133^{00} 8/26/83 PLB

ACCUM'S

Elements of Crystallography;

WITH OR WITHOUT

SERIES OF GEOMETRICAL MODELS,

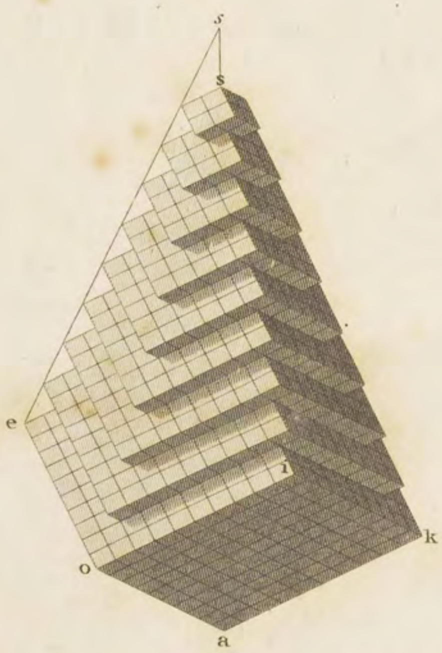
AND

WITH PLATES AND WOOD-CUTS.

J. G. BARNARD,
SKINNER-STREET, LONDON.

Plate I. to face Title.

Accum's Crystallography.



Lowry sculp.

ELEMENTS
OF
CRYSTALLOGRAPHY,
AFTER THE METHOD OF HAÜY;

WITH, OR WITHOUT,
Series of Geometrical Models,
BOTH
SOLID AND DISSECTED;
EXHIBITING THE FORMS OF CRYSTALS, THEIR GEOMETRICAL
STRUCTURE, DISSECTIONS, AND GENERAL LAWS.
ACCORDING TO WHICH THE
IMMENSE VARIETY OF ACTUALLY EXISTING CRYSTALS
ARE PRODUCED.

By FREDRICK ACCUM,
OPERATIVE CHEMIST,
LECTURER ON PRACTICAL CHEMISTRY, ON MINERALOGY, AND ON CHEMISTRY
APPLIED TO THE ARTS AND MANUFACTURES; MEMBER OF THE ROYAL
IRISH ACADEMY, FELLOW OF THE LINNÆAN SOCIETY, &c.

WITH COPPER-PLATES.

London:
PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER-ROW.

1813.

TO
THE RIGHT HONOURABLE
EARL PERCY;

TO HIS EXCELLENCY
COUNT MÜNSTER MEINHOVEL,
HIS MAJESTY'S MINISTER OF STATE FOR THE ELECTORATE OF
HANOVER; COMMISSIONER OF HIS MAJESTY'S PROPERTY, &c.

TO THE RIGHT HONOURABLE
SIR JOHN BORLASE WARREN,
BARONET; KNIGHT COMPANION OF THE MOST HONOURABLE
ORDER OF THE BATH, MEMBER OF THE KING'S MOST
HONOURABLE PRIVY COUNCIL,
ADMIRAL OF THE BLUE,
COMMANDER IN CHIEF OF HIS MAJESTY'S FLEET, ON THE
NORTH AMERICAN STATION, &c. &c.

AND TO
SIR JOHN SAUNDERS SEBRIGHT,
BARONET; REPRESENTATIVE IN PARLIAMENT FOR THE COUNTY
OF HERTFORD, &c. &c.

MY LORD,
AND
GENTLEMEN,

PERMIT me to offer to your Notice this Treatise, containing the Elements of a Department of Mineralogy, which embraces the Subject of one of the Courses of Lectures I had the honour to deliver to you.

The Ardour and Interest you have on all Occasions shewn, for promoting the Philosophy of Chemistry and the Science of Minerals, encourage me to make this Claim upon your Patronage; and I am confident you will allow me to add, that a respect for your Talents and intellectual Virtues, is among the leading Motives for my present Application.

I have the honour to be, with the highest respect,

My Lord,

and

Gentlemen,

Your most obedient humble Servant,

THE AUTHOR.

PREFACE.

Compton Street, Soho.

OUR earnestness in the pursuit of any study is, in general, proportionate to the benefits or pleasure we expect to derive from its cultivation; for where there is a prospect of recompence in any rational way, we engage in literary pursuits with ardour and spirit; but where there is no such prospect, the mind is seldom active in its exertion.

Hence the different points of view under which natural bodies, and the phenomena they present, may be studied, have given rise to various departments of learning; and these have been multiplied as the progress of mental improvement, has added new sources of information to the sciences already established.

The general attention which of late years has been paid to the science of minerals, cannot have escaped the notice of the most superficial observer.

No department of Natural History has been cultivated with more ardour and success than mineralogy; no branch of physical knowledge has become more fashionable; and in none are the votaries of science more numerous, both at home and on the Continent.

It embraces a wide circle among the curious and wealthy classes of the community; and it is intimately connected with that enthusiasm for travelling, and prevailing passion for exploring the productions of nature, which characterize the age in which we live.

When we consider how much the philosophy of the mineral kingdom has of late been advanced and perfected, by the application of the Theory of Crystallography, created by the genius and industry of the Abbé Haüy; when we contemplate the strong and steady light it has thrown on some of the most obscure branches of Mineralogy,—it appears surprising that not a single English work on the Theory of the Structure and formation of Crystals has appeared; whilst upon other departments of the science of Minerals, several excellent works have been published.

To remedy this defect, is the object of the following pages.

The Treatise now presented to the tribunal of the public, is designed, for the purpose of initiating into the Principles of Crystallography, those who possess no previous knowledge of it.

To accomplish this object, I have given such an exposition of the leading facts of the Theory as appeared best calculated to interest the mind, and fix the doctrine in the memory, in all the characters it is justly entitled to. I was well aware that an attempt to exhibit the Doctrine of Crystallography, in its whole extent, and with all its numerous mathematical relations, was an enterprise beyond my power; neither was this the subject on which I intended to write.

I have contented myself on the present occasion to attend merely to the development of the general principles of the theory, and such consequences and applications as are connected with the science of minerals.

As it is certain however that the doctrine which explains the production of crystalline forms, and their metamorphoses, abounds in mathematical and algebraic calculations, and cannot be studied with ease and success, by such as are unacquainted with the mathematics; I have, (to render this Treatise more generally useful) made arrangements to accompany it with sets of geometrical models, partly solid and partly dissected.

They who are in the habit of teaching, will readily allow, that the human mind receives information from the mathematics, with much greater facility from demonstrations afforded by tangible solids, than from mere designs drawn upon a plane surface. It requires an eye familiarized with the rules of lineal perspective, to comprehend the diversified and often complicated forms of angular polyhedra, represented by projections of straight lines only, which must naturally cross each other in many directions, in the representation of crystalline bodies.

The dissected Models, are so constructed, that they can readily be taken to pieces, and built up again in various ways, to give the untutored eye a distinct conception of the laws of that geometry of nature which are followed by the integrant particles of crystallisable bodies when they combine, and of which the orderly arrangements produce symmetrical crystals—and this in fact constitutes the science.

It is therefore presumed, that with the book in hand, and by inspection of the Models, those who are actually unacquainted with the mathematics, will be enabled to study with great advantage the Laws of Crystallography, and their mutual relations and consequences. The student will immediately comprehend why crystals are always rectilineal bodies bounded by planes and solid angles; and whence that immense variety of polyhedral forms is derived, with which the mineral kingdom has hitherto astonished the world.

It is nevertheless presumed, that the Treatise, as far as it goes, will be found complete, and may be clearly understood without the Models.

The numerous wood-cuts and plates introduced into the work, in illustration of the laws of the science, will render the geometrical solids, superfluous to those who are familiar with geometry and lineal perspective.

The graphic designs have been traced by the method of projections; the entire lines represent the edges or outlines of that part of the solid immediately turned towards the observer; and the dotted lines express those edges in the opposite part, which of course the observer could not see, unless the solid was diaphanous.

By giving this information of my intention to supply the public with series of crystallographic Models, I feel no solicitude as to any imputation of private or commercial views; such attempts are fully consistent with the purest regard to the public welfare. Conscious that the advancement of science must greatly depend on the facility with which the practical means of study can be acquired: the reader will, I have no doubt, think himself accommodated by being reminded of it.

FREDRICK ACCUM.

THE BINDER is requested to place Plate I. facing the Title, and Plate II. III. and IV. at the End of the Book.

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LIST

OF

CRYSTALLOGRAPHIC MODELS,

BOTH SOLID AND DISSECTED,

REFERRED TO IN THE WORK.

NO.

1. Cube.
2. Cube with the solid *angles truncated*, or replaced by one facet or secondary plane.
3. Cube with the *edges truncated*, or replaced by one facet.
4. Cube, *bevelled on the edges*, or having the edges replaced by two facets or secondary planes.

NO.

5. Regular octahedron composed of two four-sided pyramids put base to base.

6. Regular octahedron, having the solid angles [truncated] replaced by a secondary plane.

7. Regular octahedron, with the edges [truncated] replaced by a facet.

8. Regular octahedron, having both the edges and solid angles [bevelled] or replaced by two facets.

9. Tetrahedron, considered as one of the regular geometrical solids.

10. Regular pentagonal dodecahedron, considered as one of the regular geometrical solids.

11. Regular Icosahedron, considered as one of the regular geometrical solids.

12. Right quadrilateral pyramid.

13. Triangular prism.

14. Hexahedral prism.

15. Parallelopiped, considered as one of the primitive forms of crystals.

16. Regular octahedron, considered as one of the primitive forms of crystals.

17. Regular tetrahedron, considered as primitive form.

NO.

18. Hexahedral prism, considered as primitive form.
19. Rhomboidal dodecahedron, considered as primitive form.
20. By-pyramidal dodecahedron, considered as primitive form.
21. Dissected hexahedral prism of carbonate of lime.
22. Dissected acute rhomboid of carbonate of lime.
23. Dissected by-pyramidal dodecahedron of carbonate of lime.
24. Dissected cube of fluate of lime.
25. Dissected rhomboid of turmalin.
26. Dissected hexahedral prisms of phosphate of lime.
27. Dissected regular octahedron, considered as primitive form.
28. Dissected regular tetrahedron, considered as primitive form.
29. Dissected rhomboidal dodecahedron, considered as primitive form.
30. Dissected by-pyramidal dodecahedron, considered as primitive form.

NO.

31. Dissected cube.

32. Regular tetrahedron, considered as one of the integrant molecules of crystals.

33. Triangular prism, considered as integrant molecule.

34. Cube, considered as integrant molecule.

35. Dissected rhomboidal dodecahedron, to illustrate, [by the method of analysis,] the production of a secondary form from a primitive solid, according to the law of decrement parallel to the edges, and acting in one direction only, namely, in breadth.

36. Dissected rhomboidal dodecahedron, to illustrate the preceding statement by the method of synthesis.

37. Dissected irregular pentagonal dodecahedron, to illustrate [by the method of analysis,] the production of a secondary form from a primitive solid, according to the law of decrement parallel to the edges, acting in two directions, namely, in height and breadth.

NO.

38. The same solid, constructed to prove the preceding statement by the method of synthesis.

39. Dissected by-pyramidal dodecahedron, considered as secondary form originating from a primitive rhomboid; in illustration of the effect of the law of decrement on the edges.

40. Dissected octahedron, considered as secondary form, originating from a cube, in illustration [by the method of analysis] of the law of decrement on the *angles*, or the action of which takes place in a direction parallel to the diagonals, drawn from one angle to the opposite angle of the faces of the primitive form.

41. Dissected octahedron, constructed to prove the same law, by the method of synthesis.

42. Farther illustration of the action and effect of the law of decrement on the angles.

43. Illustration of the law of decrement [called *intermediary*], the effect of which takes place parallel to lines situated between the diagonals and the edges of the primitive solid.

NO.

44. Illustration of the law, called *mixed* decrement.

45. Model constructed to show the apparently accidental alterations to which the symmetry of crystals is subject, or the production hemitropes, macles, &c.

46. Model of a regular octahedron cut obliquely into two halves, the one of which may be turned upon the other half in a quantity equal to one-sixth part of a circle, and thus producing a solid with alternate and re-entering angles, in illustration of the transposition of the faces of crystals.

47. Model of a four-sided prism, terminated at each extremity by a four-sided pyramid.

48. The preceding model dissected exhibiting the halves of two separate four sided prisms, terminated at each extremity by trihedral prisms, apparently turned half round on each other, to form the hemitrope solid.

49. Model of two cubes grouped upon each other

NO.

to show the manner in which crystals are grouped or aggregated.

50. Model of two crystals [rectangular staurolite,] crossing each other at right angles.

THE preceding collection of models may be subdivided, for the convenience of study, into groups or series, forming distinct and progressive lessons, in some respect independent of each other, namely:

SERIES I.

MODELS.

Nos. 1, 2, 3, 4, 5, 6, 7, 8.

Crystals considered as rectilineal geometrical solids, —denominations of the exterior parts of crystals, &c.

SERIES II.

MODELS.

Nos. 1, 5, 9, 10, 11.

Regular rectilineal geometrical solids.

SERIES III.

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SERIES IV.

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Nos. 15, 16, 17, 18, 19, 20.

Primitive forms of crystals.

SERIES V.

MODELS.

Nos. 21, 22, 23, 24.

Mechanical dissection of crystals—development of the primitive forms of crystals—geometrical structure and cleavage of crystalline solids, &c.

SERIES VI.

MODELS.

Nos. 25, 26, 27, 28, 29, 30, 31.

Structure of primitive forms—development of the integrant molecules of crystals—remarkable arrangement of some of them, in the interior of the primitive forms.

SERIES VII.

MODELS.

Nos. 32, 33, 34.

Integrant molecules of crystals.

SERIES VIII.

MODELS.

Nos. 35, 36, 37, 38, 39, 40, 41, 42, 43, 44.

Laws of decrements of the structure of crystals—Decrements on the edges—Decrements on the angles

—Intermediary Decrements—Mixed Decrements, exhibiting the modes of arrangement followed by the mechanical elements of crystallisable matter, according to which the immense variety of actually existing crystals are produced.

SERIES IX.

MODELS.

Nos. 45, 46, 47, 48, 49, 50.

Singular alterations to which the symmetry of crystals is subject—reversed position of the faces of crystals—production of macles, hemitropes—grouped crystals—crystals penetrating each other, &c.

MODELS

Illustrative of Crystallography,

EXHIBITING THE PRIMITIVE FORMS OF ACTUALLY EXISTING CRYSTALS, AND THEIR PRINCIPAL TRANSITIONS OR MODIFICATIONS OF FORMS.

THE object in selecting the following assortment of crystallographic models with their descriptions, is chiefly to familiarize the student with the primitive forms of actually existing crystalline solids, and their metamorphoses or modifications of forms, so as to enable him to see at one view, what they possess in

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* These models may likewise be had with this treatise, either singly, or in sets.

common, and what is peculiar to each crystalline solid.

I. THE PARALLELOPIPED, WHICH INCLUDES THE CUBE, THE RHOMBOID, THE QUADRANGULAR PRISM, AND ALL SOLIDS BOUNDED BY SIX-SIDES, PARALLEL TWO AND TWO.

1. THE CUBE.

NO.

1. Native gold.
2. Native silver.
3. Native copper.
4. Gray cobalt ore, or bright white cobalt ore.
5. Leucite, grenatite, amphigene, or white garnet.
6. Borate of magnesia, boracite, or cubic quartz.
7. Muriate of soda, common salt, or rock salt.
8. Aploma.
9. Sulphuret of lead, galena, or potter's ore.
10. Sulphuret of iron, common iron pyrites, or martial pyrites.

2. *A Right Tetrahedral Prism with Square Bases.*

NO.

11. Sulphate of magnesia or Epsom salt.
12. Vesuvian, Idocrase, or brown volcanic hyacinth.
13. Meïonite, or white hyacinth of Somma.
14. Wernerite, or scapolite.
15. Mesotype, stilbite, cubic zeolithe, chabasie, or analcime.
16. Chromate of lead, or red Siberian lead ore.
17. Oxyd of titanium, or titanite.
18. Micaceous uranite, or oxyd of uranium.

3. *A Right Tetrahedral Prism with Rectangular Bases.*

NO.

19. Chrysoberil, cymophane, oriental and opalescent chrysolithe, peridot of commerce.
20. Euclase, peridot, or olivin.
21. Foliated zeolithe or stilbite.

NO.

22. Apophilite.

23. Tungstate of iron and manganese, or wolfram.

24. Phrenite, greenish zeolite, chrysolite of the Cape.

4. *A Right Tetrahedral Prism with Rhombic Bases.*

NO.

25. Sulphate of barytes, ponderous spar, cawk of the Derbyshire miners, baroselenite heavy spar, or Bologna stone

26. Sulphate of strontia, or celestine.

27. Topaz, topaz of Saxony, of Brazil, or Occidental topaz.

28. Mica, and when in small scales and of a glittering appearance, talc.

29. Diaspore.

30. Triphane or spodumene.

31. Arsenical pyrites, mispickel, or native arsenic alloyed with iron.

32. Sulphuret of molybdena, molybdenite.

5. *A Right Tetrahedral Prism with oblique angled Parallelogram Bases.*

NO.

33. Gypsum, sulphate of lime, selenite or specular gypsum.
34. Epidote, delphinite, thalite, glassy antinolite of Kirwan, arendalite, akanticonite, or strahlstein.
35. Axinite, thumerstone of Kirwan, yanolithe, violet shorl.

6. *An Oblique Tetrahedral Prism with Rectangular Bases.*

NO.

36. Borax, borate of soda, native borax or tinkal.
37. Cyanite, sappare or disthene.

7. *An Oblique Tetrahedral Prism with Rhombic Bases.*

NO.

38. Amphibole, hornblende, basaltine, or basaltic hornblende, opake rhomboidal shorl.
39. Pyroxene, augite, or volcanic shorl.
40. Grammatite, or tremolite.

8. *An Oblique Tetrahedral Prism with Oblique-angled Parallelogram Bases.*

NO.

41. Feldspar, when of a cream colour and silky lustre; it is called Adularia or moon stone.
42. Sulphate of copper, vitriol of copper, or native blue vitriol.

9. *A Rhomboid with Obtuse Summits.*

NO.

43. Carbonate of lime, or calcareous spar.
44. Turmalin, or electric shorl, black shorl, cockle of the Cornish miners; and if of a bright red colour, rubellit.
45. Dioptase, compact green carbonate of copper, or compact malachite or emerald copper.
46. Rock crystal, or crystallised quartz; if of a brownish or yellowish black colour, cairngorum if of a yellow colour, occidental topaz, mock topaz; if rose red, Bohemian or Silesian ruby; if of a light blue colour, mock or occidental sap-

NO.

phire, water sapphire; if of a pale violet or purple colour, amethyst.

47. Ruby or red silver, or antimonial sulphuret of silver.

10. *A Rhomboid with Acute Summits.*

NO.

48. Telesia, perfect red corundum, sapphire, oriental ruby of commerce, adamantine spar; if yellow, purple, green, and yellowish green, it is called by the jeweller oriental topaz, amethyst, emerald, and chrysolite.

49. Oligiste iron, or specular iron ore.

50. Sulphate of iron, green vitriol, martial vitriol, green copperas.

II. THE REGULAR TETRAHEDRON, OR TRIANGULAR PYRAMID.

NO.

51. Triple sulphuret of copper and iron, yellow copper pyrites, yellow or purple copper ore.

III. THE REGULAR HEXAHEDRAL PRISM.

NO.

52. Phosphate of lime, crystallised appatite, asparagus stone.

53 Emerald, smaragd, or when of a pale green colour, beryll or aqua marine.

54. Nepheline, or sommit.

55. Pinite, or micarelle.

56. Dipyre, or leucolithe.

57. Sulphuret of mercury, or native cinnabar.

IV. THE RHOMBOIDAL DODECAHEDRON.

NO.

58. Garnet, pyrope of Werner, carbuncle of the ancients, syrien, oriental, or noble garnet.

59. Sulphuret of zinc, blende or pseudo galena.

V. THE BY-PYRAMIDAL DODECAHEDRON.

NO.

60. Carbonate of barytes, or witherite.

NO.

61. Phosphate of lead, green lead ore, or green spary lead ore.

VI. THE REGULAR OCTAHEDRON.

NO.

62. Fluate of lime, fluor spar, or Derbyshire spar.
63. Muriate of ammonia, or native sal ammoniac.
64. Alum, rock alum, roach alum, or native supersulphate of alumine.
65. Spinell, true ruby, or balas ruby.
66. Muriate of copper, sandy copper, or green copper sand of Peru.
67. Diamond.
68. Native amalgam, or quicksilver alloyed with silver.
69. Ruby copper ore, red copper ore, or calciform red copper ore.
70. Magnetical iron ore, load-stone, or common magnetic iron stone.
71. Native bismuth.
72. Native antimony.

1. *The Octahedron, the Pyramids of which have Rectangular Bases.*

NO.

73. Nitrate of potash, saltpetre, nitre.
74. Carbonate of lead, spathose, or spary lead ore, white lead ore, glassy lead ore.
75. Sulphate of lead, native vitriol of lead.
76. Oxid of zinc or calamine.
77. Macle or chiastolite.
78. Arragonite or Arragon spar.
79. Shorlaceous beryll.

2. *The Octahedron, the Pyramids of which have Square Bases.*

NO.

80. Zircon, jargon, or mock diamond.
81. Anatase, oisanite, octahedrite, blue schorl, octahedral titanite.
82. Harmatome, cross stone, white cruciform hyacinth, staurotide, staurolite, or granatite.
83. Molybdate of lead, yellow lead ore.

3. *The Octahedron, the Pyramids of which have Rhombic Bases.*

NO.

84. Carbonate of soda, natron, or mineral alcali.

85. Sulphur, or brimstone.

86. Sphene.

87. Sulphuret of arsenic, or realgar, orpiment.

NOTICE.

11, Old Compton-Street, Soho.

Those Individuals who are desirous of receiving the Models enumerated in the preceding pages, (or Sets of them), will have the goodness to favour the Author with their Orders, either in a direct way, or through the medium of their Booksellers.

London, March 14th, 1813.

ERRATA.

Page 21, line 18, for "afforesce," read "effloresce."
82, — 14, for "1," read "41."
84, — 16, for "*," put "†."
104, — 12, for "course," read "cause."
110, — 16, for "contains," read "contain."
111, — 10, for sulphurate," read "sulphuret."
114, — 3, for "annalytical," read "analytical."
131, — 2, for "divorsion," read "division."
139, — 10, for "Crystal," read "Crystals."
159, — 8, for "66," read "56."
164, — 10, dele the words "difference between structure and decrement," &c.
211, — 4, for "*b a z r*," read "B *r*, *b* A."
232, — 6, for "Fieldspar," read "Feldspar."
242, — 8, for "oblique," read "obliquely."
336, — 17, dele the word "or."
342, — 9, for "tetrahedron," read "tetrahedrons."
344, — 23, dele the words "in order."

ELEMENTS

OF

CRYSTALLOGRAPHY.

PART I.

SECTION I.

DEFINITION OF THE TERM CRYSTAL. NATURE OF CRYSTALLISATION—OBJECTS OF CRYSTALLOGRAPHY—CONSTITUTION OF CRYSTALLINE SOLIDS—INCREASE OR GROWTH OF CRYSTALS CONTRASTED WITH THE GROWTH OF ORGANIC BODIES.

THE name CRYSTAL, is given to those polyhedral bodies, produced by nature and the operations of chemistry, which possess a regular geometrical form, and rectilineal interior structure.

CRYSTALLISATION is the process by which crystals are produced. It expresses the separation of the integrant particles of crystallisable bodies from a fluid, with which they were combined, so as to unite by virtue of their crystalline attraction into rectilineal solids.

The mineral kingdom presents a variety of crystallised bodies, which, on account of their beautiful forms, have at all times attracted the attention of mankind, and chemistry or the chemical art is also capable of causing a vast number of saline and other substances to assume symmetrical forms.

Observation has shewn that every substance in crystallising has a tendency to assume a peculiar figure. Common salt crystallises in cubes, Epsom salt in six-sided prisms, alum in octahedrons, sugar-candy in oblique four-sided prisms with wedge-shaped summits. But the crystalline form in any crystallisable material is liable to be altered by circumstances affecting the crystallising process, and hence the geometrical forms, which the same identical substances present, often bear no such resemblance to each other as would seem to indicate their relation. There are, nevertheless, a certain number of figures peculiar to every crystallisable body, and the crystals of that substance assume one or the other of those forms, and no other. Common salt, for example, when it has assumed its true crystalline shape, presents itself in the form of cubes; it is also met with in octahedrons, dodecahedrons, or some figure appertaining to those solids. Sugar-candy usually crystallises in oblique four-sided prisms, and it likewise occurs in cubes and in six-sided prisms, with wedge-shaped summits variously modified; alum crystallises in octahedrons, but it also occurs in cubes.

This however is not all. When we penetrate into the interior structure of crystalline solids, we become convinced that their mechanical elements are disposed in symmetry according to laws which have their measure and their value. Their state of aggregation is absolutely geometrical, and appears as if it had been affected by instruments guided by skill and intelligence.

To explain these laws of crystalline architecture is the province of CRYSTALLOGRAPHY. It is the business of this department of knowledge to elucidate to what the forms of crystals and their metamorphoses are owing; or, in other words, to account for the production of that immense variety of crystalline figures with which the mineral kingdom, and the laboratory of the chemist, have hitherto astonished the world. This science has, in our own time, been so successfully cultivated, that it has given the most dignified aspect to the philosophy of minerals. It enables us to calculate with the fewest possible data, simple in the extreme, yet mathematically certain the geometrical forms of crystals, with a like degree of accuracy, as astronomers attain in calculating the motion of the heavens. They who have been in the habit of examining crystalline substances must have noticed, that when their forms are well determined, they always constitute angular polyhedral bodies bounded by planes.

Hence those soft outlines and that roundness of figure which is so characteristic in the subjects of organic beings, and which, in fact, constitutes their elegance of forms, indicates on the contrary, among crystallised substances, a want of perfection. The characteristic of true beauty in these substances of nature undoubtedly is the straight line.

The term rectilineal structure, therefore, has been chosen to express the arrangement of the small solids which combine geometrically to form crystals, in opposition to the term of *organization*, which denotes the more complex mechanism of vegetable and animal substances. And this distinction is the more essential in the science of Crystallography, for otherwise a column of basalt, which indeed is a symmetrical rectilineal solid, might be considered as a crystal; which in reality it is not, for it does not possess a rectilineal *interior* structure.

The increase or growth of a crystal, is exceedingly different from the growth of organic beings; it does not take place by the expansion of its particles, and it produces no advantage to the individual itself; no state of its existence can be determined as the period of its perfection. The magnitude of a crystal can only be increased by the mechanical or chemical application of new matter; its increase as well as its change of form, is the result of simple combination of external materials, aided by molecular attraction.

In the vegetable and animal kingdoms each individual constitutes a whole, possessing a determinate form and structure, stamped on it by a peculiar power as a living being, which grows by appropriating different materials for its subsistence, and converting it into its own substance. All its dimensions are thus increased, its various parts uniformly preserve the same proportion, and they continue to perform their functions. It lives, continues its species, and dies. In the mineral kingdom it is otherwise. The arrangement of the subjects of this department of nature, are passive; they are merely acted on by mechanical and chemical agencies, and possess no power of changing that action.

According to Dr. Young*, a more or less perfect crystallisation is the universal cause of solidity. We may imagine that when the particles of bodies are disposed without any order, they can afford no strong resistance to a motion in any direction; but when they are regularly placed in certain situations with respect to each other, any change of form must displace them in such a manner, as to increase the distance of a whole rank at once, and hence they may be enabled to co-operate in resisting such a change.

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* Natural Philosophy, vol. 1. p. 628.

