sulphuret of Molybdena.

GENUS II.—*Salt of Molybdena.*

Species 1.—Molybdate of Lead.

ANALYSIS OF ORES OF MOLYBDENA.

Process I.—Take one part of the ore freed from its matrix, and finely levigated, put it into a retort containing 3 parts of nitric acid, adapt a receiver, and distil till no more drops fall from the neck of the retort, affuse a new portion of acid on the residue, distil it off again, and repeat this operation for several times successively, until the whole of the ore be converted into a white powder.

II.—Wash this powder in water, and dry it: it is the oxid, or acid of molybdena·

III.—Mingle the water used for washing the acid, after having concentrated it by evaporation with ammonia, till no farther precipitate ensues; add more ammonia till the precipitate is re-dissolved, and then drop into it nitric acid to saturate the excess of the ammonia, a precipitate falls down, it is also a portion of acid of molybdena, separate it by the filter, and add it to that obtained before.

IV.—Having done this, add muriate of barytes to the solution in order to ascertain the quantity of sulphuric acid formed during the process, from which the quantity of sulphur may be inferred according to the rules described, page 117.

V.—Having so far proceeded, re-dissolve the molybdic acid obtained in process III. and I. in concentrated sulphuric acid, dilute the solution with 10 times its weight of water, and drop into it ammonia, to neutralize exactly the sulphuric acid, if the molybdic acid was contaminated with iron, it will fall down in the form of a brown oxid.

VI.—To obtain the molybdic acid from the fluid left inexperiment V. evaporate the solution to dryness, and heat the salt to a dull redness, the sulphate of ammonia formed will be volatilized. If on the remaining mass nitric acid now be poured and abstracted from it repeatedly, a yellow powder will be obtained, which is pure molybdic acid.

Remark.—In this analysis the molydena is obtained in the state of an acid, or in combination with oxigen, but in the ore it exists in the metallic state. The composition or proportion of oxigen and metallic molybdena forming the molybdic acid not being yet determined, this analysis can only yield an approximation to truth.

ANALYSIS OF MOLYBDATE OF LEAD.

Process I.—Let one part of the ore be repeatedly boiled in sulphuric acid, till the acid refuse to dissolve any more, this solution which should have so little excess of acid as possible, contains the oxid, or acid of molybdena, and oxid of iron.

II.—The insoluble residue which consists mostly of sulphate of lead, must be boiled for some time with carbonate of soda, and then washed.

III.—Upon the washed precipitate pour very dilute nitric acid, in order to effect a solution. The insoluble powder (if any) is silex.

IV.—Decompose the nitric solution by the addition of sulphuric acid, the precipitate obtained, is sulphate of lead.

V.—Saturate this solution with liquid ammonia, if a precipitate ensues it is iron that was contained in the ore, collect and dry it.

VI.—Having thus far proceeded, subject the sulphuric solution, process I. to the same treatment as stated before, process VI. page 271.

ORDER XIX.

ORES OF CHROME.

Division of Ores of Chrome.

GENUS I.—*Salts of Chrome.*

Species 1.—Chromate of Lead, or Red Lead Ore of Siberia.
2.—Chromate of Iron.

GENUS II.—*Alloys of Chrome.*

Species 1.—Needle Ore.

GENUS III.—*Oxids of Chrome.*

Species 1.—Chrome Ochre.

ANALYSIS OF ORES OF CHROME.

Species 1.—*Analysis of Chromate of Lead.*

Process I.—Let one part of the finely levigated ore be boiled in forty parts of a solution of super-carbonate of potash, containing 3 parts of solid carbonate of potash, for 1 hour at least, renewing the water as it evaporates from time to time, and lastly decant the supernatant fluid.

II.—Upon the mass obtained, which consists of carbonate, and undecomposed chromate of lead, after having been washed in water, pour dilute nitric acid till it ceases to effervesce. The solution is nitrate of lead.

III.—The residue which resists the action of nitric acid, consists of chromate of lead, let it be again boiled with three times its weight of super-carbonate of potash, and a sufficient quantity of water; decant the fluid; apply nitric acid to the residue, and endeavour to effect a solution, which should be added to that obtained before. If any residue remains, treat it in a similar manner, and mingle all the different nitric solutions.

IV.—Having concentrated the nitric solutions, drop into it sulphuric acid, or a solution of sulphate of soda till no farther cloudines sensues; the obtained precipitate is sulphate of lead, 100 parts = to 30 of metallic lead.

V.—To ascertain the quantity of chromic acid add to the alcaline solutions, which were decanted from the carbonate of lead, process I. and III. dilute] nitric acid as long as any effervescence takes place; if the fluid be now evaporated, crystals of chromate of potash mixed with nitrate of potash will be obtained.

VI.—To ascertain the quantity of chromic acid, dissolve the salts obtained in water, and drop into it nitrate of lead till no farther cloudiness ensues. The precipitate is chromate of lead, 100 parts are = to 35 of chromic acid.

The analysis of chromate of lead may likewise be effected by muriatic acid, in the following manner:

Process I.—Take one part of the ore levigated as finely as possible, pour over it 2 parts of muriatic acid diluted with 1 part of water, digest for about 2 hours, decant the fluid, wash the residue, and repeat this operation for several times successively, or until the whole of the chromate of lead is converted into a white powder.

II.—The obtained solution consists of chromic acid, holding in solution a portion of muriate of lead. To get rid of the latter evoporate it, and suffer it to stand undisturbed for a few days, a precipitate will fall down, which is mnriate of lead.

III.—To free the solution from the muriatic acid, add to it gradually oxid of silver, obtained by decomposing a solution of nitrate of silver by potash, till the last portion of this substance acquires a red or purple colour. The whole of the muriatic acid will thus be got rid of, and the fluid contain only chromic acid, in a pure state.

Species 3.—*Analysis of Chromate of Iron.*

Process I.—Let one part of the ore mingled with two of potash, be fused for at least one hour in a silver crucible; pour the mass into a conveninent vessel, and when cold boil it in a sufficient quantity of water, for half an hour, and filter the fluid.

II.—Digest the insoluble part in muriatic acid, decant the solution, wash the residue, and thus treat it alternately with potash and muriatic acid, till the whole is dissolved.

III.—Evaporate the muriatic solution to dryness, wash it in water, and filter it. The residue (if any) is silex.

IV.—Into the fluid from which the silex has been separated drop ammonia in excess. The obtained precipitate is oxid of iron.

V.—Neutralize carefully the alcaline solutions with nitric acid, if a precipitate ensues it is alumine. If to the remaining fluid nitrate of lead be now added, the precipitate which falls down is chromate of lead, 100 parts when dry indicate 35 of oxid, or acid of chrome.

VI.—The nitric solutions which contain a portion of iron, together with perhaps a little chromic oxid, may now be mingled together. To separate the latter, drop into it a solution of carbonate of potash, collect the precipitate, and boil it in a solution of potash. What remains is iron.

The rest of the ores of Chrome may be analysed in a similar manner.

ORDER XX.

ORES OF TITANIUM.

Divison of Ores of Titanium.

GENUS 1.—*Oxids of Titanium.*

Species 1.—Titanium of Kirwan, Red Shorl, or Rutile Brown Titanium.
2.—Brown Ore of Kirwan, Sphene, or Rutilite.
3.—Menachanite, or Black Oxid of Titanium with iron and manganese.
4.—Iserin, or Oxid of Titanium, with Iron and Oxid of Uranium.
5.—Nigrine, Titanite of Klaproth, or Calcareo Siliceous Oxid of Titanium.
6.—Octohedrite, Oisanite, Anatase, or Blue Shorl.

ANALYSIS OF ORES OF TITANIUM.

Specis 1.—*Analysis of Titanium, Red Shorl, or Rutile.*

In this ore oxid of titanium exists in a pure state, or nearly so. Its analysis is very easy, and may be effected thus:

Process I.—Let one part of the ore reduced to an impalpable powder be fused in a silver crucible, with four or five of potash or soda, or carbonate of potash.

II.—Soften the fused mass in water, and boil the whole in that fluid for a few minutes, a precipitate will fall down, which is oxid of titanium nearly pure.

III.—Let the fluid from which the oxid of titanium is separated, be again concentrated by evaporation, it may contain a minute quantity of silex and alumine, and perhaps oxids of iron and manganese, all of which may be separated, as stated before. See analysis of iron ores.

IV.—Dissolve the oxid of titanium in sulphuric acid, on adding to this solution phosphoric acid; the titanium will be precipitated, and the iron, if it contains any, left behind.

Species 2.—*Analysis of Rutilite.*

In this ore oxid of titanium exists with lime and silex. It was analysed by Klaproth thus:

Process I.—One hundred grains of the finely levigated ore were fused for one hour in a silver crucible with four times their weight of potash. The mass being softened with water, and digested in muriatic acid, left undissolved 12 grains of silex.

II.—The muriatic solution was decomposed by carbonate of potash; the precipitate being digested in muriatic acid left 23 grains of silex.

III.—To the solution from which the silex had been separated ammonia was added, till no farther cloudiness ensued. The obtained precipitate, which was oxid of titanium, after being ignited, weighed 33 grains.

IV.—The remaining fluid being saturated at a boiling heat by carbonate of potash, yielded 33 grains of carbonate of lime.

Species 3.—*Analysis of Menachanite.*

In this ore oxid of titanium exists in combination with oxid of iron and oxid of manganese.

A specimen of this ore was examined by Vauquelin in the following manner:

Process I.—One hundred grains of the finely pulverized ore were fused with 400 of potash for one hour and a half: the fused mass was of a green colour. On being softened with water a brick-red powder became separated, weighing 124 grains.

II.—The obtained brick-red precipitate was boiled in a solution of potash for one hour, and the solution, after saturation with muriatic acid, yielded by the admixture of carbonate of potash a precipitate being oxid of titanium, weighing 3 grains.

III.—The remaining insoluble part, left in process II. was digested in muriatic acid, which acquired a yellow colour. The insoluble part, which weighed 46 grains, was oxid of titanium.

IV.—The obtained muriatic solution yielded, by being mingled with ammonia, 50 grains of oxid of iron.

V.—The alcaline solution, process I. was saturated with muriatic acid, and yielded by carbonate of potash 2 grains of carbonate of manganese.

From what has been stated, the analysis of all the rest of the ores of titanium becomes obvious.

ORDER XXI.

ORES OF MANGANESE.

Division of Ores of Manganese.

GENUS I.—*Oxids of Manganese.*

Species 1.—Grey Oxid of Manganese.
  Subspecies 1.—Radiated Grey Oxid of Manganese.
  2.—Foliated Grey Oxid of Manganese.
  3.—Compact Grey Oxid of Manganese.
  4.—Earthy Grey Oxid of Manganese.
Species 2.—Black Oxid of Manganese.
3.—Red Oxid of Manganese.

GENUS II.—*Sulphuret of Manganese.*

Species 1.—Black Sulphuret of Manganese, or Black Blende.

GENUS III.—*Salts of Manganese.*

Species 1.—Phosphate of Manganese and Iron.
2.—Carbonate or White Oxid of Manganese.

ANALYSIS OF ORES OF MANGANESE.

Although the analysis of the ores of manganese is upon the whole not difficult, chemists nevertheless do not agree with regard to the best modes to be practised in the examination of these ores. The proceedings which render the analysis of ores of manganese difficult, effect chiefly the modes of ascertaining with accuracy the quantities of oxid of iron and oxid of manganes, the modes of separating them, as well as the mode of determining that portion of oxigen which is capable of being disengaged, either by the mere action of heat, or by the application of muriatic acid: a circumstance on which the goodness or excellency of these ores when employed for the purposes of the bleacher, chiefly depend.

The foreign matters which are found in ores of manganese are chiefly the following: oxid of iron, silex, barytes, alumine, carbonarte of lime, carbon, and water. These substances are often present in such quantities as to render the ore almost useless to the bleacher. The presence of carbonate of lime is particularly hurtful; for when to this manganese, muriatic acid, or muriate of soda, and sulphuric acid be added, an effervescence takes place, which often forces the bleaching materials into the apparatus destined to receive the gas only, and thus totally spoils the operation.

Hence the ores of manganese most esteemed by the bleachers, are those which are nearly free from foreign matters, and amongst these the manganese of the North-hill mines, near Collington, in Cornwall, and those of Upton pine, near Exeter, undoubtedly hold the first place: they are composed of about 78 of oxid of manganese, whereas none of the ores of this metal discovered elsewhere have been found to contain more than 67 of this oxid.

The analysis for detecting the foreign bodies, found in the ores of manganese, may be conducted in the followign manner:

Take 400 grains of the ore peviously reduced to a fine powder, and dried at 212° Fahr. divide the whole into two equal parts, and treat the first 200 grains in the following manner.

Process I.—Put the ore into a small retort, and pour upon it about twice its weight of moderately dilute and colourless nitric acid; the carbonic acid of the carbonate of lime will be thus disengaged without the application of heat, and may be received in an inverted jar of lime-water; from the regenerated carbonate of lime thus produced, its acid may be calculated according to the known proportions. When the evolution of carbonic acid ceases, transfer the contents of the retort into a flask, add a small piece of sugar, and apply a gentle heat; when the action of the acid has ceased, pour off the fluid, and digest the remainder again with nitric acid and sugar as long as any thing ceases to be taken up; then mix together the nitric solutions and the washings of the undissolved residue.

II.—The residue left in the last process being dried at a heat below ignition and weighed, must be ignited in an open crucible to burn off the carbon, the amount of which will be indicated with sufficient exactness by the difference of weight before and after ignition.

III.—The residue of process II. is next to be boiled to dryness in a silver crucible with thrice its weight of liquid caustic soda; the hardened mass is to be dissolved in dilute muriatic acid, then evaporated nearly to dryness, and again boiled with water; a white powder remains, which is silex.

IV.—Add together the nitric solution, process I. and muriatic solution, III. and pour in liquid ammonia as long as any precipitate takes place; separate it, and add the washings to the clear liquor.

V.—To the clear fluid of process IV. add a slight excess of sulphuric acid, and make the whole boiling hot; the precipitate being speedily separated by the filter and washed, is sulphate of barytes.

VI.—Evaporate the clear fluid of process V. to a very small bulk, and mix it with cold alcohol; the precipitate is sulphate of lime.

VII.—The precipitate of process IV. is now to be digested in soda: when the action of the alcali ceases, pour off the liquor, wash the residue, add the washings to the liquor, neutralize it with muriatic acid, and then pour in carbonate of ammonia, till no further precipitate takes place. The precipitate being washed and ignited is alumine.

VIII.—The residue of process VII. which is insoluble in soda, consists of the mixed oxids of manganese and iron, which may be separated as stated page 189, process X. or, dissolve the mixt oxid in muriatic acid; saturate the solution by potash, and decompose it by succinate of soda, or ammonia: the precipitate is succinate of iron: 100 parts of it, after being ignited with a little wax=to 70 of iron.

IX.—To the fluid of process VII. add soda; the precipitate, when washed and ignited in an open crucible, is oxid of manganese in a pure state.

The component parts of the ore are now all ascertained except the water and loose oxigen, in order to determine these we must have recourse to the second portion of the ore, weighing like the first 200 grains.

Process I.—Put the ore into a small glass retort connected with a pneumatic mercurial apparatus, and make the bulb of the retort moderately red-hot as long as any gas is disengaged. By this means the water will be condensed in the receiver, and the gas will pass forwards into the inverted jar.

II.—The air thus collected being mixed with sulphate of iron, impregnated with nitrous gas, the amount of its oxigen is readily ascertained. The weight of the oxigen added to that of the brown oxid of manganese gives very nearly, though somewhat less than the entire weight of the manganese in the state in which it exists in the ore. The *disposable* oxigen, or that which may be applied to the preparation of oxy-muriatic acid, is found, by deducting 6 per cent. from the brown oxid, and adding this to the weight of the gazeous oxigen. Of the *disposable* oxigen, 16 parts represent 100 of oxy-muriatic acid, produced by distilling together the ore and common muriatic acid, or in any other way.

ANALYSIS OF OXIDS OF MANGANESE.

Sub-species 1.—*Analysis of Radiated Grey Oxid of Manganese.*

A specimen of radiated grey oxid of manganese was examined by Klaproth in the following manner:[*]

Process I.—Two hundred grains of the finely pulverized ore were digested without heat in a sufficient quantity of muriatic acid: a solution was gradually effected, with the extrication of much oxy-muriatic acid gas. The solution, which was of a dark brown colour, was divided in two equal parts, the ores of which were examined in the following manner:

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[*] Analytical Essays, vol. I. p. 243.

II.—Sulphuric acid dropt into the muriatic solution of manganese occasioned no precipitate: hence no barytes could be present.

III.—Triple prussiate of potash occasioned a a slight peach-blossom coloured precipitate, therefore scarcely any oxid of iron was present.

IV.—Carbonate of potash occasioned a white precipitate which did not change its colour on exposure to the air.

V.—Solution of soda or potash produced no effect.

VI.—Water impregnated with sulphuretted hidrogen gas produced no turbidness.

VII.—The other half of the solution was neutralized with a solution of carbonate of potash till a slight turbidness ensued; it was then boiled and filtered, and the insoluble powder which was oxid of iron separated by the filter.

VIII.—To the remaining fluid carbonate of potash was added to full saturation, at a boiling heat; a precipitate was thus obtained, which after being dried and strongly ignited, weighed 88,5 grains.

IX.—Two hundred grains more of the ore were heated thoroughly red-hot in a glass retort, connected with a pneumatic apparatus, the products obtained were 14 grains of water, and 4,5 of oxigen gas. Hence 100 parts of the ore contain

90, 5	Brown oxid of manganese.
2,25	Oxigen.
7	Water.
99,3	

Sub-species 3.—*Analysis of Compact Grey Oxid of Manganese.*

The analysis of this ore was conducted by Vauquelin, thus :*

Process I.—One hundred parts of the finely levigated ore were repeatedly digested in muriatic acid to effect a solution. The residue amounted to 1,6 part : it was a black substance, which on exposure to the air inflamed, and left behind 1,2 parts of silex.

II.—To the obtained solution sulphuric acid was added till no farther cloudiness ensued. It was sulphate of barytes, amounting to 21 parts, which are equal to 14 of barytes.

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* Journal des Min. No. XIX p. 40

III.—To the fluid from which the sulphate of barytes had been separated carbonate of potash was added till no farther cloudiness ensued; the obtained precipitate after being dried and strongly ignited, yielded 48 parts of oxid of manganese. Thus 100 parts of the ore contained

48	Oxid of Manganese.
14	Barytes
1,2	Silex.
4	Carbon.
63,6	

The remaining 36,4 parts requisite to make up the original weight of the ore employed, Vauquelin considers as oxigen employed in the production of oxy-muriatic acid (process I.) This, however, is probably a mistake: the ore perhaps contained some water, of which no notice is taken in the analysis; to this might be added as an established fact, that 100 parts of metallic manganese when precipitated from a solution in an acid by potash or soda, yield 168 black oxid of manganese; and hence 48 parts even of metallic manganese, require only 32 of oxigen.

Sub-species 4.—*Analysis of Earthy Grey Oxid of Manganese.*

The analysis of this ore wes performed by Klaproth in the following manner:*

Process I.—One hundred grains of this ore readily dissolved in the muriatic acid, that was poured upon it in the cold. They afforded with it a very dark-brown fluid: but this, after some digestion, with the assistance of heat, assumed a bright yellow colour. It deposited a blackish-grey sediment, which, upon moderate ignition in a covered crucible, weighed 9 grains. By subsequent ignition in an open vessel, its colour changed to a greyish-white, and its weight diminished about 1 grain. Therefore that blackish colour had arisen from a portion of carbon.

II.—Into the clear muriatic solution was dropped sulphuric acid. It became moderately turbid, and let fall a fine white powder, which, after being collected and examined, proved to be sulphate of barytes. It weighed 1½ grains, equivalent to 1 grain of barytes.

III.—The solution was now combined with

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* Analytical Essays, vol. I. p. 249.

carbonate of potash, till it became turbid, and the mixture heated to ebullition. An oxid of iron separated, weighing 6½ grains, after having been heated red hot.

IV.—From the remaining fluid, left in process III. which was colourless, white oxid of manganese was precipitated by the addition of carbonate of potash at a boiling heat. This oxid being brought to the state of the brown oxid, by igniting it in a covered crucible, weighed 68 grains;

Therefore, the constituent parts of this ore, are,

Brown Oxid of Manganese	68
Oxid of Iron	6,50
Carbon	1,
Barytes	1,
Silex	8,
Water	17,50
	102

The increase of weight, in this sum, probably depends, according to Klaproth, on this circumstance, that the ignited oxid of manganese had afterwards combined with a greater proportion of oxigen, than it contained in the natural composition of the crude ore.

ANALYSIS OF SULPHURET OF MANGANESE.

Process I.—One hundred grains of the ore were strongly ignited in a glass retort, connected with the pneumatic mercurial apparatus. The neck of the retort was found lined with nothing else but a hardly perceivable aqueous dew. The gas obtained was carbonic acid gas, without any trace of sulphuretted hydrogen, and amounted to 7 cubic inches, or about 5 grains in weight.

The remainder of the ignited ore had undergone no change.

II.—Another hundred grains of the same ore were covered by degrees with moderately strong nitric acid. As often as any part of this fluid was poured upon it, a violent action took place, accompanied with an effervescence, and the extrication of sulphuretted hydrogen gas. The mixture was at first turbid and brown; but on affusing the last portion of the acid it became yellow and milky, much heated, and emitted white vapours, which lined the neck of the mattrass with a yellow sulphureous coating: and the sulphur, which, at the beginning, separated in detached delicate flocks, collected in a yellowish grey porous mass.

III.—This mass, when separated by filtration, washed and dried, weighed 16 grains. On being moderately heated, it suffered a loss of 5 grains, which were sulphur and burned off. The residue being treated again with nitric acid, became dissolved; leaving ½ grain more of sulphur.

IV.—The filtered solution possessed a pale reddish colour, but was entirely deprived of it by dilution with water. To one half of it was added a solution of soda. The oxid of manganese, precipitated by it, very soon acquired a brown tinge on exposure to air. The other half of the solution was precipitated by carbonate of soda, the oxid of manganese thus obtained, retained its whitish colour unaltered in the air.

V.—Upon another 100 grains of pulverized ore were poured nitric acid, weakened with twice its weight of water, the vessel being equi-poised, together with its contents. Here the sulphuretted hydrogen gas was disengaged without heat; and that portion of it which escaped, occasioned a loss of 34 grains of weight. What remained of the separated sulphur, floated upon the solution in the form of brown, light flocks. The residue collected on the filter, weighed 3½ grains after drying. When moderately heated, only ¾ of a grain of sulphur burned away. The residue now was soluble in nitric acid, except ¼ grain of sulphur, and a few particles of quartz.

V.—When the filtered pale rose-red solution was precipitated by carbonate of soda, no effervescence ensued. The precipitated oxid appeared of a bright slate-grey; but, even while yet moist, it lost this colour again, and became white by being exposed to the air on the filter. This colour, Klaproth supposes, arose from a slight portion of the sulphuretted hydrogen gas, which still adhered to the precipitate, and was afterwards expelled by the process of washing. Of this carbonate of manganese, dried, the weight was 145 grains; but after it had been strongly ignited in a small retort, to which a receiver was joined, it weighed 82 grains. The ignited oxid retained its white colour, while the vessel was kept closed, except that its surface acquired a brown tinge.

VI.—To this ignited oxid were added, before it cooled, 41 grains of sulphur, and the retort being connected with a receiver brought to ignition in a sand-heat. After cooling the excess of sulphur was found sublimed. The residue weighed 98 grains, and had a pale green colour, This artificial sulphuret of manganese dissolved in dilute nitric acid, like the crude natural sulphuret, with effervescence, and a developement of sulphuretted hydrogen gas. In this experiment hardly any portion of sulphur remained.

VII.—Another clear solution of this black ore of manganese in nitric acid was evaporated in a retort to perfect dryness; it emitted deep red nitrous vapours, at the end of the process. The residue looked like an iron-grey solid mass, in part possessed of a metallic lustre. It was manganese completely saturated with oxigen, at the expense of the nitric acid employed.

VIII.—The muriatic and dilute sulphuric acids dissolve this mineral as easily as the nitric. These solutions were attended with effervescence and extrication of sulphuretted hydrogen gas; they were of a pale-red, and yield, after filtration by the addition of carbonate of potash, a pure, white, carbonate of manganese, which turned black by ignition in an open vessel. When in this state, it was found insoluble in nitric acid: but a perfect and colourless solution was obtained as soon as a little sugar was added. Prussiate of potash afforded with this solution a pale bluish precipitate.

The analysis being now compleated, the constituent parts of this ore are, Klaproth states thus:

White Oxid of Manganese	82
Carbonic Acid	5
Sulphur	11
	98

Concerning the traces of quartz and iron, in in the pure selected specimens of this ore, Klaproth found them too slight to deserve being put in the account.

Remark.—It is singular that Klaproth should enumerate carbonic acid as a constituent part of the ore, for this gazeous fluid would have made its appearance by the action of heat, if simply charcoal had been present. And as sulphuretted hydrogen gas was evolved by the application of nitric acid, there is reason to suppose that the manganese existed in the ore in the metallic state, or at least nearly so. The quantity of sulphur also appears to be rated much too low. For sulphuretted hydrogen gas contains about 71 per cent. of sulphur, therefore 34 grains of the gas contain 24 grains, to which is to be added 1 grain of sulphur, left in the nitric solution, after the disengagement of the sulphuretted hydrogen gas: hence the whole amount of sulphur would be 25 grains; and 82 grains of white oxid of antimony contain 66 of manganese, and 16 of oxigen. Hence the above statement thus corrected would give the component parts of the ore thus:

Manganese........	66
Sulphur	25
Carbon and Oxigen .	4
	100

ANALYSIS OF SALTS OF MANGANESE.

Species 1.—*Analysis of Phosphate of Manganese.*

For the composition of this ore we are indebted to Vauquelin,* who ascertained its constituent parts in the following manner:

Process I.—One hundred grains of the finely levigated ore, were boiled with a solution of potash for some time, and lastly evaporated to dryness in a silver bason.

II.—The alcaline mass was diffused through

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* An. de Chem. XLI p. 242.

water, and the insoluble part separated by the filter. It weighed a little more than the entire weight of the ore employed.

III.—The alcaline solution was slightly supersaturated with nitric acid, and then mingled with lime water till no farther cloudiness ensued. The obtained phosphate of lime, when dried, weighed 60 parts, which are equal to 27 of phosphoric acid.

IV:—The residue which resisted the action of the alcali, process I. was digested in acetous acid, and the whole evaporated carefully to dryness. The same operation was repeated for several times successively, and lastly it was again slightly digested in acetous acid, and the insoluble part separated by the filter. This insoluble part was oxid of iron, weighing 31 parts.

V.—The fluid obtained in process IV. was decomposed by potash; the obtained precipitate, which was oxid of manganese, after being dried, weighed 42 grains.

ORDER XXII.

ORE OF COLUMBIUM.

As only one *single* specimen of this ore is at present known, there are of course no ores of the metal called columbium. Though there is reason to believe that they will be discovered in North America.

ANALYSIS OF THE ORE OF COLUMBIUM.

Mr. Hatchett, who discovered this ore in the year 1802, on examining and arranging the minerals of the British Museum, conducted his analysis in the following manner:

Process I.—One part of pulverised ore was mixt with 5 times its weight of carbonate of potash, and fused in a silver crucible.

II.—The alcaline mass was dissolved in boiling water, the insoluble part separated by the filter, and repeatedly washed in water.

III.—The filtered fluid was mingled with muriatic acid in excess, the result was a white flocculent precipitate, being columbic acid contained in the ore.

IV.—The insoluble residue of process II .was digested in muriatic acid, in order to get rid of the iron; the acid being decanted, the residuum, after being washed, was again fused with carbonate of potash, dissolved and precipitated with nitric acid alternately, till the whole was decomposed.

V.—The muriatic solution was now decomposed by liquid ammonia, a copious ochreaceous precipitate fell down, which was re-dissolved in nitric acid, and the solution decomposed by means of ammonia. The iron was thus obtained.

VI.—The different alcaline solutions were mixed together, and being supersaturated with nitric acid, yielded the same white precipitate, (columbic acid.) The fluid from which the precipitate had been separated by nitric acid, was then saturated with ammonia, and after being boiled afforded a small quantity of oxid of iron. 200 parts of the ore, thus analysed, yielded Mr. Hatchett 42 of oxid of iron, and 155 of columbic acid. For a fuller account of Mr. Hatchett's analysis we refer the reader to his paper in the Philosophical Transactions, 1802, part I. p. 46.

ORDER XXIII.

ORES OF TANTALIUM.

Division of Ores of Tantalium.