SECTION II.

ARTIFICIAL CRYSTALLISATION—CONDITIONS AND MEANS BY WHICH IT IS EFFECTED—CRYSTALLISATION OF SALINE BODIES—CRYSTALLINE POWER, OR PRIMARY CAUSE OF THE CRYSTALLISATION OF SOLIDS—RATIO OF ITS ENERGY IN DIFFERENT BODIES.

To cause a body to crystallise, it is in the first place necessary to reduce it to the most complete state of disintegration. Its integrant particles must be placed at a distance from each other, by the interposition of a fluid, in which they have full liberty to move, and which opposes no resistance to a symmetrical arrangement being assumed, by virtue of the crystalline or attractive power with which the particles are enduced; and secondly, it is essential, that the fluid which keeps the integrant particles at a distance, should be gradually abstracted, or cease to keep them asunder, to enable the particles fully and freely to exercise their reciprocal affinities. For the particles of crystallisable bodies cannot come into contact and form crystals, as long as the forces of the attraction existing between them, and the fluid with which they are combined, is superior or greater than the natural attraction or crystalline power existing among the particles themselves.

From this simple exposition it is easy to conceive, that crystallisation is operated solely by virtue of the attraction existing between the integrant particles of bodies, which tends to bring them together, and make them adhere to each other. And as crystals assume the forms of geometrical solids, we are led to imagine that their integrant particles have a form peculiar to them, and they equally induce us to believe that the polyhedral figures belong to the particles of crystallisable bodies, having unequal sides, or some faces of greater extent than others; these particles must have a tendency to approach and unite by those faces which are the most extensive. Supposing this, it will be easy to conceive that when the particles are made to approach each other, they will unite by those faces which are best adapted to each other, or which bear the strongest relation.

It cannot be doubted, that every crystallisable substance has its proper and peculiar mode of crystallising; or, which is the same thing, that it has its elementary mechanical particles of a determinate form, different from that of every other. This unquestionably is the first cause of the remarkable differences that exist between the crystals obtained. But the great varieties of forms that appear among crystallised bodies, are evidently owing, as will be shewn hereafter, to the different geometrical modes of arrangement in which the particles are aggregated upon each other.

The processes by which crystallization is accomplished by art, are the following:

Crystallisation, as it takes place in a body from the diminution of the solvent power of a liquid which has communicated fluidity to a solid, by having combined with it.

By the term solution is understood in chemistry, that operation in which a solid body, combines with a fluid in such a manner, that the compound retains the fluid form, and is permanent and transparent.

Perfect transparency and permanent suspension of the solid are marks of perfect solution, by which it is distinguished from simple mixture or mechanical diffusion.

This process, no doubt, is nothing else than an effect of the operation of chemical affinity, exerted between the fluid and the body which is to be dissolved. Thus, when common salt is thrown into water, the salt may be considered as acted on by two forces. The cohesive or corpuscular attraction of its particles on the one hand tends to preserve it in a solid state; and its affinity for water, on the other hand, to bring it into a state of solution. The latter force, however, prevails. The chemical affinity being stronger than the corpuscular or cohesive attractions of the particles of the salt, a compound is produced, in which the particles of salt and water are no longer distinguishable by the eye, nor separable from each other by any mechanical force.

In the solid, when thus dissolved, the molecular or cohesive attraction, though overcome by a counteracting power, must nevertheless still be considered as existing, and as constantly tending to re-unite the integrant particles which are dissolved. For, if we expel or evaporate by heat, a sufficient portion of the fluid which removed the particles of the dissolved body beyond their sphere of mutual attraction, the particles of the solid become approximated, they are brought within the limits of their mutual affinity, they combine, and the solid re-appears. And if this abstraction of the fluid is accomplished gradually, and so as to leave the elementary moleculæ time to arrange themselves, if we may use the expression, to present themselves suitably to one another, the crystallisation is regular; while, on the contrary, too speedy an abstraction of the separating fluid will force them to come together suddenly, and, as it were by the first faces that offer, in which case the crystallisation is irregular, and the figure of the crystal difficult to be ascertained. And if the abstraction be altogether sudden, the body will ever form only a concrete mass, which will have scarcely any crystalline appearance.

The art of crystallising substances is chiefly built on these fundamental truths.

Hence the method of effecting the crystallisation of such bodies as require a previous state of solution, and among which the class of salts hold a distinguished rank, consists in heating the saline solution so as to dissipate gradually part of the water by evaporation. It is thus that chemists proceed for obtaining crystals of sulphat of potash, muriate of potash, &c.

The figure of the crystal has very little regularity, if the water be evaporated too hastily, as by boiling; but by keeping the saline solution in a gentle heat, very beautiful and very regular crystals are constantly obtained in a longer or shorter space of time; and there is scarcely any salt which may not be made to assume a very distinct form by this process, if it be skilfully conducted.

All crystals extend themselves more in a horizontal than a vertical direction, and acquire a much faster growth at the bottom of a tall vessel than nearer the surface. This curious fact will admit of a simple explanation; the integrant moleculæ, being denser than the solution from which they are separated, fall down, and augment by their continual accretion the expanding crystals below. There are other circumstances which materially influence the cohesive affinity of dissolved solids, in determining it to become efficient; of this kind is the refrigeration of the fluid.

This process is successfully employed for such saline bodies as are more soluble in hot water than in cold. It may readily be conceived, that a salt of this kind must exhibit this phenomenon, since it ceases to be equally soluble in water, of which the temperature is diminished; so that the portion, which remained dissolved only by means of the higher temperature, will separate by degrees as the liquor cools; and when this is completely cooled, it will retain in solution only such a quantity as cold water would dissolve. It is the same with this second process, as with the first. The more slowly the water cools, the more will the saline moleculæ be enabled to approach each other by those faces which are most suitable, and a very regular crop of crystals will be obtained. For this reason a certain degree of heat must be kept up for some time under saline solutions, diminishing it gradually.

It must be observed, that all the salts, which may be made to crystallise in this manner, are also much more soluble in general than those, for which the preceding method is employed: and as they are dissolved at first in boiling water, if this be suddenly cooled, it will let fall in a shapeless mass all the salt that was dissolved by means of the boiling heat: on the contrary, if the solution be placed, while very hot, on a sand-bath, or in a warm place, and care be taken to conduct the refrigeration slowly, the crystallisation will be very regular. Such is the mode of obtaining sulphate of soda, nitrate of pot-ash, carbonate of soda, carbonate of pot-ash, muriate of ammonia, &c. in beautiful crystals.

A third method of crystallising saline substances, is by subjecting them to spontaneous evaporation. For this purpose, a saline solution is exposed to the temperature of the atmosphere in capsules of glass or shallow stone ware basons, which must be covered with paper or gauze, to prevent any dust from falling into the liquor, without hindering its evaporation. For this operation, a separate chamber or garret should be chosen, and used for no other purpose. The solution is left thus exposed to the air, till crystals are perceived in it, which sometimes does not take place in less than four, five, or six weeks, or even longer with some salts. This process usually succeeds better than either of the others for obtaining crystals very regular in their figure, and of considerable bulk. It ought to be employed in general for all salts, if time would allow, because it is the means of having them perfectly pure.

On some occasions a combination of these processes may be advantageous, particularly for obtaining crystals of very deliquescent salts. The solutions of these bodies being briskly evaporated, are exposed immediately to a great degree of cold; but this method never affords any but irregular crystals, and sometimes concrete masses.

The form of the vessel, and the plunging of foreign bodies into saline solutions, have also much influence on crystallisation.

Both of these circumstances affect the figure and growth of the crystals, and produce in it a very great variety; for this reason threads, glass rods, slips of metal, or little sticks, are placed with advantage in the capsules or basons, in which the crystallisation is performed, with a view to obtain regular crystals. In this case the crystals are precipitated on the threads, and as the surface on which they repose has very little extent, they have commonly the greatest regularity of figure, while in attaching themselves to the oblique, irregular, uneven sides of the vessels, they are always more or less irregular.

The plunging of foreign bodies into saline solutions, has frequently another advantage; they actually determine the formation of the crystals, which would have been much slower without their presence. Thus a piece of wood, or a stone, thrown into a saline solution, becomes a base, on which the solution readily deposits crystals. Other circumstances effecting the crystallising process of bodies, will be mentioned hereafter.

We shall form some idea of the process of crystallisation effected by means of a previous state of solution, if, after having dissolved a quantity of a crystallisable salt, for instance, nitrate of ammonia, alum, nitrate of potash, or sulphate of soda [Glauber's salt], in water, we observe what takes place whilst the solution is suffered to cool; after having been previously evaporated to saturation*, or better till a drop, when placed upon a cold body, shows a disposition to crystallise; or at farthest till the evaporation has proceeded to such a degree, that a saline pellicle begins to appear on the surface of the liquor, which phenomena are proofs that the cohesive attraction of the particles of the salt is obtaining a superiority over the solvent power of the hot water, and that the solution when left undisturbed will crystallise.

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* The term *saturation* in this case implies that the combination in which a body is combined with the largest quantity of another substance; hence, when water has dissolved the largest quantity of salt which it can dissolve, it is said to be saturated.

We shall find upon the bottom and the sides of the vessel, when the solution has become cold, small heaps of salt deposited, which gradually increase in size by the accumulation of new particles, and if these masses of salt be examined by a lens, it will be seen that they consist of groups of minute solids, or crystals possessing determinate geometrical forms.

All crystals deposited from water, contain a quantity of that fluid. It is termed their, *Water of Crystallisation*, and is essential to the regularity of their form. It gives them their transparency and density, those qualities being always lost when this water is evaporated. Different saline bodies contain different quantities of water of crystallisation. There are some which contain more than half their weight; as sulphate of soda, carbonate of soda, nitrate of ammonia, the triple sulphate of alumine, &c.: others have but a small portion, as sulphate of potash, nitrate, and muriate of soda, &c. The proportion of water varies according to the nature of the salt that is crystallised, and appears to be in an inverse ratio to the force of its crystalline power. Thus sulphate of potash, which requires a large quantity of water to counterbalance the cohesive force of its particles, contains but little water of crystallisation, whereas sulphate of soda, which is readily soluble in water, holds more than half its weight of water. This water appears to be in a state of chemical combination with the salt, and not simply interposed between its crystalline laminæ. The affinity however which it exerts is but feeble, at least in those salts into the composition of which it enters largely, since a considerable proportion of it is driven off by simple exposure to the air, and such salts are said to *affloresce*, because they abandon their waters of crystallisation by mere exposure to a dry and warm atmosphere, and thus lose their transparency, their volume, and in time their form, as sulphate of soda, &c.

Those salts on the contrary, which hold their water of crystallisation very strongly combined, and eagerly attract more on exposure to a damp atmosphere, become liquid or *deliquiate*. The property is called *deliquescence*. For instance, nitrate of ammonia, &c.

The cohesive attraction is therefore to be considered as the sole cause of the crystallisation of solids. It is exerted between the integrant particles of bodies. (See p. 9.) It essentially depends on two conditions only: one of which is, that the moleculæ of bodies should be in the state of disintegration; and the other, that they should be kept in suspension in a liquid capable of abandoning them to the crystalline attraction which solicits them towards each other. In short, every thing in the process of crystallisation, is regarded as passing in the same manner as if, the force of gravity being null, and the liquid was not coerced by the sides of any surrounding matter, and as if the crystal itself remained isolated in the liquid.

But the particles of different bodies, no doubt, possess different degrees of crystalline powers, or to arrange themselves symmetrically.

Thus the integrant particles of carbonate of lime may be considered as possessing a very high degree of crystalline energy, for not only are very beautiful large crystals of this substance extremely abundant, but they are met with in the mineral kingdom with all the leading geometrical characters of calcareous spar, even when mixed with a very large portion of foreign ingredients. Thus the acute rhomboids of calcareous spar, which are found at Fontainbleau, contain more than two-thirds of their weight of granular quartz: the principal angle of pearl spar are nearly the same as that of calcareous spar, although, in many instances, the carbonat of lime in this mineral amounts to no more than about a third of its weight, the remainder being oxyd of iron and manganese; again, in the bitterspath the carbonat of lime preserves nearly its essential crystalline character, though mixed with almost half its weight of carbonate of magnesia, for the value of its geometrical angle differs little from that of the primitive figure of the characteristic angle of carbonat of lime. On the other hand, the crystalline affinity of sulphuret of copper is probably but small, and therefore the minuteness of its crystals, and their comparative rarity.

Hence also, when two solids are dissolved in one liquid, they may be separated from each other by their different crystalline energies. That solid whose particles possess the greatest crystalline tendency will separate first, and the other, which is less disposed to crystallise, may be afterwards obtained by reducing the quantity, or temperature of the solvent. The separation, however, of the two solids from each other, is seldom, if ever perfect, on account of their mutual affinity for each other.

When nitre and common salt, for example, exist together in the same solution, after separating most of the nitre by its greater disposition to crystallise, there still remains a portion of it in the saline solution. The crystals which we obtain at first, are not pure nitre, but consist of that salt, combined with a portion of common salt.

Observation and experiment have shown, that those salts that are permanent in the air, have the strongest degree of crystalline power. In those which are efflorescent this force is considerably less, and it is the weakest of all in those that deliquesce on exposure to the air. Now if two salts of the first class are dissolved together in the same quantity of water, provided they do not decompose each other, and especially if their ratios of solubility are different, although they are rendered more soluble by their mutual affinity, yet the whole quantities of them, may be obtained again in a crystalline state without leaving any uncrystallisable fluid. Thus equal parts of nitrate of potash and sulphate of potash, though soluble when mixed together in less water than would have been necessary for both in a separate state, afford by evaporation successively and in proportion to their solubility, first, sulphate of potash, and then nitrate of potash, without leaving any portion of it in the uncrystallisable liquid. But on the other hand if nitrate of soda and sulphate of soda are subjected to the same experiment, both of which have only a slight tendency to crystallise and are of nearly equal solubility, only a small quantity of sulphate of soda will separate by crystallisation, all the nitrate and the remainder of the sulphate remaining liquid and uncrystallisable. When the mutual action of the two salts is sufficient to effect a double decomposition of them, it is necessary to take into consideration the solubility of the new formed salts, in order to make a correct estimate of the quantity of uncrystallisable residue, or of their crystalline powers: and it is by taking thus advantage of the superiority of the affinity of cohesion over that of different bodies, that we are able to procure in a separate state many saline bodies in the difficult art of analysis.

It is unnecessary to expound this subject to a greater extent. A summary chemical view of it would involve a minuteness of detail altogether unsuitable to the purpose of this work.

Crystallisation as it takes place from the reduction of temperature, in a body which has had fluidity communicated to it, by the action of heat.

There are some classes of bodies which are not soluble in water, but nevertheless, are capable of assuming crystalline forms. Such, for instance are the metals; some inflammables, and a vast number of chemical compounds..

These substances when returning to the solid state after having been fused, undergo a regular crystallisation; they are made to crystallise by being previously fused, which in fact, is a solution by means of caloric.

If we melt a ladle full of bizmuth, antimony, zinc, sulphur, or muriate of lead, and allow it to cool slowly, and quietly, till a thin crust has formed on the surface, and then by means of a pointed iron, make two small opposite apertures through the crust, and quickly pour out by one, the fluid portion as carefully and with as little motion of the mass as possible, whilst the air enters by the other aperture, there will appear on removing the upper crust by means of a chissel, when the vessel has become cold, a cup shaped concavity studded with crystals, very brilliant, and more or less regular, according to the magnitude of the quantity of mass employed, the tranquillity and slowness with which it has cooled, and the dexterity with which the fluid central portion, at the moment before it commenced to solidity, was decanted from the crystallised part. The same effect will be produced by fusing the substance in a crucible, which has a hole in its bottom, lightly closed by an iron rod or stopper, which is to be drawn out, after the vessel has become removed from the fire, and the surface of the liquid become congealed. Or the substance when melted, may be poured into a deep plate or dish, placed in a slanting position, which is suddenly inclined in the opposite direction, when the mass begins to congeal; by this means the superior portion which is fluid, is made to run off, and a cake studded over with crystal is obtained. Sulphur, bismuth, sulphuret of antimony, and muriate of lead, are easily crystallised in this manner.

The conversion of water into ice, is a process of crystallisation arising from the abstraction of caloric, by the combination of which, water presents itself in a state of fluidity; its natural form being ice, hence it passes into the solid state at 32° at the loss of caloric. When water is suffered to freeze very slowly and without agitation, small needle-shaped crystals are observed on its surface, shooting out from each other at an angle either of 60 or 120°; these crystals gradually accumulate, they cross each other in all directions, and lastly, form one uniform solid mass of ice. A similar crystalline arrangement is observable in new fallen snow, the flakes of which present stars with six radii. If a piece of fistulous ice, containing water in its internal parts, be broken, and the water be suffered to run out, the external cavity when examined by the microscope, will be found studded with beautiful triangular or hexahedral prisms, curiously interlaced, and grouped upon each other.

Crystallisation effected by sublimation.

Crystallisation effected by means of sublimation, is applicable to those bodies which are readily volatilized without changing their chemical properties on exposure to a moderate heat. To illustrate this fact, take any quantity of benzoic acid, put it into a Florence flask, and apply a gentle heat to the bottom of the flask by means of a lamp. The benzoic acid will be volatilized in the form of white vapours, which again condense within the upper part of the vessel in a beautiful crystalline form. In these cases, the caloric acts as ordinary liquids with respect to a salt which they hold in solution.

It is the retiring of the substance at first interposed between the particles, which removed them to a distance from each other, so as to permit them to approach insensibly nearer to each other by virtue of their molecular attraction, and to unite under geometrical forms, when such withdrawing is made slowly enough to give them time to assume the arrangements which accord with the laws of crystallisation.

Crystallisation as it takes place by the exertion of chemical affinity.

The mutual approach of the integrant particles of crystallisable bodies held in solution by a liquid, so as to approach and to present regular angular forms, may likewise be effected, by presenting to the fluid another body which has an affinity superior to that of the crystalline solid itself, and therefore weakens its affinity, and effects a decomposition. In illustration of this principle, the action of alcohol upon most of the saline solutions may be advanced. If we make a very concentrated solution of nitrate of potash, alum, sulphate of copper, or sulphate of magnesia in water, and pour into it copiously, alcohol, the salt held in solution by the water becomes instantly precipitated in the form of exceedingly minute crystals, by virtue of the alcohol combining with the water by which the salt was dissolved.

If we spread on a plate of glass a few drops of a dilute solution of nitrate of silver, and place in contact with it a copper or brass wire, and let the whole remain undisturbed in an horizontal position; a brilliant crystallisation of metallic silver will make its appearance upon the glass next the piece of copper wire, and this arrangement of crystals will extend gradually till the whole quantity of fluid is evaporated. In this case the copper or brass unites to the oxigen of the oxid of silver dissolved in the nitric acid, which holds it in solution;

and as this takes place, the silver becomes precipitated in the metallic state, assuming a kind of arboriform arrangement, whilst the nitric acid unites to the copper.

If a piece of phosphorus be suffered to remain immersed for about twelve hours, in a solution of sulphate of copper, the phosphorus will gradually become enveloped in a coat of extremely brilliant and crystalline metallic copper, impervious to air. Because the phosphorus has a stronger affinity for oxigen than copper; it therefore de-oxidizes the solution of this metal, and the copper re-appears in its metallic form.

The precipitation of silver in a metallic state may be effected by suffering phosphorus to be immersed, for a few days, in a solution of nitrate of silver. The whole of the metal will be precipitated on the phosphorus in fine dendritic crystal. The rationale of this experiment is analogous to the former.

The metallic precipitation of lead, commonly called the lead tree, may be exhibited in the following manner. Into a quart decanter, nearly filled with water that has been boiled, put half an ounce of acetate of lead reduced to powder, shake the mixture, and suffer it to stand undisturbed for two or three days; then decant the clear fluid from the insoluble residue; reject the latter, and after having rinced the decanter with water, return into it the clear solution. If now a ball of zinc be suspended in the middle of the fluid, by tying it to a thread affixed to the stopper, and the vessel be then set in a place where it cannot be disturbed, the zinc soon becomes covered with a moss-like substance, being metallic lead, which increases gradually, and shooting out brilliant crystallised plates of metallic lead, which place themselves in a kind of symmetrical arrangement resembling a tree or shrub. The zinc has a greater affinity than lead has for oxigen, it therefore deprives the oxid of lead of it, which being thus reduced to the metallic state, can no longer remain united to the acetic acid in which it was dissolved, but must become precipitated upon the zinc, and in so doing places itself, by virtue of its molecular attraction, into such a symmetrical arrangement, as the disposition of its particles is best adapted to assume.

Crystallisation effected by a previous state of comminution and suspension in a fluid.

From the experiments of Mr. Watt, it appears, that in order to obtain bodies in the form of crystals, a previous solution is not always necessary, but that an extreme mechanical divisions and suspensions in a fluid is in some cases sufficient, so that the disunited particles have full liberty to approach each other very gradually and without starts. Mr. Watt persuades himself, that in this manner petrified wood is almost daily formed, in which, though crystallisation does not actually take place, a very perfect arrangement is indicated by the intimate union of the silicious matter of which it is composed, and that in this manner are produced other depositions which approach to a crystalline structure, although the materials of which they are composed are virtually insoluble in water.

Circumstances which are essential for the production of well formed crystals.

In order that the form of crystals may be regular, three circumstances are required; time, a sufficient space, and repose.

Time causes the superabundant fluid to be slowly dissipated, and brings the integrant particles nearer to each other by insensible concentration, and without any sudden shock. The integrant parts therefore unite according to their constant laws and form a regular crystal. Indeed it is a general rule that the slower the formation of a crystal, the more perfect is its form; it is also larger, harder, more transparent and regular.

Space, or *sufficient room*, is likewise a necessary condition for obtaining beautiful and regular crystals. If nature be restrained in her operations, the products of her labour will exhibit symptons of this state of constraint. It may be asserted, that nature forms her productions according to all the circumstances which can influence her processes.

A state of repose in the fluid is absolutely necessary to obtain very regular forms. Uninterrupted agitation opposes all symmetrical arrangement; and in this case the crop of crystals obtained, will be confused and indeterminate.

Method of obtaining large and perfect crystals of almost any size.

We are indebted to Le Blanc* for an ingenious method for obtaining large and perfect crystals almost of any size, and for varying their shape at pleasure, by causing them to be formed, or grow under certain circumstances. The process is as follows. Let the salt to be crystallised be dissolved

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* Journal de Physique, tom. iv. p. 300.

in water, concentrate the solution slowly by evaporation, to such a degree that it shall crystallise on cooling, which may be known by suffering a drop of it to cool on a plate of glass or other substance. This being done let the solution be put aside, and when perfectly cold, pour off the liquid portion from the mass of crystals at the bottom, and put it into a flat bottomed vessel. After having stood for some days, solitary crystals will be formed.

This being done, crystals will begin to form at some distance from each other, which gradually increase in size; select the most regular of these, and place them into a flat bottomed vessel at some distance from each other, and pour over them a quantity of the concentrated liquid obtained by evaporating a solution of the salt, till it crystallises on cooling. Alter the position of every crystal once at least every day, with a glass rod, that all the faces may be alternately exposed to the action of the liquid: for the side on which the crystal rests, or is in contact with the vessel, never receives any increment. The crystals will thus gradually grow or increase in size. When they have grown to such a size that their form can easily be distinguished, let the most perfect ones be selected, or those having the exact shape which we wish to obtain; and put them separately in a vessel filled with a portion of the same liquid, and let them by turned in the manner directed several times a-day. By this means they may be be obtained of almost any size we wish. When the crystal has continued in the liquid for a certain time, the quantity of salt held in solution becomes so much diminished, that the liquid begins to act upon the crystal and redissolve it. This action is first perceptible on the angles and edges of the crystal; they become blunted, and gradually loose their shape altogether. Whenever this begins to be perceived, the liquid must be poured off, and a portion of new liquid put in its place; otherwise the crystal is infallibly destroyed. They may be made to grow in length or breadth; particularly if they are of a regular form.

They will grow in length if they be made to lay upon their sides, and in breadth, when they are placed upon their bases. Crystals may thus be produced of an extraordinary size and beauty.

Influence of atmospheric pressure on the process of crystallisation.

The access of air has an import influence on the process of crystallisation. If a saturated solution of salt whilst hot be put into a vessel from which the air is excluded, it does not crystallise even when cold. But if air be admitted, the crystallisation immediately commences and proceeds with rapidity. This fact may be shown in the following manner.

Make a concentrated solution of sulphate of soda, or Glauber's salt, by adding portions of it gradually to water kept boiling, till this fluid dissolves no more: (an ounce and a half of water, will thus dissolve two ounces of salt): pour the solution whilst boiling hot into common medicine phials, previously warmed, and immediately cork them, or tie slips of wetted bladder over the orifice of the phials; so as to exclude the access of common air from the solution. This being done, set the phials by in a quiet place, without shaking; the solution will now cool to the temperature of the air, and remain perfectly fluid, but the moment the cork has been drawn, and atmospheric air becomes admitted, it begins to crystallise on its upper surface, the crystallisation shoots downward in a few seconds, like a dense white cloud, and so much heat becomes evolved, as to make the phial very sensibly warm to the hands. When the crystallisation is accomplished, the whole mass is so completely solidified, that, on inverting the phial, not a drop of it falls out.

The explanation of this phenomenon as given by Mr. Murray*, is as follows.

When the saturated solution of the salt is enclosed in the vessel, and the pressure of

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* System of Chemistry, vol. I. p. 87.

the atmosphere excluded, the particles in solution may be conceived as placed at distances too great to admit of the attraction of cohesion being asserted, so as to cause them to unite and crystallise. But when the pressure of the air, or any equivalent pressure, is brought to act on the surface of the fluid, its particles, as well as the particles of the solid contained in it, are forced nearer to each other; the distances between them are lessened; the attraction of cohesion is exerted, and the crystallisation commences. The small crystals that are thus formed at the surface, afford solid points from which other crystals are formed, and this proceeds rapidly through the whole fluid.

Singular effect of commotion; and other agencies which effect the crystallising process of saline bodies.

Although the entire absence of external motion, (as stated page 37), is peculiarly favourable for the production of well formed crystals, the crystallising process may be promoted in some instances by a slight disturbance or commotion of the fluid. This is particularly the case with the solution of those salts that are much more soluble in hot than in cold water, and have but a feeble crystalline power.

It has been observed, that in general the effect produced, depends upon a particular agitation produced in the liquid, rather than upon a rapid motion impressed upon all the mass. For we may succeed by striking lightly with the bottom of the vessel the table which supports it, or by striking against the interior parts of the said bottom with a glass tube, or feather. Sir Charles Blagden has noticed that of all the exciters of crystallisation, that which most rarely fails in its effect in such cases, is a small piece of wax with which the interior parts of the vessel are struck in some points inferior to the upper surface, so as to generate a species of tremulous motion. If water be suffered to cool without the least agitation, and very slowly below the freezing point, it does not congeal; but at the instant the vessel is agitated, there will be seen a crust of ice at the part of the vessel situated beneath the wax. We may conceive that, in this case, the agitation of the liquid, at the same time that it assists the saline particles in disengaging themselves from the aqueous particles, which still oppose a small obstacle to their re-union, will occasion a variety of different motions in the former, whence will result for a certain number among them, the positions which give the greatest advantage to crystalline affinity.

It has been remarked also, that a little crystal of salt, placed in a solution of the same salt, favours the crystallisation; because the moleculæ which compose this crystal having already the respective positions necessary to satisfy the aggregation, solicit those in their vicinity to motions the most favourable to the action of the same force; and this disposition is communicated regularly to all those which would make an effort to crystallise. The presence of a small piece of ice, which is placed in like manner in water that is already below the degree of congelation, becomes as it were a rallying point for all the moleculæ which have a tendency towards this union, and effect the congelation.

The electric state of the atmosphere it appears influences the crystallisation of saline bodies. This is particularly observable in the laboratories of chemists, when large quantities of saline solutions are made to crystallise. It frequently happens, that solutions which yields no crystals after having been sufficiently concentrated, and left to stand undisturbed for some days, suddenly deposit the most abundant crop of crystals, during or immediately after a thunder storm.

Effect of light on the production of crystals.

A very singular property may be observed in saline bodies which may be referred to crystallisation, but is likewise in some measure remote from it, because it does not depend upon the same causes.

This is the property of rising along the sides of the vessels which contain the solution. It is known by the name of saline vegetation. Thus, if a solution of muriate of ammonia or prussiate of potash previously evaporated to the point of crystallisation, be left undisturbed in a shallow vessel from which the light is excluded, this salt crystallises most effectually at the illuminated part, it rises over the margin of the vessel, and appears to be solicitous of the rays of light, and the crystallisation may thus be determined at pleasure towards any part of the vessel by the mere admission or exclusion of light, &c. Camphor possesses this property in a high degree. This substance rises by insensible evaporation in half filled vessels, and constantly attaches itself in a crystalline form at the most enlightened parts of the vessels.

SECTION III.

TERMS OF CRYSTALLOGRAPHY—GEOMETRICAL DEFINITIONS—THEORY AND MEASUREMENT OF ANGLES—NATURE OF GEOMETRICAL SOLIDS.

In every science or art there are many terms which require to be frequently mentioned, if these were described as often as they occur, it is obvious that a great loss of time would follow, and no advantage would be gained in perspicuity, because these descriptions would continually divert the mind from the leading object. And this is the more essential in a science founded on the principles of geometry and the mathematics.

All crystals with regard to their shape may be considered as *rectilineal solids*, composed of planes, edges, and solid angles.

The *planes* of crystals, are those surfaces which lie evenly between their bounding lines, and with which a straight line drawn in any direction shall coincide in every point.

The *edges* of a crystal, are formed by the junction of two planes or faces, under determinate angles.

The *solid angles* of crystals, are produced by the coincidence of two or more planes in one point. Every crystal also has two opposite ends; if the ends of a crystal terminate in solid angles, they are called *summits*; and if in surfaces, they receive the name of *bases*. The planes or faces, upon which the crystal is supposed to stand erect, is simply denominated the *base**, and the lines by which it is circumscribed, are called the edges of the *base*. The faces interposed between the two bases are called lateral-faces, and the lines by which the faces unite are called lateral edges.

The faces which compose the summit, are

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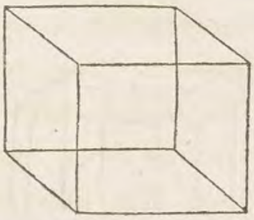
* It may be any side or face at discretion.

called accuminating faces, or faces of the terminal pyramid, and the edges by which they join, are named the edges of the pyramid.

If an edge, or solid angle, be wanting, or as if it were, cut off, by presenting a new face, the edge or angle is said to be truncated, or replaced by a secondary plane. And if it be cut off so as to present two planes or faces, joining each other, it is said to be bevelled or replaced by two secondary planes. Fig. 1* represents a cube.

Fig. 1.



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* Model, No. 1.

N. B. *The Models referred to in this work, may be had at Messrs. Accum and Garden, Compton Street, Soho.*

Fig. 2* is the same cube, *truncated on the angles a a a*, &c. the secondary planes or *truncatures.*

2.

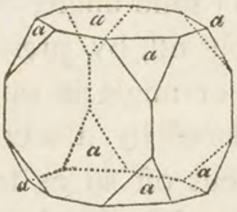
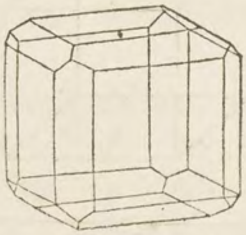


Fig. 3† is the cube, Fig. 1, *truncated on the edges.*

3.



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* Model, No. 2. † Model, No. 3.

Fig. 4* represents the cube Fig. 1, *bevelled;* because the edges of the solid are replaced by two secondary planes.

4.

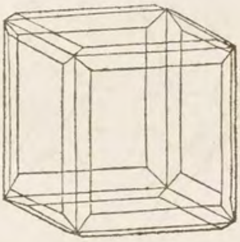
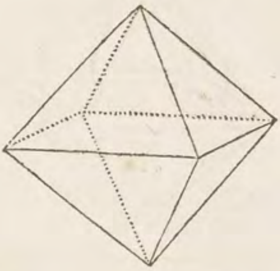


Fig. 5† is a regular octahedron, composed of two four-sided pyramids, put base to base.

5.



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* Model, No. 4. † Model, No. 5.

Fig. 6* is the same solid, having the solid angles truncated or replaced by a secondary plane.

6.

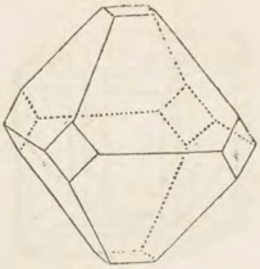
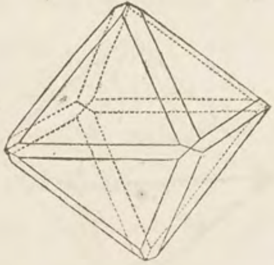


Fig. 7†. The same solid, truncated on the edges.

7.



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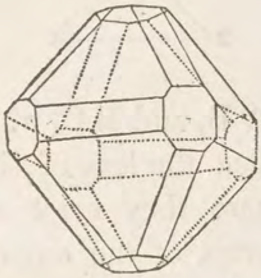
* Model, No. 6. † Model, No. 7.

Fig. 8* is the octahedron Fig. 5, truncated on all the edges and solid angles.

8.



Theory of Angles.

If two straight lines lean or incline towards each other, they will at last meet, which place of meeting is called an *angle*.

A plane angle is therefore the opening or corner, made by the mutual inclination of two straight lines, which are not in the same direction, but meeting in a point as Fig. 9.

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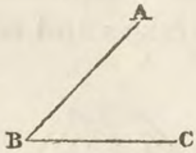
* Model, No. 8.

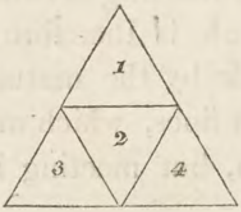
9.



The lines A B, and B C, which form the angle, are called the legs or sides, and the point B, where they meet or touch, is called the vertex of the angle, or the angular point.

A solid angle is that which is made by more than two plane angles, applied close to each other, at the same point, so that two of them are not in the same plane.

10.



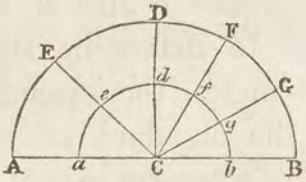
If we draw Fig. 10 upon pasteboard or any other pliable matter, and cut the lines half through, and then turn up the parts, they will form a solid angle at the point where their vertices meet each other.

Measurement of Angles.

The measure of every angle is an arc of a circle, whose centre is the angular point; hence to determine the value or measure of angles, the circumference of a circle is the standard of comparison. This circle, of whatever size it may be, is supposed to be divided into 360 equal parts, called degrees; each degree is again subdivided into 60 equal parts, called minutes, and every minute is subdivided into 60 seconds; and hence the measure of an angle is said to be so many degrees, minutes, &c. as are contained in its measuring arc. Degrees are marked by °, minutes by ′, and seconds by ″. Therefore an angle of 45 degrees, 15 minutes, and 7 seconds, is written in this manner, 45° 15′ 7″.

To measure the value of an angle, we describe a circle round the angular point as a centre, and according to the number of degrees, minutes, and seconds, cut off by the sides of the angle, so many degrees, minutes, and seconds, the angle is said to contain. For instance

11.



If from two points in the circumference of a given circle, as E and F, Fig. 11, lines are drawn to the centre as E C and F C; there is made an angle at the centre C, which is greater or less according to the number of degrees on the arc E D F, but of course it will be the same in a small circle as in a large one; because the lines will have the same inclination to each other; viz. A D B is a semicircle, whose centre is C; the arc A E D F G B, contains 180 degrees, half 360, the whole circumference.

From the middle point D, of the arc A D B, which is 90 degrees each way, from A and B, if the line C D be drawn, it will be perpendicular to A B; for A C D, and D C B are each a fourth part of the whole circumference, or half the semi-circumference of the circle; these angles are therefore said to be of 90 degrees.

If the arc A D be bisected in E, and E C be drawn, the angles A C E, and E C D will be each of 45 degrees, half A C D a right angle, or 90 degrees.

And if the arc D B be trisected, at F and G, and F C be drawn, the arc D F containing 30, and F G B 60 degrees, the angle D C F is said to be an angle of 30, and F C B an angle of 60 degrees.

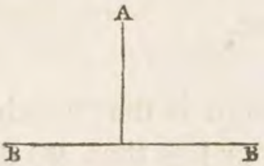
Or if on the same centre C, the arc *a e d f g* be drawn, which is also a semi-circle, it is obvious that it is also divided into the same number of parts, and in the same proportion, as the arc A E D F G B, for it is bisected in *d*, and *a d* is again bisected in *e*, and *d b* is also trisected at *f* and *g*; wherefore A D, *a d* are each a fourth; E D, *e d* an eighth; B F, *b f* a sixth; and F D, *f d*, a twelfth part of their respective circles; and the angles A C D, *a* C *d*; E C D, *e* C *d*, &c. are the same in both. From which it is obvious, that angles may be formed or measured by a circle of any radius; and also that equal arcs of the same, or of equal circles, or that an equal number of degrees in a circle of any radius, will form equal angles at the centre.

Division of Angles.

Angles are of various kinds and denomination. With regard to their magnitude they are divided into *right*, *oblique*, *acute*, and *obtuse* angles.

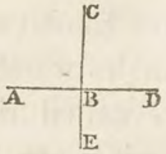
A *right angle* is that which is formed by the meeting of two straight lines, which do not incline to each other, but which are so placed that either of them is perpendicular to the other. Thus when one straight line, *a*, stands upon another line, *b*, Fig. 12, so as not to lean more to one side than to the other, both the angles which it makes with the other line are called right angles, because their measuring arc is equal to 90 degrees.

12.



If either side of a right angle be drawn out beyond the vertex, there is necessarily produced another right angle. And consequently if both sides are produced, there will be generated four right angles. Thus A B C, Fig. 13, is a right angle; if when A B or C B be drawn towards D or E, there is made another angle C B D, or A B E; and if both are produced, E B D is a fourth right angle.

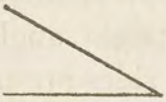
13.



Oblique angle is a common name for any angle that is not a right one, and it is either acute or obtuse.

An *acute angle* is that which is less than a right angle, or less than 90 degrees. See Fig. 14.

14.

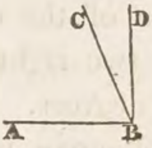


An *obtuse angle*, Fig. 15, is that which is greater than a right angle, or whose measure exceeds 90 degrees.

15.

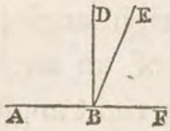
Namely, if the line C B, Fig. 16, meeting A B in the point B, falls on this side of a perpendicular, B D, at that point; this angle A B C, being less than the right angle A B D, is called acute.

16.



But if the line B E, Fig. 17, falls on the other side of the perpendicular B D; the angle A B E is obtuse.

17.



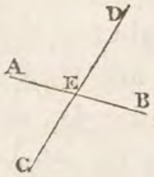
Complement of an Angle. The difference C B D, fig. 16, between an acute angle A B C, and a right angle A B D, is called the *complement* of the angle A B C. Hence the complement of an angle of 50 degrees is 40 degrees, because 40 degrees is what it wants of a right angle or 90°.

And if either side of an obtuse angle, as A B, Fig. 17, be produced, the angle E B F is the *complement* of the obtuse angle, or its deficiency to two right angles, A D B, D B F, or 180 degrees. Hence the complement of 100 degrees is — 10 degrees a negative quantity. The complement to 180 degrees is usually called the *sublement*, that is to say, what it wants to a semi-circle or 180 degrees, to distinguish it from the complement to 90 degrees, properly so called. Therefore the *sublement* is the difference of two right angles or semi-circles, and *complement* of an angle, expresses its deficiency from a right angle or 90 degrees.

Angles have other denominations which are given to them only from their situation, in respect to each other, yet still retaining the general appellation of right, acute, or obtuse, namely, *Vertical or opposite angles.* If two lines, A B and C D, Fig. 18, cut and cross each other, there are made four angles, at the point E of their mutual intersection; either two of these angles, A E D, C E B, or A E C, and D E B, touching at their vertices only, are called *vertical* or *opposite angles.*

Contiguous or adjoining angles. Any other two, as A E C, A E D, or A E C and C E B, and having one side C E, or A E, common to both angles, are called contiguous or adjoining angles.

18.

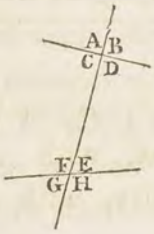


Alternate angles. If a line crosses or intersects two lines, there are made eight angles, A, B, C, D, &c. Fig. 10, of which C and F, also E and D, between the two lines, one on each side of the cutting line, are called alternate angles.

C and E, also D and F, are called internal angles on the same side.

E and A F, and B C, and G or D, and H, are called internal and opposite angles on the same side.

19.

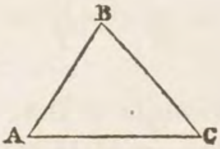


Triangles.

The fewest number of right lines that can include a space are three, which form a figure called a triangle, or three cornered figure. Triangles therefore are those plane figures which are contained by three straight lines, and which consequently have three sides and angles, from whence they take their names.

Any side of a triangle which is opposite to any angle, is said to subtend that angle. Thus A B, Fig. 20, subtends the angle C and A C; subtends the angle B, and B C; subtends the angle A.

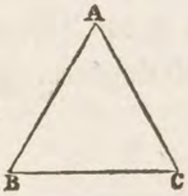
20.



Triangles are of various kinds; they are distinguished first, with regard to their sides, and secondly, with regard to their angles.

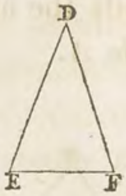
An *equilateral triangle*, is that which has all its sides equal to one another, as Fig. 21.

21.



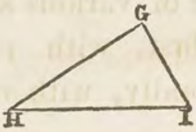
An *isosceles triangle* is that which has only two sides equal, as D E F. Fig. 22.

22.



A *scalene triangle* is that which has all its sides unequal, as G H I. Fig. 23.

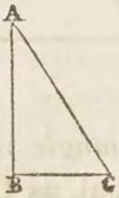
23.



Triangles, with regard to their angles, are either right angled, obtuse, or acute.

A *right angled*, or *rectangular triangle*, is that three-sided figure which has in it one right angle, as A B C, Fig. 24, containing or measuring 90 degrees.

24.



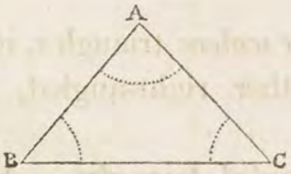
The side opposite to the right angle is called the *hypothenuse*, and the other two sides the legs.

The side which stands upright is called the perpendicular, and the other the base. Thus A C is the hypothenuse, B A the perpendicular, and C B the base.

The angles opposite to the two sides are both acute.

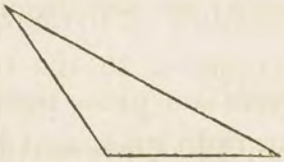
The three angles of every right lined triangle are equal to two right angles; that is to say, the angles A B C, Fig. 25, taken together, are equal to a semicircle or 180 degrees, viz. two right angles of 90 degrees each, because the three arches described on the angular points, as shown by the dotted lines, are equal to a semi-circle, or 180 degrees.

25.



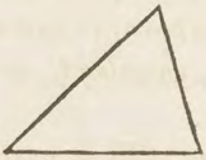
An *obtuse angled triangle*, Fig. 26, has in it one obtuse angle, or an angle, which is greater than 90 degrees.

The other two angles are acute, or less than 90 degrees.



26.

An *acute angled triangle*, Fig. 27, is that which has all its three angles acute, or less than 90 degrees. See Fig. 27.



27.

Isosceles or *scalene* triangles, it is obvious, may be either right-angled, obtuse, or acute.

Oblique-angled triangles. All triangles that are not right angled, whether they are acute or obtuse, are in general terms called oblique angled triangles.

Quadrangles or Quadrilaterals.

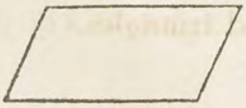
A *quadrilateral* is a plane figure, comprehended by four right lines, and having consequently also four angles; hence the names quadrangle.

The term quadrilateral comprehends the following particular species of geometrical figures; namely, *parallelogram*, *square*, *rectangle*, *rhombus*, *rhomboid*, *trapezium*, and *trapezoid*.

Parallelogram. This name is given to every quadrilateral right-lined figure, whose opposite sides are parallel to each other. It is immaterial whether the angles are right angles or not.

Fig. 28 is a parallelogram.

28.



A *square* is a parallelogram which has all its sides equal to one another, and whose angles are right ones, as Fig. 29.

29.

A *rectangle* is a parallelogram which has all its angles right angles, but has not all its sides equal. It is also called an oblong, being longer than broad. See Fig. 30.

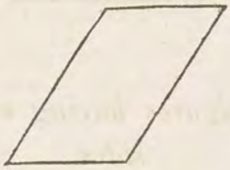
30.

A *rhombus*, or lozenge, is a parallelogram whose sides are all equal, but whose angles are not right angles, as Fig. 31.

31.

A *rhomboid* is a parallelogram which has its opposite sides equal to one another, but all its sides are not equal, nor its angles right ones. See Fig. 32.

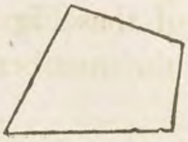
32.



Trapezium. Every other four-sided figure besides those mentioned before, are called *trapeziums.*

Fig. 33 is a trapezium.

33.



Consequently every irregular quadrangle or quadrilateral, which is not a parallelogram, is a trapezium.

A *trapezoid* has only one pair of its sides parallel, as Fig. 34.

34.

Polygons, or figures having more than four sides.

Figures bounded by more than four straight lines, are called polygons, signifying many sides. If their sides and angles are equal, they are called regular polygons;

if unequal, they are called irregular polygons.

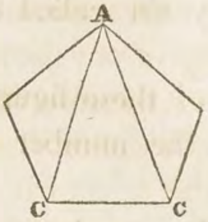
The names of these figures are derived to them from the number of their sides, namely,

A *pentagon* is a polygon that has five sides.
A *hexagon* has six sides.
A *heptagon* has seven sides.
A *octagon* has eight sides.
A *nonagon* has nine sides.
A *decagon* has ten sides.
A *duodecagon* has twelve sides.
A *quindecagon* has fifteen sides.

These eight are the most essential. When they have a greater number of sides, it is usual to call them polygons of sixteen sides, of seventeen sides, and so on. To specify every polygon would be infinite.

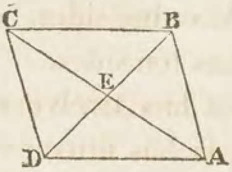
A *diagonal* is a right line drawn between any two angles that are opposite, is a polygon, as A C, Fig. 35.

35.



In parallelograms the diagonal is usually called the *diameter*, because it passes through the centre of the figure.

36.



A C, and B D, Fig. 36, are the two diagonals; E the centre where they intersect each other.

The *area* of a figure is its measure or superficial contents, viz. the quantity of space contained within its bounds, expressed in any known measure.

The *base* of a figure is called the side on which it is supposed to stand erect; it is generally applied to the lower side.

The *altitude* of a figure is called its perpendicular height from the base.

The *vertex* of a figure is the angular point in which two or more lines, forming an angle, meet, and touch each other.

The *axis* of a figure is called the line drawn from its vertex to the centre of the base.

An *upright, or right figure.* If the axis of a figure is perpendicular to the plane of its base, it is called a right or upright figure.

An *oblique figure,* is, when its axis is inclined to the base.

Quantity; denotes whatever may be measured or numbered, estimated or compared, in respect of more or less. It is of two kinds, viz. commensurable, and incommensurable.

Commensurable quantities; are such as have a common measure or aliquot part, that is, such quantities as may be measured or divided into the same equal parts, or into parts of the same magnitude, without leaving a remainder. Thus two quantities are commensurable when some determinate quantity may be found, which, being taken or multiplied, a certain number of times is equal to either, without deficiency or excess. Thus a foot and yard are commensurable, there being a third quantity which will measure each, viz. an inch, which taken twelve times make a foot, and thirty-six times a yard.

Incommensurable quantities are such as no other quantity can measure, *i. e.* there cannot be found any determinate quantity, how small soever, which, being multiplied, will be equal to each of the other; but that there will be a deficiency or excess in one or the other. Any two quantities whose proportion to each other can be expressed by numbers, are commensurable; two quantities, whose ratio cannot be expressed in numbers, are said to be incommensurable to each other.

Multiple; that quantity is called a multiple in respect of another quantity, when it contains exactly, or is equal to the other, being taken any number of times; then the less is said to measure the greater. Thus a foot is a multiple of an inch, of two, three, four, or six inches. A yard is a multiple of a foot, or of an inch, &c.

Ratio; is a mutual habitude or relation of quantities of the same kind, in respect to more or less.

Quantities are said to have ratios to one another, which being multiplied, can exceed each other.

A *plane rectilineal figure* is a superficies or space, bounded by straight lines only, and having but two dimensions, namely, length and breadth.

A *solid rectilineal figure* is a body bounded by plane surfaces only, and having three dimensions, namely, length, breadth, and thickness.

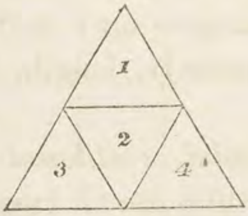
Regular solid rectilineal figures are those, whose sides are all equal, and which may be so included within a sphere or circle, that each angle shall touch the internal surface of the circumference of the circle.

Of these bodies there can be no more than five, namely:

1. The *tetrahedron*, Fig. 1 and Fig. 6, Plate II.* is a regular solid, contained under four equal and equilateral plane triangles. It may be considered as a pyramid standing on an equilateral triangular base.

A figure drawn upon pasteboard or card, similar to Fig. 37, having the lines cut half through, folded up, and glued together, will form a complete tetrahedron. The superficies of this regular solid, it must be obvious, is equal to four times the area of the base.

37.



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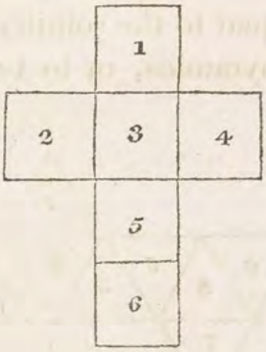
* Model, No. 9.

2. The *cube*, Fig. 3, Plate II.*, is a solid contained under six equal square planes.

If we draw a figure upon card or pasteboard, like Fig. 38, and cut the lines half through, and then turn up the parts and glue them together, we shall form a cube. It will thus be conceived that this regular solid is a body contained under six equal square planes, and that its solidity is equal to three dimensions, multiplied by each other, and that its superficies is equal to six times the area of its base, or one of its sides.

38.



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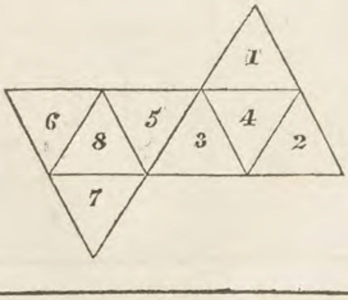
* Model, No. 1.

3. The *octahedron*, Fig. 5, Pl. II.*, is a solid, contained under eight equal and equilateral triangles. This regular solid may be conceived as consisting of two quadrangular pyramids put together base to base. Fig. 39, being drawn upon stiff paper or pasteboard, cut half through in the lines, folded up and glued together, will show in a tangible manner that the octahedron is composed of eight equilateral triangular pyramids, or of two quadrangular pyramids joined at their bases; and further, that the superficies of this solid is equal to eight times the area of one triangle, and that its solidity is equal to the solidity of the eight composing pyramids, or to two triangular ones.

39.



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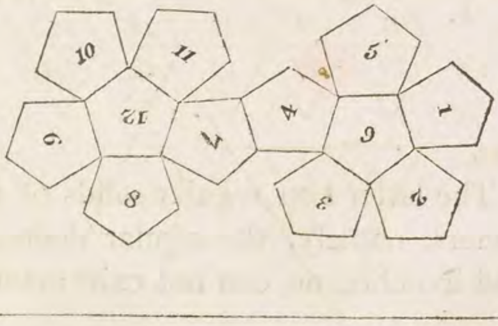
* Model, No. 5.

4. The *dodecahedron** is a regular solid, composed of twelve equal pyramids, meeting in a point at the centre of the solid; the base of each pyramid being an equilateral pentagon, and equal to each other. The superficies of this body is therefore equal to twelve times the area of one pentagon, and the solidity is equal to the solidity of the twelve composing pyramids.

If Fig. 40 be drawn upon a playing card or stiff paper, and the lines be cut half through, folded up, and glued together, the several pentagons will form a regular dodecahedron.

40.



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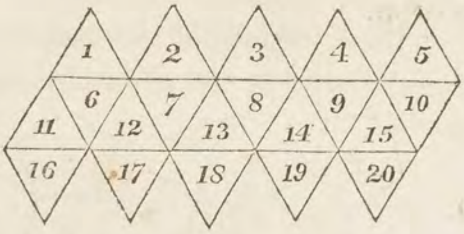
* Model, No. 10.

5. The *icosahedron** is a regular solid, made up of twenty pyramids, whose summits meet in a point at the centre of the body: the base of each pyramid being an equilateral triangle and equal to each other. The superficies therefore, is equal to twenty times the area of one triangle, and the solidity equal to the solidities of the twenty composing pyramids. If Fig. 41 be drawn upon pasteboard, and the lines be half cut through, and then folded up, it will form an *icosahedron*.

1.



The latter two regular solids of the geometers, namely, the regular dodecahedron and icosahedron, can not exist among crys-

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* Model, No. 11.

tallised bodies, for reasons which will be pointed out in the sequel of the work.

Irregular rectilineal solids, are called those bodies which have more than four sides composed of straight lines, and the sides of which are unequal : of these there are a vast variety, for instance,

A *pyramid* is a solid figure contained within, or bounded by a number of planes, whose bases may be a triangle, square, or any polygon, and whose faces are triangles terminating in a point, called the summit or vertex of the pyramid.

When the figure of the base is a quadrilateral, it is called a quadrilateral pyramid, as Fig. 42.*

42.

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* Model, No. 12.

A *pyramid* is either regular or irregular, according as the base is regular or irregular.

A *prism* is a solid figure contained under a number of planes more than four, of which the two opposite ones, or ends, are equal and parallel to one another, and all the other parallelograms. Prisms are denominated according to the number of the angles in the base or ends. Thus when the ends are a triangle, the prism is called a triangular prism, Fig. 2, Plate II. * When it is a square, it is called a square prism; when a hexagon, a hexagonal prism, Fig. 7, Pl. II.* Hence the denomination of prism, comprehends also the cube and the parallelopipedon, the former being a square prism, and the latter a rectangular one.

A *parallelopiped*, see Plate II. Fig. 4, as stated, is a prism, (or as it is sometimes,

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* Model, No. 13. † Model, No. 14.

though improperly, called an oblong cube), contained under six quadrilateral figures, whereof every opposite two, are equal and parallel to one another.

SECTION IV.