With the nature of these ores we are yet but very imperfectly acquainted. The ores of tantalium have been met with in small quantities only, in Sweden. They were discovered by Mr. Eckeberg. These ores are,

Tantalite, a compound of oxid of tantalium, iron, and manganese, and

Yttrotantalite, a compound of tantalium, iron, uranium, tungsten, and yttria. The peculiar metal which exists in these ores is said to be distinguished from all others by being insoluble in any of the acids. Whether this substance will retain its place among the metals, must be left to future investigation; at present we have only the authority of Mr. Eckeberg for inserting it.

The tantalium was obtained from the ore, by treating it repeatedly with alcalies, and nitro-muriatic acid in the usual manner. The alcaline solution, being supersaturated with an acid, deposited a white powder, which is the oxid of tantalium. The specific gravity of it, after ignition, was = 6,5. This oxid after being intensely heated, in contact with charcoal powder, acquired a metallic aspect. For a farther account the reader is referred to the Journal de Min. No. 20, An. x. p: 248.

ORDER XXIV.

ORE OF IRIDIUM AND OSMIUM.

For the discovery of this ore which contains two peculiar metals, we are indebted to Dr. Wollaston, who found it mixed with the ore of platina: it was long mistaken by chemists for plumbago. It has been mentioned already (see ore of platina) that when the ore of platina is digested with nitro-muriatic acid, an insoluble substance is left, containing two new metals, namely, iridium and osmium.

The ore of iridium, which is thus obtained, is an alloy of iridium and osmium, it is harder than the ore of platina, it is composed of scales and partly of a powder of a peculiar lustre. Its specific gravity = 19,7. There are some varieties of the ore of platina, in which this black powder, or ore, exists in larger proportions than in others.

ANALYSIS OF THE ORE OF IRIDIUM AND OSMIUM.

The analysis of the ore of iridium may be accomplished, according to Mr. Tennant, in the following manner:

Process I.—Fuse one part of the ore in a silver crucible, with 4 of potash, for about 1 hour, in a dull red heat; dissolve the mass in water, separate the insoluble residue, and wash it in water. The alcaline solution has a deep orange or yellowish brown colour.

II.—Transfer the insoluble part which resisted the action of the alcali into a Florence flask, cover it with about 4 parts of muriatic acid, and digest it in a gentle heat for 2 or 3 hours. Decant the supernatant fluid, wash the residue in water, and dry it.

III.—Let the powder, left in process II. be again treated alternately with potash and muriatic acid, until a compleat solution is effected. The acid solution contains the muriate of iridium, with a small portion of muriate of osmium, and the alcaline solution contains the oxid of the metal called osmium. To separate these two, proceed as follows:

IV.—Evaporate the solution of muriate of iridium slowly to dryness in a glass capsule, re-dissolve the mass in water, and suffer it to crystallize. The crystals are pure muriate of iridium. If these crystals be exposed to heat, both the muriatic acid, as well as the oxigen, are driven, and metallic iridium is obtained in a state of purity. The metal may likewise be obtained by immersing into the muriatic solution of iridium, any metal, except gold and platina; a black powder falls down, which is metallic iridium; the former process, however, is preferable.

V. The osmium may be obtained by simply distilling the alcaline solution, previously mingled with sulphuric acid in excess. The oxid of osmium is volatilized and passes over with the water into the receiver.

Another mode of obtaining the oxid of osmium consists in distilling at a red heat with nitrate of potash; the black powder procured from the ore of platina. By this means the oxid of osmium sublimes into the neck of the retort in the form of a semi-transparent mass, possessing the properties of the metal called osmium, in a high degree.

ORDER XXV.

ORE OF CERIUM.

Since the printing of the preceding sheets a new metallic ore has been discovered, to which the name of cerite has been given. It was discovered by Heisinger and Berzelius, at Bastnas, in Westmanland in Sweden. The metallic oxid which this mineral contains, was regarded by Klaproth as an earth, to which he gave the name of ochroite. But Vauquelin and the Swedish chemist, who also analysed the fossil, consider it as a metallic oxid, which like yttria forms the connecting link between the earths and metals.

ANALYSIS OF THE ORE OF CERIUM.

Process I.—Levigate a determinate portion of the ore and ignite it. The loss gives the quantity of water.

II.—Digest the ore repeatedly in nitro-muriatic acid till no farther action takes place.

III.—Fuse the residue which resisted the action of nitro-muriatic acid with potash, dissolve the mass in water, evaporate to dryness, pour on the dry mass dilute nitric acid, digest the whole; lastly, decant the fluid. The insoluble part is silex: let it be washed, ignited, and weighed.

IV.—Mingle the nitro-muriatic solution, process I. with the muriatic solution from which the silex has been separated, and decompose it at a boiling heat by the admixture of super-carbonate of potash, and collect the precipitate.

V.—Re-dissolve the obtained precipitate in as little muriatic acid as possible, make it boiling hot, and add to it liquid ammonia in excess, and collect the precipitate. It consists of oxid of cerium and oxid of iron.

VI.—Saturate the ammoniacal fluid obtained in process IV. with muriatic acid, and then add to it carbonate of ammonia, the precipitate obtained is carbonate of lime. This after being exposed to a red heat, gives the quantity of lime that was present in the ore.

VII.—Re-dissolve the precipitate obtained in process IV. in muriatic acid, and drop into it a solution of hydro-sulphuret of potash till the precipitate, which at first will be of a greenish colour, becomes white, and then filter the whole.

VIII.—Into the fluid obtained in process VI. let fall a solution of carbonate of potash, till no farther cloudiness ensues. The precipitate thus obtained is carbonate of cerium. Let it be heated to drive off the carbonic acid.

IX.—Re-dissolve the precipitate obtained in process VI. in as little muriatic acid as possible, and then neutralize the solution by potash. If to this fluid a solution of sulphate of soda is added, a precipitate falls down, which is sulphate of cerium; separate it by the filter.

X.—To the fluid from which the sulphate of cerium is obtained, add liquid ammonia in excess, a precipitate ensues, which is oxid of iron.

XI.—Transfer the sulphate of cerium, process IX. into a flask, and boil it with about 4 times its weight of carbonate of potash, and a sufficient quantity of water, it will thus become converted into carbonate of cerium. If this carbonate of cerium, together with that obtained before, process VII. is exposed to a red heat, till all the carbonic acid is expelled, the metal will be left behind in a pure state.

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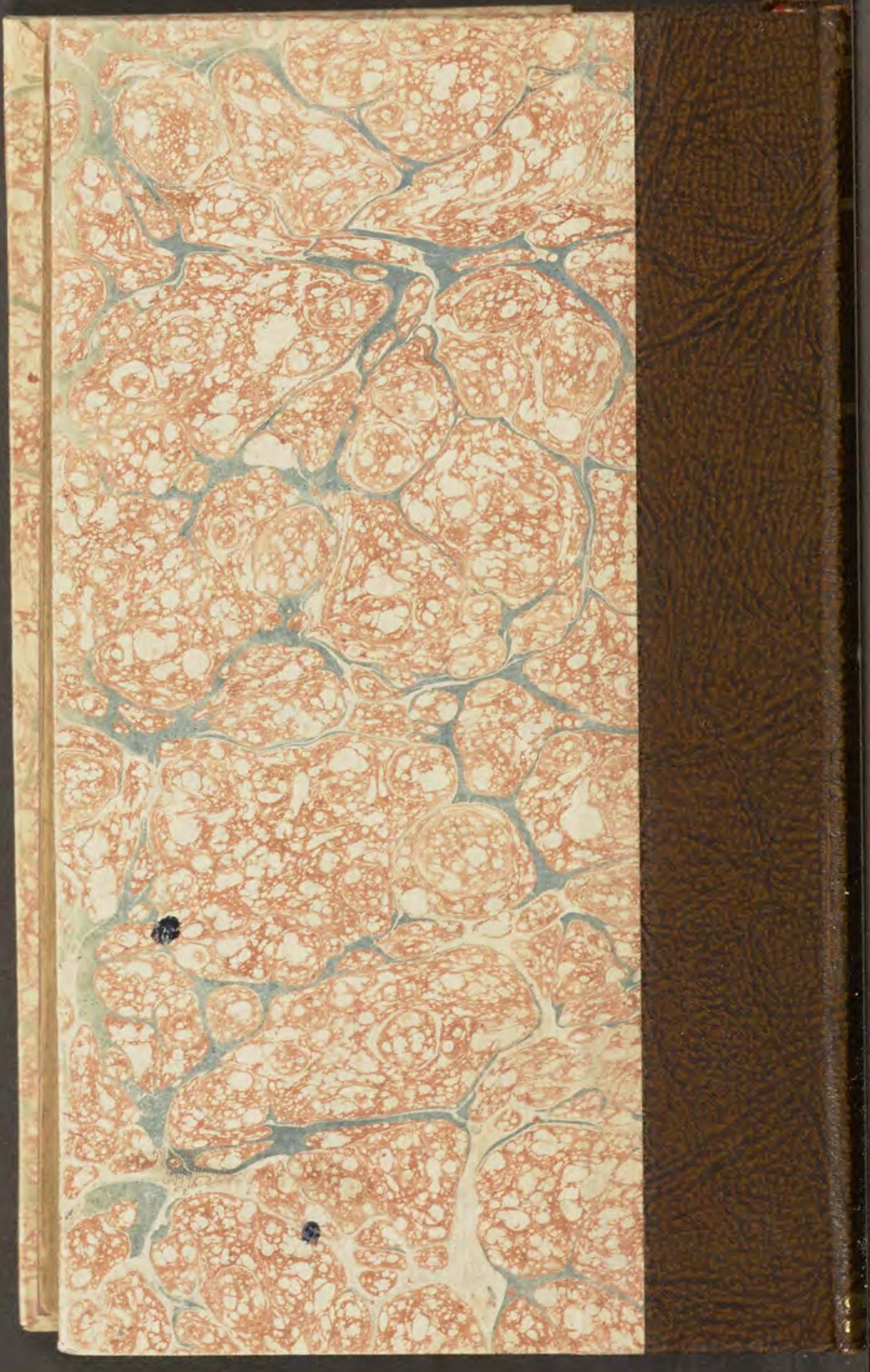

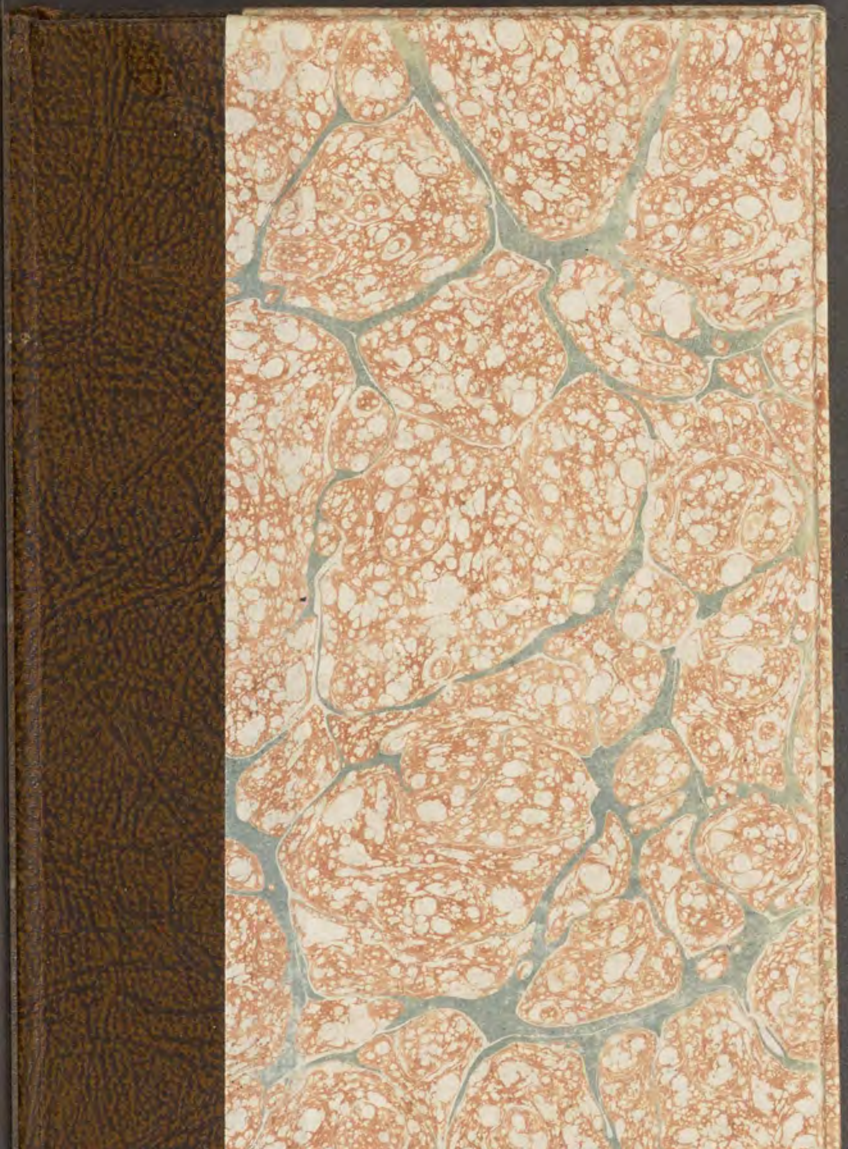

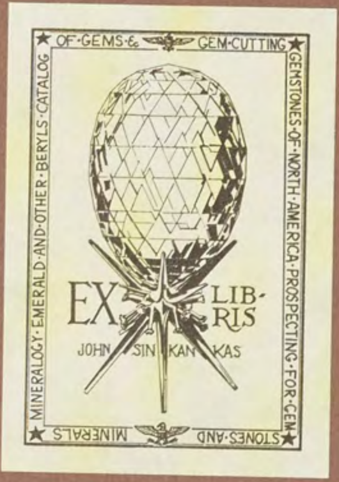
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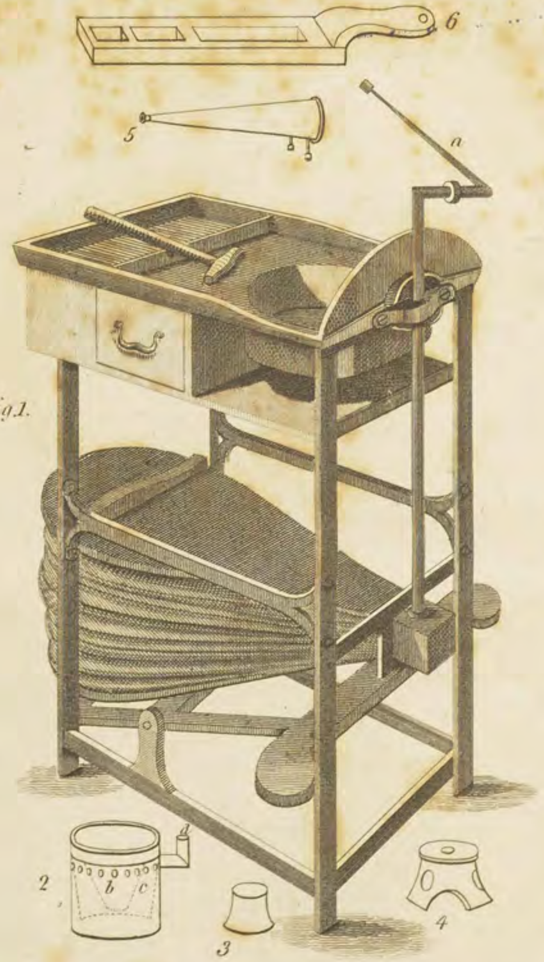

J. K. Paulding. 195

A
MANUAL
OF
ANALYTICAL MINERALOGY,

INTENDED TO FACILITATE THE

PRACTICAL
ANALYSIS OF MINERALS.

IN TWO VOLUMES.

BY
FREDRICK ACCUM,

HONORARY MEMBER OF THE ROYAL IRISH ACADEMY;
OPERATIVE CHEMIST;
LECTURER ON EXPERIMENTAL CHEMISTRY, AND ON MINERALOGY,
AND PHARMACY.

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EARTHY MINERALS,

OR

EARTHS AND STONES.

VOL II.

THE orders of stones, like those of the ores of metals, are founded on the fundamental property of their constituent parts. Each order derives its name from the particular earth which constitutes its most predominant part, and to this the different earths and stones, in which the simple earth forms the predominant, or at least the most characteristic one, are referred, allowance being made for the present imperfections of chemical analysis, and due attention being paid to analogies of other properties.

The number of simple earths known at present amount to nine. They are the following:

Silex, or Flint,
Lime, or Calcareous Earth,
Alumine, or Clay,
Magnesia,
Barytes
Strontia,
Glucine,
Zircon,
Yttria.

It is obvious, therefore, that the same orders of stones must exist.

In the strictest sense of the word, there is certainly no natural foundation for such divisions, because the discoveries of chemists have shewn that several stones are composed of two, three, or even four simple earths, and in other instances the earths of which the stone is composed are present in nearly equal quantities; hence with some mineralogists it has not been so much the chemical composition as the external characters which have been adopted in the distribution of these mineral substances.

Whenever the analysis of a stone, or earthy compound has been effected, we have reason to presume that a similarity of composition will exist in other specimens which agree with it closely in external properties or characters.

CHARACTERISTIC PROPERTIES OF EARTHS AND STONES.

Stones, if considered chemically, are either masses of simple earth or different earths, chemically combined, or earths united to an acid; they sometimes contain a small quantity of an alcali, but more generally some metallic oxids; the latter give to them the beautiful colours which many of them exhibit.

The class of earth and stones are sufficiently distinguished from other minerals by certain negative properties. They may be discriminated from ores by their specific gravity being always below 5, and by their acid solutions not being precipitable by prussiates, nor by water impregnated with sulphuretted hydrogen (yttria excepted) they are distinguished from inflammable fossils by their incapability of burning in contact with air, or when heated with nitrates, or with hyperoxe muriate of potash, and from the class of salts, by their want of saline taste, and insolubility in water.

NATURAL HISTORY OF EARTHS AND STONES.

The slightest acquaintance with the stony substances that come under our inspection, is sufficient to convince us that they were once in a soft or liquid state. A vast number of them have a regular symmetrical arrangement, they have been crystallized like salts, and must therefore have been separated from their solvent, whatever that may have been. The variety of crystals of stones discover all the figures and modifications of forms, observable in other substances, when suffered to crystallize under favourable circumstances. Moreover, many stones inclose organized substances, which they could not have admitted, but when in a soft or fluid state; others are evidently formed round different bodies, as these, having received their shape and form, the operations of art could never have introduced themselves into them.

The mere inspection of the general masses of our earth, the totality of which have a tabular form, called mineral strata, also convinces us that the surface of our globe has at one time been in a fluid state, to the greatest depth as well as the utmost height which have yet been reached.

The parallelism of the mineral strata can be accounted for on no other rational principle, it could have been produced only by subsidence from a fluid at rest, and as it extends over the entire surface of the earth, it establishes the general fluidity of the whole. The spheroidal figure of our globe itself is a demonstration that its surface to a depth much greater than we have penetrated must have been at one time fluid, or at least soft and yielding.

The bare mention of these circumstances is sufficient, as this point cannot possibly be disputed. The only difficulty that offers itself is, to ascertain the nature of that fluid which was capable of holding in solution, or perhaps in suspension, that immense mass of solid substances of which the stony part of the globe consists. Concerning this subject different theories have been advanced. Kirwan remarks, that with regard to stony matters placed deeper than one mile beneath the level of the sea, we have no reason to affirm that they were ever in a soft state, as we are absolutely unacquainted with them; with respect to those that are nearer to, or on the surface of the earth, we may for the present suppose that fluid to have been in most cases mere water, in some circumstances assisted by other agencies, and in comparatively much fewer cases, aided by volcanic fires. In vain, however, have philosophers endeavoured to form perfect theories of this subject. If it were permitted to man to follow, during several ages, the various changes which are produced on the surface of our globe, by the numerous agents that alter it, we might perhaps be in possession at this moment of the most valuable information respecting this subject; but thrown as we are upon a small point of this vast theatre of observation, we can only fix our attention for a minute to reason upon subjects which have employed the works of nature for ages, and disappear ourselves at the moment wherein we have proceeded so far as to collect a few facts.

It must nevertheless be acknowledged that those men who by the mere efforts of their imagination, have endeavoured to form ideas respecting the construction and the great phenomena of this subject, have numerous claims to our indulgence. Amongst these we have to mention particularly Kirwan, Hutton, and Werner. In their proceedings we behold the efforts of genius tormented with the desire of acquiring knowledge, and irritated at the prospect of the scanty means which nature has put in its power. They have endeavoured to embellish their hypotheses with every ornament which imagination and eloquence can furnish, either as instruments of illusion or entertainment: we ought to consider ourselves highly indebted to them.

For a circumstantial detail of these theories, as well as the nature and position of the mineral strata, their geometrical measurement, and modes of exploring them, &c. the reader is referred to the author's System of Mineralogy and Mineralogical Chemistry, vol I. part II. sect. 1 to 5, and part III. sect. 1, 2, and 3.

ANALYSIS OF EARTHS AND STONES.

The class of minerals called earths and stones, being far more extended than those called ores, which we have considered, no general method of analysis can be given that might prove useful to the student of mineralogical chemistry. We shall therefore adhere to the mode already adopted and shall examine the different orders of earths and stones, one by one.

ORDER I.

SILICEOUS STONES.

Division of Siliceous Stones.

The stones in which flint abounds are very abundantly diffused throughout the world.—They appear to have been intended by nature to constitute the nucleus or solid part of our globe, to serve as a foundation for the original mountains, and to give them that hardness and durability which has enabled them to resist the various revolutions which the surface of our planet has successively undergone. The profoundest excavations that have hitherto been made by art into the crust of our earth, have all uncovered a rock called granit which is chiefly composed of flint.

The stones belonging to this order, are more numerous than the rest.

The greatest number of the most beautiful stones, which are cut and polished, and worn as luxuries or ornament, belong to this class, such as the Bohemian ruby, the occidental topaz, the amethyst, and all the gems distinguished by lapidaries and jewellers, by the term occidental, besides those beautiful stones known by the names of carnelian, agate, opal, mocha stones, jaspar, calcedony, &c.

The order of siliceous stones may be considered under the following heads: namely,

GENUS I.

Siliceous Stones almost wholly composed of flint, or siliceous earth in a state nearly pure.

GENUS II.

Siliceous Stones composed chiefly of flint, with a portion of alumine.

GENUS III.

Siliceous Stones composed chiefly of silex, and a portion of alumine and lime.

GENUS IV.

Siliceous Stones composed chiefly of silex united to magnesia and lime.

GENUS V.

Siliceous Stones composed chiefly of silex, combined with magnesia, lime, and alumine.

GENUS VI.

Siliceous Stones composed chiefly of silex, combined with alumine and barytes.

GENUS VII.

Siliceous Stones composed chiefly of silex, united to alumine or lime, or both, and a portion of an alcali.

The metallic oxids which are usually met with in all stones, we omit to notice in the arrangement.

CHARACTERS OF SILICEOUS STONES.

Most, or at least, a great number of the stones belonging to this order are transparent; they have a vitreous appearance, and a high polish, at least when almost wholly composed of silex. They are very hard, when pulverised they form a powder harsh to the touch, which scratches or wears away metals, and scratches glass. They are not acted upon by any acid, the fluoric excepted. They likewise fuse with alcalies, and form with them, in certain proportions, glass. They also melt with glacial acid of phosphorus, and with boracic acid. They do not adhere to the tongue, they do not discover any peculiar odour when breathed on, nor do they form a tenacious mass with water. Their specific gravity is seldom more than 2,88.

It is obvious that every one of these characters is not rigorously applicable to each of these bodies. But the totallity of them possess a certain number, which renders these preliminary statements, perhaps useful to beginners.

When a stone possesses some, or most of the characters which may be considered as peculiar to the siliceous order, we may proceed to ascertain with more certainty whether it really belongs to it, or not, in the following manner:

ANALYSIS OF SILICEOUS STONES.

Genus I.—*Analysis of Siliceous Stones almost wholly composed of Flint or Silex, in a state nearly pure.*

Process I.—Let a weighed quantity of the stone, broken into small fragments, be heated to redness in a covered crucible, plunge it suddenly into cold water, and repeat this operation for several times successively, or till the stone is become considerably friable. Another portion of the stone may be heated red-hot for some hours and weighed, to learn whether it sustained any loss during this operation, which loss, if any, is water.

II.—Having done this reduce one part of the stone, thus previously rendered pulverisible, to an impalpable powder, in an agate mortar, mix it with four parts of potash, dissolved in a like quantity of water, put the mixture into a silver crucible or bason, and evaporate it over the flame of a lamp, or in a sand-bath to dryness, keeping it constantly stirred with a silver rod, to prevent the mixture from swelling and throwing part of the mass out of the crucible or bason. When the whole is evaporated to perfect dryness, place the silver crucible into a larger earthen-ware one, surrounded by sand, and expose it to a dull red heat just sufficient to fuse the mass, and keep it in that state for at least two hours, taking care not to augment the fire which would endanger the melting of the silver crucible. Instead of potash, as here directed, carbonate of potash may be used, but in that case at least six parts of the salt to one of the stone should be employed, the former however is preferable.

From the appearance of the fused alcaline mass in the crucible, some conjectures may be formed respecting the predominant earth contained in the stone; for if the mass flows thin like oil, we may be certain that silex forms the most predominant part. If it fuses pasty, opake, and is apt to swell and puff up, we are certain that silex does not form the chief constituent part, but that other earths are present in considerable quantity. If the mass when cold is of a reddish or brown colour, it contains probably a portion of oxid of iron, and if green, oxid of manganese may be suspected.

III.—When the mass has been fused, as stated before, remove the crucible out of the fire, wipe it quite clean on its outside, place it in a bason, and soften the contents of it, by dropping into it distilled water, and lastly effect a solution by adding to it about 10 or 12 times its weight of water, and boil the mixture for a few minutes in a Florence flask, or bason. If the stone was composed entirely of silex, a compleat solution will be the result. If it contained other earths, or oxids of metals, they will remain behind undissolved. These may be separated by filtration, and the modes of examining them will be seen in the sequel.

IV.—To the obtained alcaline solution add gradually muriatic acid. The first portion of the acid which is added will occasion a flocculent precipitate, which will increase by adding more acid, and give the whole a gelatinous appearance; but, if no precipitate should ensue, the acid should be added in excess.

V.—The obtained gelatinous mass, or apparent solution, should next be evaporated to dryness in a glass or wedgwood bason; if the fluid was transparent it will certainly assume a gelatinous form as it becomes more concentrated by evaporation; it should then be diligently stirred with a glass rod, till it has a granular appearance like sand, taking care not to heat it too much.

VI.—Transfer this mass into a Florence flask, cover it with muriatic acid, and digest it in that fluid for some time, decant the fluid, wash the residue, and add the water employed for that purpose to the decanted acid. The solid product obtained is silex. If it be pure it will be perfectly white, entirely insoluble in sulphuric, nitric, and muriatic acid. If it be coloured, it is contaminated with some metallic oxid, and shows that the evaporation to dryness has been performed with too much heat.

From the metallic oxid it may be freed by digestion in muriatic acid, or by igniting the whole with a little wax, and then digesting it in muriatic acid, which operation will render the oxid soluble in the acid, from which it may be separated by adding to it ammonia in excess. The silex thus purified is perfectly white, and insoluble in sulphuric, nitric, and muriatic acid: let it be freed from its water by exposing it to a red heat, and then weigh it. The deficiency of the weight of the sum total, gives the quantity of foreign bodies that are contained in the muriatic solution, process VI. or which are not acted on by the alcali in process I. The mode of separating them will be exhibited presently. The quantity of oxid of iron which is usually present in all coloured stones, may be separated by prussiate of potash, or succinate and ammonia.

To render what has been stated as obvious as possible, we shall advance several analyses of siliceous stones, as performed by Klaproth.*

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* Analytical Essays, vol. I. p. 440.

Example 1.—*Analysis of the Noble Opal.*

Process I.—A piece of noble opal, weighing $76\frac{1}{2}$ grains, was exposed to heat, in a covered crucible. It crackled at the very first application of the fire. When the noise had ceased, it was kept in ignition for half an hour longer. After cooling, the stone was found broken into small slaty splinters, of a milk-white colour and of an enamelled lustre. The yellowish ochry covering, which is perceivable even in the rough stone, and which often penetrates its minute fissures, was changed to a high yellow-red, exhibiting the colours of the rainbow. Its loss in weight was $7\frac{1}{2}$ grains, or about 10 per cent. which is to be considered as water.

II.—Hundred grains of the same stone were next finely pulverized in a flint mortar with water, and mixed with 300 grains of soda, the mixture was subjected to a moderate red-heat for two hours, in a silver crucible.