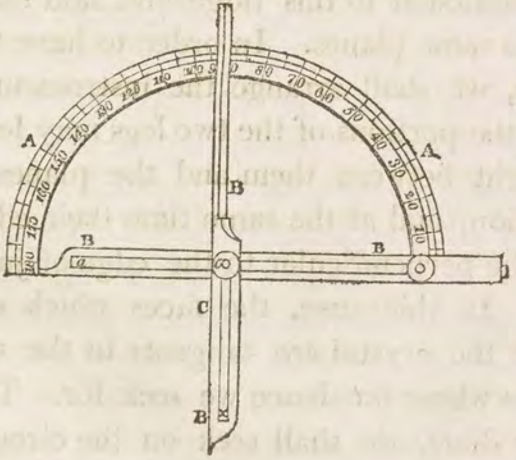
ADMEASUREMENT OF THE ANGLES OF CRYSTALS.

Pocket Goniometer.

The pocket goniometer, contrived by Carangeau for measuring the solid angles or the inclination, which one plane surface of a crystal makes with another, consists of a protractor or semi-circular scale of degrees, A A, Fig. 43, and a small pair of compasses or nippers, B B B B, destined to receive the crystal.

The protractor has a hollow centre at c, lying in the direction of that diameter, which terminates the graduation. The centre c of the pair of compasses is made moveable like those of the common proportional compasses, so as to permit the legs B B, and B C B, to be considerably lengthened or shortened, when the two pieces are applied to each other. The fixed leg B B, is represented as beneath the moveable one B C B, or radius, measuring 90 degrees, and the lower end of the centre pin which could not be shown in the wood cut, is made to fit the hole or centre C in the protractor precisely at the same time that the stud or projecting piece of brass, being admitted into the long perforation *a* of the leg B B, the piece becomes steadily attached to the protractor or semi-circle, as is seen in Fig. 43. The instrument is neatly executed in brass or silver.

43.



The application of this instrument is obvious. The crystal to be measured is applied between the pair of compasses, which being thus set, are applied to the protractor A A, and the value of the angle may of course be read off at the fiducial edge of the leg B C B.

Let us suppose, for the sake of illustration, that we wish to measure on a crystal the angle formed by two adjoining planes. We know that this angle is equal to that of two lines drawn from one and the same point of the edge which joins these planes, with the condition that they are perpendicular to this ridge and laid down on the same planes. In order to have this angle, we shall arrange the instrument so that the portions of the two legs may leave no light between them and the planes in question, and at the same time their edges may be perpendicular to the edge of junction. In this case, the faces which embrace the crystal are tangents to the two planes whose incidence we seek for. This being done, we shall seek on the circumference of the protractor, the degree which the edge or index line marks, or the angle which this line forms with that which passes by the centre *c* and by the zero point, which angle is equal to that formed by the two portions of the arms, since it is opposite to it at the summit. In the sketch 43 it is shown as giving 90 degrees.

It is an advantage to be able to shorten the legs at pleasure, to avoid the obstacles which would render the operation impracticable, and which might be occasioned either by the matrix to which the crystal adheres, or from the adjoining crystals.

But notwithstanding much ingenuity has been bestowed on this instrument it is not sufficiently accurate for the performance for which it is applied; it may nevertheless be used in many cases where no great accuracy is required, and its portability and cheapness render it an object of value to the cultivator of mineralogy.

Optical Goniometer of Dr. Wollaston.

We are indebted to Dr. Wollaston for the invention of a goniometer, which is entirely optical. Its action consists in employing a ray of light reflected from the surface, instead of the face itself; and thus accordingly, for a radius of 1-50th of an inch we may substitute either the distance of the eye from the crystal, which would naturally be about twelve or fifteen inches, or, for greater accuracy, we may by a second method substitute the distance of objects seen at a 100 yards or more from us.

The instrument consists of a circle (Plate IV.) graduated on its margin, and mounted on a horizontal axle supported by an upright pillar. This axle being perforated, admits the passage of a small axle through it, to which any crystal of moderate size may be attached by a piece of soft cement or shoe-makers' wax, with its edges or intersection of the surfaces horizontal and parallel to the axis of motion. This position of the crystal is first adjusted, so that by turning the small axle each of the two surfaces, whose inclination is to be measured, will reflect the same light to the eye. The circle is then set to zero, or 180 deg. by an index attached to the pillar that supports it.

The small axle is next turned till the further surface reflects the light of a candle or other definite object to the eye; and lastly, (the eye being steadily kept in the same place), the circle is turned by its larger axle, till the second surface reflects the same light. This second surface is thus ascertained to be in the same position as the former surface had been. The angle through which the circle has moved is in fact the supplement to the inclination of the surfaces; but as the graduations on its margin are numbered accordingly in the inverted order, this angle is correctly shown by the circle without requiring need of any calculation. It may be here noticed that it is by no means necessary to have a clean uniform fracture; for since all those small portions of a crystalline surface that are parallel to one another, though not in the same plane, glisten at once with the same light; the angle of an irregular surface may be determined nearly as well as when the reflecting surfaces are actually in the same plane. In this method (of taking the measure of an angle), when the eye and candle are only ten or twelve inches distant, a small error may arise from parallix. But such an error may be rendered insensible, even in that mode of using the instrument, by due care in placing the crystal, and when the surfaces are sufficiently smooth to reflect distinct images of objects, these errors may be entirely obviated by another mode of using it.

For this purpose, if the eye be brought within an inch distant of the reflecting surface, the reflected image of same distant chimney or other object may be seen beneath its true place, and if by turning the small axle, may be brought to correspond apparently with the bottom of the house, or with some other distant horizontal line. In this position the surface accurately bisects the angle which the height of that house subtends at the eye; then by turning the whole circle and crystal together, the other surface, however small, may be brought exactly into the same position, and the angle of the surfaces may thus be measured with a degree of precision that has not been hitherto expected in geometry.

a b, Plate IV. is the moveable circle of the goniometer, graduated on its margin or edge; *c*, the axle of the circle; *d d* a milled head by which the circle is turned; *e e*, the small axle with its milled head *f* for turning the crystal without moving the circle; *x y*, a brass plate supported by the limb *g*, and serving as a vernier or noxius; *h*, the extremity of a small spring by which the circle is stopped at 180° without the trouble of reading off; *i i*, a joint having two centres of motion, the one horizontal, the other vertical, for adjusting the position of the crystal; *k*, a sliding wire with a milled head, *m* affixed to the universal joint *i i*.

The crystal being attached, by means of a little of shoemakers' cement, to the sliding wire *k* at the point *n*, in the centre of all motion, with one of its surfaces as nearly parallel as may be to the milled head *f*, is next rendered truly parallel to the axis by turning the sliding wire *k*, till the reflected image of a horizontal line is seen to be truly horizontal. By means of the central axis, *e e* the second surface is then brought into the position of the first; and if the reflected image from the surface is found not to be horizontal, it is rendered so by turning the milled head *k*, and since this motion is parallel to the first surface it does not derange the first adjustment.

The accuracy of this instrument is such, that several errors in former observations may be corrected by it; Dr. Wollaston has corrected one in the common Carbonate of lime. The inclination of the surface of a primitive crystal of this kind, is stated at 104° 28′ 30″, but which Dr. Wollaston has determined to be 105 deg.

PART II.

SECTION I.

PHILOSOPHY OF CRYSTALLOGRAPHY—ELEMENTS OF BODIES—CHEMICAL AND MECHANICAL ANALYSIS—CRYSTALLINE POWER, OR SYMMETRICAL ATTRACTION OF THE MECHANICAL ELEMENTS OF BODIES—ATTEMPT OF NEWTON, BERGMAN, GAHN, AND ROME DE LISLE, TO ACCOUNT FOR THE PRODUCTION OF CRYSTALLINE FORMS—THEORY OF HAUY.

ALL bodies in nature, with regard to the manner in which they may be examined and the properties which they exhibit, present themselves to our observation either as simple or compound bodies, each having certain habitudes peculiar to itself. Where the matter which constitutes the substance of our globe, as well as what enters into the composition of organic beings, and the atmosphere, of one kind, it would be nothing more than a lifeless mass, destitute of all other action than that occasioned by impulse and gravity.

Simple bodies are called those of which all others are composed, and which resist further analysis; whereas compound bodies are such, as can be analysed into bodies of a less simple nature.

The ancients believed many bodies to be simple, which the superior skill and knowledge of modern chemists have most assuredly decomposed; and there is no reason to believe that in any one case has chemical analysis been able to procure the real elements or simple constituent parts of substances. A chemical element, therefore, does not so much signify a body that is absolutely undecomposable, as one that has not yet been resolved. In all probability the number of simple bodies will not remain long without alteration. We cannot pretend to say that the bodies now called so, are really simple in themselves, or that they are not formed of other elements still more simple. We can only affirm, that in all the experiments of the science, these bodies are found to act as if they were simple; that they cannot be decomposed by any of our methods; that they resist every species of analysis, and can only be combined with other bodies, or be made to undergo various syntheses. When it was ascertained that many natural substances are compounded of different principles, or other bodies still more simple, methods were successively employed to separate the principles from each other. The name of analysis was given to the art of effecting this separation; an expression which, since its adoption by chemists, has been received in every branch of human knowledge to denote the separations and decompositions, even in the order of our sensations and our ideas.

Now natural philosophy and chemistry

furnish us two modes of attaining the final results of the division or analysis of bodies.

Without entering into useless metaphysical discussions on infinity, we may suppose any substance whatever reduced to the finest and most imperceptible particles which the mind can imagine; these minute solids, or least possible quantities of a body, are called integrant particles, or mechanical elements of bodies.

Yet these elements of physical division, may be still very compound in another point of view, and undergo another species of analysis, effected by chemical agencies. When the latter is also carried to its ultimate point, we obtain the chemical elements of bodies. By the term *mechanical elements*, we therefore understand that physical solid which occupies the smallest portion of space which we can conceive; whereas the term *chemical element* expresses such a body as cannot be decomposed into a body of a less simple nature. For instance, a mass of common salt is made up of a vast multitude of particles possessing the same chemical properties, and these particles are the integrant particles of the salt. They may be further decomposed or analysed by chemical means, into parts possessing very different properties, namely muriatic acid, and soda, two substances of very different habitudes, and these are the chemical elements of the salt. With the latter substances crystallography has nothing to do, it is not possible to ascertain their forms.

The integrant particles of bodies, both with regard to their forms and the manner in which they adhere to each other, are proper objects of admeasurement, and mathematical calculation. The case however is widely different with the chemical elements, or those of which the integrant moleculæ of compound bodies are composed; the mode of their combination is not capable of being explained by geometrical calculation. It is the aggregation of the integrant particles alone which interests the crystallographer. For these particles, how minute soever we suppose them to be, cannot be destitute of magnitude; they must have a certain length, breadth, and thickness, and therefore must possess some particular shape. Besides all this, it is very conceivable that the particles of every particular body, may have a shape peculiar to themselves, and differing from the shape of the particles of every other body. Thus the particles of A may have one shape, those of B another, and those of C a third; and if the particles of bodies have length, breadth, and thickness, we cannot avoid conceiving them as composed of an indeterminate number of still more minute particles or atoms. Now the crystalline attraction of two integrant particles for each other, must be the sum of the crystalline attractions of all the atoms in each of these particles for all the atoms in the other: but the sum of these attractions must depend upon the number of attracting atoms, and upon the distance of these atoms from each other respectively; and this distance must depend upon the figure of the particles.

For it is obvious, that if two particles, one of which is a tetrahedron and the other a cube, and which contain the same number of particles, be placed at the same relative distance from a third particle, the sum of the distances of all the atoms of the first particle from all the atoms of the third particle, will be less than the sum of the distances of all the atoms of the second particle from those of the third. Consequently, in this case, though the apparent distance of the particles be the same, their real distance is different; and of course the cube will attract the third particle more strongly than the tetrahedron; that is, it will have a greater crystallisable power for it, than the tetrahedron.

And if the particles of bodies differ from each other in figure, they may differ also in density and in size: and this must also alter the absolute force of the crystallisable power, even when the distances and the figure of the attracting particles are the same. The first of these two circumstances indeed may be considered as a difference in the mass of the attracting bodies, and therefore may be detected by the weight of the aggregate; but the second, though also no less a variation in the mass, cannot be detected by any such method, though its effect upon the strength of affinity or power may be very considerable.

There is no doubt that, upon the supposition that such differences in the figure, density, and size of the attracting particles, really prevails, and it is in the highest degree probable that they do exist.

It is certain that crystallisation is effected between the integrant particles of bodies only, for these are the solids that are suspended in the fluid from which crystallisation is about to happen.

These particles which are held together, whether they be of the same nature or of a different nature, continually tend to form bodies of a polyhedral, constant, and determinate form.

This beautiful law of nature, by which she impresses on her productions a constant and regular form, appears to have been unknown to the ancients, and when chemists began to discover that almost all bodies of the mineral kingdom effected regular forms, they ascribed the fact to a peculiar kind of polarity inherent in the bodies.

This explanation however is too hypothetical to be received as a satisfactory account of the process of crystallisation. It assigns moreover a course, the existence of which we cannot prove.

The schoolmen, in order to account for the multifarious forms of crystal, had recourse to the microscope, with a view of extorting from nature the secrets of elementary forms, calling in the assistance of this instrument to trace the origin of crystals. In this case however, the microscope reveals nothing beyond what may be discovered by the unassisted eye. The smallest particles of a crystal which we can perceive by the aid of optical instruments are crystals, or parts of crystals, already formed according to certain geometrical laws, and these merely differ in their dimensions and structure from those whose augmentation has arrived at its limit. They also denominated crystals after the resemblance more or less rude, which they thought they perceived between them and known bodies; hence the name of crystals in the form of tombs, stars, diamonds, crosses, wedges, knife blades, &c.

The first attempt to account for the production of crystals in any manner that deserves the name of philosophical, was by Newton: according to him and the theory of Boscowich, the aggregation of the particles of which crystals are composed is produced by the attraction which Newton had proved to exist between the particles of bodies, and which acts as soon as they are brought within a certain distance of each other. The regularity of the figures he explained by proving, that the particles of bodies, whilst in a state of solution in a fluid, must be arranged in the liquid at equal distances, or in regular ranks and files. The consequence of which, as they are acted upon by a power which at equal distances is equal, at unequal distances unequal, will be crystals of determinate figure. In the crystallisation of salt or other bodies, the water which held the salt in solution removed the particles of the salt to a certain distance from each other, to break down the attraction of aggregation existing between them; each particle became surrounded by a number of particles of water, and when the quantity of the solvent became diminished by evaporation, the particles of the salt came nearer to each other, their attraction towards the water became diminished, whilst the attraction of the particles of the salt towards each other became consequently increased; they therefore separated from the fluid, and arranged themselves orderly in groups according to certain laws, which have their measure and their value. And as the particles, which compose the same body, have the same form, the aggregation of any number of those particles must produce, if their arrangement by undisturbed, masses of determinate figures or groups of crystals.

Such is the theory of Newton; it is worthy of the luminous and acute mind of its author. Still, however, there remain various phenomena respecting the production of the infinite variety of forms which require to be explained.

Gahn, a German philosopher, having broken a crystal of calcareous spar, found that it afforded rhomboidal fragments, and that the whole crystal appeared to be composed of small rhomboids. Bergman soon afterwards seized upon this idea of his pupil, and as he combined a knowledge of geometry with chemical science, endeavoured to trace all the observed forms of crystals to a few simple or primary ones. In the instance of calcareous spar, he demonstrated that its numerous modifications may possibly result from one single figure, the rhomboid, by the accumulation of which, in various ways, crystals of the most opposite forms may be produced. This theory he extended to crystals of every kind, and he explained the difference of exterior figure from the super-position of planes, which he calls the constituent parts of crystals, variously piled around a crystalline nucleus of a constant form, but in each case according to certain laws of decrease, and that the primitive form may be discovered from the arrangement of the laminæ, of which the crystal is composed.

About the same period with Bergman, or immediately afterwards, Rome de Lisle pursued still farther the theory of the structure of crystal. He was the first who pointed out that this department of knowledge was, perhaps, one of the most interesting objects of mineralogical science. He endeavoured to reduce the diversity of crystalline forms to a general or primitive type. He classed together, as much as he was able, crystals of the same nature; he described the various modifications under which that form appeared to be masked; and, lastly, he explained the production of the principal crystalline figures derived from a primitive form. To the descriptions and figures of the primitive forms he added the mechanical admeasurement of the principal angles, and demonstrated that these angles are constantly the same in each variety. It must be acknowledged however, that the primitive forms of Rome de Lisle were assumed entirely gratuitously, and not the result of any experimental analysis. His method was to frame an hypothesis, and then to examine its coincidence with actual appearance; on this principle any form might have been the primitive one, and any other have been deduced from it. If persuasion was the sole object of philosophy, Rome de Lisle would have been a powerful philosopher, but philosophy must convince, demonstrate, and wrest consent, however violently opposed. An enemy must not be able to make use of the same arms, or deduce the same proofs to establish a contrary opinion, nevertheless such would be the case with Rome de Lisle's principle, for any form, according to his system, may become the primitive, and any other may be deduced from it; his primitive forms were imaginary, and not the result of analysis; and they were selected merely from their supposed simplicity.

Basis of the Theory of Haüy.

Of a different nature from what has been so far stated is the theory of crystallography advanced by the Abbé Haüy. This philosopher, by a happy discovery, has actually demonstrated, where Rome de Lisle merely imagined. He has developed the primitive form of crystals by mechanical analysis, and has established a real, instead of an arbitrary, though descriptive, system of crystallography. He has also shewn, that all crystals, however complicated their form may be, contains within them a primitive geometrical nucleus, which has an invariable form in each chemical species of crystallisable material.

Accordingly, by dissecting an hexahedral prism of calcareous spar by sections parallel to each other, as will be shewn presently, we may remove successively all the laminæ in which it is enveloped, till we come to a geometrical solid, which represents a perfect rhomboid.

By separating the eight solid angles of a cube of Fluor spar, we obtain an octahedron: sulphate of Barytes produces an upright prism with rhomboidal bases; feldspar an oblique-angled parallel-opipedon; the beryll, an upright hexahedral prism; blend or sulphuret of zinc a dodecahedron with rhomboidal faces; Elba iron ore, a cube, &c. The solids thus obtained are called the primitive forms of crystals. They are enumerated page 118.

If, after coming to the last subdivision, we were to attempt to proceed in the same manner in other directions, we should break the crystal instead of dividing it.

But the solid which forms the nucleus may also be subdivided in a direction parallel to its faces, and sometimes in other directions. The same is the case with respect to the enveloping matter, which may be cleft by sections parallel to the faces of the original crystal; so that the detached parts are similar to each other, differing only in bulk, which keeps diminishing in the ratio as the division is continued. In most instances the dissection of the primitive form and the enveloping layers, may be continued in the parallels of the same planes only to any extent, and in no other direction, and this dissection of course cannot alter the form. But some of the primitive forms and their enveloping layers are farther divisible in planes that are not parallel to the faces of the crystal, and when this is the case a solid is obtained which differs from the primitive crystal to which it belongs, and these solids thus produced by different methods of dissections, are called by Haüy integrant molecules of crystals. See page 161.

The quantity of matter superposed to the primitive form is not placed indiscriminately; the arrangement is always perfectly geometrical, the layers of particles decrease regularly by the substraction of one or more rows of particles either from its edges, or its angles, or in other directions of the faces of the nucleus, and always in a geometrical order. See Laws of decrements, page 165.

The production of all possible forms of crystals therefore arises from certain laws of arrangements of the layers of particles surrounding what Haüy calls a primitive form or nucleus, which is always one of the solids before stated; and this nucleus originates from the assemblage of a certain number of integrant moleculæ possessing a constant form.

And as the order, according to which the enveloping matter becomes aggregated, may be interrupted, whether the form may be complete or not, new figures will be produced, always regular and symmetrical, and which must be varied as the arrangement of the particles are itself multiplied.

The layers of moleculæ, the substraction of which determine the decrements, is a kind of unity to which we may refer the structure of all crystals; so that we are at liberty to adhere to the data which it furnishes, in the application of calculation to every possible crystalline form. To know afterwards if this unity be divisible, or if it has fractional parts, is a matter of observation or annalitical calculation.

Such is the basis of the system of Haüy. It is similar in this to other theories, that it sets out from a principal fact, on which it makes all facts of the same kind depend, and which are only as it were corollaries. This fact is the decrement of the laminæ super-added to the primitive form; and it is by bringing back this decrement to simple and regular laws, susceptible of accurate calculation, that the theory arrives at results, the truth of which is proved by the mechanical division of crystals, and by the observations of their angles.

To the Abbé Haüy is also due the scheme of simplifying the calculation of forms, by expressing according to algebraic formulæ, the different laws of decrements which determine the modification of crystalline forms. So far, as they are the result of calculation and measurement, we may admit the laws of calculation; for whenever the super-position or substraction of simple or compound moleculæ, around a nucleus, shall by calculation give a series of planes and angles, which corresponds exactly to the angles and planes measured on natural crystals, it will amount to no more nor less than a demonstration of the rule or arrangement of the mechanical elements which have combined in the formation of the crystal.

SECTION II.

MECHANICAL DISSECTION OF CRYSTALS—DEVELOPMENT OF THE PRIMITIVE FORMS OF CRYSTALS—SYMMETRICAL ARRANGEMENT OF THE ELEMENTARY PARTS OF CRYSTALLINE BODIES—STRUCTURE OF CRYSTALS—NATURE AND NUMBER OF PRIMITIVE FORMS.

THE term mechanical division of crystals is given by the Abbé Haüy, to the operation of which we are enabled to perform, as it were, the anatomy of crystals to develop their geometrical structure. Lapidaries and jewellers, who cut and polish stones, have at all times noticed that these substances may be split more easily in some directions by fissures than in others, and that crystals can be cleft in certain directions only to afford smooth and brilliant surfaces and regular formed portions. We say *cleft* or *split*, and not sawed or cut, as the sections of crystals are not to be obtained by slow and continued efforts, but by sudden shocks or blows, resembling the art of cleaving stones. It is this which conducted Haüy to the theory he has established; namely, that if we dexterously divide in the direction of the natural joints or laminæ, the most complex crystal, we at last obtain a geometrical solid or nucleus, which observation has shown is constant in all the crystals of the same species, or chemical composition, and even in those whose external forms are most strongly contrasted.

The diversity of primitive forms ought therefore to be regarded as a certain indication of a difference in nature between two substances, and the identity of primitive form indicates, identity of composition, unless the nucleus is one of those solids which have a marked character of regularity; such as the cube, the regular octahedron, &c.

The primitive solids hitherto discovered, are the following geometrical solids.

Primitive forms of crystals.

1. THE PARALLELOPIPED, Fig. 4, Pl. II.*

2. THE REGULAR OCTAHEDRON, Fig. 5, Pl. II.†

3. THE REGULAR TETAHEDRON, Fig. 6, Pl. II.‡

4. THE REGULAR HEXAHEDRAL PRISM, Fig. 7, Pl. II.§

5. THE RHOMBOIDAL DODECAHEDRON, Fig. 3, Pl. II.||

6. THE PYRAMIDAL DODECAHEDRON, composed of two hexahedral pyramids, put base to base, Fig. 9, Pl. II.¶

A few examples will render the mechanical division of crystals obvious.

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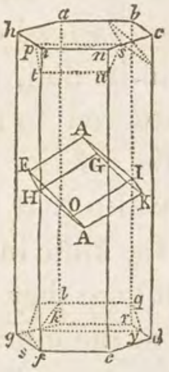
* Model, No. 15.
† Model, No. 16.
‡ Model, No. 17.
§ Model, No. 18.
|| Model, No. 19.
¶ Model, No. 20.

Let Fig. 44,* represent a regular six sided prism, which the mineral kingdom presents in one of the varieties of carbonates of lime or calcareous spars.

44.



If we attempt to split this solid with the blade of a knife, assisted by the blow of a hammer, we become convinced that among the six edges in, *n c*, *c b*, *a h*, of the superior base, three only will yield to the mechanical division. Let *i n*, represent one of these edges. The division is made according to a plane *p s u t* inclined at an angle of 45°, both to the base *a b c n c h*, and to the plane *i n e f*. Then the two edges *b c*, and *a h*, will admit

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* Model, No. 21.

of being cleft precisely similar to the preceding; but the other three, which are intermediary, if struck with the knife, resist splitting, and if broken by a greater blow the fracture and the surfaces of the detached portion, instead of being smooth and polished, will be dull, rugged, and uneven. If we proceed to the dissection of the contours of the inferior base of the crystal, we find here also that three edges only can be cleft by the knife in the same degree of obliquity; but here they are precisely the reverse of those of the upper base; namely the intermediate ones. The dotted plane *l q y z* represents the sections. The dissected model, No. 21, shews the sections itself. By extending the division farther by cuts, as exhibited in this model, we find that six new planes are developed. These in the natural crystal possess a vitreous lustre, which indicates that they coincide with the geometrical joinings or layers of particles, the assemblage of which constitute the prism.

If we continue to make sections on the model still farther, to detach successively layer after layer, parallel to the former cuts, and consequently to each other, we approach nearer and nearer to the axis of the crystal; and when the faces of the original form have been obliterated; a regular symmetrical solid, presents itself, which is the nucleus of the crystal, and which in this case is an obtuse rhomboid. A E I O K represents this rhomboid[*] in its due position, in Fig. 44, with regard to the circumscribed prism.

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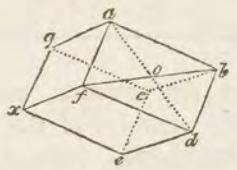
[*] Haüy gives the name of rhomboid to a parallelopipedon *a e*, Fig. 45, terminated by six rhombuses equal and similar.

45.



In every rhomboid two of the solid angles such as *a e* opposite to each other, are formed by the junction of three equal plane angles. Each of the other six solid angles is formed by a plane angle equal to each of the preceding, and by two other angles of a different measure, but equal to each other. The points

The dissected model No. 21, will render what has been stated obvious. By detaching at the upper or lower extremity, the three first sections which there present itself, the six cunei-form slices will offer to view six trapeziums; by again removing three more slices from both extremities, the prism becomes converted into a solid, terminated by twelve pentagons parallel two and two. The six faces of which are the remains of the six sides of the original prism, and the other six are the intermediate one produced by dissection.

Fig. 46* exhibits the pentagonal dodecahedron, as produced from the six sided prism, which there is represented as inscrib-

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a e are therefore the summits, and the line *a e* the axis. In any one whatever of the rhombuses *a b d f*, which compose the surface, the angle *a*, contiguous to the summit, is called the *superior angle*; the angle *d*, the *inferior angle*; and the angles *b* and *f*, are the *lateral angles*. The sides *a b*, *a f*, are the *superior edges*; and the sides *b d*, *d f*, the *inferior edges*; *b f* is the *horizontal diagonal*, and *a d* the *oblique diagonal*.

* See Model, No. 21.

ed in the original solid, that the process by which it is obtained may be better conceived.

46.

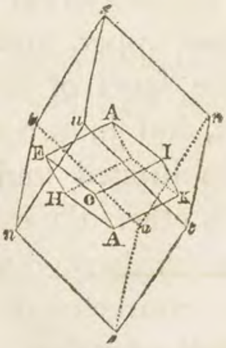
By making six more sections upon the model, always parallel to each other, namely, three at the upper, and three at the lower base, the faces of the prism diminish in height, and in proportion as the sections are multiplied and kept always parallel to each other, the external sides of the original solid have disappeared, the prism will be converted into the acute rhomboid, which represents the nucleus of the original solid.

Now, in a like manner, all the crystalline forms of calcareous spar, even those that differ most from the six sided prism, if dissected in the direction of their laminæ, will produce a rhomboid, which is precisely similar to that obtained from the beforementioned solid; and it is singular to see a nucleus issue from varieties of forms which do not present any common point of resemblance that seem to indicate their relation.