III.—The alcaline mass, obtained in process II. was gradually softened with water, supersaturated with muriatic acid, and then digested in that fluid. The fluid formed a gelatinous mass as it cooled. This mass being again diluted with water, and again digested in muriatic acid, yielded silex in the form of a white powder, which being thoroughly washed and ignited, weighed 90 grains.

IV.—The muriatic solution, together with the water employed for washing the silex, was reduced to a small bulk by evaporation, and mingled with liquid ammonia in excess; by this means only a very small quantity of a brownish flocculent precipitate separated, consisting of oxid of iron, amounting to about $\frac{1}{10}$ of a grain, after being ignited.

But, since the very pure white colour of the ignited opal evidently proved, that this slight portion of oxid of iron does not essentially belong to its constitution; and since, besides, not the least perceptible trace of any other earth appeared, Mr. Klaproth only reckons the real constituent parts of the noble opal, the following:

Silex..................	90
Water.................	10
	100

Example 2.—*Analysis of the White Opal.*

Process I.—Half an ounce of this stone, finely levigated, and intimately blended with one ounce of soda, was moderately ignited for two hours. The obtained mass was ground to powder, saturated with muriatic acid in excess; then evaporated nearly to dryness, again diluted with water, and finally thrown upon the filter. The residue being washed, dried, and ignited, yielded 237 grains of silex.

II.—The fluid from which the silex had been separated was diminished by evaporation, and combined with liquid ammonia; it afforded a slight quantity of a brownish precipitate. As the remaining fluid continued unaltered, on being mingled with carbonate of soda, it shewed, by this, that it held no other substance in solution, for otherwise a precipitate would have ensued.

III.—The precipitate obtained in process II. being re-dissolved in muriatic acid, and decomposed by dropping into it prussiate of potash, afforded some Prussian blue, of which the oxid of iron, that enter as a constituent part into this opal, was estimated, at most, one quarter of a grain. This being separated, carbonate of soda, added to the solution, still precipitated half a grain of alumine earth, which, after ignition, could not be estimated at more than one-quarter of a grain.

Thus it was found that the stone called white or common oxpal, consists chiefly of silex; for half an ounce of it yielded:

Silex.............	237	grains.
Alumine	0,25	
Oxid of iron	0,25	
	237,50	
Loss	2,50	
	240 grs. or ½ oz.	

Example 3.—*Analysis of the Yellow, or Pitch Opal.*

Process I.—One hundred grains of this fossil, broken into coarse fragments, were exposed to red-heat for half an hour in a covered crucible. The stone flew in pieces, with a crackling noise. It was slightly transparent, after this ignition, but only on the edges; its colour also was changed into a pale brownish-yellow, and the loss of weight, which it experienced, amounted to five grains. After this operation it was found very friable, and allowed of being easily ground to a subtle yellow powder.

Remark.—A stronger heat renders this opal greyish-white. The slight portion of iron which it contains, and from which it derived its colour, is reduced, in this process, to the reguline state; for by means of a good magnifying lens, extremely fine grains of iron, that have transuded, may then be discovered.

II.—The above-mentioned 95 grains of ignited and pulverised opal were mixed with 200 grains of dry carbonate of soda, or such as had lost its water of crystallization on exposure to the air, and the mixture exposed to a moderate red heat during one hour. It was next softened with water; supersaturated with muriatic acid; concentrated by evaporation to a hard jelly; once more diluted with water; and, lastly, thrown upon the filter. The silex, which, by this management was obtained, weighed 93½ grains, after having been ignited.

III.—The colourless muriatic fluid from which the silex had been obtained, was then mingled with liquid ammonia, added in excess. By this means a few brown flocks separated, which collected and ignited, afforded one grain of oxid of iron. The remainder of the fluid contained no other ingredient.

Hence one hundred grains of the yellow opal, consist of:

Silex	93,5
Oxid of Iron	1
Water	5
	99,5

Example 4.—*Analysis of the Brown-Red Semi-Opal.*

Process I.—One hundred grains of this stone finely levigated, were mixed with a solution of potash, containing 300 grains of solid alcali. The mixture, being first evaporated to dryness in a silver vessel, was next ignited for half an hour. On being suffered to cool it was softened with water; super-saturated with muriatic acid; next inspissated to a gelatinous consistence, and again diluted with water, digested, and filtered. The iliceous earth thus obtained, after being ignited, veighed 43½ grains.

II.—The muriatic solution was combined with liquid ammonia in excess. A quantity of brown oxid of iron fell down, which weighed 47 grains, when washed, dried, and ignited. The fluid left by this, remained unchanged, when combined with carbonate of potash: hence it contained no other earths or metallic oxids.

III.—The oxid of iron was re-dissolved, in muriatic acid, and precipitated by prussiate of potash. After the separation of this blue prussiate of iron, the remaining solution was examined, first with liquid ammonia, and next with carbonate of soda. It suffered no change in either case.

Therefore this stone, which, from its large proportion of iron, might, perhaps, deserve to be classed under the genus of iron ores, with the denomination of opaline iron stone, is, in the hundred, composed of

Silex	43,50
Oxid of iron	47
Water	7,50
	98

Such is the mode of examining stones chiefly composed of silex, we shall now proceed to the examination of those in which alumine enters as a constituent part.

GENUS II.—*Analysis of Siliceous Stones chiefly composed of Silex and Alumine.*

Process I.—Take one part of the finely levigated stone, fuse it with potash, as directed before, process II. page 324; soften the mass with water, as stated, process III. decompose the alcaline solution by muriatic acid, and ascertain the quantity of silex, according to the rules of process IV. V. VI. &c.

II.—Having learnt the quantity of silex, endeavour to effect a solution of the mass which resisted the action of the alcali, in process II. and which consequently could not be dissolved in water, nor perhaps by the muriatic acid; digesting it in that fluid, and then mingle this solution with the muriatic fluid from which the silex has been obtained. Concentrate the whole by evaporation as much as possible, and add to it, while boiling hot, a solution of carbonate of potash or soda, till no more precipitate ensues. Separate the precipitate by the filter, wash, and dry it. The precipitate obtained consists of alumine, if no other earths were present in the stone.

III.—To separate and to ascertain the quantity of this earth, transfer the precipitate into a Florence flask; pour over it about 3 times its weight of a concentrated solution of potash or soda, evaporate the mixture nearly to dryness, add to it water, and separate the insoluble part, if any, by the filter. The alumine will thus be dissolved in the potash or soda, whilst the other substances remain untouched in the form of a powder.

IV.—To ascertain the quantity of alumine, decompose the alcaline solution by the admixture of muriatic or nitric acid, taking care to add the acid in excess, so that the precipitate which first appeared becomes re-dissolved.

V.—Into the muriatic solution drop carbonate of ammonia in excess. The precipitate thus produced is carbonate of alumine. This precipitate after having been washed, dried, and exposed to a low red-heat in a crucible, gives the quantity of pure alumine, which was present in the stone, with tolerable accuracy.

Alumine may likewise be separated by ammonia, but not compleatly. For that purpose, liquid ammonia is to be added to the fluid from which the silex is separated. The precipitate obtained is alumine, provided no metallic oxid was present. The former process, however, is preferable. The demerits of the latter will be pointed out hereafter; for, although ammonia is a very good test to detect the presence of alumine, it cannot be used to ascertain the quantity of this earth when present in an acid solution.

EXAMPLE I.—*Analysis of the Saxon Hydrophan, or Occulus Mundi.*[*]

Process I.—One hundred grains of the Saxon hydrophan were coarsely bruised, and ignited in a retort. At the end of this process there appeared, in the receiver, an empyreumatic water, covered with a thin pellicle. The loss of weight was 5¼ grains.

II.—The stone, thus freed from water, was triturated to a subtle powder, mixed with twice its weight of soda, and fused in a silver crucible in a moderate heat for two hours. When the mass had cooled, it was super-saturated, and digested with muriatic acid to separate the silex. The muriatic solution being separated from the siliceous earth, together with the water em-

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[*] Klaproth's Analytical Essay, vol. I. p. 443.

ployed for washing it, was concentrated by evaporation, and saturated with ammonia; by which means a precipitate was produced, consisting of alumine, unmixed with iron, weighing $1\frac{5}{8}$ grains after ignition. Nothing farther was found in the remaining fluid.

One hundred parts of this hydrophane, from Saxony, therefore contain:

Silex	93,125
Alumine	1,625
Empyreumatic water	5,250
	100

EXAMPLE II.—*Analysis of the Transparent Chinese Agalmatolite, or Pagodite.*

Process I.—Two hundred grains of this stone finely pulverised, lost 11 grains of weight on being moderately ignited for half an hour.

II.—One hundred grains of this stone, freed from water were mixed with equal parts of carbonate of soda, and again subjected to a red heat for half an hour in a silver crucible. The mixture was diluted with water, and super-saturated with muriatic acid, which dissolved the whole without leaving any residue. But when the solution had been put in a sand-heat to evaporate, it formed a thick gelatinous mass; after digesting it for some time, it was filtered. The collected siliceous earth, washed and ignited weighed 105½ grains.

III.—The muriatic solution, freed from its silex, being saturated with potash, thickened to a milk-white mass; which, by a slight excess of alcali, again dissolved entirely to a limpid, colourless fluid, leaving only a few light, brown, loose flocks behind, weighing four grains.

IV.--These four grains of brown residue were digested with muriatic acid. Siliceous earth, weighing 2½ grains in the ignited state, was thus separated. This being done, the solution was next combined with prussiate of potash, and the blue precipitate produced collected; the portion of iron, which it contained, amounted to 1½ grains. Nothing else was found in the remaining fluid.

V.—The alcaline solution, process III. being saturated in excess, with sulphuric acid, and decomposed, at a boiling heat, with sub-carbonate of soda, yielded a precipitate, consisting of alumine. This alumine being purified by acetic acid, (see analysis of argillaceous stones) after being dried, weighed 72 grains. Hence 100 parts of the stone contain

Alumine, process	V.		36
Silex	II.	52,¾	54
	IV.	1,¼	
Oxid of Iron	IV.		0,75
Water	I.		5,50
			96,25

GENUS III.—*Analysis of Siliceous Stones composed of Silex, Alumine, and Lime.*

Process I.—Fuse the levigated stone with potash.

II.—Dissolve the alcaline mass in water, and decompose it by muriatic acid to obtain the silex, as stated before.

III.—Digest the residue, which resisted the action of the alcali, in muriatic acid.

IV.—Mingle the obtained muriatic solution with the fluid from which the silex has been separated; concentrate it by evaporation, and decompose it by the admixture of carbonate of potash. This precipitate consists of alumine and lime.

V.—To separate the alumine, boil the precipitate in a solution of potash, see page 336, and obtain the alumine, as stated, process IV. and V. &c. page 337.

VI.—To ascertain the quantity of lime, dissolve the insoluble part, left in process V. in muriatic acid, mingle the fluid with sulphuric acid in excess, and evaporate the mixture to dryness. The obtained compound is sulphate of lime.

VII.—To ascertain the quantity of lime, digest the product obtained in process VI. in water, decant the fluid, dry the sulphate of lime, and lastly expose it to a dull red heat, weigh it, and deduct from it 59 per cent. the remainder gives the quantity of lime which was present in the stone.

Example 1.—*Analysis of the Opake Chinese Agalmatolite, or Pagodite.*

Process I.—Two hundred grains of the stone finely scraped off from the mass, suffered a loss of 20 grains by ignition.

II.—This ignited powder was a second time exposed to red heat for half an hour, in a silver crucible, with its own quantity of dry carbonate of soda, which caused it to agglutinate. The mixture, previously drenched with water, was combined with an excess of muriatic acid, and evaporated slowly till it assumed a gelatinous appearance. When this had again been diluted with water, it deposited silex, amounting to 122 grains, when collected on filtering paper, and subsequently washed and ignited.

III.—The muriatic solution was decomposed by carbonate of potash, and the thorough separation of the precipitate was promoted by boiling. The precipitate which subsided in a highly porous state, was washed, and while yet-moist, transferred into a warmed solution of potash, in which it dissolved instantly, and left only a slight brownish residue.

IV.—Muriatic acid entirely dissolved this brownish residue, and by combining it with prussiate of potash, Prussian blue fell down, the quantity of which denoted one grain of iron in the stone.

V.—The fluid, after the separation of the iron, was decomposed in a boiling heat with carbonate of potash, which precipitated a white earth, which effervesced with sulphuric acid, and deposited gypsum; the quantity of which increased, in proportion as the volume of the mixture was reduced by evaporation. It weighed, after ignition, five grains, equal to two grains of pure calcareous earth in the ignited state. The small quantity of the fluid yet remaining yielded crystals of sulphate of alumine.

VI.—The portion which had been taken up by the alcaline lye, process III. was precipated by sulphuric acid, but it dissolved again by a slight excess of sulphuric acid. The alum last obtained in process IV. was then added to it, and the whole precipitated by carbonate of potash, assisted by a boiling heat. When afterwards washed, dried, purified by means of acetous acid,* and finally heated to redness, the precipitated alumine weighed 50 grains.

VII.—The obtained alumine was then covered with sulphuric acid, and the mixture evaporated to perfect dryness. The turbidness of the fluid, on being again dissolved in water, was caused by a portion of siliceous earth, which separated, and

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* See Analysis of Argillaceous Stones.

consisted of two grains after ignition. This being subtracted, the quantity of alumine, process V. is reduced to 48 grains; which now, by combination with acetite of potash, and crystallization, continued to the end to yield alum only.

It follows, from this decomposition of the Chinese agalmatolite, that its constituent parts give in the hundred:

Silex	Process II. VI.	61 1	62
Alumine	VI.		24
Lime	IV.		1
Oxid of iron	IV.		0,50
Water	I.		10
			97,50

Example 2.—*Analysis of the Stone called Cat's Eye.*

Process I.—Two hundred grains of the finely levigated stone were mixt with 400 of carbonate of soda, and exposed in a silver crucible to ignition for four hours. The mass was softened with water, saturated in excess with muriatic acid, and the siliceous earth separated in the usual manner: it weighed 189 grains.

II.—The muriatic solution, mixed with the water, employed for washing the silex, was concentrated by evaporation, and saturated while yet hot with carbonate of soda; the precipitate, when dried, weighed 15 grains.

III.—The obtained precipitate entirely dissolved, with effervescence, in muriatic acid.—Only a slight portion of silex remained, which after being ignited amounted to one grain.

IV.—After the grain of silex had been separated, liquid ammonia was added to the solution. A yellowish-white precipitate was thrown down; which being separated by filtration, washed and boiled, while yet moist in caustic potash, left behind oxid of iron, weighing one half grain.

V.—The alcaline solution, process IV. was mixed with muriatic acid, and the precipitate being re-dissolved by a slight excess of acid, it was again precipitated by carbonate of soda.—When washed, and dissolved in sulphuric acid, it yielded crystals of alum. This sulphate of alumine was dissolved in water, and again precipitated by carbonate of soda. The alumine, when washed and ignited, weighed three grains and a half.

VI.—The fluid which remained, after the precipitation had been effected by ammonia, process IV. was combined in a warm temperature with carbonate of potash, by which means carbonate of lime subsided, which formed selenite (sulphate of lime) when covered with sulphuric acid, see page 311. The lime separated weighed three grains

Since, therefore, 200 grains of this stone afforded

Alumine, process	V.		3½
Silex	I. III.	189 1	190
Lime	VI.		3
Oxid of iron	IV.		½
			197 grs.

It follows, that it contains in one hundred,

Silex	95
Alumine	1,75
Lime	1,50
Oxid of Iron	0,25
	98,50
Loss	1,50
	100

GENUS IV.—*Analysis of Siliceous Stones containing silex, magnesia and lime.*

Process I.—Fuse one part of the finely levigated stone with 3 or 4 of potash, as directed, process II. page 324.

II.—Dissolve the alcaline mass in water, and separate the silex by muriatic acid, see process III. page 325 and 326.

III.—Digest the insoluble matter left in process II. in muriatic acid, mingle the obtained solution with the fluid from which the silex has been separated, and evaporate the whole nearly to dryness.

V.—Cover the mass with sulphuric acid, evaporate the mixture, and lastly, heat it till no more fumes rise. This mass consists of sulphate of lime and sulphate of magnesia.

VI.—To separate the sulphate of magnesia pour a small quantity of water on the dry mass, and digest it for a few minutes, the sulphate of magnesia will become dissolved, and the sulphate of lime will be left behind.

VII.—To learn the quantity of magnesia, decompose the solution of this salt, obtained in process VI. by carbonate of potash, dry the precipitate, and expose it to a red heat for about half an hour, or till it dissolves in dilute muriatic acid without effervescence.

VIII.—To learn the quantity of lime, dry the sulphate of lime, (process VI.) expose it to a dull red heat, and weigh it. 59 per cent. being deducted from it, the remainder gives the quantity of lime.

GENUS V.—*Analysis of Siliceous Stones composed of Silex, Alumine, and Barytes.*

Process I.—Fuse one part of the stone with potash, dissolve the mass in water, and separate the silex, as directed before, by muriatic acid.

II.—Dissolve the insoluble mass, left in process I. with muriatic acid; mingle the solution with the fluid from which the silex has been obtained, and decompose the mixture by carbonate of potash: this precipitate consists of carbonate of alumine and carbonate of barytes.

III.—Re-dissolve the mixt precipitate in muriatic acid, and drop into it sulphate of potash, or sulphuric acid, till no farther cloudiness ensues. The obtained precipitate is sulphate of barytes.

IV.—Boil the sulphate of barytes, with four or five times its weight of carbonate of potash in a sufficient quantity of water, for at least two hours, supplying the water as it evaporates. By this means a double exchange of principles takes place, the sulphuric acid of the barytes joins to the potash, and forms sulphate of potash, which is kept in solution; and the carbonic acid of the carbonate of potash goes to the barytes forming carbonate of barytes, which remains at the bottom. If this artificial carbonate of barytes be exposed to a violent heat, its carbonic acid will be disengaged, and the barytes be left behind in a pure state.

V.—To ascertain the quantity of alumine, evaporate the fluid from which the sulphate of barytes has been separated, process III. to a small compass, decompose it by carbonate of potash: the precipitate obtained is carbonate of alumine.

VI.—Boil this precipitate in a solution of potash or soda, and decompose the alcaline solution by muriatic acid: the precipitate obtained is alumine.

For some farther particulars with regard to the separation of alumine from lime and magnesia, the reader is referred to the analysis of argillaceous stones, and to page 336.

GENUS VII.—*Analysis of Siliceous Stones composed chiefly of Silex and Alumine, with a portion of an Alcali.*

For the following easy and expeditious method of analysing stones, containing an alcali in combination, we are indebted to Mr. Davy.*

Process I.—Let one hundred grains of the stone finely levigated be fused in a platina or silver crucible for half an hour, in a strong red heat, with 200 grains of boracic acid.

II.—Digest the fused mass in 1½ oz. of nitric acid, diluted with 7 or 8 times its quantity of water, till the whole is decomposed; concentrate the fluid, by which means the silex will become separated, if any was present; let it be washed with water, to free it from the adhering boracic acid, and saline matter.

III.—Evaporate the fluid from which the silex has been separated to about 16 cubic inches or less; drop into it a solution of carbonate of ammonia in excess, and boil the mix-

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* Philosoph. Trans. Part II. 1805.

ture for a few minutes; and then separate the insoluble part. By this means all the earths and metallic oxids that were present in the stone are separated.

IV.—Let the fluid next be mingled with nitric acid till it tastes strongly acid, and again evaporate it till the whole of the boracic acid is separated; nothing now remains but the nitric acid in combination with the alcali of the mineral, and with ammonia.

V.—To free the mass from the nitrate of ammonia, let it be evaporated to dryness, and expose it to a heat of about 500, the nitrate of ammonia will be decomposed, and become volatilized in the gazeous state, and the nitrate of potash or soda remain behind in the vessel.

VI.—To obtain the alcali in a pure state, the nitric acid may be driven off by exposure to a dull red heat. To learn whether the alcali be potash or soda, drop into its solution in water, muriate of platina, which will occasion a buff or orange-coloured precipitate with potash, but not with soda.

The remaining earth, viz. the alumine, may be separated as stated before.

Remark.—The presence of potash in a stone containing alumine may also be detected by boiling the finely powdered mineral repeatedly to dryness, with concentrated sulphuric acid, then washing the dry mass with water, adding to it a little excess of acid; and, lastly, evaporate the solution to a small bulk. If crystals of alum should appear, it is a proof of potash, because this salt can never be obtained, in a crystallized form, without the addition of this alcali.

But, since a stone may contain potash, and a little or no alumine, in which case no crystals of alum can be formed, it is necessary, in the latter case, to add a portion of alumine to the sulphuric acid. Or the mineral may be so hard as to resist the action of sulphuric acid; it will then be necessary to fuse it (in the manner directed before,) with soda. The fused mass is to be dissolved in water, and supersaturated with sulphuric acid. It should next be evaporated to dryness, re-dissolved in water; and filtered, to separate the silex. The solution on being evaporated affords crystals of sulphate of soda, and afterwards crystals of sulphate of potash, should the latter alcali be contained in the mineral.

Klaproth first discovered potash in the leucite. On summing up the results of its first analysis, he found that there appeared to be a considerable loss of weight, and by boiling the stone with diluted muriatic acid, and evaporation, he obtained crystals of muriate of potash.—Another proof of the presence of potash was, that, when sulphuric acid was boiled with it, the solution gave crystals of alum, to which potash is essential. He also boiled the stone with muriatic acid, and, after dissolving the muriate of alumine by alcohol, muriate of potash remained. The leucite contained less potash than other kinds. The same alcali has also been detected in lepidolite, and in several other stones.

The potash contained in sulphate of alumine, may be separated from the earth by adding a solution of barytes as long as any precipitate is produced. The alumine and sulphate of barytes will fall down together, and the potash remain in solution. Its presence may be known by the tests, already stated.

Soda may be detected in a mineral by the following experiments: Let the powdered stone be treated with sulphuric acid, as stated before; wash off the solution, and add pure ammonia till the precipitation ceases; then filter, evapoporate the solution to dryness, and raise the heat so as to expel the sulphate of ammonia:

The sulphate of soda will remain, and may be known by its characters.

We shall conclude this subject by giving the analysis of several minerals containing an alcali, as performed by Klaproth.

Example 1.—*Analysis of Cryolite.*

Process I.—Sixty grains of cryolite finely levigated, were mixed in a platina bason with 120 grains of sulphuric acid, covered with a pane of glass, which had a thin coating of wax and characters traced through it. Very soon fluoric acid vapours arose, by which, after 12 hours, the uncovered glass was found etched to a considerable depth. The mass was upon this diluted with water, and evaporated to dryness. When the remaining saline mass, had again been mixed with water and filtered, a white earth was left on the paper.

II.—The obtained solution, on being again evaporated, yielded, as before, a crystallized saline mass; but as a portion of uncombined sulphuric acid still adhered to it, it was separated by the affusion of alcohol, which being decanted and combined with liquid ammonia, let fall another slight quantity of earth. This, together with that before obtained, was dissolved in sulphuric acid.

III.—The concrete salt, that has been washed with alcohol, was re-dissolved in water, and suffered to evaporate spontaneously. It yielded regular clear crystals, weighing 18½ grains, which were found to be sulphate of soda. The remainder of the solution coagulated in the open air into an irregular, small-grained saline mass, which, being dissolved in water, was mixed with the above-mentioned solution of earth in sulphuric acid, process II. then precipitated with carbonate of ammonia, and filtered. The precipitated earth, being washed, was entirely soluble in a solution of soda, poured on it whilst yet moist. After this solution had been again neutralized by sulphuric acid, it was decomposed by carbonate of potash. The obtained precipitate being re-dissolved in sulphuric acid, and combined with a proper proportion of potash, yielded crystallized sulphate of alumine.

IV.—The fluid from which the alumine had been obtained by carbonate of ammonia, was first neutralized with acetic acid, and then precipitated by acetate of barytes. The filtered solution was evaporated to dryness, and lastly, heated to redness in a platina crucible. The melted saline mass being rendered blackish from the admixture of coal, was again dissolved in water, and freed by filtration from the coaly particles. It was then evaporated, and yielded 26 grains of dry carbonate of soda. This salt, saturated with nitric acid, yielded regular rhomboidical crystals of nitrate of soda, weighing 40 grains.

" Thus have I," says Klaproth, " besides the two constituent parts of cryolite mentioned by Abildgaard, unexpectedly found soda as its third essential constituent part. My satisfaction occasioned by this discovery was heightened by the circumstance, that cryolite is the first instance that came to my knowledge of a stone, in which soda is contained in a constituent part."

Mr. Vauquelin, who likewise has examined cryolite, suspects that, perhaps, during the decomposition effected by sulphuric acid, part of the aluminous ingredient is carried off along with the fluoric acid. In fact it would hardly be possible to explain, in what manner 28 per cent. of alumine, the quantity fonnd by Vauquelin in that fossil, should be capable of fixing such a quantity of fluoric acid as is necessary to make the neutral compound, which is generated by this combination, amount to 100 grains.—

However, this difficulty is removed by the presence of soda discovered in the mineral.

For the purpose of determining the proportions of the constituent parts of cryolite, Mr. Klaproth repeated its analysis in the manner, we shall now describe.

Process I.—To free 100 grains of cryolite, entirely from its fluoric acid, they were digested and evaporated to dryness in a platina crucible with 300 grains of concentrated sulphuric acid. The mixture boiled at first, emitting fluoric acid vapours and numerous air-bubbles. The residue, previously drenched with water, gelatinized on evaporation to a soft, granular saline mass, which readily became soluble in a little water.

II. Liquid ammonia precipitated from the clear solution the alumine earth which weighed 46 grains when edulcorated and dried, but 24 when ignited. The solution of this earth, in dilute sulphuric acid, with the assistance of heat, and combined with a proper proportion of pot-ash, yielded regular crystals of alum.

III. The fluid, from which the alumine had been precipitated by ammonia, was first neutralized with acetic acid, then combined with acetate of barytes, and filtered to separate the sulphate of barytes. The clear fluid was now wholly evaporated; the dry residue, after being ignited in a platina crucible, was re-dissolved, and being rendered free, by filtration, from the few adhering coaly particles, was a second time evaporated to perfect dryness. It thus afforded 62 ½ grains of dry carbonate of soda, equal to 36 grains of soda. This product being saturated with acetic acid, yielded crystallized acetate of soda.

If we now from the quantity of the fossil employed, subtract the weight of alumine and soda obtained, the remainder will give the weight of the fluoric acid, including, perhaps, the water of crystallization. One hundred parts of cryolite, therefore, consist, according to this analysis, of

Soda	36
Alumine	24
Fluoric acid, including water	40
	100

Example 2.—*Analysis of Sonorous Porphyry.*

This stone is also called Klingstone, or Echodolite, or Phonalite, was accomplished by Klaproth thus:

Process I.—One hundred grains of the finely powdered stone, were mixed with a solution, or lye, containing 250 grains of pot-ash, when inspissated and ignited in a silver crucible. It acquired at first a blackish colour, which afterwards disappeared. The ignited mass was greenish, it was softened with water; muriatic acid was added in excess, it dissolved the whole, and afforded a clear solution. This solution assumed a greenish appearance on evaporation to drynes: the dry mass was re-dissolved in water sharpened with a little muriatic acid, and the siliceous earth separated in the usual manner. It weighed 57¼ grains.

II.—The muriatic fluid was mingled with liquid caustic ammonia, the obtained precipitate was of a light brown colour, the excess of ammonia in the remaining fluid, first neutralized with muriatic acid, yielded a slight precipitate by oxalate of ammonia, which, collected and exposed to a strong red heat, left 2¼ grains of carbonate of lens.

III.—The light brown precipitate, process II. was transferred into a boiling solution of pot-ash. It soon was taken up, leaving a residue of blackish brown flocks, which were collected on a filter. The solution, when supersaturated with muriatic acid and precipitated with carbonate of ammonia, yielded carbonate of alumine earth, which, dried and ignited, weighed 23½ grains; and when combined with sulphuric acid and pot-ash, yielded pure acedulous sulphate of alumine.

IV.—The residue, left un-dissolved by the solution of pot-ash, yielded with muriatic acid a yellow tincture. This solution was perfectly neutralized, and then decomposed with succinate of soda. The succinate of iron obtained, after being ignited, amounted to 3¼ grains.

V.—The residue of this yellow fluid, process IV. was examined with carbonate of ammonia. This alcali threw down another small portion of a yellowish white earth, which became black after ignition: it weighed ¾ grain. On being dissolved in a few drops of muriatic acid, and combined with sulphuric acid, it yielded sulphate of lime. That small portion, which remained of it, being combined with ammonia, then evaporated and ignited, left an oxid of manganese behind, which imparted a clear amethyst colour when fused with phosphoric acid. The mentioned ¾ of a grain may be estimated at ½ grain of lime, and ¼ grain of oxid of manganese.

Finding, that the sum of the products, obtained in this decomposition, was by far too short of the weight of the mineral employed, and thus shewed that another constituent part was to be sought for, the following experiment was again undertaken.

VI.—Upon 300 grains of the stone, finely triturated, were poured, in a retort, 600 grains of sulphuric acid, diluted with an equal quantity of water; the whole was digested for a while: and lastly, the fluid distilled over to moderate dryness. The fluid in the receiver was poured back upon the residue a second time, digested, and again abstracted by distillation. The mass left in the vessel was softened by boiling water, the fluid filtered; the obtained residue washed, dried, and ignited. It weighed 258 grains. As the merely silicious part would have given no more than 171$\frac{3}{4}$ grains; it was evident, that the sulphuric acid had been incapable of effecting a thorough decomposition of the stone: as also could well be inferred even from the little change the residue had undergone.

VII.—On concentrating by evaporation, the sulphuric solution, there appeared 10$\frac{1}{2}$ grains of sulphate of lime in thin needles; which, being removed, the evaporation of the saline fluid was continued with a gentle heat to the point of crystallization; but the crystals formed on cooling, were unlike the crystals of alum.

VIII.—These crystals being re-dissolved in water, the solution was mixt with the fluid that remained after the crystallization, and the whole precipitated with ammonia. When the brown precipitate had been filtered off, the clear fluid was evaporated to dryness. The obtained mass was exposed to a heat of so high a degree that the sulphate of ammonia was volatilized. A salt of 22 grains weight remained behind, which was sulphate of soda.

However, since by this treatment with sulphuric acid the fossil was found but partially decomposed, and therefore, the proportion of the soda could not exactly be determined, the following experiments were made:

IX.—One hundred grains of the levigated stone were mixed by trituration, with 400 grains of crystallized nitrate of barytes, and in a capacious vessel exposed to a heat gradually raised to ignition.

X.—The fused mass being suffered to cool, was pale blue, spongy, and easily pulverizable. When softened with water and treated with muriatic acid it dissolved entirely, yielding a clear, yellow solution. This solution was evaporated, and at the same time gradually combined with as much sulphuric acid as was necessary not only to precipitate the barytes in the state of sulphate of barytes, but also that the same acid, after the total expulsion of the muriatic acid, continued notably predominant in the fluid.

XI.—Having reduced the saline mass to a moderate dryness, it was again diffused through water: the insoluble part consisted of sulphate of barytes and the siliceous ingredient of the stone. The fluid was mingled with ammonia, the precipitate obtained was filtered off, the neutralized liquor evaporated to dryness, and then kept in a moderately intense heat, until all the sulphate of ammonia was driven off. The remaining portion when dissolved in water and crystallized, proved to be pure sulphate of soda. This was again dissolved, and decomposed with acetate of barytes; the precipitated sulphate of barytes was separated, the filtered clear fluid evaporated, and the dry acetate of soda heated to redness in a platina crucible. The coaly residue gave by solution in water and filtration, a clear, colourless fluid, which upon evaporation to dryness left 14 grains of carbonate of soda, of which the portion of soda makes $8\frac{1}{10}$ grains. This, when neutralized with nitric acid, yielded crystals of nitrate of soda.

“ Yet it may be fairly supposed,” says our author, “ that, in the natural composition of the stone, the soda exists in a somewhat greater proportion than is indicated by the quantity obtained. For, besides that in general some loss is unavoidable in the different operations, I think that already at the ignition of the barytes a certain portion of the soda is volatilized: which to suppose I am induced to believe from the vapours which visibly escape in a filamentous form on removing the lid of the vessel.

After these operations we now return to the results of the analysis. These then give the constituent parts and their proportions in the hundred, as follows:

Silex	process I.	57. 25
Alumine	III.	23. 50
Lime	II. 2. 25 V. 0. 50	2. 75
Oxid of Iron	IV.	3. 25
Oxid of Manganese.	IV.	0. 25
Soda	XII.	8. 10
	Loss	5. 5
		98. 10

"The reflecting natural philosopher will know, without our suggesting it, how to appreciate the value of this discovery of the presence of soda, as a constituent part, in a stone which occurs in masses of the size of whole mountains. It opens to him a new view, and leads him a long step farther in his geological inquiries. We now see that there is no longer any occasion for the theory hitherto prevailing, according to which it was imagined necessary to consider all the soda, which in nature occurs either in a free, that is uncombined, or in a carbonated state, arising from a decomposition of common salt, or of sea salt, or of that from saline springs, supposed to have been carried on by nature, and to have taken place in an unknown manner."

The sonorous porphyry, employed in the preceding experiments, was obtained from the Donnersberg, near Milleschau, the highest of the middle mountains in Bohemia. The whole mass of this majestic mountain, which is above two thousand five hundred feet high, extending to many square miles, absolutely consists only of this very stone.

If we reflect, that in this enormous mass of rock, the soda constitutes nearly the twelfth part of the whole mountain, it will not be thought an exaggeration to say, that this mountain alone is capable of supplying for a long succession of years to come, all Europe with a sufficient quantity of soda; presupposing however, that experiments should be devised to separate this alcali from the stone by a cheap and profitable method, and which there is reason to hope the brilliant experiments of the decomposition of alcalies, lately discovered by Davy, will soon be accomplished.

Example 3.—*Analysis of the Pitchstone.*

Process I.*—One hundred grains of pitchstone from Meissen, in coarse fragments, were heated to redness for thirty minutes, in a covered crucible. They returned from the fire of a white-grey, marbled with yellow, opake, and of a meager and rough feel, though they had naturally an appearance of glazing. They lost 8½ grains in weight.

II.—One hundred grains of this finely pulverized pitch stone were mingled with a solution of 200 grains of soda, and the mixture evaporated in a silver crucible, and kept for half an hour

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* Klaproth's Analytical Essays, vol. II. p. 205.

in a moderately strong red heat. The mass was white, inclining to bluish. After being softened with water and saturated in excess with muriatic acid, 73 grains of silex were obtained in the usual manner.

III.—The muriatic solution from which the silex had been obtained, was mixed in excess with soda, and digested in a heat of ebullition. In this process most of the precipitate formed at the beginning, again became dissolved; yet leaving a brown insoluble residue. This being separated, the alcaline fluid was neutralized with muriatic acid, and precipitated with carbonate of soda. The alumine of which the precipitate consisted, was weighed, dried, and ignited. It amounted to 14½ grains. The whole of it combined with sulphuric acid and potash, yielded crystals of alum.

IV.—That small portion of the precipitate, which was left undissolved by the alcali, process III. was first dissolved in muriatic acid, and then combined with sulphuric acid. Sulphate of lime was generated, which was collected and washed with weak alcohol. The filtered fluid being again reduced to a smaller compass by evaporation, and then combined with sulphuric acid, yielded another small portion of sulphate of lime. The quantity of this together with the first, weighed three grains, which indicate one grain of lime.

V.—The fluid, being now freed from lime the portion of iron which it yet contained was precipitated by carbonate of ammonia. It weighed one grain. The remainder of the fluid was evaporated to dryness; and on re-dissolving the saline mass in water, oxid of manganese separated in fine, minute flocks, the slight quantity of which could not be estimated higher than $\frac{1}{10}$ grain.

IV.—Having so far proceeded, one hundred grains of pulverized pitch stone were mixed with 300 grains of nitrate of barytes in crystals, and ignited in a porcelain vessel till the nitrate had been entirely decomposed. The mass being softened in water, was first neutralized with muriatic acid, and then combined with sulphuric acid in such a proportion, that the latter, on evaporating the mixture, and after the muriatic acid had been expelled by heat, remained still preminant. The evaporated mass was washed with hot water, the residuum separated by filtration, and the clear fluid saturated with carbonate of ammonia added in excess. After the precipitate produced by this means, had been separated the fluid was reduced to a dry salt by evaporation, and its portion of sulphate of ammonia volatilized in a porcelain vessel exposed to a moderate heat. A salt thus remained, consisting sulphate of soda. This being re-dissolved and decomposed by acetate of barytes, the filtered solution was evaporated to a red heat in a platina crucible. The saline residue being re-dissolved, filtered, and again evaporated to dryness, gave three grains of carbonate of soda, amounting to 1¾ grains of soda; which neutralized with nitric acid, yielded the usual rhomboidal crystals of nitrate of soda.

Therefore, one hundred grains of this pitch stone from Meissen consist of:

Silex	process II.	73.
Alumine	III.	14. 50
Lime	IV.	1.
Oxid of Iron	V.	1.
Oxid of Manganese	V.	0. 10
Soda	III.	1. 75
Water	I.	8. 50
		99. 85

Example 4.—*Analysis of Pumice Stone.*

Process I.—One hundred grains of finely pulverized pumice stone, were mixed with 300 grains of crystallized nitrate of barytes, and the mixture exposed to an intense red heat, till the nitrate of barytes was compleatly decomposed.

II.—The ignited mass was powdered, drenched with water, dissolved in muriatic acid, supersaturated with a sufficient quantity of sulphuric acid, and evaporared to dryness.

III.—The mass was elixiviated with water, passed through the filter, the clear sulphuric solution decomposed with carbonate of ammonia, and the precipitate collected on the filter.

IV.—The fluid from which the precipitate was obtained was a second time evaporated, and the remaining dry salt ignited till the sulphate of ammonia had been entirely driven off. There remained a fixed neutral salt.

V.—This product was dissolved in water; the solution decomposed by acetate of barytes, the fluid after separating the produced sulphate of barytes, was evaporated to dryness, and the residue exposed to a strong red heat. On a subsequent solution in water, filtration and evaporation to dryness, there remained five grains of a carbonate of soda, which being saturated with nitric acid yielded nitrate of soda. For those 5 grains of carbonate of soda, 3 grains of pure soda must be put in the account.

But as the figure of the crystals of nitrate of soda seemed to pass into prisms they were dissolved in a little water, and mingled with a saturated solution of tartareous acid. A notable quantity of acidulous tartrite of potash deposited in small grains, which shewed that the obtained soda was contaminated with potash.

To determine the proportion of potash to that of soda in pumice stone, was not well practicable in this experiment, on account of the small quantity.

However, by the result from this experiment the sum of the constituent parts of pumice stone was rendered more complete, namely:

Silex	77. 50
Alumine	17. 50
Oxid of iron, and a little magnesia	1. 75
Soda and Potash	3.
	99. 75

Example 5.—*Analysis of Basalt.*

In the chemical decomposition of basalt, undertaken by Klaproth, the principal design was to ascertain whether this stone, was geognostically allied with the sonorous porphyry, and whether like this it contains soda as a constituent part.

Process I.—For this purpose, one hundred grains of levigated basalt were mixed with 400 grains of nitrate of barytes, and treated in the same manner as has been stated before: 4½ grs. of dry carbonate of soda were obtained, which are equal to 2,60 grains of soda. The other constituent parts Klaproth proved in the following manner:

II.—One hundred grains of pulverized basalt were ignited, for two hours, with 400 grains of carbonate of soda, at a degree of heat at which the mixture would not fuse. It agglutinated into a moderately hard yellow mass, which being powdered, and softened in water, was neutralized with muriatic acid, next supersaturated with nitric acid, and evaporated to dryness. The dry mass, which had a yellow colour, was diffused through water a little acidulated with muriatic acid, and after a short digestion filtered. The silex obtained weighed, after ignition, 44½ grains.

III.—The muriatic solution was precipitated at a temperature of 212° Fahr. by carbonate of soda. The obtained precipitate was digested with a solution of soda, and the residue separarated by filtration. The alcaline fluid, when combined with muriatic acid, added in a small excess, was precipitated with carbonate of ammonia. By this means alumine fell down, amounting to 16¾ grains, when washed and ignited: and yielding alum when treated with sulphuric acid and potash.

IV.—The brown residue of process II. was dissolved in muriatic acid, carefully watching the precise point of saturation, and to the solution was added succinate of ammonia to precipitate the iron. The obtained succinate of iron, when washed and ignited, gave 20 grains of oxid of iron attractable by the magnet.

V.—The fluid, thus freed from iron, was treated, in a boiling heat, with carbonate of soda. The white precipitate produced was dissolved in nitric acid, and the solution combined with sulphuric acid, which threw down a considerable quantity of sulphate of lime. This being separated, the remainder of the fluid was evaporated almost to dryness, again diluted with a mixture of water and spirit of wine, and the sulphate of lime then separated was added to the preceding. The sulphate of lime was next composed by boiling it with carbonate of soda; and the carbonate of lime thus obtained, washed and dried, weighed 17 grains, which indicate 9½ grains of lime.

VI.—The fluid remaining from the last operation was mixt with soda, which occasioned a slimy precipitate: this was dissolved in sulphuric acid, and evaporated. At the first impression of heat, brown loose flocks fell down which left the solution colourless. These flocks, separated by filtration, proved to be oxid of manganese; yet their slight quantity permitted only an estimation by guess at about ⅛ grain.

VII.—The small quantity that yet remained of the fluid was evaporated to dryness, and the residue exposed in a crucible to a strong red-heat. This, being re-dissolved in water, left another slight portion of alumine, tinged by iron, and contaminated with manganese, weighing ½ grain; but the clear solution entirely crystallized into sulphate of magnesia. The earthy base of this salt, precipitated in the carbonated state by carbonate of soda, weighed 6 grains; for which must be accounted $2\frac{1}{4}$ grains of magnesia.

From this analysis of the basalt result the following constituent parts:

Silex	process II.	44. 50
Alumine	III. IV.	16. 75
Oxid of Iron	V.	20.
Lime	V.	9. 50
Magnesia	VII.	2. 25
Oxid of Manganese	VI.	0. 12
Soda	I.	2. 60
Water	I.	2.
		97. 72

With these results pretty well agree those of the analysis which Bergmann has published in his valuable dissertation, *De productis vulcanicis*, namely:

Silex	50
Alumine	15
Lime	8
Iron	25
Magnesia	2
	100

Though Bergmann mentions the lime in the carbonated state, yet he has omitted to prove that it is contained as such in the composition of basalt. But what concerns the soda, it is no matter of wonder that it has escaped his attention, since at that time it could not be suspected that this alcali should one day appear in the state of an essential constituent part of solid stones.

TABULAR ARRANGEMENT

OF

SILICEOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.*

Siliceous Stones composed of Silex nearly in a state of purity.

Crystallized quartz, or rock crystal
Purple quartz, or amethyst
Blue quartz, occidental saphir, or water saphir
Smoky quartz, or cairn gorum crystal
Black quartz
Blood-red quartz, or compostella hyacinth
Phrase, or green quartz

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* For the external characters of these, and the rest of the mineral substances mentioned in this Essay, the reader is referred to the author's System of Mineralogy.

Chrysophrase
Rose, or milk quartz
Iridiscent quartz
Spangled quartz, or avanturine
Compact, or common quartz
Fibrous quartz
Hialin quartz

Siliceous Stones containing a considerable portion of Alumine.

Chalcedony
Cocholong, or milk white chalcedony
Iridescent cocholong
Onix
Sardonix, or red striped onix
Agate
Landscape agate
Ribbon agate
Moss agate, or mocha stone
Tube agate
Star agate
Clouded agate
Coral agate
Jasper agate
Punctuated agate
Agatized wood

Jasper
Egyptian jasper, or Egyptian pebble
Opal jasper
Striped, or banded jasper
Opal
Noble opal
Hydrophan opal
Semi opal
Wood opal
Jasper opal
Hyalite, or Muller's glass
Menelite
Cat's eye
Heliotrop, or blood-stone
Carnelian
Flint
Jasper flint
Pitchstone
Pimelite
Plasma
Hornstone petrosilex, or chert
Rhomboidal hornstone
Red hornstone
Hornstone porphyry
Woodstone, or agatized hornstone
Jasperized hornstone

Siliceous Stones containing Alumine and lime.

Zeolite
Mezotype, or radiated zeolite
Fibrous zeolite
Mealy zeolite
Lamellar zeolite, or stilbite
Analcime cubicite, cubic zeolite
Lomoniti, or efflorescent zeolite
Aedilite, or siliceous zeolite
Crocolite
Paranthene, micarel, scapolite, rapidolite
Thalite, epidote, arandalite, delphenite, acanticone, acanticonite, pistacite, or strahlite
Scorza
Garnet
Noble garnet
Bohemian garnet, or pyrope, carbuncle
Common garnet
Topazolite
Alochroite
Dauorite
Zoisite
Yanite
Diopside
Bergmanite

Chusite
Fuscite
Gabronite
Limbelite
Petalite
Pseudo nepheline
Tabular spar
Succinite

Siliceous Stones containing a portion of magnesia, alumine, and lime.

Melanite, or black garnet
Dialage, smaragdite, or emeraldite
Schiller spar
Pistacite
Anthophilite
Malacolite, or sahlite
Pyroxene, augiti, volcanite, or black volcanic shorl
Amphibole, or hornblende
Common hornblende
Basaltic hornblende
Labrador hornblende
Shorlaceous hornblende
Meïonite

Siliceous Stones containing a portion of alcali, with alumine, silex, and lime.

Lepidolite
Leucite, or amphigene
Natrolite
Pumice stone
Andalusite, or mecaphilite
Retenite, or deadolite,
Pitchstone
Echodolite, or sonorous porphyry
Adularia
Common feldspar
Ichtyopthalmite
Obsidian
Vitreous obsidian
Black obsidian
Green obsidian
Pearlspar
Marekanite
Crysolite, cryolite, fluate of alumine and soda
Porcelain jasper
Basalt
Basaltic hornblende

ORDER II.

CALCAREOUS STONES.

Division of Calcareous Stones.

To this class of earths and stones belong all those minerals in which lime forms the most predominant, or most characteristic part. They may be divided in the following manner:

GENUS I.—*Native Carbonates of Lime; or Stones chiefly composed of Calcareous Earth united to Carbonic Acid.*

GENUS II.—*Sulphates of Lime; or Stones chiefly composed of Lime and Sulphuric Acid.*

GENUS III.—*Fluates of Lime; or Lime combined with Fluoric Acid.*

GENUS IV.—*Phosphates of Lime; or Stones chiefly composed of Lime united to Phosphoric Acid.*

GENUS V.—*Borates of Lime.*

GENUS VI.—*Arseniates of Lime.*

CHARACTERS OF CALCAREOUS STONES.

The totality of the characters peculiar to the class of calcareous stones, are chiefly the following: They do not scratch glass. They do not fuse with alcalies into a homogenous transparent mass. They do not fuse with glacial acid of phosphorous, or with boracic acid. They do not adhere to the tongue, nor do they form a kneadable mass when reduced to powder, and mixt with water. They can all be scratched with a penknife or steel point. Most of them are more or less acted on by, or are soluble in, nitric or muriatic acid, or are at least so after having been boiled with a solution of sub-carbonate of potash. Their neutral solution in acids are all decomposable by oxalates, and fluates of soda, potash, and ammonia, and the precipitate is insoluble in nitric or muriatic acids.

ANALYSIS OF CALCAREOUS STONES.

As it is impossible to point out a ready method which could be applicable to the examination of all stones of this genus, we shall consider them under two sections, namely:

1st.—*Calcareous stones which are readily soluble in nitric or muriatic acid, dilute with* 3 *or* 4 *parts of water, and with more or less effervescence.*

2dly.—*Calcareous stones which are not soluble in nitric or muriatic acid; or at least far more difficult, and which do not effervesce.*

To the first species belong all the stones properly called carbonates of lime, or lime-stones. They may be distinguished and analysed in the following manner:

ANALYSIS OF CALCAREOUS STONES WHICH ARE READILY SOLUBLE IN NITRIC OR MURIATIC ACID, AND WITH MORE OR LESS EFFERVESCENCE.

GENUS I.—*Analysis of Carbonates of Lime.*

The stones belonging to this division are wholly soluble in nitric or muriatic acid, with effervescence, or nearly so. They yield carbonic acid gas when exposed to heat, and become converted into quick-lime.

They may be examined in the following manner:

Process I.—Take a weighed quantity of the stone reduced to an impalpable powder, digest it repeatedly, with a gentle heat, in muriatic acid, till this fluid exercises no farther action on it, which may be known by letting fall into the acid, that has been decanted, and rendered neutral by an alcali, a solution of carbonate of potash in excess; if no precipitate ensues, the digestion may be discontinued. The insoluble residue, if any, should be washed, dryed, and weighed.

II.—To the obtained muriatic solution add 20 times its bulk of water, and drop into an aliquot portion of it, a crystal of sulphate of soda or potash. If the stone contained barytes or strontia, or both these earths, a precipitate will ensue, if not, the solution remains transparent. The modes of ascertaining the quantities and proceedings of separating these earths, are unnecessary to be detailed here. They will be stated under the articles analysis of stones of the barytic and stontian genus.

III.—Add to the filtered solution, after being made boiling hot, and from which the barytes or strontia has been separated, by means of sulphate of soda, a solution of sub-carbonate of soda, till no farther cloudiness ensues, collect the precipitate, wash and dry it, at least so much that it may be conveniently transferred from the filter.

IV.—The precipitate obtained in process III. may contain, besides lime, also a portion of magnesia and alumine. To separate the latter, boil the precipitate with a concentrated solution of potash or soda, in a silver bason, for at least one hour, supplying the water as it evaporates. The alumine will by this means become dissolved in the alcali, and the magnesia and lime will remain behind untouched.

V.—To ascertain the presence and quantity of alumine in the stone, mingle the alcaline solution with muriatic acid, till no farther precipitate ensues; decant the supernatant fluid, wash the precipitate, dry it, and lastly, ignite it for about half an hour. The product obtained, gives the quantity of alumine.

VI.—To ascertain the quantity of lime and magnesia, re-dissolve the precipitate, freed from its alumine, (process IV.) in muriatic acid;

evaporate the solution to dryness; weigh the dry mass, and pour over it, in a glass bason, more than twice its own weight of concentrated sulphuric acid; stir the mixture well together, heat it gradually, and increase the heat till the excess of sulphuric acid is expelled, or till no more pungent dense vapours are disengaged.

VII.—Digest the dry mass, previously levigated with a little alcohol, as fine as possible, in about twice its weight of cold water, which will dissolve the sulphate of magnesia, and leave the sulphate of lime. The latter may be separated by the filter, after having been repeatedly washed in small portions of water.

VIII.—To ascertain the quantity of magnesia, if any was present, heat the fluid obtained in process VII. to ebullition, and then drop into it a solution of carbonate of potash. The precipitate produced is carbonate of magnesia. Let it be ignited for about half an hour: what remains is magnesia.

IX.—To learn the quantity of lime, let the insoluble precipitate (the sulphate of lime, obtained in process VII.) be dried in a low red heat, weigh it, and then deduct from it 59 per cent. the remainder (viz. 41) gives the quantity of lime.

To ascertain the quantity of carbonic acid contained in the stone, introduce a weighed quantity of it into a bottle furnished with a spiral tube, and proceed according to the rules pointed out in the description of the plates.—See apparatus for easily ascertaining the quantity of carbonic acid contained in mineral substances.

The stones belonging to this class almost all contain more or less alumine and magnesia. The mode of analysis given is that usually employed, and answers well for ordinary enquiries. The most perfect separation of these earths from each other is nevertheless attended with considerable difficulty, as has been stated already in the preceding pages, and will be again considered under the analysis of argillaceous stones.

The presence of magnesia in lime stones having been lately found to prove extremely injurious to vegetation, when employed as a manure, we shall briefly notice that magnesian lime stone may readily be discriminated from that which is purely calcareous, and therefore fit for agriculture, by the extreme slowness of its solution in acids, which is so considerable that even the softest kind of the former is much longer dissolving than marble.

To ascertain, by chemical means, whether a lime stone be fit for agricultural, or architectural purposes, the following is the easiest, though not the most accurate, process.

Process I.—Put into a florence flask 100 grains of lime stone reduced to powder; and pour on it by degrees $\frac{1}{2}$ oz. of sulphuric acid, on each affusion of the acid a violent effervescence will ensue; when this ceases, stir the acid and lime together with a small glass rod, and heat the mixture over a lamp till it becomes dry.

II.—Reduce the mixture to powder, as far as possible, and pour over it 2 or 3 oz. of water; heat the mixture for about a quarter of an hour, and when cold transfer the whole on a filter, the weight of which has previously been ascertained. Wash the insoluble residue on the filter, by pouring over it small portions of water at a time, and add the water thus expended to the filtered fluid.

III.—To the before obtained solution add gradually $\frac{1}{2}$ oz. of sub-carbonate of potash, previously dissolved in about 2 or 3 oz. of water, which, if magnesia be present, will produce a very copious white precipitate; if not, a slight milkiness will ensue.

IV.—Heat the liquor (if magnesia be present) by setting it in a tea cup near the fire; let the precipitate subside; pour off the clear fluid, which may be thrown away, and wash the white precipitate with warm water, then pour it on a filter, the weight of which is known, dry and weigh the whole. The result shows how much carbonate of magnesia was contained in the original stone; or deducting 60 per cent. how much pure magnesia 100 parts of the lime contain. If burnt lime has been used, deduct from the weight of the precipitate 60 per cent. and the remainder gives the weight of magnesia in each 100 grains of burnt lime. We are indebted to Mr. Tennant for having first discovered the deleterious habitudes of the magnesian lime stone, when applied as manure in agriculture, and their unfitness for mortars and cements.—A correct drawing and description of this stone is given in Sowerby's British Mineralogy, No. XLIII. 1807.

ANALYSIS OF MARLS..

The name of marl is given to a mixture, chiefly composed of carbonate of lime and clay, in which the carbonate considerably exceeds the other ingredients. In agriculture the following varieties are chiefly distinguished: viz.

Common Marl, which includes not only the earthy marl, which is commonly of a yellowish grey colour, composed of more or less cohesive dusty particles, soiling a little the finger, and rather rough to the touch: and,

Stone Marl, or indurated marl, is usually of a smoky grey, or bluish colour; or sometimes of an ochre yellow, or brownish red. It has a slaty texture; it readily disentegrates by exposure to the air or weather, and frequently contains shells. Shell marl is called either the earthy or the indurated, abounding with shells.

All marls are useful in agriculture, only in proportion to the quantity of calcareous earth they contain: unless they contain more than 30 per cent. of lime they are of no value to the farmer.

From what has been stated already, the analysis of marls becomes obvious. Of all the modes of trials the one best suited to the unlearned farmer is to observe how much carbonic acid the marl gives out, and this he may ascertain by dissolving a little of it in dilute muriatic acid, and observing what portion of its weight it loses by the escape of the carbonic acid. Thus, if an ounce of marl loses 40 grains, he may conclude that the ounce contained only 100 grains of calcareous earth, and that it would be his interest to pay five times as much for a load of lime as he must pay for a load of marl at the same distance.

Process I.—To find the composition of marl, pour a few ounces of dilute muriatic acid into a flask, place it into a scale and let it be ballanced.

II.—Then reduce a few ounces of dry marl to powder, and let it be carefully and gradually put into the flask, until after repeated additions no further effervescence ensues.

III.—Let the remainder of the powdered marl be weighed, by which means the quantity projected will be known.

IV.—Let the ballance be then restored. The difference of weight between the quantity projected, and that requisite to restore the equilibrium will show the weight of the carbonic acid gas lost during effervescence.

If the loss amount to 13 per cent. of the quantity of marl projected, or from 13 to 33 grains per cent. the marl analysed is calcareous marl, that is to say, marl rich in calcareous earth.

Marls in which clay abounds, (clayey or argillaceous marls,) seldom lose more than 8 or 10 per cent of their weight by this treatment. The presence of argillaceous earths in marls may likewise be judged by drying it, after being washed well, when being kneaded together, dried and burnt, it will harden and form a brick.

Sandy marls usually lose the same quantity of carbonic acid, and frequently still less.

ANALYSIS OF CALCAREOUS STONES WHICH ARE NOT SOLUBLE IN DILUTE NITRIC OR MURIATIC ACID, OR AT LEAST VERY DIFFICULT, AND WHICH DO NOT EFFERVESCE WITH THESE AGENTS.

GENUS II.—*Analysis of Sulphate of Lime.*

Process I.—Let one part of the mineral, finely powdered, be boiled with 4 or 5 times its weight of corbonate of potash, in a sufficient quantity of water, for at least 2 or 3 hours, renewing the fluid as it evaporates, and collect the insoluble residue.

II.—Transfer the insoluble part into a flask, containing diluted nitric acid; effect a solution, if possible; examine the solution for barytes and strontia, (see analysis of barytic stones) and separate the earth which it may contain, according to the rules laid down already.