For instance. Let us place by the side of each other, calcareous spar, in the form of a regular six sided prism. Fig. 44.*

Calcareous spar, in the form of a rhomboid. Fig. 47.†

47.



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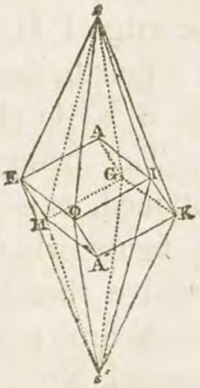
* Model, No. 21. † Model, No. 22.

And calcareous spar in the form of a pyramidal dodecahedron with isosceles triangular faces, Fig. 48.*

48.



We can scarcely perceive how three varieties of calcareous spar or carbonate of lime, so dissimilar at first sight, and so foreign to each other, with regard to their exterior forms, should contain concealed within them one and the same shaped nucleus. This however is the case, and the fact may be proved, by penetrating

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* Model, No. 23.

into the exterior structure of these solids, namely :

To dissect the pyramidal dodecahedron, Fig. 48,* it is only necessary to make one cut through the edge E O, OI ; a second through E I I ; a fourth, through O I, I K ; a fifth through B K, G H ; and a sixth through E O. This being done, the nucleus will be obtained, as is obvious at first sight from the figure which exhibits the nucleus or primitive rhomboid within the pyramidal dodecahedron in its proper position. See also model, No. 23.

To dissect the crystal of calcareous spar, Fig. 47,† which itself is a rhomboid somewhat acute, all that is necessary to be done is, to direct the cuts parallel to the six extreme edges in such a manner, that each of them may be equally inclined to the planes it cuts into ; namely, we have to make sections upon the edges S T, S U, S N, on one hand, and S T, S U, S N, on

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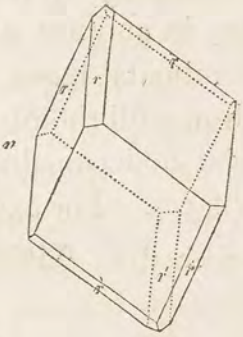
* Model, No. 23. † Model, No. 22.

the other; in such a way, that the cutting planes are equally inclined upon the faces which they cut. The first section will lay open six pentagonal faces *r*, *r*, *r*, *r*, *r*, *r*, Fig. 49.*

49.



parallel to the faces of the nucleus, and it is easy conceived that by continuing the cuts always in the same directions, and parallel to each other, until the internal faces of the rhomboid have been obliterated, we shall have a new rhomboid, which will be the nucleus or primitive form.*

There are a vast number of varieties of calcareous spar which bear no resemblance

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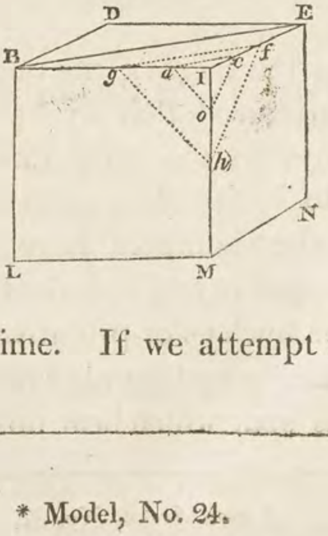
* See Model, No. 22.

to each other, but all of them contain, concealed within them, a nucleus precisely similar to that under consideration.

If we attempt the anatomy of a crystal belonging to another species of mineral, the nucleus will be changed. In such substance it will be a cube, in another a rectangular prism, with rhomboidal bases, here it will be a dodecahedron with rhomboidal planes, there a pyramidal dodecahedron with isosceles triangular faces. For example, let B D E N M L, Fig. 50,* represent a cube of fluate of lime. If we attempt to divide

50.



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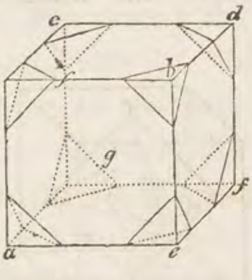
* Model, No. 24.

this cube by sections parallel to its faces, it will resist of being cleft by cuts in that direction, and if a greater force be employed than is necessary to split the crystal, nothing but irregular fragments will be obtained. But if the cuts be directed in the line *g f*, Fig. 50, parallel to the diagonal line B E upon one of its faces and at an angle of about fifty-four and a half, we shall accomplish the object, the solid angle *I g h f* will become detached, and the part obtained will be a triangular pyramid, and the new face presented, will be an equilateral triangle *g f h*, Fig. 51, shows the clevage of this crystal, *d c*, *b f* the angles to be cleft.

51.



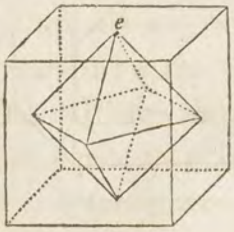
If we continue the divisions further and further upon the eight solid angles, *d c b f*,

&c. Fig. 51, the cuts will be first replaced by eight equilateral triangles, and when the sections intersect each other, the equilateral triangular faces will disappear, and become changed into hexagons, Fig. 52.

52.

And when nothing more remains, of the faces of the original cube, an octahedron with equilateral faces will make its appearance, which in this case is the nucleus contained in this species of mineral. *e*, inscribed into Fig. 53, exhibits this nucleus in its due position.

53.



The dissected model No. 24, will palpably illustrate the mechanical diversion of this crystal, and the position of its nucleus.

It is not always necessary to dissect a crystal in order to reduce it to its primitive form or nucleus. Because in certain instances, crystallisation at once produces the nucleus, whereas again certain mineral productions are very rarely met with in the primitive form. There exist, for example, crystals of calcareous spar which differ in no respect from the rhomboid which we extract out of the regular hexahedral prism, Fig. 44, page 119, and from the other varieties we have mentioned, and there are natural crystals of octahedral fluate of lime, but these instances are rare. It frequently happens also, that among the faces of a secondary crystal there are some which are parallel to those of the primitive nucleus. Thus we meet with varieties of carbonate of lime which are exactly similar to that of Fig. 54, (see p. 132,) in which crystallisation has left hextagonal faces, situated like those which we obtain by dividing the six sided prism, represented Fig. 44. In such cases the route is, as it were, traced out before hand, previous to arriving at the nucleus.

54.

Before we leave this subject we shall advance one example more, in illustration of what has been so far stated, with regard to the mechanical division of crystals, and the development of the primitive forms. For example;

If we endeavour to split some hexahedral prisms of corundum in a direction, either perpendicular or parallel to their axes, we meet with a very considerable resistance: the crystals may, indeed, be broken in these directions; but the rugged and irregular surface of the broken parts, clearly proves that the direction in which the crystalline laminæ have been deposited one upon another has not been followed. The regular hexahedral prism of this mineral cannot therefore be considered as the form of the nucleus of the crystal; and, consequently, is not the primitive form of the crystals of this substance. If, in order to discover the direction of the crystalline laminæ, a variety of crystals be examined, some will hardly fail to be met with, which, on their solid angles, formed by the junction of the sides of the prism, with the planes of the extremities, present small isosceles triangles. These are sometimes greater, and sometimes smaller, and form solid angles, of 122° 34′, with the extreme planes of the crystal. They are in some instances, real faces of the crystal, but most frequently they evidently are the effect of some violence on that part. The smoothness and brilliancy of these small faces, in the latter case, shew that a piece has been detached in the natural direction of crystalline laminæ. It is, indeed, much less difficult to separate a portion of the crystal at those angles, than at any other part; and in following the natural direction of the faces, with a little patience and dexterity, all the crystalline laminæ may be detached, and progressively increase the size of the triangular face. This operation, however, cannot be done indiscriminately on all the solid angles of the crystals, but only on the alternate ones at the same extremity, and in a contrary direction to each other. As to the other angles, they may be broken, but it is impossible to detach them. When, instead of the solid angles of an hexahedral prism, small triangular planes are met with (which frequently happens, whether caused by violence or otherwise), they are always placed in the direction above mentioned. If by following this indication of nature, we continue to detach the crystalline laminæ, we shall at last cause the form of the hexahedral prism to disappear totally, and in place of it, a rhomboidal parallelopiped will be obtained, of which the plane angles at the rhombs, in this case will be 86° and 94°; the solid angles at the summit will measure 84° 31′; and that taken at the reunion of the basis will be 95° 29′.

We can split this parallelopiped only in a direction parallel to its faces; it will still consequently preserve the same form, which is that of the nucleus of this substance, and its primitive form. It is, therefore, by a modification of the rhomboidal parallelopiped that nature has formed the regular hexahedral prism, which this substance presents.

Thus the application of general laws, to ascertain constant characters, after they shall have been fully verified, may be very simple and general; and hence the following facts have been deduced; namely, that the small solids or primitive forms of crystals, in all those which belong to the same species, that is to say, which agree in their chemical constitution, have one invariable geometrical form. They accurately correspond with each other in their shape, and the dimensions of their angles. But it is by no means true, as has been hastily asserted, that *every species* has a peculiar primitive form. Thus muriate of soda, sulphuret of lead, sulphuret of iron, boracite, &c. have the same primitive form; namely, a cube, and are besides composed of the same integrant moleculæ, which is also a cube. In a like manner fluate of lime, alum, diamond, bismuth, ruby copper, spinell, antimony, &c. afford, by calculation and mechanical division, a regular octahedron for their primitive figure, composed of regular tetrahedral integrant particles. With the exception however of these nuclei, which are regular geometrical solids, [see page 117], and therefore unsusceptible of any variation in their dimensions, it may be affirmed that no two nuclei of different species or dissimilar substances, have *precisely the same dimensions*; thus the primitive form both of calcareous spar and tourmaline is an obtuse rhomboid, but in the former the obtuse angles are = 105° 5′, while in the latter they are = 113° 34′.

Those regular geometrical forms, although they belong to different species, may be considered as the limits at which nature arrives by different ways, while each of the figures placed between these limits, seems to be confined to one particular chemical compound only.

In the magnesian carbonate of lime, or bitter-spar, which is a different chemical compound, the primitive form is well known to be a regular rhomboid, as well as that of carbonate of lime, and so nearly resembling it, as to have been hitherto supposed the same; differs from this quantity by 1° 10′ in the measures of these crystals; for that of the magnesian carbonate is full 106¼°.

The primitive angle of iron-spar Dr. Wollaston has found still more remote from that of the common carbonate of lime, which it exceeds by nearly two degrees. This philosopher has examined various specimens, some pure white, others brown, some transparent, others opake.

Dr. Wollaston believes that it is not unlikely, that when substances which agree so nearly in their primitive angle, are intermixed in certain proportions, they may each exert their crystalline power; and may occasion that confused appearance of crystallisation with curved surfaces, known by the name pearl-spar present. And although he has not made any accurate comparative analyses which may be adduced in support of the hypothesis, that mixtures are more subject to curvatures than pure chemical compounds; but it is very evident from the numerous analyses that have been made of iron-spar by other chemists, how extremely variable they are in their composition, and consequently how probable it is, that the greater part of them are to be regarded as mixtures; nevertheless it is also possible, that there may exist a triple carbonate of lime and iron as a strict chemical compound.

SECTION III.

MECHANICAL ANALYSIS OF THE PRIMITIVE FORMS OF CRYSTALS—DEVELLOPMENT OF THE INTEGRANT PARTICLES OF CRYSTALLINE BODIES; REMARKABLE ARRANGEMENT OF SOME OF THEM, IN THE INTERIOR OF THE PRIMITIVE FORMS——NATURE AND NUMBER OF THE INTEGRANT PARTICLES OF CRYSTAL.

FROM what has been stated in the preceding sections it becomes obvious, that the name of *primitive form* has been given to those solids of a constant figure, which are contained symmetrically each, in all the crystals of one, and the same species or chemical composition, unless it is one of those forms which possess a particular character of perfection and regularity, (see page 117 and 135,) and which may be extracted out of them by a skilful mechanical division. All crystals, it is true, are not susceptible of mechanical dissections, but those which refuse to be cleft, the theory seconds by various indications the cleavage, and consequently determines the primitive form, from theoretical calculations of certain exterior vestiges which the crystal presents. For instance those striæ that are observable on the faces of many secondary crystals, when the operations of nature have not attained the perfection of which they are capable, frequently indicate, by their directions, the progress of crystallisation, or the direction of the component laminæ; they therefore assist us in catching by analogy, the form and position of the nucleus, which otherwise might escape observation. Nevertheless, these indications require to be used with caution, for it sometimes happens that the surface of the nucleus itself is striated. This singularity seems to be the effect of an imperfect decrement, which experiences such great interruptions, that the faces resulting from it, sensibly coincide with the primitive faces. In like manner, it is not impossible, that the faces of a secondary crystal may have striæ, in a direction different from that which ought to result from the progress of the decrement. But there are cases in which the striæ are so palpable, as to show plainly the mechanism of the structure.

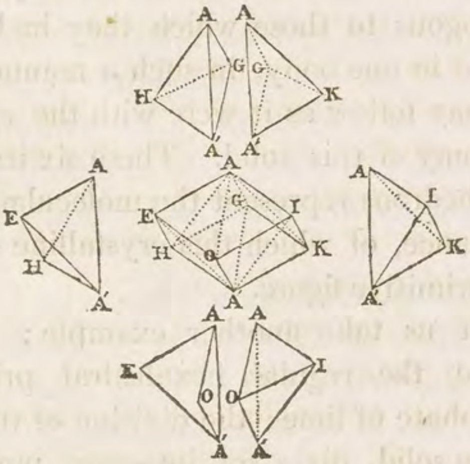
The relations which serve to connect the different original crystals of one and the same substance with a common or primitive form, are founded on the laws of structure (which will be explained presently,) whose tendency is to determine the number and arrangement of the planes or layers of particles which compose the surface of each crystal. From a necessary consequence and acquaintance with the progress of these laws, it becomes merely requisite to have our eyes on the primitive form, and the value of the decrements which its angles or edges undergo, in order to represent the polyhedron resulting from it, and to see in what manner in idea we may effect the metamorphosis of the nucleus from which this polyhedron is derived.

But the nucleus or primitive form of a crystal, is by no means the ultimate result to which the mechanical anatomy of these bodies may be carried. It is a character common to all primitive forms, to be divisible by successive sections, parallel to their different faces, and sometimes also in other directions. The products obtained, will be solids of different forms, from those of the primitive, from which they originated. These solids have received the appellation of *integrant* moleculæ, or *integrant particles of crystals.*

When the nucleus is a parallelopiped, that is to say, a solid bounded by six faces two and two alike, as for instance, the cube, and the rhomboid, which can be divided by blows in a direction parallel to the six faces, it is evident that the figure of the integrant particle is itself a parallelopiped, similar to the nucleus, and differing from it only in bulk, which continually decreases in the ratio as the subdivision is carried further.

It may however happen that the primitive parallelopiped, is farther divisible by planes, *not parallel* to its external faces, but diagonally, or in other directions; for instance, let us conceive that A A K H, &c. Fig. 55,* the central figure in this page,

55.



represents the rhomboid of turmalin, and that it admits of divisions, as it actually does, parallel to the six rhombuses which terminates the crystal, and with the help of planes, each of which passes by an

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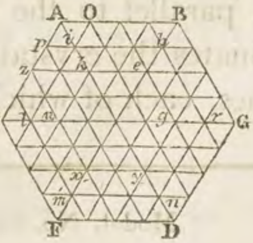
[*] Model, No. 25.

oblique diagonal A O, by the axis A A′, and the edge A O, comprehended between the same diagonal and the axis. These sections will detach six irregular tetrahedrons, which have been figured separately around the primitive central rhomboid, in positions analogous to those which they had when joined in one body, in such a manner, that we may follow as it were with the eye, the anatomy of this solid. These six irregular tetrahedrons represent the moleculæ of the substance, of which this crystalline solid is the primitive figure.

Let us take another example; for instance, the regular hexahedral prism of phosphate of lime; the division of this primitive solid, gives for integrant moleculæ equilateral triangular prisms, as may be perceived by inspecting Fig. 56.

56.



We there see one of the faces of the prism divided parallel to its six sides, and consequently into equilateral triangles, each of which is the base of a small triangular prism, which represents the integrant moleculæ *.

In some cases the mechanical division yields particles of different figures combined together throughout the whole extent of the primitive solid; the crystal in this case affords products of a mixt structure, but this division does not invalidate the theory.

The analysis of the octahedron will illustrate this fact. In this solid the sections by planes, parallel to its faces, give in succession to the ultimate point to which the division is carried, moleculæ, of two different forms, namely, tetrahedrons and octahedrons; but every probable reason occurs to reject the octahedron, and to adopt the most simple solid, namely, the tetrahedron, as

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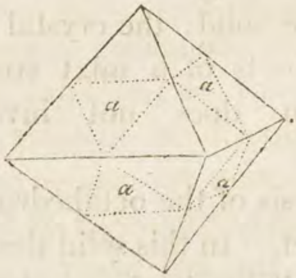
* Model, No. 26.

the true integrant particle. So that, in whatever manner the octahedron is directed, it always gives solids of two kinds without ever arriving to unity. The division of the primitive form of fluate of lime, which may easily be cleft by twenty-four sections, as shewn by the dotted lines Fig. 57*, and likewise through the centre

57.



will illustrate this analysis. The result will be six octahedrons and eight tetrahedra. The equilateral triangles *a a a a* represent each, one of the exterior faces of the tetrahedra, the three others are lost in the solid, where they unite in a common point, and

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* Model, No. 27.

are confounded with the centre of the crystal.

The division of the regular tetrahedron, as primitive form, likewise leads to a mixt structure of a similar kind, namely, tetrahedrons, leaving octahedral vacuities*.

The analysis of the *rhomboidal dodecahedron* gives as results, tetrahedrons, the faces of which are, without doubt, equal and similar isosceles triangles. These by being taken in groups of six, form rhomboids of a bulk proportional to their own†, so that this solid may be conceived as being itself immediately composed of four rhomboids, and in the last analysis of twenty-four tetrahedrons, without leaving any vacuities between them. For as the dodecahedron has eight solid angles, each formed by three planes, the assemblage of which forms four rhomboids, which have for exterior summits the four angles.

With respect to the division of the pyra-

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* Model, No. 28. † Model, No. 29.

midal dodecahedron, composed of two six-sided pyramids, with isosceles triangular faces, put base to base, we cannot extract the moleculæ, which compose this solid, without dividing it in directions different from those which would be parallel to the faces. The tranchant plane in this case ought to pass by the axis and by the ridges, contiguous to the summits, whence irregular tetrahedrons result as integrant particles*.

Such is the structure of the primitive solids of crystals. There is a remarkable relation which serves to connect the crystalline stru/cture of substances, whose molecule is the tetrahedron or triangular prism, with that of substances, which have, as primitive forms, simple assemblages of elementary parallelopipedons. This connection consists in the tetrahedral or prismatic moleculæ, being always assorted in such a manner, in the interior of the primitive

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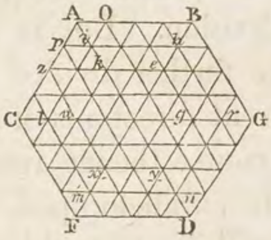
* Model, No. 30.

form and of secondary crystals, that on taking them by small groups of twos, fours, sixes, or eights, they compose parallelopipedons, so that in reality the ranges subtracted by the effect of decrements are nothing else, as well as the whole crystal, than sums of these parallelopipedons.

That we may comprehend how this takes place, let A B D, D, &c. Fig. 58,*

58.



be one of the basis of a regular six-sided prism, subdivided into small triangles, which are the basis of so many integrant moleculæ. It is evident, that any two given triangles adjoining the other, such

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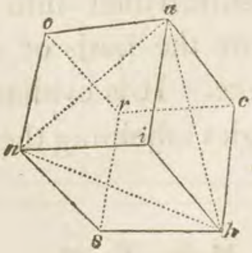
* Model, No. 26.

as A *p* *i*, A O, *i*, &c. compose a rhombus, and consequently the two prisms to which they belong form by their union a prism with rhomboidal basis, which is one of the kinds of parallelopipeds.

There is no crystal from which a nucleus, in the form of a parallelopiped, may not be obtained, if we confine ourselves to six sections, parallel two and two. In a great number of substances this parallelopiped is the ultimate product afforded by the mechanical division. But in some minerals it can be further divided by sections made in different directions of its faces, the moleculæ of course thence resulting differ from that of the parallelopiped. The following example will illustrate this statement.

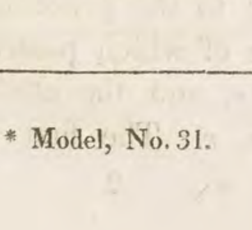
Let *a c h s n o*, Fig 59, be a cube, having

59.



two of its solid angles, *a*, *s*, situated on the same verticle line. This line will be the axis of the cube, and the points *a* and *s* will be its summits. Let it be supposed that this cube is devisible by sections, each of which, such as *a h n*, passes through one of the summits *a*, and by two oblique diagonals *a h*, *a n*, contiguous to this summit. This section will detach the soli angle *i*; and as there are six solid angles, situated laterally, viz. *i*, *h*, *c*, *r*, *o*, *n*, the six sections will produce an acute rhomboid, the summits of which will be confounded with those of the cube. Fig. 60,*

60.



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* Model, No. 31.

represents this rhomboid existing in the cube, in such a manner, that its six lateral solid angles, *b*, *d*, *f*, *p*, *g*, *e*, correspond to the middle of the faces *a c h i*, *c r s h*, *h i n s*, &c. of the cube.

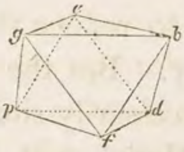
Besides, it may be proved by theory, that the cube results from a decrement which takes place by a single range of small rhomboids, similar to the acute rhomboid, on the six oblique ridges *ab*, *ag*, *ae*, *sd*, *sf*, *sp*. This decrement produces two faces, one on each side of each of these ridges, which makes in all twelve faces. But as the two faces, which have the same ridge for their line of departure, are on the same plane by the nature of the decrement, the twelve faces will be reduced to six, which are squares; so that the secondary solid is a cube.

Suppose that the cube, Fig. 59, admits, in regard to its summits *a*, *s*, two new divisions similar to the preceding six, that is to say, one of which passes through the points *c*, *i*, *o*, and the other through the points *h*, *n*, *r*. The first will pass also through the points *b*, *g*, *e*, and the second through the points *d*, *f*, *p*, Fig. 60, and 61, of the rhomboid, from which it follows, that these two divisions will detach each a regular tetrahedron *b a g e* or *d s f p*, Fig. 61,[*]

61.

so that the rhomboid will be found converted into a regular octahedron *e f*, Fig. 62,[†]

62.



which will be the real nucleus of the cube;

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[*] Model, No. 31.

[†] See the same Model, No. 31, which will render obvious what relates to this subject.

since it is produced by divisions similarly made, in regard to the eight solid angles of the cube.

If we suppose the same cube to be divisible, throughout its whole extent, by sections analogous to the preceding, it is clear that each of the small rhomboids of which it is the assemblage, will be found, in like manner, subdivided into an octahedron, with two regular tetrahedra applied on the two opposite faces of the octahedron.* Indeed, in whatever manner we proceed to subdivide either the cube, the rhomboid, or the octahedron, we shall always have solids of two forms, that is to say, octahedra and tetrahedra, without ever being able to reduce the result of the division to unity. But the moleculæ of a crystal being necessarily similar, it appears probable, says Haüy, that the structure is, as it were, interspersed with a multitude of small vacuities, occupied either by the water of crystallisation, or by some other

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* See Model, No. 31.

substance, so that, if it were possible to carry the division to its limits, one of the two kinds of solids in question would disappear, and the whole crystal would be found composed only of moleculæ of the other form.

This view is the more admissible, as each octahedron being enveloped by eight tetrahedra, and each tetrahedron being equally enveloped by four octahedra,* which ever of the forms we imagine to be suppressed, the solids that remain will join exactly by their edges; so that, in this respect, there will be continuity and uniformity throughout the whole extent of the mass.

The manner in which each octahedron is enveloped by eight tetrahedra may be readily conceived, if we take care that in dividing the cube (Fig. 59) only by the six sections, which give the rhomboid, we may depart at pleasure from any two, *a s*, *o h*, *c n*, *i r*, of the eight solid angles, provided that these two angles be opposite to each

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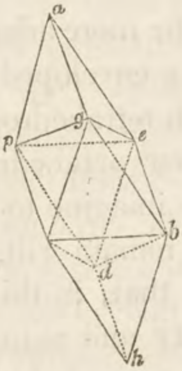
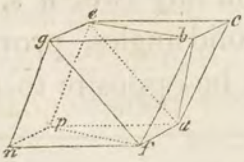
* Model, No. 27.

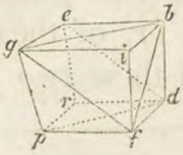
other. But if we depart from the angles *a s*, the rhomboid will have the position shewn, Fig. 61. But by departing from the solid angles *o*, *h*, these angles will become the summit of a new rhomboid, Fig. 63, composed of the same octahedron as that of Fig. 62, with two new tetrahedra applied on the faces *b d f*, *e g p*, Fig. 63, which were unoccupied on the rhomboid of Fig. 61. Fig. 64, and Fig. 65,



63.



64.



65.

represent one, the case in which the two tetrahedra repose on the faces *d b e*, *f g p*, of the octahedron; the other, that in which they would rest on the faces *b f g*, *d e p*. It is thence seen, that whatever may be the two solid angles of the cube assumed for the points of departure, we shall always have the same octahedron, with two tetrahedra, contiguous by their summits to the two solid angles in question; and as there are eight of these solid angles, the central octahedron will be circumscribed by eight tetrahedra, which will rest on its faces. The same effect will take place, if we continue the division always parallel to the first sections. Each face of the octahedron, then, however small we may suppose that octahedron to be, adheres to a face of the tetrahedron, and reciprocally. Each tetrahedron then is enveloped by four octahedra. This structure is that of fluor spar.

By dividing a cube of this substance we may, at pleasure, extract rhomboids, having the angles formed by their planes equal to

120° or regular octahedra, or tetrahedra, equally regular. There are a small number of other substances, such as rock crystal, carbonate of lead, &c. which being mechanically divided beyond the term at which we should have a rhomboid or parallelopipedon, give also parts of various different forms assorted together in a manner even more complex than in fluate of lime. These mixt structures necessarily occasion uncertainty respecting the real figure of the integral moleculæ which belong to the substances in question. We have, however, observed that the tetrahedron is always one of those solids which concur to the formation of small rhomboids or parallelopipedons that would be drawn from the crystal by a first division. On the other hand, there are substances, which, being divided in all possible directions, resolve themselves only into tetrahedra. Of this number are garnet, blend, and tourmaline.

In short, several minerals are divisible into right triangular prisms. Such as the apatite or phosphate of lime, the primitive form of which is a regular right hexahedral prism, divisible parallel to its bases and its planes, from which necessarily result right prisms with three planes, as may be seen by inspecting Fig. 66, which represents one of the bases of the hexahedral prism divided into small equilateral triangles, which are the bases of so many moleculæ, and which, being taken two and two, as A *i p p k*, C *l* G *r*, &c. form quadrilateral prisms with rhombuses for their bases.*

By adopting then the tetrahedron in the doubtful case, we reduce, in general, all forms of integral moleculæ to three, remarkable for their simplicity; viz. the parallelopipedon, which includes the cube; the triangular prism; and the tetrahedron.

This simplicity may furnish a reason for the preference given to the tetrahedron in

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* Model, No. 26.

fluor spar, and the other substances of which we have spoken. The Abbé Haüy, however, forbears deciding on this subject, as the want of accurate and precise observations leaves to theory nothing but conjectures and probabilities.

But the essential object is, that the different forms to which the mixt structures in question conduct, are assorted in such a manner, that their assemblage is equivalent to a sum of small parallelopipedons, as we have seen to be the case in regard to fluor spar; and that the laminæ of superposition, applied on the nucleus, decrease by subtractions of one or more ranges of these parallelopipedons; so that the basis of the theory exists independently of the choice which might be made of any of the forms obtained by the mechanical division.