GENUS III.—*Analysis of Fluates of Lime.*

The stones belonging to this genus are composed of lime united to fluoric acid; they are both amorphous and crystallised; they decrepitate, and become phosphorescent when exposed to heat, except the colourless ones, which become electric by friction. They are generally crystallised in cubes. They are more or less transparent, and exhibit various colours, particularly violet, purple, red, yellow, and white. They melt before the blow-pipe into a transparent glass. They take a fine polish, and are worked into vases, vessels, and a variety of ornaments. The stones belonging to this genus are all decomposable by sulphuric acid, the fluoric acid becomes expelled, and may be known by the property of dissolving glass; for that purpose let a quantity of the powder be moistened with sulphuric acid in a leaden or pewter vessel; heat the mixture over a lamp, and expose to the acid vapours, a plate of glass, which will soon become corroded. Their phosphorescent property may be evinced, by throwing the stone, reduced to a coarse powder, upon a shovel, or plate of metal, heated so as not to be visible in the day. They may be examined in the following manner:

Process I.—Take one part of the stone finely pulverised, put it into a leaden retort, pour over it four parts of sulphuric acid, join to the retort a leaden receiver, containing two parts of water, lute the junctures of the vessel, and distil till no more vapours come over. The water in the receiver will be converted into fluoric acid.

II.—Wash the mass contained in the retort in a small portion of water, boil the insoluble residue with carbonate of potash, as directed, page 394; re-disssolve it in nitric or muriatic acid, and examine it as stated, page 395.

III.—Decompose the fluid from which the insoluble part of process I. was separated by carbonate of potash, and assay it for lime, magnesia, and alumine, as stated before 386, &c.

GENUS IV.—*Analysis of Phosphates of Lime.*

Process I.—Digest a determined quantity of the mineral in 5 times its quantity of muriatic acid, and repeat this operation till the fluid acts no more upon the residue, decant the liquid, dilute it with water, and filter it.

II.—Mingle the muriatic solution with liquid ammonia, collect the precipitate, wash, dry, and heat it.

III.—Re-dissolve this precipitate in a sufficient quantity of nitric acid, and precipitate by the addition of sulphuric acid. The whole must then be filtered, and the insoluble part washed with as little water as possible.

IV.—The filtered fluid must now be evaporated to the consistence of a syrup. If the stone consists of phosphate of lime, the fluid thus obtained will be phosphoric acid. That it is phosphoric acid may be proved by its copious precipitation of lime water, by its giving white precipitates with the solutions of sulphate of iron and nitrate of mercury, and its incapability of precipitating nitrate and muriate of barytes.

GENUS V.—*Analysis of Borate of Lime.*

To this genus belongs only a single species, namely, the mineral called Dalholite.

Process I.—Digest one part of the mineral repeatedly in nitric acid by heat, till a new addition of acid does not produce any further action on the residue.

II.—Decompose the nitric solution by carbonate of soda, and separate the precipitate by filtration.

III.—Mingle the solution with sulphuric acid, till the taste of the latter predominates: evaporate the fluid to dryness.

IV.—Transfer the dry mass into alcohol, digest it by heat, and then evaporate the alcoholic solution. If now a salt is left behind, which reddens tincture of litmus, and which tinges the flame of burning alcohol green, the substance examined was borate of lime, or boracite. If the alcoholic solution is evaporated the boracic acid will be obtained in a pure state. The remainder of the dry mass may be analysed by the rules stated before.

The analysis of arseniate of lime has been stated already.

TABULAR ARRANGEMENT

OF

CALCAREOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION, AND EXTERNAL CHARACTERS.

GENUS I.—*Carbonates of Lime.*

Compact, or common lime stone
Foliated lime stone
Calcareous spar
Magnesian lime stone
Fibrous lime stone, or sattin spar
Granular lime stone, including all the varieties of marble
Siliceous lime stone
Testaceous carbonate of lime, or schaalstone
Compact fetid, or bituminous lime stone, swine stone

Ochreaceous foetid lime stone
Pisolite, or pea stone
Oolite, or roe stone, ketton stone, meconite, or ammite
Botroydal carbonate of lime, or calcareous stalactite
Coralliform lime stone, or flos ferri
Margaritiform lime stone, or pearl spar
Madreporite
Dolomite
Argentine, or slate spar, schifer spar
Magnesian argentine, silvery chalk, or schaum earth
Brown spar, sidero calcite, ferriferous carbonate of lime, ferrugenous pearl spar
Arragonite
Chalk
Rock, or mountain milk
Calctuff
Calcareous marls

GENUS II.—*Sulphates of Lime.*

Fibrous sulphate of lime, or fibrous gypsum
Granular foliated gypsum, or alabaster
Earthy gypsum, or gyps earth
Granular anhydrous gypsum, or bardiglio marbl

Compact anhydrous gypsum, muriacite, cube or rhomb spar

GENUS III.—*Fluates of Lime.*

Earthy fluate of lime, blue John of the Derbyshire miners, or Derbyshire spar
Compact fluate of lime
Argillaceous fluate of lime, or chlorophane

GENUS IV.—*Phosphates of Lime.*

Native phosphate of lime, phospholite, or apatite
Earthy phosphate or moroxite of lime
Conchoidal phosphate of lime, asparagus stone, or chrysolite of Rome de Lisle
Foliated phosphate of lime
Siliceous phosphate of lime

GENUS V.—*Borate of Lime.*

Native borate of lime, or datholite

GENUS VI.—*Arseniate of Lime.*

Native arseniate of lime, or pharmacolite.

ORDER III.

ARGILLACEOUS STONES.

Division of Argillaceous Stones.

Under this head mineralogists comprehend not only those earths and stones in which alumine forms the most predominant part, but also those to which this earth gives a peculiar character. Hence all the clays are arranged among the argillaceous minerals, because the characters of alumine are particularly conspicuous in them, although in the greatest number of them this earth never forms the most predominant part. It is remarkable that alumine has the peculiar property of imparting characteristic properties to a very large proportion of other earths, when in combination with them. Is found nearly pure in the hardest gems only.

The oriental ruby, the oriental topaz, the oriental emerald, the oriental saphir, &c. all belong to this class; minerals in which the existence of alumine was for ages unsuspected, and where it exhibits properties widely different from those which it exhibits in clay; or in the minerals commonly called argillaceous.

The earths and stones in which alumine enters as a leading constituent part, may be divided in the following manner:

GENUS I.—*Argillaceous Stones composed of Alumine united to a small portion of silex and lime.*

GENUS II.—*Argillaceous Stones composed of alumine, united to a portion of silex, lime, and magnesia.*

GENUS III.—*Argillaceous Stones composed of alumine and a portion of silex and barytes.*

CHARACTERS OF ARGILLACEOUS STONES.

Although from what has been premised, page 402, it becomes obvious that no general characters can be given, that might serve for discriminating argillaceous stones, without error, from other mineral compounds: the greatest number of those earthy combinations of which alumine constitutes a leading ingredient, may, however, be said to possess the following habitudes, namely: they are entirely destitute of transparency, devoid of vitreous lustre, and have an acid dry appearance, or exhibit, when broken, an earthy fracture. The greatest number of them are acted on, or are more or less dissolved, by acids, particularly when assisted by heat. They may be scratched with a knife, and emit a peculiar odour when breathed on, a few excepted, known by the name of a clayey or earthy smell.

The greatest number feel rather soft to the touch, and suffer impressions by the finger nails. They become very hard, and less in bulk, after having been exposed to heat. They readily absorb water, and retain it obstinately. They also form with water, when reduced to a fine powder, a kneadable tenaceous and ductile mass. They fuse with lime, but not with alcalies; at least they require a very large portion of alcali to render the combination perfect.

If a mineral be found, whose properties coincides, or nearly so, with the description here given, we may ascertain whether it propertly belongs to the argillaceous stones, thus:

ANALYSIS OF ARGILLACEOUS STONES.

If the mineral is not very hard, or exists in such a state of aggregation, as permits it to be readily converted into a fine powder, the following mode of analysis may be pursued:

Process I.—Expose a weighed quantity of the stone, broken into small pieces, to a red, or better to a white heat in an earthen ware retort, and collect the moisture, if any, in the usual manner, by means of a receiver adapted to the retort.

II.—Take another portion of the stone, finely pulverised, boil it to dryness with 4 parts of its weight of concentrated sulphuric acid diluted with 1 of water, and a small portion of potash, or acetite of potash.

III.—Transfer the mass into water, boil it for a few minutes, separate the insoluble residue, dry it, and then boil it again with sulphuric acid and potash, and proceed as before for several times successively, until no further action takes place. The silex and lime will thus be left behind. These earths may be examined with regard to their purity, in the manner stated already.—See analysis of Siliceous and Calcareous Stones.

IV.—To ascertain the quantity of alumine, which by this means will be converted into sulphate of alumine and potash, concentrate the solution by evaporation, and decompose it at a boiling heat, by a solution of sub-carbonate of potash. This precipitate, after having been exposed to heat, to free it from carbonic acid, gives the quantity of alumine that was present in the stone, though not in a state of perfect purity. For be it understood that from whatever acid solution alumine is separated by virtue of an alcali, it always retains a minute portion of the substance employed to precipitate it.*

V.—To ascertain the true quantity of this earth, which is present in the mineral, the precipitate must be re-dissolved in acetous acid, again precipitated by liquid ammonia perfectly free from carbonic acid, dried, and ignited.

During the evaporation of the solution of alumine, from which the silex has been separated, as stated before, process IV. portions of the latter earth become separated even to the last; these should be collected, and added to that obtained already, as will be shown presently.—See analysis of adamantine spar, or corundum, &c.

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* See the Author's System of Chemistry, 2nd edition, vol. I: p. 221.

VI.—The oxid of iron which is usually present may be separated from the silex by heating it in a crucible with a little wax, which renders the iron soluble in dilute muriatic or sulphuric acid, when applied, and the silex is left behind pure. The oxid of iron may then be precipitated from the acid solution by liquid ammonia.—See analysis of iron ores.

Example 1.—*Analysis of Native Alumine.*

Process I.—One hundred grains of native alumine,* from Schemnitz, were exposed to a strong red heat for one hour in a covered crucible. After cooling, they had lost 41 grains, which was water. No alteration was effected in the appearance of the earth, during this process, except that the pieces of the mineral were become a little rifty, and considerably diminished in size.

II.—Another hundred grains of the same earth were gradually conveyed into sulphuric acid a little diluted. They dissolved in this fluid without effervescence. The sulphuric solution was perfectly colourless; but on being

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* Klaproth's Analytical Essays, vol. I. p. 221.

evaporated it formed a clear transparent coagulated mass, the surface of which, after a few days, became covered with a number of solitary pyramidal crystals.

III.—The mass was next drenched and digested with an abundance of water: the siliceous earth thus separated, weighed 14 grains after being ignited.

IV.—The solution, freed from silex was combined with the requisite portion of pot-ash, and evaporated; it afforded pure alum; from which the alumine was afterwards precipitated by subcarbonate of pot-ash, and purified in the manner just mentioned; namely, by acetous acid.

Hence the constituent parts of the so-called native alumine, are, according to Klaproth,

Alumine	45
Silex	14
Water	41
	100

Example 2.—*Analysis of Wavellite, or Hydragellite.*

The analysis of this mineral, which consists almost wholly of alumine and water, was effected by Mr. Davy in the following manner.*

Process I.—Eighty grains of the mineral were introduced into a small glass tube having a bulb of sufficient capacity. To the end of this tube a small glass globe, attached to another tube, communicating with a pneumatic mercurial apparatus, was joined by fusion, by means of the blow-pipe. The bulb of the tube was exposed to the heat of an Argand lamp; and the globe was preserved cool by being placed in a vessel of cold water. In consequence of this arrangement, the fluid disengaged by the heat became condensed, and no elastic matter could be lost. The process was continued for half an hour, when the glass tube was quite red. A very minute portion only of permanently elastic fluid passed into the pneumatic apparatus, and when examined, it proved to be common air. The quantity of clear fluid collected, when poured into another vessel, weighed 19 grains, but when the interior of the apparatus had been carefully wiped and dried the whole loss indi-

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* Philosoph. Trans. 1805, and Nicholson's Journal, 1805, vol. XII. p. 153.

cated was 21 grains. The 19 grains of fluid had a faint smell, similar to that of burning peat; it was transparent, and tasted like distilled water: it slightly reddened litmus paper: it produced no cloudiness in solutions of muriate of barytes, of acetite of lead, of nitrate of silver, or of sulphate of iron.

II.—The 59 grains of solid matter were dissolved in dilute sulphuric acid, which left no residuum; and the solution was mixed with potash, in sufficient quantity to cause the alumine at first precipitated again to dissolve. What remained undissolved by potash, after being collected and properly washed, was heated strongly and weighed; its quantity was a grain and a quarter. It was white, caustic to the taste, and had all the properties of lime.

III.—The solution was mixed with nitric acid till it became sour. Carbonate of ammonia was then poured into it till the effect of decomposition ceased. The whole thrown into a filtrating apparatus left solid matter, which when carefully washed and dried at the heat of ignition, weighed 56 grains. They were pure alumine: hence the general results of the experiments, when calculated upon, indicated for 100 parts of the mineral:

Alumine	70 grs.
Lime	1.4
Water	26.2
Loss	2.4
	100

N. B. The loss Mr. Davy is inclined to attribute to some fluid remaining in the stone after the process of distillation; for he learnt from several experiments, that a red heat is not sufficient to expel all the matter capable of being volatilized, and that the full effect can only be produced by a strong white heat.

Fifty grains of a very transparent part of the fossil, by being exposed in a red heat for fifteen minutes, lost 13 grains; but when they were heated to whiteness, the deficiency amounted to 15 grains, and the case was similar in other trials.

Example 3.—*Analysis of Adamantine Spar, or Corundum, from Bengal.*

Process I.—One hundred grains of the stone triturated with water in a flint mortar, were found, after drying and ignition, to have increased 11 grains in weight,* which was owing to particles of flint abraded from the mortar.

II·—Upon these 100 grains, four ounces of a solution of potash, containing one half its weight of alcali, were affused in a silver crucible; and the mixture evaporated to dryness. The mass being then ignited for three hours, was again softened with water, and diffused through that fluid and filtered. The residue weighed 47 grains.

III.—The obtained fluid, process II. let fall, on being saturated with muriatic acid, a copious white precipitate, which was immediately redissolved by a slight excess of acid.

IV.—The above obtained 47 grains, process II. completely dissolved in muriatic acid. When this solution was mixed with liquid ammonia, it afforded a slimy and very puffy precipitate. Carbonate of ammonia was then added to the liquor, which had been immediately separated from this precipitate by filtering, but no farther precipitation ensued.

V·—The obtained precipitate was transferred into a solution of potash and digested for some

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* Klaproth's Analytical Essays, vol. I. p. 65.

time. The mixture assumed the appearance of a solution of gum arabic. On adding more potash, the whole formed a limpid fluid, except some few brown flocks, which, after having been dried, weighed $2\frac{1}{4}$ grains.

VI.—Muriatic acid being affused upon this flocculent precipitate, a small portion of silex again separated, and liquid ammonia precipitated from the clear solution oxid of iron, weighing, after ignition, $1\frac{1}{4}$ grain.

VII.—From the alcaline solution, V. muriatic acid threw down a precipitate, which was entirely re-dissolved by a small excess of that fluid.

VIII.—Both the solutions, process VII. and III. were next mixt and precipitated by carbonate of potash at a boiling heat, and the dried precipitate was again dissolved in dilute sulphuric acid. When this solution, after the addition of a sufficient quantity of potash, had been evaporated to the point of crystallization, it readily afforded clear and regular crystals of alum.

IX.—The remaining part of the solution in sulphuric acid, process VIII. thickened spontaneously to a clear jelly, on subsequent evaporation. This gelatinous matter, being digested with an abundant quantity of water, and repeatedly agitated, again liquefied by degrees. Upon this, some silex subsided; which, when separated by means of a filter, and ignited, amounted together with that obtained, process VI. to 15½ grains, after having been boiled and digested in sulphuric acid.

X.—The above solution in sulphuric acid, was then evaporated for further crystallization. It continued to the end to yield successively regularly crystallized sulphate of alumine: but the very last portion was still contaminated with siliceous earth, amounting to 1 grain after ignition.

XI.—All these several portions of alum were dissolved in water, and precipitated in a boiling heat by sub-carbonate of potash: and when the alumine which they afforded had been purified by means of acetic acid, as stated before, they gave 82½ grains of pure alumine.

Therefore, the products obtained by the decomposition of the adamantine spar from Bengal yielded to Klaproth,

Alumine	process XI.		89,50
Oxid of Iron	VI.		1,25
Silex	IX.	15½	
	X.	1	
		16½	
Subtract, process I.		11	
Remain		5½	5,50
			96,25
Loss. . . .			3,75
			100

Example 4.—*Analysis of Chrysoberil.*

Process I.—One hundred grains of chrysoberyl,* previously reduced to a powder, were levigated with water to perfect fineness in a flint mortar. After the powder had become dry, it was subjected to gentle ignition, in order to free it from all moisture. However, its weight was increased 13 grains, by the abraded particles of the mortar and pestle.

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* Klaproth, ibid. p. 86.

II.—Upon these 113 grains, introduced into a silver crucible, was poured so much of a solution of potash, that the proportion of alcali which it contained amounted to 800 grains: the mass was evaporated to dryness, and lastly fused for about two hours.

III.—The fused alcaline mass being softened in the crucible with water, the solution was thrown upon a filter. When the fluid had passed through the paper, there remained a loose, light-grey powder, which being washed and dried, weighed 66½ grains.

IV.—The alcaline fluid that had heen separated from this powder, together with the water employed for washing the residue in the last process, was first evaporated, to lessen its bulk, and then saturated with muriatic acid. An abundant white precipitate fell down, which was instantly re-dissolved by a small excess of acid. Carbonate of potash being added, again occasioned a precipitate, which being collected, washed, and dried, was porous and white as snow: it weighed 138½ grains.

V.—The light grey pulverulent residue, of process III. amounting to 66½ grains, on being digested in muriatic acid, left again a residue; which being washed, dried, and ignited, weighed

24½ grains, and was found, upon farther examination, to be another portion of pure silex.

VI.—The muriatic solution obtained, process V. which was separated from the silex, was next decomposed at a boiling heat, by liquid ammonia, which occasioned a yellowish precipitate. It was washed; and, while yet moist, boiled with a solution of potash; in which it entirely dissolved, some few brown particles excepted; which was oxid of iron, weighing, after ignition, 1½ grain.

VII.—The alcaline solution, process VI. being saturated with muriatic acid, yielded a white precipitate, which, by a slight excess of acid, again formed a clear solution. The precipitate was a second time precipitated, by boiling it with carbonate of potash. Its weight amounted, after desiccation, 29 grains.

VIII.—These last 29 grains, together with the preceding 138½ grains of the product, process IV. to which was also added the two grains which were collected from the washings by evaporation, were digested with dilute sulphuric acid. The whole was dissolved, excepting a portion of silex, which weighed 4 grains.

IX.—When this solution was a little evaporated at a low temperature, tender, spicular, or spear shaped crystals, gradually separated; which were collected. They presented all the marks of selenite, or sulphate of lime; and, on decomposition by a solution of carbonate of potash, in boiling heat, they afforded 11 grains of carbonate of lime = to 6 of lime. This calcareous earth of the chrysoberyl was, doubtless, before contained in the precipitate of process IV. and previous to its falling down, it was held in solution merely by the water, as it was then in the state of lime free from carbonic acid.

X.—This sulphuric solution was now combined with the proportion of carbonate of potash requisite to the formation of alum, which yielded, by degrees, regular crystals. Towards the end, however, a slight portion of silex appeared, which being ignited, weighed 2½ grains. The total weight of the sulphate of alumine obtained amounted to 604 grains.

This alum was re-dissolved in boiling water, and decomposed by carbonate of potash, at the heat of ebullition. After the precipitated alumine had been washed, dried, and gently ignited, it was digested with distilled vinegar; the solution being neutralized by liquid ammonia, the alumine was again precipitated by this treatment, which, after being again washed, dried, and heated to redness, proved to be perfectly pure. It weighed 71½ grains.

We may, therefore, infer, that the constituent parts of the chrysoberyl, exhibited by this analysis, consist in the hundred, of

Alumine	process X.		71,5
Lime	VIII.		6
Oxid of Iron	VI.		1,5
Silex	V.	24½	
	VIII.	4	
	X.	2½	
		31	
	Subtract, process I.	13	
	Remain..........		18
			97
		Loss	3
			100

Example 5.—*Analysis of Cimolite.*

Process I.—One hundred grains of cimolite, in entire pieces, were exposed, for half an hour, to the heat of a furnace, in a covered crucible. After cooling, it was found split into slaty fragments, of uneven surfaces. This process was accompanied, at the commencement of ignition, with a crackling noise. The cimolite acquired, at first, a brownish grey colour, which again disappeared. It lost 24 grains in weight during this operation.

II.—Two hundred grains of finely pulverised cimolite, being next mixed, and ignited with thrice their quantity of potash, in the usual manner, afforded, after cooling, a blueish, or greenish-white mass, which, being softened with water, left an insoluble part, which was separated by the filter.

III.—The alcaline fluid, which was colourless, was mingled with sulphuric acid in excess. The siliceous earth separated in the usual manner weighed 44 grains, when perfectly dried.

IV.—The residue of process I. which was not taken up by the alcali in that process, weighed 220 grains. It was dissolved by degrees, by being digested in sulphuric acid; but no compleat solution was effected. It left behind five grains of silex.

V.—Both the sulphuric solutions, namely, process III. and IV: were added together, and partly evaporated; after which, crystals of alum appeared, on suffering the liquor to cool. The remainder of the fluid, on being farther evaporated, became gelatinous. When mixed with water, digested, and filtered, there again separated a portion of silex, in the form of pellucid vitreous grains, the weight of which was 64 grains.

VI.—The remaining fluid was mixt with prussiate of potash, which produced a deep blue precipitate; by the quantity of which the proportion of oxid of iron was determined in the usual manner at 2½ grains.

VII.—The iron being separated, a small quantity of potash was added to that part of the sulphuric solution which yet remained. By this treatment, and subsequent evaporations, crystals of alum were obtained, in succession, to the end. But, at the same time, there still separated, from time to time, some siliceous earth, amounting to 13 grains.

VIII.—The whole of the alum produced was, lastly, re-dissolved in water, and the alumine separated by carbonate of potash. This alumine being purified and ignited, amounted to 46 grains.

Therefore, the above 200 grains of cimolite yielded:

Silex, process	III. IV. V. VII.	44 5 64 13	126 grains.
Alumine	VIII.		46
Oxid of Iron	VI.		2½
Loss by ignition	I.		24
			198½ grains.

Whence, one hundred parts of cimolite contain:

Silex	63
Alumine	23
Oxid of Iron	1,25
Water	12
	99.25

From what has been so far stated, the analysis of argillaceous earths and stones will become obvious. The extreme hardness of some of these compounds belonging to this class, particularly those usually called gems, render the analysis of them difficult. Mr. Chenevix, however, has succeeded, by help of borax, in decomposing them. His method is as follows:

Process I.—Take one part of the stone, levigated as fine as possible, mix it with 3 or 4 times its weight of glass of borax, (borax compleatly freed from water by fusion) and expose the mixture to a violent heat, in a platina crucible, for at least 2 or 3 hours.

II.—To detach the mass from the vessel to which it adheres very firmly, digest the whole for some hours in muriatic acid, to effect a solution.

III.—Into the obtained fluid let fall sub-carbonate of ammonia till no further cloudiness ensues, and collect the precipitate on the filter. All the earths which were present will then be thrown down.

IV.—Re-dissolve the obtained precipitate in muriatic acid, the borax being thus got rid of, the analysis may be finished in the manner already stated.

Remark.—Mr. Chenevix separated the alumine in his analysis of the corundum, from its alcaline solution in potash, by muriate of ammonia; the potash, in this case, joins to the muriatic acid of the muriate of ammonia, and the ammonia set free, determines the precipitation of the alumine, which, when washed, is is perfectly pure.* We owe to Mr. Chenevix some very singular observations, with regard to the affinities of alumine with other earths, which are of the utmost importance to the practical analyst, as it regards the truth of all analyses in which this earth enters, namely, it is well known that magnesia cannot be completely separated from its acid solutions by ammonia, for part of the magnesia combines with ammonia, and forms with it and the acid a triple salt; but the case is otherwise, when magnesia is associated with alumine in the same solution; in that case the ammonia first separates the greatest portion of alumine, together with a *larger* quantity of magnesia than would have been precipitated by the ammonia *only*, or *without* the presence of alumine; and it is only after the ammonia has thus acted, that a farther addition of it forms the ammoniacal triple salt of magnesia above-mentioned. The same case takes place when a carbonated alcali, fully satu-

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* Philoseph. Trans. 1802, p. 33.

rated with carbonic acid, is employed. For, if this alcali be added to a solution containing magnesia, no precipitate takes place; or if any, as is the case, if the alcali be not fully saturated with carbonic acid, the carbonate of magnesia formed is immediately re-dissolved; but if alumine be present, the alcali throws down both of the earths in combination: hence the power of the resolubility is lost, except that dose of the alumine which exceeds the saturating affinity of magnesia. For these singular and important facts we are indebted to Mr. Chenevix, who first published them in the 28th volume of the An. Chem. p. 203.—See page 437 of this work.

Lime, likewise, has a powerful affinity for alumine; for when these two earths are present in a solution, ammonia, when added to it, will separate a portion of lime, which is not the case when lime alone exists in the fluid; hence the mode of separating lime from the other earths, by means of ammonia, with a view of leaving the lime in solution, as often directed, is certainly objectionable, for a portion of the lime falls down, together with the other earth, and the quantity of it will therefore be less than it ought to be. To remedy this defect it is advisable to throw down the whole contents of the solution by a carbonated alcali, to convert all the substances into carbonates. The subsequent application of potash or soda will then take up the alumine, and not touch the lime, which is now in a carbonated state.

Magnesia and alumine may also be separated by succinate of soda, which precipitates the latter earth only.

With regard to the oxids of iron, which are usually present in all argillaceous fossils, the separation of it is by no means troublesome. The alcali employed in taking up the alumine does not touch the oxid of iron, if in a state of red oxid, to which it may be brought by exposure to heat, or nitric acid; if a portion should, however, adhere to the alumine, it may be removed by dissolving the alumine in muriatic or nitric acid, and then separating the iron by prussiate of potash.

Mr. Chenevix has suggested several modes of performing the very difficult operation of separating magnesia from alumine. The first is founded on the insolubility of malate of lime, and the production of a very deliquescent salt: namely, malate of magnesia. If this acid therefore be added to a solution containing both these earths, the malate of magnesia may be removed by the operation called deliquation, or by ablution with alcohol, which does not touch the malate of alumine, but very readily dissolves the malate of magnesia. The second mode consists in the application of water impregnated with sulphuretted hydrogen gas, which, with magnesia, forms a salt readily soluble in water, without acting on the alumine. And a third mode is by the application of Prussic acid, which also forms, with magnesia, a readily souble, and with alumine, a very insoluble compound. It is not necessary that these re-agents should be added in a naked state, hydo-sulphuret of potash, or an alcaline prussiate, answer equally well. The malic acid appears to deserve the preference to the two others; for, if iron is present, the malate of iron is very soluble, but the prussiate and hydro-sulphuret of iron are insoluble, or nearly so; hence the malic acid yield the alumine in a pure state, whereas by the application of the other two, a subsequent process is requisite to get rid of this metal.

Klaproth separates these earths when no others are present, by dissolving them in sulphuric acid, thus converting the alumine into sulphate of alumine, and evaporating the whole to dryness, and strongly igniting it for half an hour. If now water be added, the sulphate of magnesia will only be soluble, and the sulphate of alumine only on the addition of a portion of sulphuric acid and potash. In this case it is however necessary that the sulphuric acid should be perfectly pure. The sulphuric acid of commerce cannot be employed, for it always contains a small portion of sulphate of potash, which would at once produce alum and not sulphate of alumine.

We shall treat again on the modes of separating these earths under the article, analysis of mineral waters.

TABULAR ARRANGEMENT

OF

ARGILLACEOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.

Argillaceous Stones chiefly composed of Alumine almost pure, or united to a portion of Silex and Lime.

Telesia, saphir, or perfect corundum, oriental ruby of the jewellers
White telesia, oriental or water saphir, white corundum
Yellow telesia, or oriental topaz
Blue telesia, or oriental saphir
Violet telesia, or oriental amethyst
Green telesia, or oriental emerald
Imperfect corundum, or adamantine spar
Scotch corundum* or andalusite.

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* Sowerby's Mineralogy, pl. 69.