By the help of this result, the decrements to which crystals are subject, whatever be their primitive forms, are found brought back to those which take place in substances where this form, as well as that of the moleculæ, are indivisible parallelopipedons; and theory has the advantage of being able to generalize its object, by connecting with one fact that multitude of facts which by their diversity seem to be little susceptible of concurring in a common point.

Integrant particles of Crystals.

The forms of the integrant particles of crystals, as far as experiment and observation have gone, may be reduced, as stated page 159, to three, namely,

1. THE REGULAR TETRAHEDRON, the simplest of the pyramids, Fig. 1, Pl. II.*

2. THE TRIANGULAR PRISM, the simplest of the prisms, Fig. 2, Pl. II.† and,

3. THE CUBE, the simplest of the solids, whose faces are six in number, and parallel two and two, Fig. 3, Pl. II.‡

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* Model, No. 32.

† Model, No. 33.

‡ Model, No. 34.

These geometrical solids, which perform the office of the integrant moleculæ, are all the most simple, namely, those with four sides, the least number possible to contain a solid, those with five, and those with six. They are all susceptible of an infinite variety in the dimensions of their sides, and in the inclination of the faces which terminate them, although all have a fixed term of regularity toward which they tend. Thus the cube sometimes presents itself as a rhomboid, with an acute or obtuse summit, or as a parallelopiped, or as a right or oblique quadrangular prism, with a square, rectangular or rhombic base. In some cases the triangular prism is merely isosceles, in others it is equilateral, and in this last case the relation between its height and the side of its base is various. The tetrahedron undergoes analogous results; it is sometimes regular, at others irregular. And if these figures, says Haüy, are not those of the true integrant molecules employed by the mechanism of nature in the structure of crystals, they deserve at least to supply their places in our limited conceptions. With such slender means nature composes forms in an indefinite number, and sufficient to establish a theory which embraces so many extended results.

Since the integrant particles are the last products of the crystal which preserves an exact proportion of its chemical composition, they constitute the ultimate results to which the mechanical analysis can be carried. And although the further practical analysis of these bodies is out of our power, yet we can form a very correct idea, and indeed it may be demonstrated, that by a further mechanical subdivision, were it possible, their forms would not change. The integrant particles thus exhibited are therefore the representative of the last product obtained by mechanical analysis, and their union constitutes the crystal.

In a geometrical point of view they may be pronounced as containing the *minimum* of space under the *maximum* of surface, whence the primary forms of crystals which are its first results, comprehend the *maximum* of space under the *minimum* of surface, provided the inclination of the planes be equal.

A table exhibiting the crystalline forms of minerals, which have a common primitive form with the same dimensions, &c. will be given at the end of this work. See table of crystalline forms.

SECTION IV.

LAWS OF DECREMENT OF THE STRUCTURE OF CRYSTALS—NATURE AND PRODUCTION OF SECONDARY FORMS, SIMPLE AND COMPOUND—DECREMENTS ON THE EDGES—DECREMENTS ON THE ANGLES—INTERMEDIARY DECREMENTS—MIXT DECREMENTS—DIFFERENCE BETWEEN STRUCTURE AND DECREMENT, &c.

IN the preceding section it has been stated, that the nucleus is the symmetrical solid, which constitutes the primary form arising from the union of the integrant particles, and constituting the first result of their composition; now *secondary forms* are called all those which differ from the primitive; they originate from the addition of similar particles enveloping a primitive solid, and piled round it according to certain laws. They are of two kinds, namely, *simple* and *compound*. The former originate from a simple law of decrement; the latter are produced by the action of several laws of decrement acting at once, or from a single law, which has not attained its limit.

In speaking of those solids we shall suppose them situated always in such a manner, that the line which may be considered as their axis has a vertical position, and then the faces parallel to this axis will themselves bear the name of *vertical faces*, whereas *horizontal faces* are called those which are perpendicular; and the name *oblique faces* those which are inclined towards it.

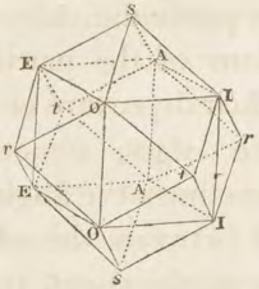
The laws of architecture or peculiar modes of arrangements of the particles, according to which are produced these forms by virtue of those regular coverings of crystalline laminæ, which disguise under such various forms one and the same primitive figure, are called *laws of decrease* or *laws of decrement* of the structure of crystals, and the layers of particles superposed upon the nucleus receive the name of *laminæ of superposition.*

Observation and the calculus have shewn, that these laminæ superposed to the nucleus, gradually decrease in number, sometimes on all the sides of the nucleus at once, in consequence of the substraction of one or more of their layers, sometimes on particular sides only, so that the abstractions of the particles have, for the limit of their departure or origin, sometimes all the edges, sometimes certain sides, and sometimes the angles, sometimes lines situated between the edges and the angles of the nucleus, and it is the determination of these laws of diminution, whether partial, or total, or modified according to certain geometrical rules, which disguise the nucleus under such various forms, and which give rise to such infinite variety of crystalline solids met with in nature. The laws of diminution or decrement which have been observed are the following.

I. *Decrements on the Edges.*

To render what has been stated more obvious, let us proceed to illustrate by the methods of synthesis and analysis, the production of secondary forms. We shall for that purpose take the rhomboidal dodecahedron, Fig. 66, and Fig. 8, Plate II.*

66.



which indeed ranks among the primitive forms, but it also presents itself occasionally as a secondary solid, and in this case it has, for a nucleus, sometimes a cube, sometimes an octahedron. Let us suppose the nucleus to be a cube.

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* Model, No. 35.

To prove this by analysis it will be necessary to cut off successively the six solid angles as S R T, &c. Fig. 66, composed of four planes each, by cuts passing through the minor diagonals of the faces. These sections will successively lay open six squares A I, O I, E O O E, I O O I, &c. which will be the faces of the cube*. This cube being evidently an assemblage of integrant particles of the same form, it will be necessary that each of the six pyramids resting on its faces be itself composed of cubes equal to each other, as well as to those which constitute the primitive nucleus. This condition will be fulfilled, if we suppose that each of the faces of the cube supports a series of decreasing laminæ composed of cubical particles, every one of which exceeds that immediately above it by one row of particles on each of its six sides. This arrangement is

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* Model, No. 35.

represented by Fig. 1, Pl. III.* where it may be seen, that the last layer or plate of particles is reduced to a single cube, marked *s*. In the figure only three of the quadrangular pyramids are shown as superadded to the nucleus, it is easy to supply the other pyramids mentaly. On examining the figure attentively, we shall find that it has been traced on the supposition that the cubic nucleus has on each of its edges seventeen ridges of molecules; whence it follows, that each of its faces is composed of two hundred and eighty-nine facets of moleculæ, and that the whole solid is equal to four thousand nine hundred and thirteen moleculæ. On this hypothesis, there are eight laminæ of superposition, the last of which is reduced to a simple cube, whose edges determine the numbers of molecules which form the series fifteen, thirteen, eleven, nine, seven, five, three, one, the

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* Model, No. 36.

difference being two, because there is one course in breadth, substracted from each extremity.

Now it is easy to conceive that the different series will produce the triangular faces O S I, O E S, I O T, O O T, O T I, &c. Fig. 1, Plate III. and Fig. 66, page 168, of these pyramids by the diminishing edges of the laminæ of superposition, which are obviously found on the same place; so that they are alternately re-entering and salient. But there are six pyramids, and consequently twenty-four triangles. And as the diminution is uniform throughout the extent of the adjacent triangles upon the contiguous pyramids, it results that the triangles, taken two by two, form a rhombus. The surface of the solid will therefore be composed of twelve equal and similar rhombi, that is to say, this solid will have the same form as that which is the object of the problem.

In explaining this structure of a crystal, or the production of a secondary form, from a primitive solid, although the representation in the Fig. 1, Pl. III.* be such as shew the decrement of the laminæ, by rows of particles visible to the eye, or of such a size as resembles quadrangular flights of steps resting on the six faces of the cube, it is obvious, if we substitute for this kind of coarse masonry, which possesses the advantage of speaking to the eye, the indefinitely delicate architecture of nature, the number of laminæ may be so immensely great, and the minuteness of their cubical particles so beyond comparison small, that the depressions or channels of their edges will be altogether imperceptible to our senses, and the surfaces will appear perfect planes, and this is what takes place in the crystals produced by the hand of nature.

Such is an example of the production of a simple secondary form, from a primitive solid, by superposition of laminæ accord-

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* And also in the Model, No. 36.

ing to a certain law of decrement, and to enumerate the result, we say that this rhomboidal dodecahedron is produced in virtue of a diminution by a single row of ranges of moleculæ, parallel to all the edges of the cubic nucleus. A crystal which has a cube for its primitive figure may therefore have a dodecahedron for its secondary form. To prove this by synthesis, it is only necessary to rear a series of cubical laminæ on each of the six sides of the cubic nucleus*, in such a manner that each layer decreases in surface on all the six edges, by the value of one row of cubical particles of which it consists, and thus continuing the superstructure until the last layer or apex is reduced by the progressive route of the decrement to a single cube.

In the figure, Plate III. Fig. 1,† the ratio

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* Model, No. 36.

† And also in the Model, No. 36.

N. B. Any number of small cubes, [and also triangular prisms, or tetrahedrons,] calculated to imitate of the decrement is represented as equal to one row of particles, substracted from the breadth of the superposed laminæ, therefore the height of the pyramid is equal to half its length of one of the sides of its base. For the second laminæ is less by one range in every direction than the first, and the third is less than the second, and so on. And as the sections are to be smooth, the joints as stated already, must form one inclined plane, therefore the ranges and even the particles at the joints must not encroach on each other; and hence it follows that the number of ranges successively substracted from each laminæ can never be incommensurable. Hence the theory demonstrates that the existence of a regular dodecahedron is not possible by virtue of any law of decrement. And indeed it does not exist in mineralogy.

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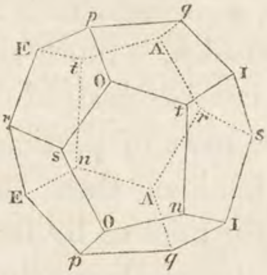
artificially, the structure of the quadrangular pyramid under consideration, may be had, with this treatise.

If the decrement in breadth, as it is called, or parallel to the sides of the primitive form, [as in the case just cited,] where the effect of the decrement is in the direction of the breadth, is more rapid, that is to say, if it consists instead of one, of. 2, 3, 4, or more rows of particles, less than the inferior laminæ, then the pyramids produced on the nucleus by this decrement being more flattened, their contiguous faces can no longer be found two by two in the same plane, the surface of the secondary crystal will then be composed of twenty-four distinct isosceles triangles all inclined together.

Besides all this, the decrements of the laminæ of superposition may be considered as taking place not merely in *breadth*, but also in *height*, and the ratio, or common difference of this latter, like the former, may also vary from 1, 2, 3, 4, 5, to 6, or more rows of particles, in which case the height will be to the breadth of the pyramid as $1:1$, $1:\frac{1}{2}$, $1:\frac{1}{3}$, $1:\frac{1}{4}$, $1:\frac{1}{5}$, $1:\frac{1}{6}$, &c. and it not unfrequently happens that these two kinds of decrements are united in the same crystal. The dodecahedron, Fig. 67,* with pentagonal faces*, is an example of the combination of these two kinds of decrements; it results from a diminution of square plates on a cubical nucleus, by two rows in breadth, on two of the sides of the nucleus, and by two rows in height on the two other sides, and as the decrements by two rows in breadth tend to produce a more inclined face, than the decrements by two rows in height, each pile of superposed laminæ will terminate not in a single cube, but in a range of cubes, or supposing the


67.

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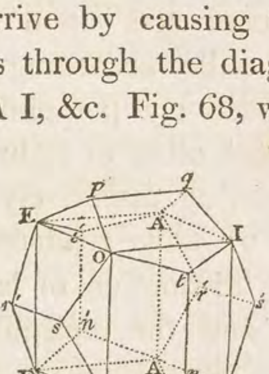
* Model, No. 37.

cubes infinitely small, instead of terminating in a point, it will terminate in a ridge or wedge-shaped summit. And the whole solid will be bounded by twelve equal and similar pentagonal faces, on account of the regularity of the nucleus and the symmetry of the decrement.

These two kinds of decrement actually exist in the following example, taken from the sulphuret of iron with pentagonal faces*. This dodecahedron has a cube for its nucleus, at the extraction of which we should arrive by causing the cutting planes to pass through the diagonals O I, O E, A E, A I, &c. Fig. 68, which inter-

68.



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* Model, No. 37.

cept the angles opposite to the basis, whence it appears, that the portions superadded to the nucleus, instead of being pyramids as in the dodecahedron with rhomboidal faces, are a species of wedge, resulting, as stated, from two decrements, the one through two ranges in breadth parallel to the two opposite edges O I, C E, of the corresponding face A E, O I, of the nucleus; the other through two ranges in height parallel to the other edges F O, A I of the same face, by which we see that each decrement acts upon the different faces of the cube, according to three directions respectively perpendicular, or so as to cross each other at right angles.

On considering attentively Fig. 2, Pl. III.* where we have rendered sensible to the eye, the distinction of laminæ of superposition, and the moleculæ of which they are the assemblage, it will be seen that the progress of the *decrement in breadth*, which contributes, for example, to the for-

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* Model, No. 38.

mation of the additional part I O, *p q*, and which takes place parallel to the edge O I and to its opposite, being more rapid than that of the decrement in height, which is made parallel to the edge O I, and to opposite, the two faces that spring from the former must be more inclined than those which are produced by the second; in such sort, that each pile of decreasing laminæ no longer terminates in a point but in an edge *p q*;* moreover each trapezoid, such as *o p q i*, Fig. 68, page 177, what results from the decrement in breadth being upon the same plane with the triangle *o s i*, in consequence of this that the decrement in height, which determines the latter, is only the repetition in a contrary direction of this decrement in breadth, the aggregate of the two figures forms a pentagon *p o f i q*; whence it follows, that the secondary solid is terminated by twelve equal and similar pentagons, by reason of

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* Model, No. 38.

the regular figure of the nucleus, and of the symmetry of the decrements.*

If it be supposed that the decrements act according to two other laws, one of which is always the inverse of that which is combined with it, in such manner, that there shall be three, four, &c. ranges substracted in breadth, and as many in height, the result will still be a dodecahedron of twelve equal and similar pentagons. It is very evident that all these dodecahedrons differ either from one another, or from the proceeding dodecahedron, by the measure of their angles. A multitude of new polyhedrons may be constructed, in illustration of this fact, by simply piling cubes in different ways, and according to the value of the decrement we wish to produce.

Besides all this, the decrement may not take place on all the edges but only on one or two of them, whilst no decrement at all takes place on the others, the result of which must be secondary forms very different from each other: or the retrench-

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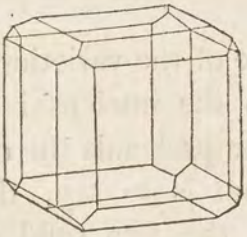
* Model, No. 37.

ment of the laminæ may cease to be added before they have reached their smallest possible size, the consequence of which will be a secondary form, again different. Thus, in the example given in illustration of the synthesis of the structure of the dodecahedron by virtue of a decrement, by one range of small cubes on the eight edges of a cubic nucleus, page 173; if the superposition of the laminæ had ceased before the pyramids were completed, the crystal would have consisted of eighteen faces, six squares parallel to the faces of the nucleus, and twelve hexahedrons parallel to the faces of the secondary dodecahedrons. See Fig. 69.*

69.



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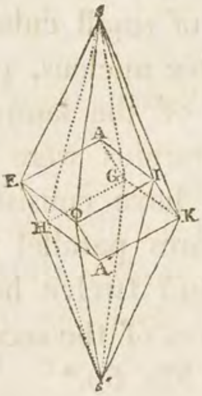
* Model, No. 3.

We shall conclude that which regards the law of *decrement on the edges*, by an example drawn from the pyramidal dodecahedron, whose faces are scalene triangles, Fig. 70, which, as we have said p. 125, is one of the varieties of carbonate of lime; here the nucleus is a rhomboid, which also comprehends the cube, the axis of which, that is to say, the line passing through the two solid angles A A, composed each of three equal obtuse angles, must be situated vertically, that

70.



this rhomboid may be presented to the eye under its true aspect, it results that symmetry does not require as with respect to the cube, that the decrements operating on any one E O, of the edges of one of the faces, as A E O I, for instance, should be repeated on the opposite edge A I, since this latter which is contiguous to one of the summits, has in some measure a mode of being different from the other; it is enough that all what takes places with regard to the edge E O, obtains equally in respect of the five others, O I, I K, K G, G H, H E, similar situated. One may judge solely from an inspection of Fig. 70*, that these six borders or edges which are common to the nucleus, and to the secondary crystal, serve as lines of departure to so many decrements, which in this case take place only with respect to them, without any relation to the upper

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* Model, No. 23.

edges. That is to say, six in the upper part, and as many in the lower, and all these triangles will be scalene, on account of the obliquity of the parting lines. The figure on the plate facing the title of this work*, will illustrate this kind of arrangement. It represents only the kind of upper pyramid added to the nucleus, which being thus partly uncovered, enables us to comprehend more easily the progress and effects of the decrement by two courses. The salient and re-entering alternatives that are formed by the laminæ of superposition towards their decreasing edges, being nothing as to sense in the crystal produced by nature, the position line *e s* will represent one of the edges contiguous to the summit, such as it will be seen on the same crystal; the difference between the geometrical summit *s* of the dodecahedron, and the phy-

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* Model, No. 39.

sical summit S, vanishes by reason of the extreme minuteness of the particles. In the design, each edge of the nucleus has been divided into ten; whence it follows that every face is an assemblage of a hundred small rhombs, which are the external facets of as many moleculæ. This construction requires but eight laminæ of superposition for each of the same faces; and these laminæ being united together, three and three, in the places which correspond to the upper edges of the nucleus, form kinds of decreasing envelopes which are successively generated, and the last of which is composed of eight small rhomboids.* If we consider the position of the line *e s*, which represents one of the terminating edges, composed of all the solid angles which are contiguous to it, we shall remark that the geometrical summit *s* of the dodecahedron is situated above the physical

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* Model, No. 39.

summit S, but this difference is considered as nothing, on account of the extreme minuteness of particles.

What we have said as to increments assumed by the laminæ of superposition towards their upper edges, in continuing to envelop the crystal on this same side, is a consequence of this general principle, namely, that the portions of laminæ, situated out of the reach of the decrement, extend, by mutually retrieving themselves, in such a manner as to avoid the re-entering angles which seem excluded by the crystallisation, at least in solitary crystals. But we may abstract these simply auxiliary variations, as the effect of decrements only determines the form of the secondary crystal. It is even sufficient to take the decrements at their origin, in order to have as many planes; and these again being afterwards extended in idea until they meet, lead to the complete form of the polyhedron which they tend to produce. Hence it is thus that we confine ourselves to the consideration of the initial effect of decrements, in calculation of which the progress is always much more simple and expeditious than that of reasoning.

2. *Decrements on the Angles.*

Independently of the decrements which take place parallel to the edges of the faces of the nucleus, others occur in different directions, namely,

Decrements on the angles are called those arrangements or decreases of the laminæ of superposition, of which the lines proceed in a direction parallel to the diagonals of the faces of the primitive nucleus.

This decrement, which therefore has angles for the points of departure, and the action of which takes place parallel to the diagonals drawn from one angle to the opposite angle of the faces of the primitive nucleus, follows the same laws as the former, and will readily be understood from the following example.

Let O I, I O, Fig. 71, be one of the

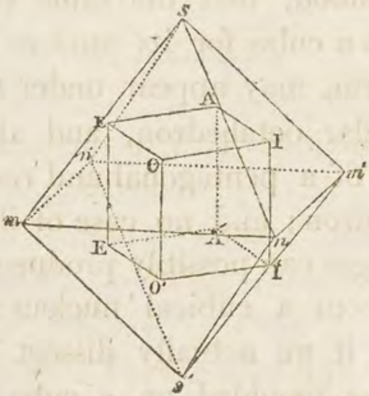
71.

faces of a cubic nucleus, subdivided into a multitude of little squares which will be the faces of so many moleculæ.

The ranges or rows of these particles may be considered in two different directions, namely, in the direction of the edges, as the files lying in the line *a n q w s*, &c. and also in the direction of the diagonals of the ranges, one of which is represented by *a b c d e f*, &c. another by *n t l m p o*, and a third by *q v k u x y z*, the only difference is, that here the moleculæ of the ranges parallel to the edges, are simply placed side by side, instead of which those that compose the ranges parallel to the edges, touch each other by one of their *faces*, the former being parallel to the diagonals, are as if dove-tailed into each other, they touch by a ridge only, hence the faces produced by virtue of the decrement are no longer simply striated as in the decrease on the edges, but are full of small points, which being all on a level, and escaping the eye from their minuteness, present the aspect of a plain surface.

To illustrate this law of decrement let it be understood, that the same substance, which has a cube for its nucleus as a primitive form, may appear under the shape of a regular octahedron, and also under the form of a pentagonal and rhomboidal dodecahedron; and no case of decrement on the edges can possibly produce an octahedron from a cubical nucleus; on the contrary, if we actually dissect a regular octahedron moulded on a cube we shall perceive, that the primitive nucleus is so situated with regard to the octahedron, that each of the eight solid angles of the former correspond with the centre of the triangular faces of the latter*. A fact wholly irreconcileable with the law of decrement on the edges. To extract the nucleus of this octahedron, it is therefore necessary to remove the six solid angles of the octahedron by cuts perpendicular to the axis, passing through the same angle, and therefore parallel to the faces of the cube†.

72.



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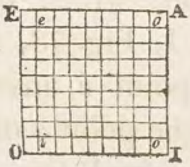
* Model, No. 40. † Model, No. 40.

To explain this law more fully we shall here again adopt the synthetical method, and run over the series of laminæ of superposition, indicating the auxiliary variations which they undergo, and which assist the effect of the decrement, to which every thing may be referred. Let A E, O I, Fig. 73,* be the superior base of the nucleus subdivided into eighty-one small squares, or facets of moleculæ, which will be the basis of so many cubes, of which the primitive cube is composed. What we are about to say relative to this base may equally be applied to the five other faces of the cube.

73.



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* Model, No. 41, will fully explain the synthesis of this crystal.

74.

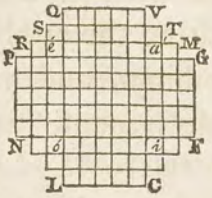
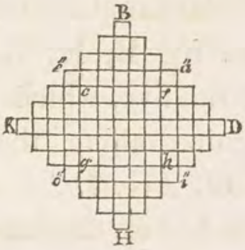


Fig. 74, represents the first lamina of superposition, which must be placed above A E, O I, Fig. 73, in such a manner that the point *é* answers to the *é*, the point *á* to the point *a* of 73, the point *ó* to the point *o*, and the point *í* to the point *i*. We see, in the first place, by this arrangement, that the squares E *e*, A *a*, O *o*, I *i*, Fig. 73, remain uncovered, which is the initial effect of the law of decrement alluded to.

We see moreover, that the edges Q V, P N, L C, F G, Fig. 74, project by one row beyond the edges E A, E O, O I, I A, Fig. 73, which is necessary, that the nucleus may be enveloped towards the same edges, and that the solid may increase as usual in the parts to which the decrement does not extend.

The superior face of the second laminæ will be similar to B K, H D, Fig. 75,

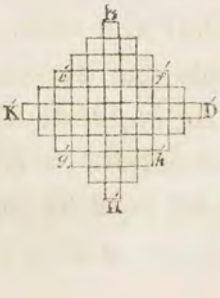
75.



and it must be placed above the preceding, in such a manner that the points e'', a'', i'', o'', may answer to the points e', a', i', Fig. 74, leaving the squares, which have their external angles situated in Q, S, R, P, V, T, M, G, &c. and continuing to effect the decrement by a row. We also see here that the solid increases successively towards the analogous edges at E A, E O, A I, O I, Fig. 73, since between B and H, for example, Fig. 75, there are thirteen squares instead of there being only eleven between Q V and L C, Fig. 74; but as the effect of the decrement confines more and more the surface of the laminæ in the direction of the diagonals, nothing else is wanted than to add towards the unchanging edges a single cube, denoted by B, K, H, or D, Fig. 75, instead of the five, which terminate the preceding lamina along the lines Q V, P N, L C, F G, Fig. 75.

The great faces of the lamina of superposition, which were hitherto octagons, Q V, G F, C L, N P, Fig. 74, having reached the figure of the square B K, H D, Fig. C 75, will, after passing this point, decrease, so that the following laminæ will have for its great superior face, the square B′ K′ H′ D′, Fig. 76, which is less by

76.



one row in every direction than the square B K, H D, Fig. 75; we shall dispose the first above the second, so as to make the points *c′*, *f′*, *h′*, *g′*, Fig 76, answer to the points *c*, *f*, *h*, *g*, Fig. 75. Figs. 77, 78, 79, and 80, represent the four laminæ which ought

77.

78.

79.

80.

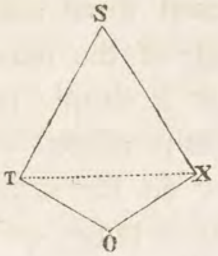
81.

successively to rise above the preceding, with this condition, that the similar letters correspond as above. The last laminæ will be reduced to a single cube, Fig. 81, and which ought to rest on that represented by the same letter, Fig. 80.

It follows from what has been said, that the laminæ of superposition, when applied on the base E A I O, Fig. 73, produce, by the assemblage of the decreasing edges, four faces, which, issuing from the points E, A, I, O, are inclined towards each other under the form of a pyramidal summit.

We must now remark, that the edges in question have lengths which commence by increasing, as we may observe by inspecting Fig. 74, and Fig. 75, and then proceed to diminish, as we may judge by the following figures. Hence it results, that the faces produced by the same edges go on enlarging from their origin to a certain point; and when past this, they begin to contract themselves so as to constitute two triangles joined base to base, or a quadrilater. We see, Fig. 24, one of these quadrilaters, and in which the inferior angle *o* is blended with the angle O of the nucleus, Fig. 82, and the diago-

82.



nal *t x* represents the edge H K, Fig. 76, of the laminæ B K H D, which is the most extensive in the direction of this same edge. As the number of the laminæ of superposition producing the triangle *t o x*, Fig. 82, is less than that of the laminæ constituting the triangle *t o x*, and as there is here only a single lamina which precedes the lamina B K H D, Fig. 76, while there are six which follow it as far as the cube *z*, Fig. 81, inclusively, the triangle *t s x*, Fig. 82, composed of the aggregate of the borders of these last laminæ, will be much higher than the inferior triangle *t o x*, as expressed by the figure.

The surface of the secondary solid will therefore be formed of twenty-four quadrilaterals, disposed three and three around each solid angle of the nucleus; but as, in decrements by a simple range on all the edges, the faces produced on both sides of each edge are on the same plane; so in decrements by a range on all the angles, the faces which originate in the three sides of each solid angle, such as O, Fig. 72, page 190, are on a level so as to form but one face: and since the cube has eight solid angles, each composed of three plain angles, the secondary crystals will have eight faces, which, on account of the regularity of the nucleus, will be equilateral triangles, *i. e.* the secondary crystal will be a regular octahedron. One of these triangles is represented at Fig. 83, Z N I C so as to

83.

enable us to judge, at a single glance, of the arrangement of the cubes which concur in forming it.

This level of faces produced by subtractions of a range from both sides of the same edge, or around the same solid angle, is a general result of the crystallisation which takes place for any primitive form whatever.