Spinel, or true ruby, balass ruby, or rose-red shorl
Violet red spinel
Yellow red spinel
Orange red spinel, or rubicelli
Emery
Wavellite, or hydragillite
Brazilian topaz
White hyacinth, sommet, or nepheline
Chrysoberil, or Cimophane
Dypyre, leucolite, or shorlite
Sommite, or white hyacinth
Cimolite
Automalite
Turmaline, or shorl
Yellow, or Brazilian shorl
Green shorl
Saphyrine shorl
Siliceous shorl
Clay stone
Pure clay, or Koolin
Petuntse
Porcellain clay
Pipe clay
Variegated clay
Brick clay
Loam

Yellow ochre
Lythomarge
Fuller's earth
Bole
Tripoli
Argillaceous marl

Argillaceous Stones composed of Alumine, with a portion of Silex, Lime, and Magnesia.

Ceilanite, or Pleonaste
Ceyanite, Sappare, or Disthene
Clinkstone
Mica
Micarel
Wacke, or grey wacke
Grey wacke slate
Argillaceous shistus, or argillite
Alum slate
Novaculite and honestone
Drawing slate
Adhesive slate
Chlorite
Chlorite slate
Foliated Cholorite
Diaspore

Phrenite
Kaupolite, or foliated phrenite

Argillaceous Stones containing a portion of Silex and Barytes.

Staurolite, stauro-baryte, ercticite, andreolite, or grenatite

ORDER IV.

MAGNESIAN STONES.

Division of Magnesian Stones.

To this order of earths and stones belong not only those which are chiefly composed of magnesia, but those minerals also in which, though in smaller proportion, there exists the totallity of the characters, which may be said to be characteristic of the genus. Magnesian stones sometimes consist of two earths, sometimes of three. They may be divided in the following manner:

Genus I.—*Magnesian Stones chiefly composed of Magnesia united to Boracic Acid, or Borates of Magnesia.*

Genus II.—*Magnesian Stones chiefly composed of Magnesia, with a portion of Silex and Lime.*

GENUS III.—*Magnesian Stones chiefly composed of Magnesia, with a portion of Silex and Alumine.*

CHARACTERS OF MAGNESIAN STONES.

Most of the stones of this order have a greenish colour, more or less deep, but they possess more or less a glittering or shining surface, seldom, if at all, an earthy appearance; they do not adhere to the tongue; they very seldom exhibit a regular crystalline form; they do not, or few of them only, effervesce with acids, but they are soluble in boiling sulphuric acid. Their texture is generally scaley or lamellar: seldom they have an even texture. They are only semi-transparent, but oftener inclined to opake.—Their substances are more or less smooth; hence they feel soft, or rather soapy to the touch: they do not stain the fingers, nor do they soften in water like many of the argillaceous stones. They discover no clayey smell when breathed upon: they may be cut with a knife, or with a machine, or turned on the lathe: they do not contract or harden after having been exposed to heat, and are infusible with potash.

ANALYSIS OF MAGNESIAN STONES.

The native combinations of magnesian stones, as stated already, consist chiefly of two or three earths, namely, magnesia, alumine, and lime, and in general some metallic oxid; the analysis of them must become easy, on considering what has been said in the preceding pages. The separation of magnesia from alumine, to which it has a very marked affinity, is attended with some peculiar difficulties. They certainly depend on the strong affinity which exists between these earths, which modifies and alters the usual modes in which they are acted on by the different chemical agents, when in a detached state. This affinity was first pointed out by Chenevix.* Namely: when magnesia is dissolved by an acid, it is only partially precipitated by liquid ammonia, and if there be an excess of acid, the earth is not precipitated at all; for ammonia has a tendency to form with

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* An. de Chem. VIII. p. 168.

them a terrary compound. Hence when liquid ámmonia is added to a solution of a magnesian salt, part of the magnesia is precipitated, but another portion remains in combination with the acid, and the ammonia, forming a soluble salt. These ammoniacal magnesian salts were first noticed by Bergman,* and more fully examined by Fourcroy† and Chenevix. But the case is otherwise when alumine is present. In that case the decomposition is compleat, for the whole of the magnesia is precipitated together with the alumine, see p. 424. Thus Chenevix found that on adding an excess of ammonia to a solution of muriate of magnesia, mixed with a large proportion of muriate of alumine, nothing remained in solution but muriate of ammonia. Hence, also, when a solution of carbonate (not sub-carbonate) of potash, is poured into a solution of Epsom salt, or sulphate of magnesia, no precipitate ensues, the mixture remains perfectly transparent, because the carbonic acid evolved is sufficient to hold the whole in solution; but, if sub-carbonate of potash is emplyed, an abundant precipitate is produced, and, if alumine be present, the carbonate of potash will throw

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* Chemical Essays. † Annales de Chemie, tom. IV.

down a precipitate, consisting of both the earths. When this precipitate is boiled in a solution of potash, only a very small portion of alumine is dissolved, the greater part being retained by its affinity for magnesia. By dissolving the residuum in muriatic acid, and then adding to the solution carbonate of potash, a portion of magnesia is retained in solution. Potash boiled on the residue dissolves a fresh dose of alumine, and by repeating these operations alternately, the two earths may be separated from each other. Thus we see that the action of magnesia on alumine is the reverse of the action of alumine on lime.

The last promotes the solution of the lime, whereas the first prevents the solution of the alumine.

This being premised, we shall state the general modes employed in the analysis of magnesian stones, together with a few examples given by Klaproth.

Process I.—Let one part of the stone be ground to a fine powder, pour over it two or three parts of sulphuric acid, diluted with half a part of water, boil the mixture to dryness, and heat it till no more white fumes rise.

II.—Transfer the dry mass into twice its weight of water, digest it in the cold for some hours, and then filter it. It yields, on evaporation, a crystalline salt of a bitter taste. Dissolve it in water.

III.—Decompose this solution by sub-carbonate of potash, dry the precipitate, and heat it; which, if the stone contained magnesia only, will be the earth called magnesia, which may be distinguished from alumine by being insoluble in caustic potash, and forming bitter salts with sulphuric acid.

Example 1.—*Analysis of Miemite.*

Process I.—One hundred grains of Miemite were ground to a fine powder, and covered with nitric acid. The action was slow, and attended with a weak effervescence; but on the application of heat, the solution was rapidly accomplished, with a very violent effervescence. Only a few brown flocks remained, which dissolved by the admixture of a few drops of muriatic acid.

II.—The obtained solution was mingled with liquid ammonia in excess, which yielded a brown precipitate. This being washed, was boiled while yet moist in a solution of soda, to free it from alumine; but nothing was found soluble in it. The same precipitate was therefore next dissolved in sulphuric acid, the solution evaporated to dryness, and, lastly, ignited for half an hour. This mass being re-dissolved in water, some brown-red flocks remained, which after being again ignited, weighed 2¼ grains, and proved to be oxid of iron, with a slight trace of manganese. As there is no doubt but the iron is contained in the stone in the carbonated state; three grains of carbonate of iron must be accounted for it. The fluid from which this oxid has been separated, on being evaporated, yielded sulphate of magnesia.

III.—That fluid which afforded on the addition of liquid ammonia the before-mentioned brown precipitate, was combined in a boiling heat with carbonate of potash; a white light precipitate fell down, which being washed and mingled with dilute sulphuric acid, produced sulphate of lime. It was carefully collected and decomposed by boiling it with a solution of carbonated soda, as stated before (see analysis of siliceous and calcareous stones.) The carbonate of lime, thus produced, weighed 53 grains, when dried in a warm place.

IV.—What remained of the fluid from which the sulphate of lime had been separated, yielded on farther evaporation, crystals of sulphate of magnesia. This, together with that portion obtained in process II. was decomposed in a boiling heat by carbonated soda. The sub-carbonate of magnesia which was here obtained, being washed and dried in a gentle heat, amounted to 42½ grains.

V.—One hundred grains of the same miemite in entire pieces, were exposed in a covered crucible, to a strong red heat for 30 minutes. They were rendered friable, and had acquired a dark isabella-yellow colour, and lost 52 grains of weight.

Yet, since the whole weight of the carbonic acid contained in the mentioned 53 grains of carbonate of lime, as well as in the 42½ grains of magnesia, and in the 3 grains of oxid of iron, according to the usual proportions, can amount only to 39 grains; it is obvious, says our author, that the surplus of 13 grains lost by the ignition, must be considered as water expelled. Of these, in fact, we again find the greatest part in the carbonate of magnesia. For, the quantity of water with which this earth, while precipitating, combines so intimately, that it parts with it only at a red heat, at which also its carbonic acid is driven out, amounts in 100 parts of carbonate of magnesia to 27; while the carbonic acid contained in it amounts only to 33.

The constituent parts of miemite, therefore, are in the hundred:

Carbonate of Magnesia	42.50
Carbonate of Lime	53.
Carbonate of Iron, with a vestige Manganese	3.
	98.50

Example 2.—*Analysis of the Prismatic Magnesian Spar.*

Process I.—One hundred grains were finely triturated, and introduced into cylindrical glass, which held a quantity of nitric acid sufficient to effect the solution, and was previously put in equilibrium in a scale. The acid acted but feebly, the solution proceeded but slowly, and was accompanied by no great effervescence. After the end of the solution, a loss of 47¼ grains was found, owing to carbonic acid which had escaped.

II.—The solution which was at first yellowish, but colourless when diluted with water, was not disturbed by adding to it a few drops of sulphuric acid; a proof that it contained neither barytic nor strontian earth. It was mixed with as much carbonate of potash as was necessary to neutralize the predominant acid, and then assayed for iron by means of succinate of soda. The precipitated succinate of iron, when ignited, obeyed the magnet. After a few drops of oil had been burnt over it, it presented itself as a black oxid of iron, weighing 2½ grains. But since the iron exists in this fossil in the carbonated state, we must reckon 4 grains for it.

III.—The solution freed from iron, was decomposed with carbonate of potash at a boiling heat. The precipitate obtained, amounted to 96½ grains, when washed and dried.

IV.—This precipitate was saturated with dilute sulphuric acid. By this means sulphate of lime, mixed with sulphate of magnesia, was obtained; the mixture being evaporated to dryness, and elixiviated with cold water, the filtered fluid yielded nothing but crystals of sulphate of magnesia. This being re-dissolved in water, and decomposed in a heat of ebullition by means of sub-carbonate of potash, afforded 36½ grains of dried carbonate of magnesia; which deducted from the preceding 96½ grains, reduces the amount of the carbonate of lime to 60 grains.

Hence one hundred grains of the prismatic magnesian spar yielded,

Carbonate of Magnesia	36.50
Carbonate of Lime..........	60.
Carbonate of Iron..........	4.
	100.50

However, since the quantity of carbonic acid, combined with those proportions of the three constituent parts here stated, amounts only to 40½ grains, and in particular in the

36.½	grains of	carbonate of magnesia to	12 grs.
60.	do.	carbonate of lime	— 27
4.	do.	carbonate of iron	— 1.50
			40.50

whereas the native fossil itself contains 47¼ grains, process I. hence 6¾ grains more: some correction in the above statement is necessary, and this relative to the proportion of the carbonic acid combined with the magnesia.

"The carbonate of magnesia, prepared in the usual way by precipitation from acids, contains upon average 40 per cent. of magnesia, 27 water, 33 carbonic acid. But magnesia, like potash and soda, is capable of appropriating to itself a greater proportion of carbonic acid. For, if carbonate of magnesia, when recently prepared and still moist, be diffused in water, poured into a capacious bottle filled with carbonic acid gas and agitated, the volume of the gas will be found to decrease in a much greater proportion, than can be absorbed by the quantity of water employed to drench the earth. Thus soda, perfectly saturated with carbonic acid, whether by nature or by art, contains less water of crystallization, in proportion as the quantity of carbonic acid combined with it increases. From analogy it was reasonable to conjecture, that the same is the case with magnesia; and this supposition is confirmed by the greater proportion of carbonic acid, discovered in that magnesia, which is a co-constituent part of the fossil here examined, which is a true carbonate, and the artificial, a sub-carbonate."

If now we determine by computation the proportion of the earths and oxid of iron in a state of purity, it amounts in the above-mentioned

36½ grains of	Magnesia	to	14.50 grs.
60 do.	Carbonate of Lime	—	33
4 do.	Iron	—	2.50
			50.
Adding Carbonic acid			47.25
			97.25
Consequently, for the proportion of water remain only			2.75
			100.

According to this calculation, one hundred parts of the prismatic magnesian spar contain,

Magnesia	14,50
Lime	33.
Oxid of Iron	2,25
Carbonic Acid	47.50
Water, and perhaps some loss	2.75
	100.

Example 3.—*Analysis of the Tyrolese Magnesian Spar.*

Process I.—An entire piece, weighing 100 grains, was ignited in a covered crucible for two hours; yet, notwithstanding its sparry texture, it remained entire, without flying to pieces. It was rendered ash-grey, and wholly opake, though preserving some lustre. At the same time its weight was lessened 45 grains.

II.—The action of mineral acids upon this magnesian spar, while in gross framents, was not perceptible; but if pulverized, they attacked and dissolved it gradually, attended with a continued gentle effervescence. With the sulphuric acid, selenite was generated, and the supernatant solution was of a pale-reddish colour. Nitric acid produced a colourless solution, and the muriatic acid a yellow one.

But when pieces of calcined magnesian spar were employed, the solution went on rapidly. And in that case the nitric acid left a metallic residue behind, which was of a brown-red colour.

III.—Three hundred grains of finely powdered magnesian spar, mixed with an equal quantity of potash, were ignited for two hours n a crucible. The mass returned black out of the fire, except that its middle part was rendered of a dark ash-grey. When triturated, and covered with water, it became light-green. Muriatic acid affused upon it, in sufficient quantity, dissolved the whole, forming a clear yellow tincture.

IV.—This solution was decomposed by carbonate of potash at a boiling heat. Dilute sulphuric acid was next poured upon the precipitate, and the sulphate of lime thus produced, separated from the remaining fluid by the filter.

V.—The solution that remained after the separation of the sulphate of lime, and which contained sulphate of magnesia, was evaporated to perfect dryness, heated red hot for two hours, and lastly re-dissolved in hot water. Upon the filter there remained an oxid of iron, weighing nine grains, wholly obeying the magnet.

VI.—The solution, now freed from the oxid of iron, afforded by subsequent evaporation and crystallization, sulphate of magnesia; which, when decomposed by potash, with the assistance of heat, yielded 133 grains of carbonate of magnesia.

VII.—The sulphate of lime obtained in process IV. being decomposed by boiling it with carbonate of potash, furnished 160 grains of carbonate of lime. To examine whether this still contained any magnesia, it was re-dissolved in nitric acid, and mixed with ammonia, and filtered. The precipitate then formed dissolved in sulphuric acid, and being again precipitated by carbonate of potash, it still yielded three grains of magnesia; which subtracted, leaves 157 grains for the quantity of carbonate of lime.

Consequently, the above 300 grains of the Tyrolese magnesian spar, yielded

Magnesia process	VI.	133	136 grs.
	VII.	3	
Carbonate of lime	VII.		157
Oxid of iron, containing some manganese	V.		9
			302 grs.

As no loss of weight, but rather an excess, appear in the constituent parts, given separately, we may conclude, that those ingredients might, perhaps, have been capable of undergoing a still greater degree of desiccation.

Therefore, a hundred parts of magnesian spar consist of:

Magnesia	45
Carbonate of Lime	52
Oxid of Iron, impregnated with manganese	3
	100

Example 4.—*Analysis of the Silici-Murite, or Meerscham.*

Process I.—One hundred grains of Murite were subjected to a brisk red heat in a crucible, for one hour, they lost 30 grains. But, in other respects, they suffered no alteration in their external appearance. By the result of a previous experiment, hereafter to be mentioned, the loss of weight, which this fossil sustains by ignition, was found to be five parts of water and one of carbonic acid. The above loss of 30 grains is, consequently, divided into 25 grains of water and five grains of carbonic acid.

II.—The remaining ignited 70 grains were reduced to a most subtle powder, which was first reduced with water to a pulpy consistence. Half an ounce of strong sulphuric acid was then added; and all the fluid distilled over to dryness. The residue being softened with boiling water, its undissolved portion separated by means of the filter. This being washed, dried, and ignited, yielded 50½ grains of pure silex.

III.—The clear, colourless fluid shewed, by the taste, that it was a solution of sulphate of magnesia. When concentrated by evaporation, it deposited a small quantity of sulphate of lime. This being decomposed by carbonate of ammonia, afforded one grain of carbonated lime, for which half a grain of lime must be reckoned.

IV.—When the sulphate of lime had been separated, the solution yielded, by crystallization, only sulphate of magnesia. From this salt, re-dissolved in water, and decomposed in a boiling heat, by carbonate of potash, 37½ grains of carbonate of magnesia were obtained, which were reduced, after an hour's ignition, to 17¼ of magnesia.

An hundred parts of this stone, therefore, contain:

Magnesia	17,25
Silex	50,50
Lime	0,50
Water	25
Carbonic acid	5
	98,25

Mr. Klaproth could not accurately ascertain, in the humid way, the proportion of the carbonic acid of this fossil; since acids do not completely dissolve or decompose it in the cold, and hence do not at all effervesce with it, or only imperceptibly. For this reason, he attempted it in the dry way, in the following manner: 200 grains of pulverized silici-murite were introduced into a small glass retort, connected with the mercurial apparatus, and kept in ignition until the vessel was near fusing. The water that passed over was collected in the intermediate vessel or cylinder, while the gas was caught in a receiver above the mercury. The water weighed 35 grains. It was yellowish, and emitted a smell like petroleum; it also manifested a slight vestige of ammonia, which, however, was soon succeeded by a feeble trace of an acid. The gas, deducting the common air contained in the apparatus, amounted to 13 cubic inches, whose weight is nearly seven grains. This was entirely absorbed by lime-water.

Example 5.—*Analysis of the Semi Indurated Steatite.*

Process I.—Two hundred grains of this steatites, finely scraped with a knife, were subjected to a red heat, in a crucible, during one hour. They lost 11 grains, the ignited powder of the stone received a yellow colour.

II.—This being mixed in a silver crucible with a solution of potash, of which the potash was double the weight of the pulverized stone, and, after having been evaporated to dryness, was kept in ignition for half an hour. The mass was again dissolved in water, and digested with muriatic acid, added in excess. The siliceous earth thus separated weighed 119 grains.

III.—The muriatic solution being mingled with carbonate of potash at a boiling heat. A brownish precipitate was produced. This being treated with muriatic acid, the solution evaporated, and the dry saline mass strongly ignited for half an hour. Having re-dissolved this saline mass in water, a brown oxid of iron was separated by filtration. The clear solution was combined with carbonate of potash, at the temperature of boiling. By these means, 147 grains of very loose and white sub-carbonate of magnesia were precipitated. One half of this, re-dissolved in sulphuric acid, and crystallized, afforded pure sulphate of magnesia. The other half, when heated to redness, weighed 30½ grains.

IV.—The red oxid of iron, that had separated from the aqueous solution of the ignited saline mass, process III. weighed nine grains. But, as the portion of iron existing in the mixture of steatites cannot be considered in the state of red oxid, but only as being in the state of black oxid of iron, attractible by the magnet, it was deflagrated with linseed oil, in a covered crucible.—This oxid of iron now weighed only five grains.

According to this analysis, the steatites (from Bareuth) consists, in hundred parts, of:

Magnesia	59,50
Silex	30,50
Oxid of Iron	2,50
Water	5,50
	98

Example 6.—*Analysis of the Steatite, or Soap Rock, from Cornwall.*

Process I.—One ounce of it, in select pieces, was exposed to an intense red heat, placing the coated glass retort in open fire. There distilled over a little tasteless water. The steatite lost 75 grains, and acquired a darker colour, and a considerable degree of hardness.

II.—It was next, after previous pulverization, ignited with two ounces of carbonate of potash. The mass was levigated with water, and digested in an excess of muriatic acid. By this means, a large quantity of a white, porous earth, subsided; which being washed, and exposed to a red heat, weighed 204 grains, and was pure siliceous earth.

III.—When the filtered solution had been combined with prussiate of potash, a blue precipitate was produced, which being collected, washed, dried, and ignited with a little wax, yielded oxid of iron attractable by the magnet, and weighing seven grains; of which, on subtracting the portion of iron belonging to the prussiate of potash employed, 3¾ grains must be considered as belonging to the steatites.

IV.—From the muriatic solution, freed from iron, the earthy contents were precipitated by carbonate of potash. The precipitate obtained weighed 192 grains, after being gently ignited. These were covered with a proportionate quantity of distilled vinegar; digested with a low heat, and, lastly, thrown upon the filter. The insoluble part that remained on the paper, and which weighed 93 grains, when dried and ignited, was mixed with three times its weight of sulphuric acid; the mixture evaporated nearly to dryness in a sand heat; the dry saline mass diffused through water; and lastly filtered. By this treatment there yet remained 26 grains of silex.

V.—The sulphuric solution, therefore contained 67 grains of earth; which precipitated by a carbonate alcali, and examined in the usual way, was found to be merely alumine.

VI.—Of the first 192 grains of the earthy precipitate, process IV. 99 grains were taken up by the acetic acid. These were also precipitated by carbonate of potash. The earth thus obtained was assayed by sulphuric acid, and found to be magnesia.

Therefore, one ounce of this steatite from Cornwall yielded:

Magnesia		99 grs.
Silex	204 26	230
Alumine		67
Oxid of iron		3,75
Water		75
		474,75.
	Loss	5,25
		480

Or, an hundred parts of it, averaging the small fractions, contain:

Magnesia	20,50
Silex	48
Alumine	14
Oxid of Iron	1
Water	15,50
	99

TABULAR ARRANGEMENT

OF

MAGNESIAN STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.

Native carbonate of magnesia
Silici-muriacite, meerschaum, or kiffekiel
Nephritic stone, or jade
Green nephrite, or lemanite
Axe stone
Steatite, soap rock, or Spanish chalk
Agalmaltolite, pagodite, or figure stone
Serpentine, commom
Noble serpentine
Potstone
Lithomarge
Friable lithomarge
Indurated lithomarge

Schillerstone
Chlorite, common
Foliated chlorite
Chlorite slate
Earthy chlorite
Green earth
Talc, common
Indurated talc
Earthy talc, or talcite
Foliated, Venetian talc, or Muscovy glass
Asbestus
Amianth, fine fibrous, flexible asbestus, or mountain flax
Byssolite
Ligniform asbestus, or rock wood
Suberiform asbestus, mountain cork, or mountain leather
Actynolite, actinote, or strahlstein
Magnesian spar
Tremolite
Glassy tremolite
Asbestiform tremolite
Chiastolite, crucite, or macle
Olivin, or volcanic chrysolite
Miemite
Boracite, or borate of magnesia

ORDER V.

BARYTIC STONES.

Division of Barytic Stones.

This order comphrehends only two genera, namely:

GENUS I.—*Carbonate of Barytes.*

GENUS II.—*Sulphate of Barytes.*

CHARACTERS OF BARYTIC STONES.

The stones belonging to this order are particularly distinguished by their superior specific gravity, in which they exceed all other stones and earthy minerals. Their specific gravity is four, or at least near to it: exposed to heat they emit a phosphorescent light. They have rather a spongy appearance: they are less hard than siliceous stones, and may be scratched with a knife.

ANALYSIS OF BARYTIC STONES.

Analysis of Carbonate of Barytes.

Process I.—Dissolve a determinate quantity of the mineral, in nitric acid, diluted with 10 of water, and assay a portion of this solution by sulphate of soda; if a precipitate ensues, on adding a small quantity of this salt to the solution of the earth diluted with 20 times its bulk of water, we may conclude that either barytes or strontia is present.

II.—To ascertain which of these earths, (viz. barytes or strontia) is present, or, if both are contained in the solution, to separate them from each other, add sulphate of soda till the precipitate ceases; decant the supernatant liquid; wash the sediment on a filter, and dry it.—Then digest it, with four times its weight of subcarbonate of potash, and a sufficient quantity of water, in a gentle heat, during two or three hours. A double exchange of principles ensues, and we obtain a carbonate of barytes or strontia, or a mixture of both. Pour on these, nitric acid, of the specific gravity 1.4, diluted with an equal weight of distilled water.

This will dissolve the strontia, but not the barytes. To determine whether any strontia has been taken up by the acid, evaporate the solution to dryness, and dissolve the dry mass in alcohol. This alcoholic solution, if it contain nitrate of strontia, will burn with a carmine red flame

Barytes and strontia may also be separated from each other in the following manner: to a saturated solution of the two earths in an acid, add prussiate of potash, which, if pure, will occasion no immediate precipitation; but, after some time, small and insoluble crystals will form on the surface of the jar. These are the prussiate of barytes, which may be changed into the carbonate by a red heat, continued, with the access of air, till the black colour disappears. The strontia may be afterward separated from the solution by carbonate of potash.

A third method of separating strontia from barytes is founded on the stronger affinity of barytes, than of the former earth, for acids. Hence if the two earths be present in the same solution, add a solution of pure barytes till the precipitation ceases. The barytes will seize the acid, and will throw down the strontia.

The strontia solution, in this case, should have no excess of acid, which would prevent the action of the barytic earth.

Having thus ascertained the presence of these earths, evaporate the nitric solution to dryness, and expose it to a red heat in a crucible; the earth thus obtained is barytes; it is soluble in 20 times its weight of water; and if the solution be evaporated, yields crystals of long four-sided prisms. It separates sulphuric acid from all its combinations. If we drop a crystal of this earth into a solution of sulphate of soda, a white precipitate will instantly ensue.

The Analysis of Sulphate of Barytes is analogous to the examination of sulphate of strontia, which shall be noticed presently.

TABULAR ARRANGEMENT

OF

BARYTIC STONES.

Carbonate of barytes, witherite, or barolite
Striated carbonate of barytes
Foliated carbonate of barytes
Sulphate of barytes, or baroselenite
Compact sulphate of barytes
Curved lamellar ditto
Straight lamellar ditto
Columnar ditto
Prismatic, or acicular ditto
Bolognese ditto
Granular ditto

ORDER VI.

STRONTIA STONES.

Division of Strontia Stones.

Of this order of earth there are likewise only two genera known at present. In the one, the strontia earth is combined with carbonic acid; and in the other it is united to sulphuric acid. The first species appears in solid masses; it is composed of long fibres, adhering to each other, and disposed in a radiated manner. Its colour is generally whitish, and asparagus green, which appears deeper towards the centre of the mass. When broken, its surface is a little shining in certain directions; it is brittle, and has a little transparency. Its surface can be scratched with a knife: its specific gravity is from 3.4 to 3.66. The solution of this earth in nitric or muriatic acid, when evaporated to dryness, tinges the flame of alcohol, carmine red.

Sulphate of strontia occurs both amorphous and crystallised, most commonly in bevelled tables, sometimes in rhomboidal cubes, set edge-ways in the matrix. Its texture is foliated, and more or less transparent. The specific gravity of this mineral reaches from 3.51 to 3.96. Its colour is most commonly reddish, or sky blue, and sometimes colourless.

ANALYSIS OF STRONTIA STONES.

Analysis of Carbonate of Strontia.

Process I.—Dissolve a determinate quantity of the stone supposed to be carbonate of strontia in dilute nitric acid, evaporate the solution, and suffer it to crystallise; collect a portion of these crystals, and, when dry, moisten them with alcohol in a silver spoon. Set fire to the mixture, and hold it while burning over the flame of a candle, so as to cause a quick and rapid combustion. The flame of the alcohol will be tinged beautifully red.

II.—Expose the nitrate of strontia to a red heat, and obtain the earth from this nitrate in a similar manner as directed for obtaining barytes. The earth thus obtained should amount to more than one half of the stone employed.

Analysis of Sulphate of Strontia.

Process I.—Boil one part of sulphate of strontia, reduced to an impalpable powder, with 4 or 6 of carbonate of potash in 12 of water for about two hours, renewing the water as it evaporates, and agitate the mixture frequently.

II.—Decant the supernatant fluid, and wash the insoluble residue in water.

III.—Transfer this insoluble powder into dilute nitric acid, and effect a solution.

IV.—Evaporate the fluid to dryness, and expose it to a red heat: the earth thus obtained is strontia; dissolve it in water; evaporate the solution, and suffer it to crystallise. The remaining fluid may be examined for lime, &c. in the usual manner.

Vauquelin analysed an impure specimen of sulphate of strontia, as follows:

Process I.—On 200 parts of the mineral, diluted nitric acid was poured. A violent effervescence took place, and part of it was dissolved. The undissolved portion, after being heated red hot, weighed 167. Therefore 33 parts were dissolved.

II.—The nitric solution was evaporated to dryness: a reddish substance remained, which indicated the presence of oxid of iron. This substance was re-dissolved in water, and some liquid ammonia mixed with it; a reddish precipitate appeared, which, when dried, weighed one, and was oxid of iron. The remainder of the solution was precipitated by carbonate of potash. The precipitate weighed, when dried, 20, and possessed the properties of carbonate of lime. Therefore 200 parts of this mineral contain 20 of carbonate of lime, one of oxid of iron, and the remainder of the 33 parts he concluded to be water.

III.—The 167 parts, which were insoluble in nitric acid, were mixed with 500 parts of carbonate of potash, and 7000 parts of water, and boiled for a considerable time. The solution was then filtered, and the residuum washed and dried. The liquid scarcely effervesced with acids; but with barytes it produced a copious precipitate, totally insoluble in muriatic acid. Therefore it contained sulphuric acid.

IV.—The undissolved residuum, when dried, weighed 129 parts. It dissolved completely in muriatic acid. The solution crystallized in needles; when dissolved in alcohol, it burnt with a purple flame; and, in short, had all the properties of muriate of strontia. Therefore these 129 parts were carbonate of strontia. Now, 100 parts of this carbonate contain 30 of carbonic acid; therefore 129 contain 38.7. Hence the mineral must contain in 200 parts 90.3 of strontian.

Now, the insoluble residuum of 167 parts was pure sulphate of strontia: and we have seen that it contained 90.3 of strontia. Therefore the sulphuric acid must amount to 76.7 parts.

TABULAR ARRANGEMENT

OF

STRONTIA STONES.

Carbonate of strontia, or stronianite
Sulphate of strontia, or celestine
Compact sulphate of strontia
Fibrous sulphate of strontia
Foliated sulphate of strontia

ORDER VII.

STONES BELONGING TO THE GLUCINE ORDER.

Division of the Stones belonging to the Glucine order.

This earth has hitherto been found only in three stones, namely; in the Aigue-marine, or Beryl, a transparent stone of a green colour; in the Emerald of Peru, or Smaragd, a stone of a similar colour; and in the Euclase.

ANALYSIS OF THE BERYL, OR EMERALD OF PERU.

Process I.—Take any quantity of beryl or emerald, and having reduced it to a very fine powder, mix it with about three times its weight of potash in a liquid form, and digest it to dryness in a silver crucible, after which let it be moderately ignited for about half an hour: the resulting mass will be found to be entirely soluble in a slight excess of muriatic acid, and the solution, after being evaporated to dryness and then diffused in water, will deposit nearly the whole of the silex.

II.—The muriatic solution is now to be supersaturated with potash or soda and boiled, by which the oxid of iron and of chrome, if any is present, will be separated.

III.—The clear liquor being again supersaturated with muriatic acid and afterwards mixed at a boiling temperature with carbonate of soda, deposits the whole of its earthy contents in the form of a white soft precipitate.

IV.—This precipitate after being well washed in water, is to be dissolved in sulphuric acid, and the solution being transferred into a ground stoppered bottle is to be considerably supersaturated with carbonate of ammonia: both the alumine and glucine will be at first precipitated, but this last, by the assistance of occasional agitation will be re-dissolved in the course of a few hours.

V.—The earthy residue is to be again dissolved in sulphuric acid, and sulphate of potash being added, a copious deposit of crystals of alum will take place.

VI.—The residuary liquor and washings of the crystals being again treated with a large excess of carbonated ammonia, the remaining portions of glucine becomes extracted, and the two ammoniacal solutions are to be added together. This fluid when boiled in a retort deposits the whole of the glucine in the state of a white powder, and combined with carbonic acid: after being washed and dried it must be ignited, by which it will lose carbonic acid and moisture to the amount of about half its weight, and the residue is pure glucine.

The remaining earths may be separated according to the rules laid down before, under the articles **Analysis of Siliceous and Calcareous Stones.**

ORDER VIII.

STONES BELONGING TO THE ZIRCON ORDER.

Division of the Stones belonging to the Zircon order.

There are only two stones hitherto known belonging to this order, namely: Zircon, or Jargon, and the Hyacinth.

ANALYSIS OF THE ZIRCON OR JARGON.

The analysis of this precious stone may be accomplished in the following manner:

Process I.—The mineral being very accurately pulverised is to be mixed with six times its weight of perfectly caustic potash dissolved in a little water. The mass being evaporated to dryness in a silver crucible is to be kept at a low red heat for two hours: after this, being allowed to cool, it will be found strongly adherent to the crucible, and must accordingly be covered with 10 or 12 times its weight of water, to which must then be added a sufficiency of muriatic acid in order to supersaturate the alcali. By a gentle digestion the whole of the mass will be dissolved, and the clear solution is to be evaporated slowly to dryness, stirring it about all the time to facilitate the separation of the silex.

II.—The residue of the evaporation is now to be digested with a moderate quantity of water slightly acidulated by muriatic acid, which will take up the zircon and oxid of iron, leaving the silex behind. This evaporation and re-solution in very dilute muriatic acid is to be repeated two or three times, that every particle of silex may be separated.

III.—To the muriatic solution is now to be added carbonate of ammonia, which at first occasion an abundant precipitate, but by adding an excess of the alcali the whole of the zircon will be re-dissolved and the oxid of iron falls down to the bottom.

IV.—The clear filtered liquor is to be boiled for two or three hours, by which the excess of ammonia will be driven off, and the zircon be deposited in the state of carbonate, and in the form of a white powder. This powder being washed and properly dried is afterwards to be ignited, by which about 43 per cent. of water and carbonic acid will be driven off, the remainder being pure zircon.

ORDER IX.

STONES BELONGING TO THE YTTRIA ORDER.

Division of Stones belonging to the Yttria order.

The only mineral known to contain the peculiar earth called Yttria, is Gadolinite.

The mineral called Yttro-Tantalite contains this earth only in a minute quantity, and is properly an ore, belonging to the ores of tantalium, where it has been noticed already.

ANALYSIS OF THE GADOLINITE.

Process I.—Gadolinite being ground to a fine powder is digested with diluted nitric acid, and evaporated to dryness, taking care to increase the heat towards the end of the process, in order to ensure the complete oxidation of the iron, which it always contains in abundance.

II.—The whole is now to be re-dissolved in water, and as the solution still contains a little iron this may be got rid of either by again evaporating to dryness and subsequent digestion in water, or by precipitating the iron by a drop or two of ammonia.

III.—The solution is now mixed with caustic ammonia as long as any precipitate is produced; and the supernatant liquor and washings of the precipitate being mixed with carbonated potash a little carbonate of lime is thrown down.

IV.—The first precipitate of process III. is re-dissolved in nitric acid, and by the cautious and gradual addition of hydro-sulphuret of potash the oxid of manganese is separated.

V.—The clear liquor now only contains nitrate of yttria, from which the earth is procured by caustic ammonia.

VI.—The insoluble residues, process II. consist of silex and oxid of iron, which are separated by muriatic acid, the earth remaining undissolved.

Another method is,

Process I.—To fuse the mineral with twice its weight of caustic potash, to digest the mass in boiling water, and then separate the liquor while hot from the undissolved portion by the filter.

II.—The fluid will be of a fine green colour, indicating the presence of manganese, and by exposure to the air will become colourless, the oxid of manganese being precipitated in the form of a black powder.

III.—The clear liquor is now to be saturated with nitric acid, and the same fluid very much diluted is to be digested on the insoluble portion, process I. The two nitric solutions being mixed together and evaporated to dryness, and re-digested in water contain only the nitrates of lime and yttria; while the portion insoluble in nitric acid consists of silex and oxid of iron, both of which are to be separated in the manner already described.

ANALYSIS OF SOILS.

In the preceding pages it has been endeavoured to exhibit a view of analysing earths and stones, as constituting particular orders or genera, and species; we shall now consider the method of analysing soils.

Land, considered as the basis of vegetation, is called *soil*. Soils consist of different combinations of earths, intermingled with a portion of animal and vegetable matter.

The following abstract, for determining the composition of a soil, are copied from a Memoir, presented by Mr. Davy to the Board of Agriculture.

1.—*Utility of investigation relating to the Analysis of Soils.*—The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science: many useful facts and observations, with regard to it, have been furnished by Mr. Young; it has been examined by Lord Dundonald, in his treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan, in his excellent essay on manures: but the enquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honor of laying before the board an account of those methods of analysing soils which appear most precise and simple, and most likely to be useful to the practical farmer; they are founded partly upon the labours of the gentlemen whose names have been just mentioned, and partly upon some later improvements.

The substances which are found in soils are certain mixtures or combinations of some of the primitive earths, animal or vegetable matter in a decomposing state, certain saline compounds, and the oxid of iron. These bodies always retain water, and exist in very different proportions in different lands; and the end of analytical experiments is the detection of their quantities and mode of union.

2.—*Mode of collecting Soils for Analysis.*—In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens that upon plains the whole of the upper stratum of the land is of the same kind, and in this case one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils, when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains: these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote to a certain extent their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; argillaceous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on; and calcareous soils are soft, and much less adhesive than argillaceous soils.

3.—Mode of ascertaining the quantity of Water of Absorption in Soils.—Soils, though as dry as they can be made by continued exposure to the air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a bason of porcelain, to a temperature equal to 300.* Fahrenheit; and in case a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish: as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted; and when in four hundred grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will ge-

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* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

nerally be found to contain a large proportion of alumine. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and the siliceous earth as most abundant.

4.—*Of the separation of Stones, Gravel, and vegetable fibres, from Soils.*—None of the loose stones, gravel, or large vegetable fibres, should be divided from the pure soil till after the water is drawn off: for these bodies are themselves often highly absorbent and retentive, and in consequence influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acid; if siliceous, they will be sufficiently hard to scratch glass; and if of the common argillaceous class of stones, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

5.—*Separation of the Sand and Clay, or Loam, from each other.*—The greatest number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marle, and vegetable and animal matter. This may be effected in a way sufficiently accurate, by agitating the soil in water. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the minutely divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed; the sand must likewise be weighed, and their respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline matter, and the soluble animal and vegetable matters, if any exist in the soil.

6.—*Examination of the Sand.*—By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part: it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole indicates the proportion of calcareous sand.

7.—*Examination of the finely divided Matter of Soils, and mode of detecting Mild Lime and Magnesia.*—The finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, in a quantity equal to twice the weight of the earthy matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxid of iron, but very seldom any alumine.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solutions, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of common prussiate of potash must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxid of iron, and the solution of the prussiate must be dropped in till no further effect is produced. To ascertain its quantity it must be collected in the same manner as other solid precipitates, and heated red; the result is oxid of iron.

Into the fluid, freed from oxid of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alcaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid; and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumine should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with caustic potash, sufficient to cover the solid matter. This substance dissolves alumine, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* about 45 per cent. so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is unknown, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid, and one part of the matter of the soil, must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases: the difference between their weight before and after the experiment denotes the quantity of carbonic acid lost; for every four grains and a half of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper. The estimation is, for every ounce measure of carbonic acid two grains of carbonate of lime.

8.—*Mode of ascertaining the quantity of insoluble finely divided Animal and Vegetable Matter.*—After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time of ignition almost always denotes a considerable portion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposible substances may be assisted by the agency of nitrate of ammonia, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and is itself at the same time decomposed and lost.

9.—*Mode of separating argillaceous and Siliceous Matter, and Oxid of Iron.*—The substances remaining after the decomposition of the vegetable and animal matter are generally minute particles of earthy matter, containing usually alumine and silex with combined oxid of iron.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance remaining after the action of the acid may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumine and the oxid of iron, if any exist, are both dissolved by the sulphuric acid; they may be separated by carbonate of ammoniac, added to excess: it throws down the alumine, and leaves the oxid of iron in solution, and this substance may be separated from the liquid by boiling.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid: this, however, is scarcely ever the case; but the process for detecting them and ascertaining their quantities is the same in both instances.

The method of analysis by sulphuric acid is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent, and the residuum of the incineration must be heated red for half an hour, with four times its weight of this substance, in a crucible of silver, or of well-baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxid of iron and all the earths, except silex, will be dissolved in combination as muriates. The silex, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

10.—*Mode of discovering Soluble Animal and Vegetable Matter, and Saline Substances.*—If any saline matter or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour, and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous or gelatinous substance; if it be white and transparent, it may be considered as principally saline matter. Nitrate of potash (nitre), or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magnesia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammonia, but precipitate solution of muriate of barytes.

11.—*Mode of detecting sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*— Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process of gypsum: Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

12.—*Statement of Results and Products.*—When the examination of a soil is completed, the products should be classed, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate, or sulphate, of lime is discovered by the independent process 11, a correction must be made for the independent process, by subtracting a sum equal to its weight from the quantity of carbonate of lime obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

		Grains.
Of water of absorption		18
Of loose stone and gravel, principally siliceous		42
Of undecompounded vegetable fibres		10
Of fine siliceous sand		200
Of minutely divided matter separated by filtration, and consisting of		
Carbonate of lime	25	
Carbonate of magnesia	4	
Matter destructible by heat, principally vegetable	10	
Silex	40	
Alumine	33	
Oxid of Iron	4	
Soluble matter, principally sulphate of potash and vegetable extract	5	
Gypsum	3	
Phosphate of lime	2	
		126
Amount of all the products		395
Loss		4

In this instance the loss is supposed small; but, in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

13.—*This general Method of Analysis, may, in many cases, be much simplified.*—When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid, 7, may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air, 8; and in the analysis of chalks and loams, he will be often able to omit the experiment by sulphuric acid, 9.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with : but, in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

14.—*On the improvement of Soils, as connected with the principle of their composition.*—In cases when a barren soil is examined with a view to its improvement, it ought, in all cases, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation : the difference given by their analysis would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marle, or chalk, to lands, there are no particular chemical principles to be observed; but when quick lime is used, great care must be taken that it is not obtained from the magnesian limestone; for in this case, as has been shewn by Mr. Tennant, it is exceedingly injurious to land.* The magnesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analysed by the process of carbonate of lime and magnesia, 7.

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much pulverisation and exposure to air, by paring and burning, or the agency of lately made quick-lime. And the

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* Philosoph. Trans. for 1799, p: 305. This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

defect of animal and vegetable matter must be supplied by animal or vegetable manure.

15.—*Sterile Soils in different climates and situations must differ in composition.*—The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils absorb moisture, a principle essential to their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys.* The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may

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* Kirwan, Trans. Irish Academy, Vol. V. p. 175.

occasionally be prevented from being barren, in a moist climate by the influence of a substratum of sand or gravel.

16.—*Of the chemical composition of fertile Corn Soils in this climate.*—Those soils that are most productive of corn contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is, however, very various, and, in some cases, exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one-ninth of sand, chiefly siliceous, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere.*

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighth of the parings of lime-stone, was very proper for wheat.

17.—*Of the composition of Soils proper for bulbous roots and for trees*—In general, bulbous roots require a soil much more sandy, and less absorbent than the grasses. A very good potatoe soil, from Varfal, in Cornwall, afforded me seven-eighths of siliceous sand; and its absorbent

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* This soil was sent to me by T. Poole, Esq. of Nether Stowey. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

power was so small, that one hundred parts lost only two by drying at 400° Fahrenheit.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils, which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield Place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter; and one hundred parts of the entire soil, submitted to analysis, produced,

Water	3 parts
Silex	54
Alumine	28
Carbonate of lime	3
Oxid of iron	5
Decomposing vegetable matter	4
Loss	3

18.—*Advantages of Improvements made by changing the Composition of earthy Parts of Soils.*—From the great difference of the causes that influence the productiveness of lands, it is obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops: but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expence.

Description of the Apparatus for the Analysis of Soils.—Fig. 1, Plate I. *a*, *b*, *c*, *d*, *e*, *f*. The different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils:

a, represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *f*, the graduated measure; *f*, *e*, the bottle for containing the bladder *d*. When this instrument is used, a given quantity of soil is introduced into *a*; *b* is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced into the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e*, *f*, which is filled with water. The graduated measure is placed under the spout of *f e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder, and displaces a quantity of water in *e f* equal to it in bulk, and this water flows through the tube or spout into the graduated measure; the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which, two grains of carbonate of lime may be estimated.

PART IV.

CLASS 3.

MINERAL OR NATIVE SALTS.

By the name of mineral or native salts, we understand, strictly speaking, all those native mineral substances which are found, consisting of an earthy, metallic, or alcaline base, combined with an acid. They naturally divide themselves into several genera, namely; calcareous salts, comprehending the combination of calcareous earth, with different acids; such as carbonates, sulphates, phosphates, fluates, and borates of lime: Barytic salts, comprehending the combinations of barytic earth, with sulphuric and carbonic acids; strontian salts, or strontian earth, united to the same acids, &c. Most of these have been considered under the class of earths, and stones. We have therefore to consider here merely those which are readily soluble in water, and which are usually called mineral salts; for they possess the properties of saline bodies, in a more striking degree. They are divided in the Chemical Systems of Mineralogy, in the following manner:

Division of Mineral or Native Salts.

GENUS I.—*Muriates.*

Species 1.—Muriate of Soda, or Common Salt.
  Varieties 1.—Foliated Common Salt.
    2.—Fibrous Common Salt.
    3.—Lake Salt
    4.—Rock or Stone Salt.

GENUS II.—*Muriates.*

Species 1.—Muriate of Ammonia, or Native Sal Ammoniac.

GENUS III.—*Nitrates.*

Species 1.—Nitrate of Soda, or Native Saltpetre.

GENUS IV.—*Sulphates.*

Species 1.—Sulphate of Soda, or Native Glauber Salt.
2.—Sulphate of Magnesia, or Native Epsom Salt.
3.—Sulphate of Magnesia and Iron, or Hair Salt.
4.—Sulphate of Alumine and Soda, or Native Alum
5.—Sulphate of Iron, or Native Vitriol.
6.—Sulphate of Copper.
7.—Sulphate of Zinc.
8.—Sulphate of Cobalt.

GENUS V.—*Borates.*

Species 1.—Borate of Soda, or Native Borax.
2.—Borate of Magnesia and Lime, or Salsoline.

GENUS VI.—*Carbonates.*

Species 1.—Carbonate of Soda, or Native Natron.

GENUS VII.—*Boracic Acid.*

GENERAL ANALYSIS OF NATIVE OR MINERAL SALTS.

Process I.—In order to investigate whether an unknown mineral contains some saline matter, put a determinate quantity, reduced to an impalpable powder, into a flask, pour over it 30 times its weight of water, digest the mixture in a temperature of about 130°, and agitate it frequently. Having stood for about 6 hours, decant the transparent fluid, separate the insoluble part, by pouring it on a filter, whose weight is known; dry it in a heat not exceeding 212°, and ascertain its weight. If the weight be considerably less than the joint weight of the filter and powder, before digestion, we are certain that some salt has been taken up by the water; the deficiency of weight will indicate its quantity. Being thus convinced, that the substance under examination belongs to the class of minerals, properly called salts, we have next to find out the nature of it, more accurately, in the following manner:

II.—Drop into a wine-glass full of the solution, obtained by digesting the mineral in water, as directed before, a few drops of tincture of litmus, or immerse into it a piece of litmus paper, and notice if the blue colour of the tincture, or of the paper, becomes altered, or not.

If the paper becomes red, the fluid contains an uncombined acid, or a salt with excess of acid. In order to ascertain the nature of the acid which is present, drop into the solution muriate of barytes; if an insoluble precipitate ensues, sulphuric acid is present; but if the precipitate is soluble in muriatic acid, phosphoric acid may be expected. If nitrate of silver occasions a precipitate, muriatic salts, or muriatic acid was present.

III.—If water that has been suffered to act on a saline substance, changes the yellow colour of turmeric paper brown, it contains an alcaline substance, and the salt belongs to the class of alcaline salts.

IV.—If a substance is found not to change the colour of the turmeric brown, or that of litmus red, and if it does not effervesce on the addition of an alcali, the salt is then distinguished to be a neutral, or compound salt, composed of an acid, and a certain base: we have then to determine the nature of the base, that is to say, to find out whether the salt has a metallic, earthy, or an alcali for its basis. This may be accomplished in the following manner:

ANALYSIS OF SALTS WITH METALLIC BASES.

Process I.—Drop into the solution, obtained as described before, a few drops of prussiate of potash; if a copious blue precipitate ensues, it then contains a metallic oxid, and belongs to the salts called metallic salts.

II.—To ascertain the genus to which it belongs, by determining the acid whereby its basis is neutralized, add to a little of the saturated saline solution, an equal portion of alcohol; if this occasions the salt to precipitate, and if a few drops of muriate of barytes, added to a little of the dissolved salt, occasion a copious precipitate, we know that the acid present is sulphuric acid, and that the salt belongs to the genus called *sulphates*.

III.—To determine the metallic oxid, with which the acid was combined, we add to it first a solution of carbonate of ammonia; if this occasion a blue precipitate, which is redissolved by an excess of ammonia, add an acid, a little in excess; we then immerse into it a cylinder of iron, and suffer it to stand undisturbed for some days. If the iron cylinder becomes covered with a coat of copper, we then have found that the salt had copper for its basis, and therefore belonged to that species which is called *sulphate of copper.*

IV.—But if these phenomena are not perceived, we let fall into the solution a few drops of prussiate of potash. If this produces a blue precipitate, the basis is then supposed to be iron, and in this case it must also occasion a black colour when mixed with tincture of galls. If such phenomena take place, the salt belongs to that species called *sulphate of iron.*

V.—If neither of these phenomena ensue, and the fluid exhibits a rose colour, we add a few drops of tincture of galls; if this occasions a blue precipitate, and a precipitate is also produced by the addition of potash, which, when fused with borax before the blow-pipe, produces a blue glass, we then have ascertained the basis of the salt to be cobalt, and this with sulphuric acid before detected, makes it to be that species called *sulphate of cobalt.*

VI.—If neither of these marks should be perceived, we place a polished cylinder of copper into the concentrated solution; and if this occasions a white metallic precipitate upon the surface of the copper cylinder, which can be volatilized again by exposing the cylinder to heat, we then know the basis to be mercury; having ascertained the principal component part of the salt, which is distinguished by the name of *sulphate of mercury*.

VII.—But if the fluid should not prove any of these mentioned properties of mixture, and if it yields a white salt on evaporation, if prussiate of potash added to it, produces a greenish white precipitate, and if a cylinder of iron, and copper, when placed in the solution, occasions no precipitate, we then suppose the substance to be the species called *sulphate of zinc*. These are the principal metallic salts hitherto found in the earth.

ANALYSIS OF SALTS WITH ALCALINE BASES.

Process I.—If in a solution of salt prussiate of potash does not occasion a blue precipitate, the salt is of a different nature from those mentioned before. We have then to find out its composition, by adding to it a solution of subcarbonate of potash, or soda. If this occasions no precipitate, the salt then probably belongs to the neutral salts, with alcaline bases. It may, however, happen, that salts of that kind exist in the solution, associated with salts of a metallic or earthy base. In this case the examination becomes difficult; because the alcali added, which acts as the re-agent to precipitate the two last, makes it doubtful to ascertain whether the neutral salts were formed during the process, or whether they originally existed in the solution. The following method, recommended by Mr. Henry, will in that case prove useful.

II.—Precipitate the metallic oxid, by adding to the solution prussiate of ammonia, and separate the earth, by adding to it a solution of carbonate of ammonia, taking care to have previously heated the fluid to at least 180°, or upwards, in order to insure the decomposition of magnesian salts, which cannot be effected by carbonate of ammonia in the cold. Separate the liquor by filtration, and evaporate it to dryness; then expose the dry mass to a dull red heat, in order to expel the ammoniacal salts. The salts, with fixed alcaline bases, will remain behind. By this process, indeed it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be learned by adding to the salt under examination, before its solution in water, some potash, which, if ammonia be contained in the salt, will produce its peculiar odour.

III.—In order to ascertain the acid with which the ammonia is combined, we mingle a solution of the salt with lime-water. If a precipitate ensues, which on adding a few drops of muriatic acid, again becomes dissolved with effervescence, the salt belonged to the class of salts, called *carbonate of ammonia.*

IV.—If on the contrary no such effects take place, but a copious precipitate ensues on adding to the solution a few drops of muriate of barytes, we then conclude that the salts is *sulphate of ammonia.*

V.—But if neither of these changes ensue, we drop into the solution a few drops of sulphate of silver; if this produces an insoluble white precipitate, the salts consist of muriatic acid and ammonia, and is consequently *muriate of ammonia.*

VI.—But suppose ammonia did not enter into the composition of the salt, and had not been detected as stated before, but another alcaline basis was present, we then add to the solution of the salt in water a few drops of muriate of platina: if a turbidness ensues, the basis of the salt is potash, and the salt of course belongs to the class of salts with a basis of *vegetable alcali*; but if no such effect takes place, we conclude that the basis of the salt is soda, and that it belongs to the class of salts, with a basis of the *mineral alcali*.

VIII.—If a little of the salt, when mixt with charcoal powder, and thrown into an ignited crucible deflagrates, we know that nitric acid is present, and that it belongs to the class of salts called *nitrates*.

The presence of other acids may be detected as stated before.

ANALYSIS OF SALTS WITH EARTHY BASES.

Process I.—If a solution of salt, in which prussiate of potash occasions no precipitate, affords a copious precipitate by the addition of carbonate of potash, it proves that the salt has an earth for its basis, and consequently belongs to the class of *earthy salts*.

II.—In order to ascertain the acid which is combined with the earth, we proceed as directed in the preceding pages.

III.—We next endeavour to ascertain the earths: if we find that the precipitate is soluble in sulphuric acid, and yields with it, by the addition of a small quantity of alcali, a salt which has a sweet styptic taste, and which has the properties of alum, we know that the basis of the salt was alumine, and that it belongs to the class of *salts*, called *alum*.

IV.—But if the salt obtained by neutralizing the earth with sulphuric acid has a bitterish taste, and becomes decomposed by sub-carbonate of potash, and yields a precipitate which when ignited remains soluble in nitric and acetic acids; it then belongs to the class of salts, having magnesia for its basis, called *magnesian salts*.

In this manner we may ascertain the different salts which have hitherto been found amongst the mineral substances. There are others met with in mineral waters, the presence and nature of which must be ascertained in a different manner. The salts here considered are only such as are found each in a separate state, and which appear homogenous.

Before we conclude this subject we shall exhibit an

EXAMPLE OF AN ANALYSIS OF A MIXTURE OF DIFFERENT SALINE SUBSTANCES.

Suppose we had ascertained by previous experiments, in the way mentioned in the foregoing part, that an earth contained a mixture of different salts, viz. *sulphate of magnesia*, *muriate of potash*, *sulphate of iron*, *sulphate of potash*, and, *sulphate of soda*; we then may proceed in the following way:

Process I.—Let a certain quantity of such earthy substance which has been previously dried for two hours in the heat of boiling water, be extracted and freed from saline parts, by digesting it with about 50 parts of distilled water, in a glass matrass; filter the whole, and wash the remainder upon the filter, with a little water, then dry it in the same heat, and for the same time as before, and ascertain its weight. The loss, indicates the quantity of saline parts which were contained in it.

II.—Let a certain quantity of the saline liquid be evaporated to dryness by a gentle heat.

III.—Digest the residue with high rectified spirit of wine, as long as the spirit will dissolve any part of the salt. This spirituous solution mix with a little water, and again separate the spirit by distillation.

IV.—Evaporate the remaining aqueous solution nearly to dryness, and suffer it to crystallise; let the salt be dried in the same degree of heat as the earth had been exposed, and ascertain its weight, which will indicate the proportion of the salt which was taken up by the spirit, and which was muriate of potash; this salt may be again decomposed, by dissolving a little of it in water, and adding to it sulphate of silver: this will occasion a precipitate which indicates the muriatic acid; and carbonate of potash added to it, will occasion no earthy precipitate, if the salt was merely composed of muriatic acid and potash.

V.—The salt which was not acted upon by the spirit, is then to be dissolved with a sufficient quantity of distilled water, mingled with a little acetous acid, and prussiate of lime gradually dropped into it, until it does not occasion any more blue precipitate. The precipitate thus formed, must be collected on a filter, washed with a little water, dried, and made red hot in a small crucible, whose weight is previously ascertained, and which has been ignited before the precipitate was put in; after which, the crucible is taken out of the fire and again weighed, thus the proportion of the oxid of iron is ascertained.

VI.—The remaining liquid from which the iron is separated, is gradually to be mixed with acetite of barytes as long as any precipitate is thereby occasioned: the precipitate consists of the barytes contained in the acetous solution which was added, and of the sulphuric acid contained in the salts; the whole is then put upon a filter, the precipitate carefully collected, dried, and its weight ascertained. One hundred grains of such precipitate, are equal to 23.5 grains of sulphuric acid.

VII.—The remaining solution consists now of *magnesia, potash, soda, and acetous acid*; to separate them let it be evaporated to dryness, and ignite it in a smooth crucible, until the acetous acid has been driven off by the heat; the remaining substance is to be extracted by warm water, as long as the water takes up any of it; the whole must then be transferred upon a filter, and the earth, which was the magnesia, be collected, dried, ignited, and its weight ascertained.