The circumstance just considered, and which occurs in muriate of soda, sulphuret of iron, sulphuret of lead, &c. affords a new example of a form which, although primitive in certain species, performs in others the function of a secondary one. Theory thus traces the limit that separates objects which the eye would be tempted to confound.

If the decrements had not their complete effect, that is to say, if they stopped short of the limit where the faces they produce incline to unite in a point, some faces parallel to those of the nucleus would remain on the secondary crystal. The first would then have fourteen faces, namely, six ranged like those of a cube, and eight situated like those of a regular octahedron.* Nothing is more common in crystals of sulphuret of iron, than this modification, to which Haüy has given the name of cubo-octahedral sulphuret of iron. Here the remark again occurs which we made with respect to decrements on the edges. If we confine our consideration to the immediate effects of decrements on the angles of two opposite faces, for example, on those of the bases A E O I, A′ E′ O′ I′, Fig. 72, and if we subsequently imagine the eight faces to which these decrements give existence, are prolonged between the bases to the point of intersecting each other, the result will always be a regular octahedron, supposing that the decrements obtain their limit.

If the law of these decrements followed a more rapid course, viz. if more than one course was subtracted, then the three trapezoids S T O X, Fig. 82, of which three

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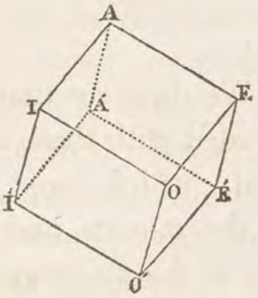
* Model, No. 42.

would be formed around the same solid angle, could no longer be on a single plane; they would incline towards each other, and the secondary solid would have twenty-four faces which would also be trapezoids, but with angles of a different measure.

Let us now choose for a primitive form the rhomboid represented by Figure 84,

84.

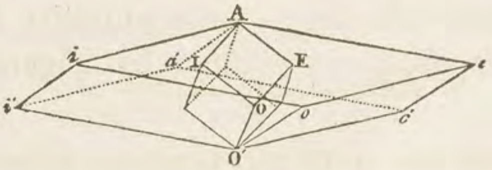


which differs from the cube in being a little more acute.

Suppose that the laminæ which adhere over all the faces of this rhomboid decrease solely on the angles contiguous to the summits A, O, and that this decrement takes place by two ranges; then, instead of twenty-four faces no more than six will be formed; and if we conceive them prolonged until they meet, they will compose the surface of a very obtuse rhomboid, which will be the secondary form.

Fig. 85 represents this rhomboid with

85.



its nucleus. We there see that its summits A, O′, are blended with those of the primitive rhomboid, which are the parting limits of the decrements, and that each of its faces, such as A *e o i*, corresponds with one of the faces A E O I of the nucleus, in such a manner that the diagonal which passes by the points *e*, *i*, is parallel to that which goes from E to I, and has merely a more elevated position.

Observation shows that this result is realized by crystallisation in a variety of oligiste or specular iron ore, which bears the name of binary specular iron ore.

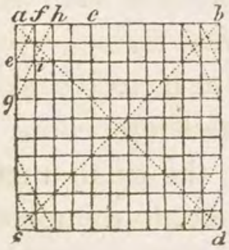
The decrement on the angles, like those on the edges, are susceptible of many variations with regard to height or in breadth, and the effects thence resulting may be calculated, but on this subject it is unnecessary to speak.

3. *Intermediary decrements.*

There are certain crystals in which the decrements are neither parallel to the edges, nor to the diagonals of the faces of the primitive nucleus, but in directions parallel to lines situated between the diagonals and the edges.

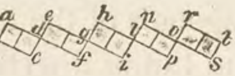
For example, let *a b d e*, Fig. 86, repre-

86.



sent the face of a cube, divided into a multitude of little squares. The decrement called intermediary, in this case does not effect the cubes in the directions of the diagonals *a d*, or *e b*, but it takes places according to lines situated between the diagonals *a d*, and *c b*, namely, in directions represented by *f e*, *h i g*, or in any other imaginable direction, and this happens when the abstractions are made by ranges of double, triple, &c. particles. Fig. 87 exhibits an

87.



instance of the subtractions in question; and it is seen that the moleculæ which compose the range represented by that figure are assorted in such a manner as if of two there were formed only one; so that we need only to conceive the crystal composed of parallelopipedons having their bases equal to the small rectangles *a b c d*, *e d f g*, *h g i l*, &c. to reduce this case under that of the common decrements on the angles. This particular decrement is uncommon, it follows otherwise the same laws.*

It is a general rule therefore, *that in all cases the laminæ decrease in arithmetical progression, and its rates or the number of ranges is always commensurable.*

We have seen that in the case of a decrement by one range round one and the same solid angle, O, Fig. 72, the three faces produced were always on a level, and that in this case we might confine ourselves to the consideration of the effect of the decrements with respect to one of the plane angles, which concurred to the formation of the solid angle, by supposing this effect to be prolonged above the adjacent faces. In this case the decrements which take place on these latter faces, are reckoned as intervening in a subsidiary manner, in order to favour the action of the principal decrement.

In general, whenever a solid angle of the

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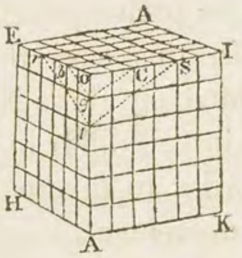
* Model, No. 49, will be sufficient to illustrate the action of the law of decrement, called intermediary.

primitive form undergoes decrements which tend to give rise to a facet in its place, *whatever be the law* of that to which we refer the production of this facet, there are always auxiliary decrements, the concurrence of which is necessary in order that the facet in question may be properly prolonged. Now, when this decrement, which we consider in preference, takes place by two or more ranges, the auxiliary decrements which form a continuity with it follow a law entirely peculiar, namely,

Let A A, Fig. 88, be any given parallelopipedon, which undergoes a decrement by two ranges on the angle E O I, or its

88.



base A E O I. It is evident, that the edges of the laminæ of superposition will have directions *b c*, *r s*,* parallel to the diagonal, which goes from E to I, and situated in such a manner that there will be on the edges O E, O I, two ridges of moleculæ, comprised either between the term of departure O and *b c*, or between *b c* and *r s*. But as we have said, the laminæ applied on the adjacent faces I O A′ K, E O A′ H are lineally disposed like *b g*, *r t*. For since the lower edge of the first laminæ, applied on A E O I, coincides with

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* We must conceive that the subtractions, which are here represented on the quadrilater A E O I, take place successively on the different laminæ of superposition. The distances between each of these laminæ and the succeeding one being the same with that which exists between the lines *b c*, *r s*, and all the rest similarly situated, we may, for the sake of greater convenience, refer the whole, as we do in the present instance, to the quadrilater A E O I, as a kind of scale which gives the measurements of the subtractions operated by the decrement on the corresponding laminæ.

b c, and as the height of this lamina answers to a ridge of a moleculæ, we may, with a little attention, conceive that the plane *b c g*, which in one part also coincides with *b c*, and in another is removed from the base A E O I in a quantity measured by a ridge O *g* of a molecule, is necessarily parallel to the face produced by the decrement. It is the same with the plane *r t s;* from which it follows, that if we suppress the part situated above *r t s* we shall have a solid, on which the facet *r t s* will represent the effect of the decrement under consideration.

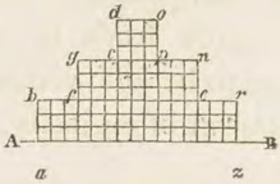
We may now observe, that the directions *c g*, *s t*, of the laminæ applied to the face I O A′ K, (and the same may be said of the face E O A′ H), in virtue of the auxiliary decrement, are no longer parallel either to the edges or to the diagonal, but are situated between both. A fortiori, the defect of parallelism will take place, if we suppose that the decrement on the angle E O I of the base proceeds by three, four, or more ranges. Decrements of this kind are called *intermediate;* and we conceive that they may be referred to an infinity of different directions, according as they are more or less removed from the one or other of their limits, which are the parallelism with the ridges and the parallelism with the diagonals.

We see by these details, to which we could give a much greater latitude, that the intermediate laws, the existence of which is in other respects hitherto confined to a trifling number of cases, produce forms equally simple with those which originate from the ordinary laws, and that their theory even leads to results which would deserve to be followed and developed as a simple object of curiosity.

4. *Mixed Decrements.*

It may happen that each lamina of superposition exceeds the following by two ranges of particles in breadth or parallel to the edges, and that it may at the same time have an altitude triple that of a single molecule, or by three ranges in breadth and two in height. In this case, therefore, the decrement, whether it takes place on the angles or on the edges, varies according to laws, the proportion of which cannot be expressed but by the fraction two-thirds or three-fourths. It may happen, for example, that each lamina exceeds the following by two rows parallel to the edges, and that it may at the same time have an altitude triple that of a simple molecula. Fig. 89,* represents a vertical geometrical section of one of the kinds of pyramids which would result from this decrement; the effect of which may be readily con-

89.



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* Model, No. 44.

ceived by considering that A B is a horizontal line, taken upon the upper base of the nucleus; *b a z r*, the section of the first laminæ of superposition; *g f e n*, that of the second; and *d c p o* the third. The theory of this law may easily be referred to that of decrements, in which there is only a single range substracted in one of the two directions. It occurs but rarely. Haüy has only met with mixed decrements in some metallic crystals.

In what has been so far stated we have confined ourselves simply to the consideration of those forms which depend upon a single law of decrement, and what produces *simple secondary forms.*

The name, *compound secondary forms*, is given to those which proceed from several simultaneous laws of decrement, acting at once, or from a single law which has not attained its limit; and which of course has left on the secondary crystal, faces parallel to those of the primitive nucleus.

Let us suppose, for example, that the

law which gives the octahedron originating from the cube, Fig. 72, page 190, is combined with that from which results the dodecahedron with pentagonal faces, Fig. 68, page 177. The first will give rise to eight faces, which will have as centres the solid angles of the nucleus, and it is easy to see that each of these faces, for instance that whose centre coincides with the solid angle O, Figs. 67, p. 175, and 68, p. 177, will be parallel to the equilateral triangle whose sides would pass by the points *p*, *s*, *t*. In the same way the face whose centre will be confounded with the angle *o*, will be parallel to the equilateral triangle, whose sides would pass by the points *s*, *n*, *p*; but the second law produces faces situated like pentagonals cut by the sides of the triangles *p s t*, *s n p*. Now the sections of these triangles on the pentagon *t* O *s* O′ *n*, reduce the latter into an isoscele triangle, which has for its base the line *t n*, and whose two other sides pass, the one by the points *t*, *s*, the other by the points *n*, *s*. It is the same with the other pentagons;

whence it follows that the secondary solid will be an isosahedron terminated by eight equilateral triangles, and twelve isoscele triangles.

Such is the nature of the decrements of the structure of crystals, which account for the metamorphoses which these bodies present; and the truth of which is rendered legitimate by the mechanical division of crystalline bodies, and the geometrical calculation of their angles.

From what has been stated with regard to the laws of decrement, the problem which must be proposed to discover the generation of each of the forms of crystals may therefore be expressed thus;

A secondary crystal being given, as well as the figure of its nucleus, and that of its integrant particle, being likewise given, supposing moreover that each of the laminæ, that will be added to the nucleus, does not project so far or overlaps by the preceeding in certain parts, by a quantity equal to one, two, three, &c. ranges of moleculæ, *to determine among the different laws of decre-*

ments, the law from which a similar form to that proposed will result, with respect to the number, the figure, and the disposition of its faces, and the measure of both its faces and solid angles.

Before we conclude this subject we shall transcribe some ingenious speculations advanced by the Abbé Bueé,* concerning the question why the same crystallisable material is induced to crystallise in such vast varieties of forms, for this question has not been treated by the Abbé Haüy.

First causes, says the Abbé Bueé, are not the object of this discussion. He states the question thus:—Why does the same subject crystallise in such a variety of forms, always symmetrical and always terminated by planes?

"The solution of this question seems to require three conditions:

"1st. That the particles of the substance dissolved in the fluid all leave the state of

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* Nicholson's Journal, vol. ix. October, 1804.

rest at the same instant, to form the crystal by their aggregation.

"2dly. That, while these particles are in the act of drawing near to each other, no foreign power shall imprint on them any other motion than a common motion, whether it be in a straight line, or rotary round their common centre of gravity.

"3dly. That the particles all arrive at the state of rest at the same instant, which takes place when the act of crystallisation is finished. The second condition is necessary, and infers the first and third. The natural consequence of these conditions will be, that the aggregation of the particles will only take place conformably to a law acting equally on all of them, whatever the law may be.

"Since they all leave the state of rest at the same instant, they are in equilibrio previous to that instant. Since they all arrive at the state of rest at the same instant, they are in equilibrio after that instant; but when particles that are acted upon by no other force than that which they exercise on each other, are in equilibrio, they are in the closest possible union that concomitant circumstances will permit. If the particles were in equilibrio previous to their leaving the state of rest, something must have obstructed their approach. Let us suppose that *something* to be the interposition remains equilibrium is maintained. But this can only be the case, inasmuch as the whole of the particles of the interposed substance are in equilibrio with the whole of the particles dissolved and about to leave the state of rest, which in the future I shall call the *proper particles.* If by any cause which acts uniformly on the whole surface of the dissolving fluid any of the interposed particles are subtracted, the proper particles must cease to be in equilibrio. A step toward aggregation will immediately take place, and the equilibrium will be restored. A further subtraction will produce a further step toward aggregation, and a consequent equilibrium; and these operations will be repeated so long as the cause of subtraction continues, and the longer its duration the larger will be the resulting crystalline mass.

"If the above mode of reasoning be admitted, it will suffice to apply the laws of equilibrium to deduce the laws of crystalline forms. The laws of equilibrium to which I allude, are those of the equilibrium of fluids, which certain modifications I shall presently state. According to these laws, that the preceding conditions may take place in the formation of a crystal, it will be necessary that they take place in the formation of each and every part of it, whatever may be the figure or the smallness of those parts. They must also take place in those last crystals which contain the least possible number of particles; and as these particles are in equilibrio, and in the greatest possible state of proximity to each other which circumstances will permit, it must follow, to fulfil all the conditions, that these particles form a symmetrical polyëdron. This peculiar disposition of the crystalline particles constitutes the modification, to which I alluded, in the laws of the equilibrium of fluids; it being necessary in this case to take the number of crystalline particles into account, which is not the case when treating of the particles of a fluid.

"In a fluid, the particles and their reciprocal distances are supposed infinitely small; but the crystalline particles and their distances to each other must be supposed finite. This material difference will necessarily cause a difference between the forms of their aggregates. Those formed with the particles of a fluïd will be bounded by curved lines; the crystalline aggregates, on the contrary, will be terminated by straight lines; and when these straight lines are not too small, the boundaries will be sensibly rectilinear.

"To ascertain what the power is that holds the particles in the state of rest, though not in close contact, is not the question; but the form of the polyhedrons which they produce. The closer adhesion of the particles to be obtained by the subtraction of caloric, sufficiently demonstrates that the particles are not in close contact with each other, and the constancy of the crystalline forms equally proves that they are in equilibrio.

"We shall now proceed to the construction of a crystal with these crystalline particles. That the constancy of the form in the large crystal be preserved, the particles must be in equilibrio. That the equilibrium be preserved, the forces that solicit the particles to motion must mutually destroy each other. That the mutual destruction of those forces be effected, these forces after having been decomposed into other relatively parallel to three axes perpendicular to each other, and having a common point of intersection, must each meet in its direction another force equal and diametrically opposed to it. This will be obtained if the similar particles are arranged on straight lines parallel two and two at equal opposite distances from the common centre, and bisected by lines passing through that centre; but if the particles are thus arranged, they must produce symmetrical solids bounded by planes; and they are thus arranged: for if a foreign force, an excess of caloric for example, does not impede the free arrangement of the particles in the formation of the crystal, their exterior disposition will follow as much as possible their interior arrangement; but their interior arrangement must be on straight lines, or the crystal would cease to be homogeneous; their exterior disposition will therefore be on straight lines.

" As the circumstances giving rise to the approach of the particles may be in the highest degree variable, it must follow as the forms produced may be diversified in the extreme. This is the answer I should submit for the solution of the question proposed.

" When speaking of the approach of the proper particles, I said that it might be occasioned by the subtraction of certain interposed particles which obstructed the approach of the proper particles. The former are generally water, caloric, or any fluid elastic or not. Their exit may perhaps make place for others, such as light, electricity, &c. &c. But the essential point is, that whatever these particles may be, they are in perfect equilibrio with the proper particles, otherwise they would become perturbing forces.

" Hence it follows, that not only the integrant particles of the crystals, but all those that are mixed with them, the chemical or component particles and even the vacuities, must follow the same laws. It also follows, that if each species of particle (even the chemical) that enters into the formation of the crystal be separately considered, each species will have its distinct symmetrical and polyhedral form. The forms will penetrate each other, while the particles will not only not penetrate, but not even touch each other. All forms would stand in the same predicament as the regular octahedron, which contains, as has been shewn by the Abbé Haüy, six regular octahedrons and eight regular tetrahedrons, each tetrahedron containing one octahedron and four tetrahedrons. It will further follow, if the chemical electments can be looked upon as particles which are not in contact with each other, that we may from thence mathematically determine chemical affinities.

PART III.

SECTION I.

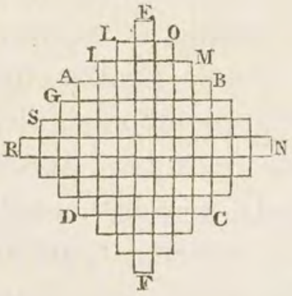
DIFFERENCE BETWEEN STRUCTURE AND INCREMENT, AS RELATING TO THE PRODUCTION OF CRYSTALS—SINGULAR ALTERATIONS ABSOLUTELY ACCIDENTAL, TO WHICH THE SYMMETRY OF CRYSTALS IS SUBJECT; REVERSED POSITIONS OF THE FACES OF CRYSTALS——PRODUCTION OF TWIN-CRYSTALS, HEMITROPES, MACLES, &C.

IN the preceding development of the theory of crystallography, we have supposed that the component laminæ of crystals originally of one and the same species, issue from one common nucleus, undergoing decrements subjected to certain laws, upon which the forms of these crystals depended.

But here it is only a conception, adopted to make us more easily perceive the mutual connections of the form in question. Properly speaking, a crystal in its entire state is only a regular group of similar moleculæ. It does not commence by a nucleus of a size proportioned to the volume which it ought to acquire, or, what comes to the same thing, by a nucleus equal to that which we extract by the aid of mechanical division ; and the laminæ which cover this nucleus are not applied successively over each other in the same order in which the theory regards them. The proof of this is, that among crystals of different dimensions which are frequently attached to the same support, those which can only be distinguished by the microscope are as complete as the most bulky ; from which it follows, that they have the same structure, viz. they already contain a small nucleus proportioned to their diameter, and inveloped by the number of decreasing laminæ necessary, in order that the polyhedron should be provided with all its faces. We do not perceive these various transitions of the primitive to the secondary forms, which ought to take place if crystallisation constructed as if by courses, the species of pyramids superadded to the nucleus, in going from the base to the summit. This however is only generally true; for it sometimes happens, in artificial crystallisation, (and it is very probable that we may say as much of that of natural bodies), that a form, which had attained a certain degree of increment, suddenly undergoes variations by the effect of some particular circumstance. We must therefore conceive, for example, that from the first instant a crystal, similar to the dodecahedron with rhomboidal planes derived from the cube (see page 168, &c. Figure 65), is already a very small dodecahedron, which contains a cubical nucleus proportionally small, and that in the following instance this kind of embryo increases without changing its form, by new strata which envelop it on all sides; so that the nucleus increases on its part, always preserving the same relation with the entire crystal.

We shall make this idea apparent, by a construction relative to the dodecahedron now mentioned, and represented by means of a plain figure. What we shall say of this figure may easily be applied to a solid, since we may always conceive a plain figure, like a section made in a solid. Let E R F N, Fig. 90, be an assortment of small squares,

90.



in which the square A B C D, composed of forty-nine imperfect squares, represents the section of the nucleus*, and the extreme squares R S, G A, I L, &c. that of the kind of steps formed by the laminæ of superposition. We may conceive, that the assortment has commenced by the square A B C D, and that different piles of small squares are afterwards applied on each of the central square; for example, on the side A B, in the first place, the five squares comprehend between I and M, afterwards the three squares contained between L and O, and then the square E. This progress corresponds with that which would take place if the dodecahedron commenced by a cube proportioned to its volume, and which afterwards increased by an addition of laminæ continually decreasing.

But on the other hand, we may ima-

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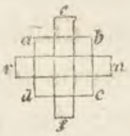
* This section is that which would pass by the points *s s*, Fig. 66, page 168, of the dodecahedron, and by the centres of the ridges E O, A I, &c. of the nucleus.

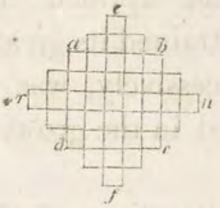
gine that the assortment had been at first similar to that which is represented by Fig. 91,

91. 

in which the square *a b c d* is only composed of nine moleculæ, and bears on each of its sides only a single square *e n f* or *r*. If we refer, in imagination, this assortment to the solid of which it is the section, we shall easily judge that this solid had for its nucleus a cube composed of twenty-seven molecules, and of which each face, composed of nine squares, carried on that of the middle, a small cube, so that the decrement by one range is already exhibited in this initial dodecahedron.

This assortment, by means of an application of new squares, will become that of Fig. 92, in which the central square *a b c d* is formed of twenty-five small squares, and carries on each of its sides a pile of three squares, besides a terminal square *e n f* or *r*. Here we have already two laminæ of superposition instead of one only. Finally, by an ulterior application, the assortment of Fig. 92, will be changed into that of Fig. 90, where we see three laminæ of superposition.

92.



These different transitions, of which we are at liberty to continue the series as far as we please, will give an idea of the manner in which secondary crystals may increase in volume by preserving their form; from which we may judge that the structure is combined with this augmentation; so that the law, according to which all the laminæ applied on the nucleus when it has attained its greatest dimensions decrease successively, was already, as it were displayed in the growing crystal.

Singular alterations absolutely accidental to which the symmetry of crystals is subject; reversed positions of their faces; production of hemitropes or macles, &c.

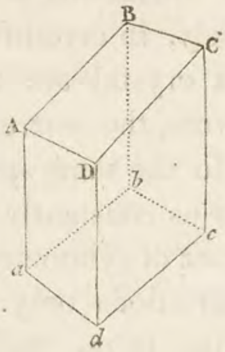
WE have hitherto considered crystallisation as impressing on its results the character of the greatest possible perfection, and producing nothing but isolated forms, exempt from every salient angle that could affect their purity and symmetry. It remains for us to describe certain accidents which, under the appearance of exceptions or anomalies, still possess a latent tendency towards the same laws to which the structure is subjected, when nothing deranges their progress or disturbs their harmony.

The forms of crystals are subject to various kinds of alterations absolutely accidental. Namely, in certain cases some of the faces of a crystal are nearer to, or more distant from, the centre than in others which belong to the same species, in such a way however as constantly to preserve a certain character of symmetry. In several cases these variations only fall on the dimensions of the faces, and not on the number of their sides. In other cases, the faces themselves, or some of them at least, change their figure by the increase or diminution of the number of their sides.

In ordinary crystals, the faces adjacent to each other always form salient, and never re-entering angles. But crystalline forms also exist which present these last angles; and Romé de L'Isle was the first who observed, that this effect took place when one of the two moieties of a crystal was in a reversed position with respect to the other. A very simple example will enable us to conceive this reversed position.

Let us suppose that B *d*, Fig. 93,* re-

93.



presents an oblique prism of hemi-trope field-spar with rhomboidal bases, situated in such a manner that the faces A D *d a*, C D *d c*, are vertical, and B D are the acute angles of the base; and the latter proceeds in a rising direction from A to C. Let us besides suppose, that the prism is cut into halves, by means of a plane which should pass by the diagonals drawn from

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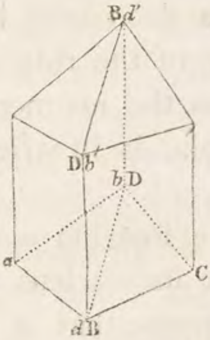
* Model, No. 45.

B to D, and from *b* to *d*, and that the half situated on the left, remaining fixed, the other is reversed without being separated from the former. The crystal will be presented under the aspect which we see in Fig. 94,* where the triangle $b'\ d'\ c'$, which

94.



was one of the halves of the lower base, Fig. 93, is now situated in the upper part Fig. 94, and forms a salient angle with the fixed triangle A B D, while the triangle B D C, Fig. 94, which was one of the

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* Model, No. 45.

halves of the superior base, Fig. 93, is transported into the lower part, Fig. 94, and forms a re-entering angle with the fixed triangle *a b d*.

We can easily conceive that the plane of junction D B *b d* of the two halves of a rhomboid, is situated like a face produced in virtue of a decrement by one range on one or other of the ridges A *a*, C *c*, Fig. 93; and thus the manner in which these two halves join, is in strict relation to the structure.

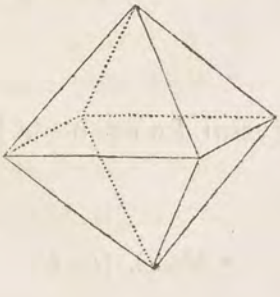
Now if we imagine a secondary form, which has for its nucleus the same prism, and if we suppose that it has been cut in the directions of the plane D B *b d*, and that one of its halves is reversed in such a manner, that the half of the nucleus which corresponds with it, assumes the same position as in the preceding case, the assortment might be such that there is still a re-entering angle on one hand and a salient angle on the other, which will result from the mutual incidences of the faces produced by the decrements.

In certain cases the plane of junction, on which the two halves of the crystal are joined, is situated parallel to one of the faces of the nucleus, and the assortment does not admit of presenting a re-entering angle opposed to a salient angle.

The Abbé Haüy has given to these reversed crystals the name hemi-tropes, denoting one-half reversed. Romé de L'Isle calls them *macles*. But this name being already applied to a very common species of mineral, Haüy thought proper to avoid the double application of the term.

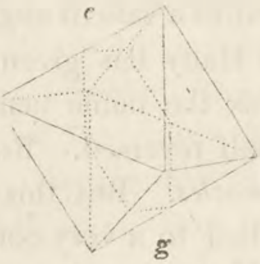
The *transposed spinel*, exhibits striking example of the transposition of the faces of certain crystals. The primitive form of the spinel or true ruby, is a regular octahedron, Fig. 95, composed of two four-sided

95.



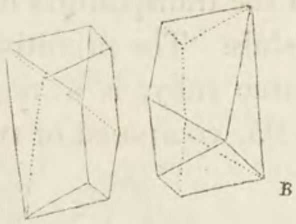
pyramids applied base to base, with equilateral triangular faces. Now, if we conceive that this solid be cut obliquely from *e* to *g*, Fig. 96,* into two halves,

96.



as shown by A B, Fig. 97, and that one-

97.



half of the crystal, for example B, had turned

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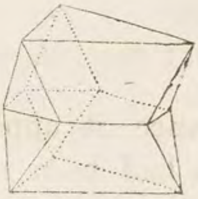
* Model, No. 46.

upon the other half A, in a quantity equal to a sixth part of a circle; the crystal would present itself as shewn, Fig. 98,* exhibiting a solid with alternate salient and re-entering angles.

98.



The ores of tin, also present some very singular hemi-trope crystals. The so called twin crystal of oxide of tin, is very common It consists of a four-sided prism, terminated at each extremity by a four-sided pyramid †, which, by a transposition

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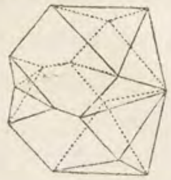
* Model, No. 46.