VIII.—The salt which the water had extracted from the residue, is again saturated with acetous acid, and if, after stirring the solution, any earthy precipitate is observed, it is to be filtered again, and the earth collected upon the filter: it is the portion of magnesia which had been taken up by the alcali, which is likewise to be dried and added to the weight of the magnesia obtained before.

IX.—The filtered liquid is again evaporated by a gentle heat to dryness and afterwards digested in alcohol. This will take up the potash combined with muriatic acid, and leave the soda behind; the alcoholic solution is evaporated to dryness, and re-dissolved in distilled water; and then mixed with acetite of lead, until all the muriatic acid is thereby separated; the precipitated muriate of lead is then separated by filtration, and the filtered liquid evaporated to dryness; afterwards ignited a little in a small smooth crucible, whose weight has been previously ascertained; when the acetous acid has been driven off by heat, the crucible is removed, and when cooled, it is immediately weighed: the overplus of the weight of the crucible indicates the weight of the potash. The muriate of soda, which was not dissolved, is likewise treated in the same way, and thus the quantity of the soda ascertained.

If we now take each of the four separated ingredients, namely, the magnesia, soda, potash, and the iron, and saturate each separately with sulphuric acid, and then crystallise them; we become enabled by that means to ascertain the quantity of each of the salts in the state as they were contained in the earthy substance, pretty accurately.

This being a nice process, it requires great accuracy; and the rules for accomplishing it, would occupy more room than can be allotted them in this work.

PART V.

CLASS 4.

INFLAMMABLE FOSSILS.

The class of minerals remaining to be noticed, are those called inflammable or combustible fossils. They are divided in the following manner:

Genus i.—*Sulphur.*

Species 1.—Native Sulphur.
  Varieties 1.—Coherent Native Sulphur.
    2.—Earthy Native Sulphur.
    3.—Volcanic Native Sulphur.

Genus ii.—*Bitumen.*

Species 1.—Mineral or Fossil Oil.

Species 2.—Mineral Bitumen.

Varieties 1.—Elastic Mineral Bitumen.
2.—Earthy Mineral Bitumen.
3.—Slaggy Mineral Bitumen.

Species 3.—Brown Coal.

Varieties 1.—Bituminous Wood.
2.—Earthy Coal.
3.—Alum Earth.
4.—Common Brown Coal.
5.—Moor Coal.

Species 4.—Black or Pit Coal.

Varieties 1.—Pitch Coal.
2.—Columnar Coal.
3.—Slate Coal.
4.—Cannel Coal.
5.—Foliated Coal.
6.—Coarse Coal.

GENUS III.—*Graphite.*

Species 1.—Glance Coal.

Varieties 1.—Conchoidal.
2.—Slaty.

Species 2—Graphite.

  Varieties 1.—Scaly.
  2.—Compact.

Species 3.—Mineral Charcoal.

Genus IV.—*Amber.*

Species 1.—Amber.

  Varieties 1.—White.
  2.—Yellow.
  3.—Mellite, or honey stone

CHARACTERS OF INFLAMMABLE FOSSILS.

Inflammable fossils are such mineral substances as burn more or less easily, or whose principal character is inflammability at not very high temperatures. They are all insoluble, at least in their totallity in alcohol, as well as in water, and acids; but yield generally more or less to some species of volatile oil, or to sulphuric ether. Their specific gravity is below or scarcely exceed 2°, unless loaded with foreign matter.

NATURAL HISTORY OF COALS.

Coals are commonly found in hilly situations, always under strata of grit, which is a mixture of sand and clay; or under schistus, which is an indurated clay, splitting into layers, forming either slates, or a substance called shivers; according to its fracture. Coals are found on the mountains in strata, from a few inches to some feet in thickness, alternating with strata of grit stone and shistus. The beds of coals run in various directions, generally with a dip or inclination from the horizontal position. They are frequently intercepted by columns of other matter; and the continuation of the bed may be higher, or lower, than the part from which it has been, or seems to have been separated. The continuation too sometimes take the same, sometimes a very different degree of inclination, or dip. It generally happens that the first stratum of coals, that we come to, is not worth working, either from the inferior quality of the coal, or from the stratum being of too little depth. From the degree and direction of the dip, and the level of the country, much information is to be obtained, concerning the proper places for opening the pit. A variety of circumstances require to be taken into consideration to work a coal mine to the greatest advantage, or to determine whether a mine ought to be worked at all. Even in countries or in those parts of the country, where none have been found, very probable conjectures may be formed concerning their presence, by attending to the soil, to the general appearance of the country, and to the kind of clay, sand, or other earth, that is found when the soil is removed. There are certain appearances that indicate the presence of coals; but these indications are subject to variations, and often appreciable by other rules. The business of mining in this department, is therefore intricate as that of ores, and none ought to enter upon it, without a practical knowledge of it, or the assistance of a practical miner.

With respect to the origin of coals, the most probable supposition is this:

That they originate from vegetables; but a few forests being buried in the earth are not sufficient to form the mountains of coal which exist in its bowels. A greater cause more proportioned to the magnitude of the effect is required; and we find it only in that prodigious quantity of vegetables which grow in the sea, and is increased by the immense mass of those which are carried down by rivers. These vegetables carried away by the currents, are agitated, heaped together, and broken by the waves, and afterwards become covered with strata of argillaceous earth, or sand; they undergo a gradual decomposition, and form so many strata of coal, placed alternately with strata of clay and sand. It is indeed easier to conceive how these masses of vegetables may form strata of coal, than that remains of shells, should form so great a part of the globe.

That the coal itself is of vegetable origin, is fairly inferred from a variety of vegetables, remains, and impressions of animals, that are both found in the strata of coal, and in the earthy strata, above and below them. That it is of submarine origin, also appears obvious from the presence of shells, the impressions of fish, and other productions of the ocean. The popular opinion that coals grow like vegetables, so that the mines that are exhausted may be opened again and worked after a series of years, is too erroneous to need any formal refutation. We need not however be alarmed for the want of future generations, as to this useful article. The immense beds of coal yet untouched will amply supply many thousands of generations to come; and there is no doubt but the same process that produced what we at present use, is still continued, and that some future convulsions of nature will bring to light new coal mountains perhaps from the bottom of the ocean; for that it is most probable is the place where nature had fixed her laboratory, for preparing this fuel for distant ages. For the modern practice of searching for coals the reader is referred to the author's System of Mineralogy, article *Coal.*

ANALYSIS OF INFLAMMABLE FOSSILS.

The complete analysis of inflammable fossils would require a particular treatise: our object, however, is merely to determine in a ready manner the relative proportion of combustible matter, or carbon, which different species of coal are capable of yielding to be enabled to judge in some respect which are most advantageous in the ordinary processes of combustion: for the method of accomplishing this we are indebted to Kirwan. The only combustible substance of what it will be necessary to speak for that purpose, are coals.

Coals, at least those which are chiefly employed for fuel are composed of carbon or charcoal, bitumen, some portion of earth, and a small quantity of metallic matter.

The proportion of carbon may be ascertained by observing the quantity of nitrate of potash which a given quantity of coal is capable of decomposing. This may be effected in the following manner. Let 500 grains, or more of perfectly pure nitrate of potash be fused in a crucible, and when red hot, let the coal to be examined, coarsely powdered, be projected on the fused nitre, by little at a time, not exceeding one or two grains. Immediately when the detonation produced by the addition of one projection of coal has ceased, add a new portion till it produces no farther effect. The proportion of carbon in the coal is directly proportionate to the quantity required for the decomposition of the nitrate of potash. Thus Kirwan found that 12.709 of carbon are necessary to decompose 100 of nitrate of potash: it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitrate of potash which it is capable of decomposing. Kirwan found that 480 grains of nitrate of potash required 50 of Kilkenny coal to decompose it by this method. Therefore 10 grains would have decomposed 96 of nitrate of potash; precisely the quantity of charcoal which would have produced the same effect. Therefore Kilkenny coal is composed almost entirely of carbon. Cannel coal, when burnt in this manner, left a residuum of 3.12 in the 100 parts of earthy ashes, 66.5 of it were required to decompose 480 grains of nitrate of potash, but 50 of charaoal would have been sufficient: therefore 66.5 grains of Cannel coal contain 50 grains of charcoal, and 2.08 of earth; the remaining 14.42 grains must be bitumen.

In a similar manner the composition of any other coal may be ascertained.

The proportion of earthy, or metallic ingredients may be ascertained by burning the coal, with free access of air. What remains unburnt must be considered as an impurity, its weight may be ascertained, and the nature of the earthy and metallic substances analysed, according to the rules laid down in the preceding pages.

PART VI.

ANALYSIS

OF

MINERAL WATERS.

The compleat and accurate analysis of mineral waters is one of the most difficult subjects of chemical research, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Such minuteness, however, is scarecely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of them. We shall not attempt, therefore, to lay down rules for the most accurate analysis, but shall only describe such as are suited to afford an insight into the kind, but not to decide the exact proportion of the constituent principles of natural waters.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The temperature of the water must be carefully observed, and the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water must be found according to the rules pointed out, page 29.

EXAMINATION OF MINERAL WATERS BY RE-AGENTS.

The readiest way of judging of the contents of mineral waters are by apylying tests or re-agents. The chief of which are the following:

Infusion of Litmus, is a test of most uncombined acids.

If the infusion redden the unboiled, but not the boiled water, we may infer, that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

To ascertain whether the change be produced by carbonic acid or by sulphuretted hydrogen, when experiment show that the reddening cause is volatile, add barytic water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little muriatic acid. Sulphuretted hydrogen may also be contained, along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described. Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying.

Infusion of Litmus reddened by Phosphoric Acid,—Tincture of Brazil-wood,—Tincture of Turmeric, and Paper stained with each of these three Substances,—Tincture of Red Cabbage.— All these different tests have one and the same object.

Infusion of litmus, reddened by phosphoric acid, or litmus paper reddened by it, has its blue colour restored by alcalies and earths, and by carbonated alcalies and carbonated earths. Turmeric paper and tincture are changed to a reddish-brown by alcalies, whether freed from carbonic acid or not, by earths, freed from carbonic acid, but not by carbonated earths.

The red infusion of brazil-wood, and paper stained with it, become blue by alcalies and earths, and even by the latter, when dissolved by an excess of carbonic acid. In the last-mentioned case, however, the change will either cease to appear, or will be much less remarkable, when the water has been boiled.

Tincture of cabbage, is, by the same causes, turned green; as is also paper stained with the juice of the violet, or with the scrapings of radishes.

Tincture of Galls.—Tincture of galls is employed for discovering iron, with which it produces a black tinge. The iron, however, in order to be detected by this test, must be in the state of a red oxid, or, if oxidized in a less degree, its effects will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation, or boiling, we may know whether the iron be held in solution by carbonic acid, or by a fixed acid; for,

1. If it produce its effect before the application of heat, and not afterward, carbonic acid is the solvent.

2. If after, as well as before, a fixed and vulgarly called mineral acid is the solvent.

3. If, by the boiling, a yellowish powder be precipitated, and yet galls continue to strike the water black, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid.

Sulphuric Acid.—Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alcalies or earths.

2. If lime be present the addition of sulphuric acid occasions, after a few days, a white precipitate.

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric or muriatic salts, in a dry state, or dissolved in very little water, on adding sulphuric acid, and applying heat, are decomposed; and if a stopper, moistened with solution of ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

Oxalic Acid and Oxalates.—This acid is a most delicate test of lime, which it separates from all its combinations.

1. If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs, by means of a quill or glass tube, we may infer that lime (or barytes, which has never yet been found pure in waters) is present in an uncombined state.

2. If the oxalic acid occasion a precipitate before, but not after boiling, the lime is dissolved by an excess of carbonic acid.

3. If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present; because some acids decompose the oxalic, and others dissolving the oxalate of lime, prevent it from appearing. (Vide Kirwan on Waters, page 88.)

The oxalate of ammonia or of potash are not liable to the above objection, and are preferable, as re-agents, to the uncombined acid. Yet even these oxalates fail to detect lime when supersaturated with muriatic or nitric acids; and, if such an excess be present, it must be saturated, before adding the test, with ammonia. A precipitate will then be produced.

The quantity of lime, contained in the precipitate, may be known, by first igniting it with access of air, which converts the oxalate into a carbonate; and by expelling, from this last, the carbonic acid, by a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit.

Fluate of ammonia is also a most delicate test of lime.

Barytic Water.—1. Barytic Water is a very effectual test for detecting the presence of carbonic acid, with which it forms a precipitate which is soluble with effervescence in dilute nitric, or better in muriatic acid.

2. Barytic water is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate *not soluble* in muriatic acid.

Metals.—Of the metals, silver, bismuth, and mercury, are tests of the presence of hidro-sulphurets, and of sulphuretted hidrogen gas. If a little quicksilver be put into a bottle, containing water impregnated with either of these substances, its surface soon acquires a black film, and, on shaking the bottle, a blackish powder separates from it. Silver leaf and bismuth are speedily tarnished by the same cause.

Sulphate, Nitrate, and Acetate of Silver.— These solutions are all, in some measure, applicable to the same purpose.

They are peculiarly adapted to the discovery of muriatic acid and of muriates, with which they form a white precipitate. A precipitation, however, may arise from other causes, which it may be proper to state. The solutions of silver in acids are precipitated by carbonated alcalies and earths. The agency of the alcalies and earths may be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved. The nitrate and acetate of silver are decomposed by the sulphuric and sulphureous acids; but this may be prevented by adding, previously, a few drops of nitrate or acetite of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted, and the solution of silver added. Should a precipitate now take place, the presence of muriatic acid, or some of its combinations, may be suspected. To obviate uncertainty, whether a precipitate be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when no uncombined alcali or earth is present, is affected only by the latter acid.

The solutions of silver are also precipitated by sulphuretted hidrogen, and by hidro-sulphurets; but the precipitate is then reddish, or brown, or black; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble, in great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

The solutions of silver are precipitated by extractive matter; but in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

Acetate of lead.—Acetate of lead is a test of sulphuretted hidrogen and of hidro-sulphurets of alcalies, which occasion a black precipitate; and if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hidrogen gas, they are soon rendered visible, especially when the water is a little warmed.

Muriate, Nitrate, and Acetate of Barytes.—These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate, insoluble in dilute muriatic acid. They are decomposed, however, by carbonated alcalies; but the precipitates occasioned by carbonates is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding previously a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. I. p. 168.) about 45½ of sulphuric acid of the specific gravity 1850; according to Clayfield, (Nicholson's Journal, 4to, iii. 38.) 33 of acid, of specific gravity 2240; according to Thenard, after calcination, about 25; and according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried sulphate of soda; while 136.36 of the same substance indicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

From Klaproth's experiments, it appears that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallised salt. The same chemist has shown that 100 grains of sulphate of barytes are produced by the precipitation of 71 grains of sulphate of lime.

Prussiates of Potash and of Lime.—Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily assume a blue colour, on the addition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron, with the solutions of which in acids it produces a Prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alcalies or earths, which, if present, prevent the detection of very minute quantities of iron.

1. If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate of potash, the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

2. Should the precipitation ensue in the boiled water, the solvent is a fixed acid, the nature of which must be ascertained by other tests.

In using the prussiate of potash for the discovery of iron, considerable caution is necessary, in order to attain accurate results. The prussiate should, on all occasions, be previously crystallised; and the quantity of oxid of iron essential to its constitution, or at least an invariable accompaniment, should be previously ascertained in the following manner: Expose a known weight of the crystallised salt to a low red heat in a silver crucible. After fusing and boiling up, it will become dry, and will then blacken. Let it cool; wash off the soluble part; collect the rest on a filter; dry it, and again calcine it with a little wax. Let it be again weighed, and the result will shew the proportion of oxid of iron present in the salt which has been examined. This varies from 22 to 30 and upwards per cent. When the test is employed for discovering iron, let a known weight of the salt be dissolved in a given quantity of water; add the solution gradually; and observe how much is expended in effecting the precipition. Before collecting the precipitate, warm the liquid, which generally throws down a further portion of Prussian blue. Let the whole be washed and dried, and then ignited with wax. From the weight of the oxid obtained, deduct that quantity, which, by the former experiment, is known to be present in the prussiate that has been added; and the remainder will denote the quantity of oxid of iron present in the liquor which is under examination.

Succinate of Soda and Succinate of Ammonia are also tests for iron.

In applying these agents it is necessary not to use more than is sufficient for the purpose; because an excess of them re-dissolves the precipitate. The best mode of proceeding is to heat the solution containing iron, and to add gradually the solution of succinate, until it ceases to produce any effect. A brownish precipitate is obtained, consisting of succinate of iron. This, when heated with a little wax, in a low red heat, gives an oxid of iron containing about 70 per cent. of the metal.

The succinates, however, precipitate alumine, provided there be no considerable excess of acid in the aluminous salt. On magnesia they have no action, and hence they may be successfully employed in the separation of these two earths.

Phosphate of Soda.—An easy and valuable method of precipitating magnesia has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses; first to dissolve the carbonate of magnesia formed, when it is added to the solution of magnesian salt. For this purpose a solution of carbonate of ammonia, prepared with a portion of that salt which has been exposed, spread on a paper, for a few hours, to the air, is to be added to the solution of the magnesian salt sufficiently concentrated; or to a water suspected to contain magnesia, after being very much reduced by evaporation. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of magnesia, or about 64 of muriate of magnesia.

Muriate of Lime.—Muriate of lime is principally of use in discovering the presence of alcaline carbonates, which, though they very rarely occur, have sometimes been found in mineral waters. Of all the three alcaline carbonates, muriate of lime is a sufficient re-agent; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid,

With respect to the discrimination of the different alcalies, potash may be detected by muriate of platina, see page 517. Carbonate of ammonia may be discovered by its smell; and by its precipitating a neutral salt of alumine, while it has no action apparently on magnesian salts.

To estimate the proportion of an alcaline carbonate present in any water, saturate its base with sulphuric acid, and note the weight of real acid which is required. Now 100 grains of real sulphuric acid saturate 121.48 potash, and 78.32 soda.

Analysis of Waters by Evaporation.—The reader, who may wish for rules for the complete and accurate analysis of mineral waters, will find in almost every chemical work a chapter allotted to this subject. He may consult Kirwan's Essay on the Analysis of Mineral Waters, London, 1799. As this manual, however, may sometimes be employed as a travelling companion, and may attend the mineralogist where other works cannot be had, it may be proper to state, briefly, the mode of analysing waters by the more certain, but still not unobjectionable, mode of evaporation.

Before evaporation, however, the gaseous products of the water must be collected, which may be done by filling with it a large glass bottle, or retort, capable of holding about 50 cubic inches, and furnished with a ground stopper and bent tube. The bottle is to be placed up to its neck, in a kettle filled with brine, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what is lost by evaporation. The disengaged gas is conveyed, by a bent tube, into a graduated jar, filled with, and inverted in, mercury, where its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar till the water has obtained its maximum of temperature. This must be suffered to escape, and its quantity to be deducted from that of the water submitted to experiment.

In determining, with precision the quantity of gas, it is neccessary to attend to the state of the barometer and thermometer.

The gases most commonly found in mineral waters, are *carbonic acid*; *sulphuretted hidrogen*; *nitrogen*; *oxigen gas*; and, in the neighbourhood of volcanoes only, *sulphureous acid gas*.

To determine the proportion of the gases, constituting any mixture obtained from a mineral water in the foregoing manner, the following experiments may be made. If the use of reagents has not detected the presence of sulphuretted hidrogen, and there is reason to believe, from the same evidence, that carbonic acid forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver; pass up a small portion of solution of potash, and agitate this in contact with the gas; the amount of the diminution will show how much carbonic acid has been absorbed; and, if the quantity submitted to experiment was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxigen and azotic gases; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer.

If sulphuretted hidrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hidrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hidrogen by oxi-muriatic acid gas (obtained from muriatic and hyper oxi-muriate of potash), adding the latter gas very cautiously, as long as it produces any condensation. Or, perhaps, a better plan of effecting the separation is the following, recommended by Mr. Henry: half fill a graduated vial with the mixed carbonic acid and sulphuretted hidrogen gases, and expel the rest of the water by oxi-muriatic acid gas. Let the mouth of the bottle be then closed with a well ground stopper, and let the mixture be kept twenty-four hours. Then withdraw the stopper under water, a quantity of which fluid will immediately rush in. Allow the bottle to stand half an hour without agitation. The redundant oxi-muriatic acid gas will thus be absorbed; and very little of the carbonic acid will disappear. Supposing that, to 10 cubic inches of the mixed gases, 10 inches of oxi-muriatic gas have been added, and that, after absorption, by standing over water, 5 inches remain, the result of this experiment shews, that the mixture consisted of equal parts of sulphuretted hidrogen and carbonic acid gases.

Whenever this complicated admixture of gases occurs, as in the Harrowgate and in some of the Cheltenham waters; it is advisable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphuretted hydrogen; and that of azote and oxigen by the other. In the latter instance, remove both the absorbable gases by caustic potash, and examine the remainder in the manner already directed.

Nitrogen gas sometimes occurs in mineral waters, almost in an unmixed state. When this happens, the gas will be known by the characters already described as belonging to it. Sulphureous acid gas may be detected by its peculiar smell of burning sulphur, and by its discharging the colour of an infusion of roses, which has been reddened by the smallest quantity of any acid adequate to the effect.

(*a*) The water should next be evaporated to dryness. The dry mass, when collected and accurately weighed, is to be put in a bottle, and highly rectified alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol, and dry and weigh the remainder.

(*b*) To the undissolved residue, add nine times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

(*c*) Boil the residuum, for a quarter of an hour, in sometimes more than 500 times its weight of water, and afterwards filter.

(*d*) The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

I.—The solution in alcohol (*a*) may contain one or all of the following salts: muriates of lime, magnesia, or barytes, or nitrates of the same earths. Sometimes, also, the alcohol may take up sulphate of iron, in which the metal is highly oxidized, as will appear by its reddish-brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add above half its weight of strong sulphuric acid; and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes; the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis of the salts, let the heat be continued till no more fumes arise, and let it then be raised to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates

may be separately decomposed, by boiling with three or four times their weight of carbonate of potash. The carbonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid, and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up. Lime and magnesia may also be separated by the use of phoshate of soda, as stated in page 545.

II.—The watery solution (*b*) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallisation. For this purpose let one half be evaporated by a very gentle heat, not exceeding 80° or 90°. Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda, or common salt. The remaining solution, on cooling very gradually, will perhaps, afford crystals distinguishable by their form and other qualities. When various salts however are contained in the same solution, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must therefore be examined by tests, or re-agents.

The presence of an uncombined alcali, as well as uncombined acids, will be discovered by the stained papers, and tests already pointed out. The vegetable alcali or potash, may be distinguished from the mineral, or soda, by muriate of platina, see page 517.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and that of the base. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III.—The solution by boiling water contains scarcely any thing besides sulphate of lime.

IV.—The residuum (*d*) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly oxidized iron. Evaporate the solution to dryness. If it contain acetate of lime only, a substance will be obtained which does not attract moisture from the air; if magnesia be present, the mass will deliquesce. To separate the lime from the magnesia, proceed as in I.

The residue insoluble in acetous acid, may contain alumine, iron, and silex. The two first may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterward by a fixed alcali.

For a more circumstantial detail the reader is referred to Kirwan's excellent Essay on the Analysis of Mineral Waters; and for illustrative examples of several practical analyses to the Author's Analysis of the Mineral Waters of Cheltenham, and its neighbourhood.

THE END.

DESCRIPTION

OF

THE PLATES.

PLATE I.

Fig. 1. represents a hydrostatic balance, of which a description has been given already, pages 19, 20, 21.

Fig. 2, represents a perspective view of a portable universal furnace. It is made of hammered sheet iron, and lined with fire bricks 3 inches thick. The height of the body of the furnace is 18 inches, its inner diameter measures 8 inches. In the front of the furnace are 3 openings, *a a a*, perpendicularly over each other, furnished with doors. In either of the two upper openings a muffle may be placed, for performing the operations of assaying, or for roasting and desulphurating ores, to prepare them for the subsequent operations of reduction or smelting.. The lower door closes the ash-pit, and serves to regulate the heat at pleasure, by opening or shutting it more or less, accordingly.. B is the cover of the furnace. It consists of a thick iron plate, lined with fire clay. In the center of this cover is a hole through which the operation carried on in the furnace, or the state of the fire may be inspected without scorching the face. C is a stopper made of crucible ware, which fits the hole in the cover B. D. is the elbow of the chimney, which may be elongated by an additional tube, and then directed into the fire place of the apartment. If a very intense heat be required, the tube or chimney of the furnace should be at least 5 or 6 ft. high. If the fire be well attended to, the intensity of the heat will be sufficient for the reduction of the ores of iron, copper, nickel, cobalt, or any other processes which require the most violent heat. A great variety of operations in the small way may be carried on in this useful furnace, which being heavy and substantial, is very durable and not liable to be damaged by accidental blows, or easily displaced. It is besides extremely convenient, and perfectly safe in a room. The thickness of the walls of the chimney prevent the operator from being at all molested by the intensity of the heat. Coke and charcoal are the best fuel for this furnace, but common coal answers also very well.

Fig. 3, is an improved lamp-furnace. It consists of a brass rod screwed into a solid foot of the same metal. On this rod slides a circular lamp, *a a*, constructed on Argand's plan, which may, by means of a spring, be elevated or depressed at pleasure: *b b* are circular rings for supporting flasks, basons, retorts, &c. They may be set nearer to, or farther from the flame of the lamp by means of the socket and thumb screws, F F.

Fig. 4 represents Davy's apparatus for the analysis of soils.—See page 505.

Fig. 5, a blow-pipe spoon, which should be made of platina.—See page 36.

Fig. 6, an apparatus for easily ascertaining the quantity of carbonic acid disengaged from any substance by the action of an acid: it consists of a bottle closed by a cork or stopper, into which is fixed a spiral tube terminating into a capillary opening. To use this apparatus, ascertain first what quantity of muriatic or nitric acid is required to saturate a given quantity of the substance, intended to be submitted to the experiment. Having done this, put the quantity of acid or rather more into the bottle, and weigh the whole accurately; then add to it the substance, the quantity of carbonic acid gas of which is to be ascertained, cork the bottle as expeditiously as possible, and suffer the carbonic acid to escape. When the effervescence has completely ceased, let the whole apparatus be again weighed, and the loss of weight will indicate the quantity of carbonic acid contained in the substance, with tolerable acccuracy.

The spiral tube prevents the carbonic acid from carrying off moisture.

Fig. 7, a chemical thermometer so constructed that the lower part of the scale board may be turned up by means of a hinge, which renders the instrument very useful for taking the temperature of small quantities of fluids, or of mixtures in which acids form a part. The chemical thermometer should be graduated from 40° below 0 up to 600° Fahrenheit. The figures expressing the value of the graduations are omitted in the drawing.

Fig. 8, a bottle for readily ascertaining specific gravities of fluid. It consists of a vial with a slender neck, and ground stopper, having a mark made with a diamond in the neck of it. When this bottle is filled up to the mark with distilled water of a given temperature it should hold exactly 1000, 2000, or any even number of grains. The quantity which it is found to contain of any other fluid at the same temperature denotes the specific gravity of the latter fluid, For example, if it holds 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the sulphuric acid is to that of water as 1850 to 1000.

PLATE II.

Fig. 1. a portable forge. An instrument of great utility, chiefly for the reduction of ores in the *dry way*, for by means of it the most intense heat may quickly be produced, and conveniently applied to any substance whatever. *a*. a blowpipe which may occasionally be attached to the double bellows.

Fig. 2, an apparatus for drying the products of analysis. The substance to be dried must be placed in the conical glass vessel *b*, and when the vessel *c* is filled with water up to the side tube *d*, the desiccation may be performed by putting the apparatus over a lamp, and keeping the water in a state of ebullition. It is particularly useful in drying the precipitates obtained in analyses; for it is well known that the same mineral, analysed by different chemists, has been found to yield different proportions of the same ingredients, and that the different weights of the constituent parts, in many cases, are often more apparent than real; arising entirely from the various degrees of desiccation that has been employed by different analysts, and sometimes even by the same person. This point is of such importance, and is productive of so much trouble, that every chemist who has analysed a mineral water, or crystallised, or separated small quantities of deliquescent salts, will at once perceive the utility of the apparatus in this respect.

Fig. 3, and 4, Crucible stands.

Fig. 5, an improved blowpipe. It consists of a conical tube furnished with a small pipe near the base, to which jets, or caps of different perforations may be adapted. The air is forced into the blow-pipe by the mouth of the operator, or by means of a bladder or double bellows attached to the instrument. The substance to be fused must be placed upon a piece of charcoal, or held in a small spoon made of platina, or wrapped up in a piece of platina foil. The quantity of the substance to be examined by means of the blow-pipe ought not to exceed the size of a pepper corn.

Fig. 6, an ingot, spoken of page 38.

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