† Model, No. 47.

of the parts, presents itself as shown, Fig. 99.

99.



In this instance it appears as if an oblique section had been made, and the two portions had turned half round on each other, so as to form at each extremity two re-entering angles*.

Another accident, extremely common, is the manner in which grouped crystals are inserted into each other. This kind of apparent penetration is subject to so many diversities, that frequently, among crystals of the same groupe, we do not find two relative positions resembling each other. But although, in general, the positions in grouped crystals are infinitely variable, we find, on a closer examination, that they are

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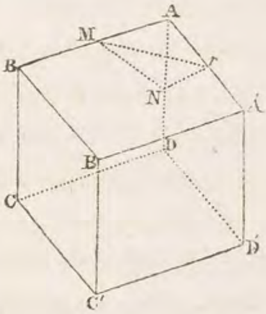
* Model, No. 48.

subjected to certain laws always analogous to those of the structure; and that these crystals, instead of being tumultuously precipitated on each other, have in some measure concerted their arrangement.

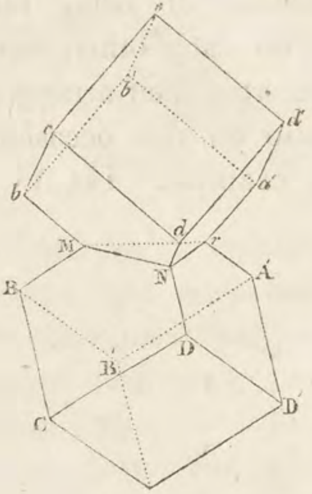
Let us also on this occasion choose a very simple example. Let A C′, Fig. 100, be a cube, and M N *r* an equilateral triangular facet, produced in the place of the angle A, in virtue of a decrement by one range round this same angle.

100.



Let us suppose a second cube modified in the same manner, and affixed to the former by the facet which results from the decrement indicated by M, N, *r*. We shall thus have the assortment represented by Fig. 101*.

101.



We may now conceive that one of the two cubes, that, for example, which is placed below, is increased in all its dimensions, except at the places where the other forms an obstacle to it. In proportion as this increment becomes more considerable, the upper cube will be more and more enveloped in the inferior one, and it may even finish by being entirely masked or concealed by it.

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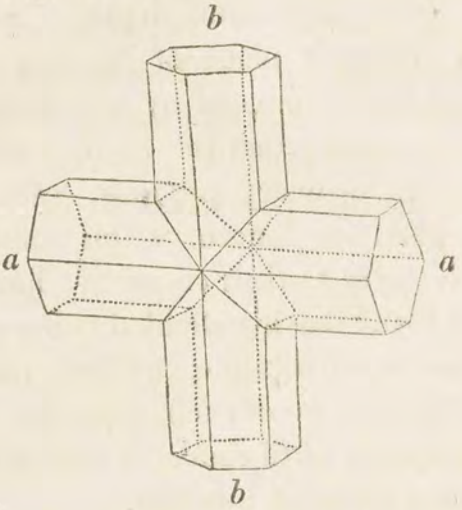
* Model, No. 49.

We observe crystals effectually sunk into each other at various depths; but which have always a plane of junction situated like a face produced by a decrement, in such a manner that the two structures follow their ordinary progress, each on its own part, the length of this same plane, which serves as their respective limit. The Abbé Haüy having divided cubes of fluate of lime inserted into each other, remarked, that the laminæ of each, extended without interruption, until suddenly stopped by the common plane of junction.

The example now quoted relates to a very simple and very regular law of decrement. But frequently the laws which determine the plane of junction are more or less remote from this simplicity, and there are a few which are somewhat extraordinary.

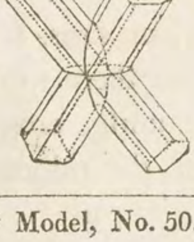
When two prisms cross towards the middle of their axis, there are two planes of junction, which unite, crossing each other as is the case in the mineral called staurolite, Fig. 102*,

102.



If the two prisms *a a* and *b b* cross each other, as in Fig. 102, at right angles, the mineral receives the name of rectangular staurolite. If the two prisms cross each other oblique, as Fig. 103, it is called

103.



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* Model, No. 50.

oblique angled staurolite. In Fig. 103, the prisms intersect each other at an angle of 60°; and it may be demonstrated, that the planes also have positions analogous to those which would be determined immediately by the known laws of decrement.

SECTION II.

ELECTRICITY OF CRYSTALS AS CONNECTED WITH THEIR GEOMETRICAL FORM, AND CRYSTALLINE SYMMETRY —ELECTRIC POLES; THEIR SITUATION, AND MODES OF DISTINGUISHING THEM, &c.

THERE appears to exist a singular relation between the forms of such crystals as possess the capability of becoming electric by heat or friction, and their crystalline symmetry. All those crystalline bodies as are susceptible of becoming electric by heat or friction, Haüy has observed, deviate remarkably with regard to the symmetry of their faces.

The parts in which the two electricities reside, though similarly situated at the two extremities of the crystal, differ materially in their configuration; one of them undergoes decrements, which are evanescent upon the opposite part, or to which decrements correspond that are subjected to another law; which may enable an observer to predict beforehand, simply from the inspection of the crystal, on what side either species of electricity will be found, when the crystal shall be submitted to the test of experiment.

The electrical state of minerals is either *plus* or *minus*, [positive or negative.] Haüy has found, that each of the minerals has always at least two points, of which one is the seat of positive, or *plus*, and the other that of negative, or *minus* electricity. To these points, which are always placed in two opposite parts of the mineral, Haüy gives the name of *electric poles*. To distinguish these poles one from the other, a very simple apparatus has been adopted. It consists of a needle of silver or of brass, terminated at its extremities by two globules. This needle, like the common compass needle, is moveable upon a pivot, or stem, having a very fine point, and at the bottom a broad base or foot. This stem with the needle are insulated by placing them upon a cylindrical support of resin. To use this apparatus we place a finger of the left hand upon the foot or base of the upright stem, and taking into the right hand a stick of sealing wax which has been rubbed, present it, during a second or two, at a small distance from the stem; this being done, we withdraw first the finger, and afterwards the stick. Thus will the needle be found electrified minus; in such manner that, according as we bring near to one of the globules, the negative or the plus pole of a crystal electrified by heat, the globule is attracted or repelled. The electricity of the needle will be preserved a quarter of an hour or longer, and we may, while generating it, render it either very sensible or very weak, (according as it may be required for the experiment proposed) by varying the distance between the stem and the stick of sealing wax.

The *tourmalin*, being the first in which the property of becoming electric by heat was traced, and which crystallises usually in nine-sided prisms four sides, terminated by three, six, nine, or more sided pyramids. When this crystal is at the ordinary temperature, it is only susceptible of being electrified by friction, and in that case the part rubbed always acquires positive electricity. But if a tourmalin be gently heated, it becomes electric; and if its two extremities be afterwards presented alternately to the little globe, we shall observe that the one attracts and the other repels that globe, from which we may ascertain the poles wherein the respective electricities reside. That side which terminated by the pyramid is positive, the other negative. When the crystal is of a large size, flashes of light may be seen along its surface. Now it may be conceived that the tourmalin, having only its natural quantity of electricity, which is alone acted on, if its positive pole is turned towards the globule, it will be in the same case as if it were solicited singly by a quantity of positive electricity whose force was equal to the difference between the forces of its two poles, arising from the different distances at which they act: therefore the globule will be repelled. Similar reasoning will prove that, on the contrary, attraction ought to be evinced, if the tourmalin is presented to the globule by its negative pole.

But if the needle were not insulated, it is easy to conceive that the presence of either of the poles of the tourmalin would generate, in the globule nearest to that pole, an electricity contrary to its own; whence it follows that the globule would, in this case, be constantly attracted.

If one of the poles of the tourmalin be presented to light bodies, such as grains of ashes, or saw-dust, each grain, becoming in like manner a slight electric body, whose part turned towards the pole which acts upon it has acquired a contrary electricity to that of such pole, will be carried towards the tourmalin. Having arrived at contact, it will generally remain applied there; for the tourmalin, which is a non-conducting body, not being able to communicate its electricity to the light body, all will continue in the same state as before. It often enough happens, however, that some of these grains are repelled as soon as they have touched the stone. This effect obtains when the minute body has met with some ferruginous or other conducting particles, situated at the surface of the tourmalin. In such case, if it be supposed for example that this particle possessed negative electricity, a portion of its electricity will pass to the contiguous part of the little body, which is occupied by the positive electricity, and will unite or restore the equilibrium. Then the negative electricity which enveloped the other part of the little body finding itself in excess, that body will be entirely in the negative state; whence it must follow, that the conducting moleculæ, which is in a similar state, will repel it. Hence we see in what manner those authors must be understood, who assert, that the tourmalin is attracted and repelled indifferently by its two ends, without producing those constant effects of attraction on one side, and repulsion on the other, which we have ascribed to it. These latter effects only take place with a tourmalin placed opposite a body which is already itself in a certain state of electricity. The others, which are variable, have respect to the case where the bodies on which the tourmalin acts were previously in their natural state.

In a tourmalin the electric densities diminish rapidly in departing from the extremities, so that they are nothing, or next to nothing, in a sensible space situated towards the middle of the prism: of consequence, the centres of action are situated near the extremities. It may be rendered perceptible to a certain degree, by moving a tourmalin to and fro that has one of its faces opposite one of the globules of the little needle: we shall observe that this globule has a marked tendency towards one point of the crystal; but when it corresponds with the mean part, so that the two centres of action are each equally remote from it, we shall not find any motion, except a mere fluttering or vibration given to the globule.

Two electrical crystals of tourmalins presented one to another, mutually attract by the poles animated with contrary electricities, and repel mutually by the poles which shew the same kind of electricity.

If we heat two tourmalins, and after having laid one of them across upon a flat piece of cork, floating on the surface of water, we select one of its poles, and to it present successively the two poles of the tourmalin. When the poles thus brought near to one another have different electricities, we shall see the floating tourmalin move towards the other, and follow it in all its motions. If, on the contrary, the neighbouring poles are solicited by opposite states of electricities, the floating tourmalin will turn about to present itself to the other by the contrary pole, and then approach to it in virtue of the electric attraction.

The tourmalin begins to evince electricity when it has arrived at a certain elevation of temperature [of about 212°, F.] But among bodies of this species there exist some to which we need only, as it were, shew fire, that they should manifest their electricity. If the tourmalin be more and more heated, there will be a term where it will cease to yield signs of the electricity. It often happens that after having withdrawn it from the fire, we are obliged to leave it to return of itself to a moderate temperature, that it should have any action upon the little bodies which are presented to it. But it would seem that beyond the term where its electricity has become insensible through the action of too strong a heat, there is another where its effects are reproduced in an inverse sense. We have caused the foci of two burning glasses to fall upon the extremities of a tourmalin, and have observed that each pole, after having acquired its ordinary electricity, would next cease to act, and lastly would pass to the opposite state; so that the attraction, after having become zero, would give place to repulsion, or reciprocally.

If a tourmalin be broken at the moment when it manifests its electricity, each fragment, however small it may be, has its two moieties in two opposite states, in like manner as the entire tourmalin; which must at first appear very singular, since this fragment, supposing for example it were situated at one of the extremities of the crystal still whole, would then be solicited only by a single kind of electricity. This difficulty may be happily resolved by the help of a very plausible hypothesis similar to that advanced by Coulomb with regard to such magnetic bodies as present the same singularity, that is to say, by considering every integrant particle of a tourmalin to be itself a little tourmalin provided with its two poles. It hence results that in the entire tourmalin there will be a series of poles alternately plus and minus; and such are the quantities of free electricity which appertain to these different poles, that in all the half of the tourmalin yet unbroken, which manifests the plus electricity, the plus poles of the integrant moleculæ are superior in force to the minus poles in contact with them; while the contrary obtains in the half which manifests the minus electricity: whence it follows that the tourmalin is in the same state (speaking generally) as if each of its halves were only solicited by quantities of plus or minus electricity equal to the differences between the fluids of the neighbouring poles. Now, if the crystal be cut at any place whatever as the section can only take place *between* two moleculæ, the part detached will necessarily commence with a pole of one kind, and terminate with a pole of a contrary nature.

In the variety of the tourmalin, which Haüy calls *isogone*, the shape of which is that of a nine-sided prism, terminated at one end by a summit having three faces, and at the other by a summit having six faces; and experiments prove that the first summit is the seat of minus electricity, while the second manifests plus.

Of all the crystals that exhibit this correlation between the exterior configuration and the electric agency, the most remarkable are those which appertain to the mineral named *boracite* or *borate of magnesia*, whose form is, generally, that of a cube truncated, or incomplete on all its edges, and farther bevelled, that is to say, modified by facts corresponding to the solid angles. Here the two electricities act according to the directions of four axes, each of which passes through two opposite solid angles of the cube. In one of the varieties which Haüy calls *defective*, one of the two solid angles situated at the extremities of the same axis is entire, the other has given way to a decrement or facet. Now minus electricity is evinced at the angle which has not undergone any alteration, and plus at the facet which supplies the place of the opposite angle; thus making eight electric poles, four positive and four negative.

We may now ask whether, in the midst of the imposing apparatus of our artificial machines, and of that diversity of phenomena which it presents to the astonished eye, there is any thing more calculated to excite the interest of philosophers than these little electrical instruments executed by crystallisation, than this combination of distinct and contrary actions, confined within a crystal whose greatest dimension is probably less than a twelfth of an inch?

Of the series of crystals of the mineral kingdoms which become electric simply by heat, the following are the most conspicuous:—Borate of magnesia, Brazilian topaz, Tourmalin, Phrenite, Crystallised Oxide of zinc, or Electric Calamine, Siberite, Lepidolite, Kaupolite.

SECTION III.

DOUBLE REFRACTION OF CRYSTALS.—MEANS EMPLOYED FOR OBSERVING IT—MINERALS POSSESSING THE POWER OF DOUBLE REFRACTION.

WHEN a ray of light passes obliquely from one medium into another of a different density, it is bent out of its straight course, and assumes a new direction. This deviation which is called *refraction*, is subjected to a constant law.

Certain substances have the singular property to solicit the ray which penetrates them to divide itself into two parts which follow two different directions. This is called *double refraction ;* hence objects seen through them appear double.

When the refraction is simple, we only perceive a single image of an object seen through two faces of the solid employed on this occasion, whereas, if it were double, we might in the same case see two images of the object. This property was first noticed by Erasmus Bartholinus, by looking at the image of a line, through a transparent rhomboid of carbonate of lime which came from Iceland, and hence called Iceland crystal, or double refracting spar.

If a ray of light be received perpendicularly upon a plane surface of this crystal, one part of it passes through without altering its direction; another part on the contrary is refracted in a plane parallel to the diagonal, joining the two obtuse angles of the crystal, so that objects seen through it appear double. This property no doubt depends on the particular arrangement of the crystalline laminæ composing the crystal. In order to obtain this effect with most of the crystals endowed with the property in question, we must choose two faces of the crystal inclined towards each other, whether we employ a crystal given by nature or a piece cut by the lapidary.

The quantity of double refraction, or, what comes to the same thing, the opening of the angle formed between each other by the rays, by means of which the eye sees the two images, varies from one substance to the other, every thing else being considered according to the nature of the substances themselves.

In the zircon, for instance, the double refraction is very strong, whereas it is much less perceptible in the emerald. Besides, this quantity varies in every substance, from various causes. In general it increases or diminishes, according as the refrangent angle, or that which is formed between each other by the two faces, through which we view objects, is more or less open.

But there is another cause of variation, which is combined with the foregoing, and which depends on the position of the refrangent surfaces relatively to the faces of the primitive form: and such is the influence of this cause, that under two equal refrangent angles differently situated, we may have distances evidently unequal between the images of the same object, and there is even a limit at which the effect of the double refraction becomes null, *i. e.* the two images are then confounded into one.

This limit takes place, for instance, in rock crystal or quartz and in the emerald, when one of the faces which belong to the refrangent angle is perpendicular to the axis. It takes place in sulphate of barytes, when one of the same faces being parallel to the axis, is at the same time parallel to a plane which should pass by the great diagonals of the bases of the primitive form.

There is a second method employed for observing the double refractive power. It consists in taking a pin by the point, and presenting it against the window at a certain distance from the eye, against which we keep at the same time the mineral applied by one of its faces. By making the pin assume various positions, we shall find that there is one in which we see two distinct images of the pin parallel to each other, and generally prismatic *(irisées)*. Then, if we gently turn the pin until it is perpendicular to its first position, we shall see the two images approach by degrees, until they fall upon one and the same line, in such a manner, however, that one of the two heads will frequently exceed the other. We may also make use of a card on which we have traced a line with ink of a good tint.

When the double refraction is not considerable, it may happen that the two images touch each other. But, upon attentively examining the head of the pin, we can distinguish at this place as it were two small circles which intersect each other: and besides, we shall observe that the same colour which edges on one side the prismatic band reappears on the line of the middle part, where the same series recommences.

The separation between the images is

more sensible, the distance between the object and the eye and all other circumstances being alike, when the diaphanous body used in the experiment is of a greater thickness. And if we suppose this thickness, in its turn, to be constant, and the object removed from the eye, the two images will be more and more removed from each other, at the same time that they will be diminished in distinctness.

The following is a third advantageous process for short-sighted people. Place a lighted candle at a certain distance in a dark room. Having afterwards made a a hole in a card with the point of a pin, apply it to one of the faces of the stone, so as to make the hole correspond to a point of this face; then having approached with the eye the opposite face, seek the position proper for enabling you to perceive the flame of the candle. You will then have the two images distinct and well defined, because the effect of the hole made with the pin is to dismiss the kind of irradiation which dazzles them, when we employ the stone by itself.

If a ray of light which has suffered double refraction from one crystal be received by another crystal, placed in a similar and parallel position, there is no division of the image.

But if the second crystal be placed so that its planes of perpendicular refraction are at right angles to those of the first crystal, there then is a new phenomenon, and that part of the ray which before passed through the ordinary refraction, removes the extraordinary one. And reciprocally, that which underwent the ordinary refraction suffers the extraordinary one.

If the second crystal be moved gradually round in the same plane, when it has made a quarter of a revolution, there will be four divisions of the ray, and they will be reduced to two in the half of the revolution, so that the refractive power depends upon the relation of the arrangement of the particles of the crystal with regard to the rays passing through them.

The minerals, which possess the power of double refraction, are the following:

Iceland spar, sulphate of lime, sulphate of barytes, sulphate of strontia, quartz or rock crystal, zircon, emerald, corundum, euclase, arragonite, feldspar, peridote, sulphur, carbonate of lead, sulphate of iron.

PART IV.

SECTION I.

PRINCIPLES OF CRYSTALLOGRAPHIC NOMENCLATURE—APPLICATION OF THE WORD PRIMITIVE—SECONDARY FORMS CONSIDERED WITH RESPECT TO THE MODIFICATIONS WHICH THEY PRESENT OF THE PRIMITIVE FORM—SECONDARY FORMS CONSIDERED IN THEMSELVES, AND AS BEING PURELY GEOMETRICAL—SECONDARY FORMS CONSIDERED RELATIVELY TO CERTAIN FACETS, OR CERTAIN RIDGES, REMARKABLE FOR THEIR ARRANGEMENT OR POSITION—SECONDARY FORMS CONSIDERED RELATIVELY TO THE LAWS OF DECREMENT ON WHICH THEY DEPEND, &c.

IF the language of mineralogy has been so long defective, from the bad choice of specific expressions, the almost total deficiency of names with respect to the varieties of crystallisation has left a void, which was no less an inconvenience. There was no exception, except with respect to a small number of these varieties, the forms of which were so simple that they would suggest as if of themselves the epithets of *cubical*, *octahedral*, *dodecahedral*, &c. which ought to be added to the names of the species. The more compound forms were indicated by definitions, the length of which was in some measure proportional to the number of the facets; or, if it was wanted to abridge these definitions, by borrowing them from a resemblance between the crystal and some familiar object*, this was done with so little rationality, that it would have been desirable for the honour of the comparison if such names were less known.

Convinced of the necessity of introducing the utmost precision into this part of

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* The following are examples of this kind; *nail-headed calcareous spar*, *dog-toothed calcareous spar*, &c.

mineralogical language, so much neglected hitherto, Haüy has attempted to designate the various crystalline forms by simple and significant names, taken from the characters of these forms, or from the properties which result from their structure, and from the laws of decrement on which they depend. We shall here present the readers with the series of these names, under the form of a methodical system. We hope that those who peruse it with attention will find an assistant for engraving these names on their memory, by connecting them with considerations which are easily classified in the mind. They will perceive that, by a kind of economy of language, extremely useful in such cases, the same name is frequently applicable to varieties taken in different species. It is true that on one hand the word which serves to designate such a variety might also serve another variety of the same species. For example: Haüy denominates *binary*, a form which depends on a decrement by two ranges. Now supposing this decrement to take place on the edges, it is possible that another variety of the same substance may be owing to a decrement which takes place by two ranges on the angles. But in this case the system will present for the latter another name borrowed from a different consideration. The inconvenience just mentioned is common to all nomenclatures, and seems unavoidable. Thus, in the language of botany, one variety will bear the name of *crassifolia*, or of *rotundifolia*, while another variety of the same species shares with the first the character which has served to distinguish it. The essential requisite is, that the method should be copious enough to furnish at least to all the known wants of science. It is presumed that, by means of this attempt, a great part of the forms which shall be discovered in future will be found to have been named beforehand; and as to those which require new names, we shall have at least a system from which to designate them. In all descriptions of researches, it becomes easier to go forward when the route is traced.

Principles of the Nomenclature.

The primitive form of any given substance is always designated by the word *primitive* added to the name of the species.

Examples:—*Primitive zircon*, *primitive carbonate of lime*, *primitive sulphate of lime*, &c.

We may consider secondary forms:—

1. With respect to the modifications of the primitive form, when the faces of the latter are combined with those which result from the laws of decrement.

2. By themselves, and as purely geometrical forms.

3. With respect to certain facets or certain ridges remarkable by their assortment or their positions.

4. With respect to the laws of decrements on which they depend.

5. With respect to the geometrical properties which they present.

6. Finally, with respect to certain particular accidents.

1. *Secondary forms considered with respect to the modifications which they present of the primitive form.*

The crystal is called,

Pyramidated (pyramidé), when the primitive form being a prism, has on each of its bases a pyramid which has as many faces as the prism has sides.

Example: Pyramidated phosphate of lime.

Prismated (prismé), when the primitive form being composed of two pyramids joined at their bases, these pyramids are separated by a prism.

Ex. Prismated zircon, prismated quartz.

Semi-prismated, when there is only the half of the number of ridges situated around the common base, which are intercepted by faces.

Example. Semi-prismated sulphate of lead.

Based (basé), when, the primitive form being a rhomboid, or an assemblage of two pyramids, the summits are intercepted by facets perpendicular to the axis, and performing the function of bases.

Ex. Based carbonate of lime, based sulphur.

Pointed (epointé), when all the solid angles of the primitive form are intercepted by solitary facets.

Ex. Pointed mesotype.

We shall also use the terms *bi-pointed (bisépointé)*, tripointed *(triépointé)*, quadripointed *(quadriépointé)*, according as each solid angle may be intercepted by two, three, or four facets.

Ex. Tripointed analcime, quadripointed sulphuret of iron.

Marginated (emarginé), when all the ridges of the primitive form are each of them intercepted by a facet.

Ex. Marginated garnet.

We shall also use the term *bi-marginated*, *tri-marginated*, as each ridge is intercepted by two or three facets.

Example. Tri-marginated garnet.

Peri-hexahedral, *peri-octahedral*, *peri-decahedral*, *peri-dodecahedral*, when the primitive form being a prism with four sides, is changed by the effect of decrements into a hexahedral, octahedral, decahedral, or dodecahedral prism.

We also denominate *peri-dodecahedron* a crystal, the nucleus of which being a regular hexahedral prism, has its six longitudinal ridges intercepted by as many facets.

Ex. Peri-hexahedral sulphate of copper, peri-dodecahedral emerald.

Recurved (raccourci), when the primitive form being a prism with rhombic bases, the longitudinal ridges contiguous to the grand diagonal are intercepted by two facets, which make it appear diminished in the direction of its length.

Ex. Recurved sulphate of barytes.

Retreated (rétréci), when the primitive form being a prism with rhombic bases, the longitudinal ridges contiguous to the small diagonal are intercepted by two facets which make it appear diminished in the direction of its breadth.

Example. Retreated sulphate of barytes.

2. *Secondary forms considered in themselves, and as being purely geometrical.*

The crystal is called,

Cubical, when it presents the form of the cube, which in this case is always secondary.

Ex. Cubical fluate of lime.

Cuboidal, when its form differs a little from the cube.

Ex. Cuboidal carbonate of lime.

Tetrahedral, when it presents the form of the regular tetrahedron, as a secondary form.

Ex. Tetrahedral sulphuret of zinc.

Octahedral, when it presents the form of this solid, as secondary.

Example. Octahedral muriate of soda.

Prismatic, when it has the form of a straight or oblique prism, the panes of which are inclined one hundred and twenty degrees among each other.

Ex. Prismatic carbonate of lime, prismatic feldspar.

Dodecahedral, when its surface is composed of twelve triangular, quadrangular, or pentagonal faces, all equal and similar, or solely of two measurements of different angles.

Ex. Dodecahedral quartz, dodecahedral zircon, dodecahedral sulphuret of iron.

If the dodecahedron had not all its faces of the same number of sides, it would be sufficient to bring them to this aspect in imagination, by varying its dimensions.

Icosahedral, when its surface is composed of twenty triangles, of which twelve are isosceles, and eight equilateral.

Example. Icosahedral sulphuret of iron.

Trapezoidal, when its surface is composed of twenty-four equal and similar trapezoids.

Ex. Trapezoidal garnet.

Triacontahedral, when its surface is composed of thirty rhombuses.

Ex. Triacontahedral sulphuret of iron.

Enneacontahedral, when its surface is composed of ninety faces.

Ex. Enneacontahedral idocrase.

Birhomboidal, when its surface is composed of twelve faces, which being taken by sixes, and lengthened in imagination until they intersect, would form two different rhomboids.

Ex. Birhomboidal carbonate of lime.

We say *trirhomboidal* in the same manner.

Ex. Trirhomboidal carbonate of lime.

Biform, *triform*, when it contains a combination of two or three remarkable forms;

such as the cube, the rhomboid, the octahedron, the regular hexahedral prism, &c.

Example. Triform sulphate of alumine.

Cubo-octahedral, *cubo-dodecahedral*, *cubo-tetrahedral*, &c., when it contains a combination of the two forms indicated by these expressions.

Ex. Cubo-octahedral fluate of lime, cubo-dodecahedral sulphuret of iron, cubo-tetrahedral gray copper.

Trapezian, when its lateral surface is composed of trapezia situated on two rows between two bases.

Ex. Trapezian sulphate of barytes.

Ditetrahedral, i. e. twice tetrahedral, when its form is that of a tetrahedral prism with dihedral summits.

Ex. Ditetrahedral grammatite.

Dihexahedral, when it forms a hexahedral prism with trihedral summits.

Ex. Dihexahedral feldspar.

We say in the same manner, *dioctahedral*, *didecahedral*, *didodecahedral*.

Example. Dioctahedral topaz, didecahedral feldspar, didodecahedral phosphate of lime.

Trihexahedral, *tetrahexahedral*, *pentahexahedral*, *heptahexahedral*, when its surface is composed of three, four, five, seven rows of facets disposed in sixes the one above the other.

Ex. Trihexahedral nitrate of potash, pentahexahedral quartz, heptahexahedral nitrate of potash.

We also say in the same manner, *tridodecahedral*.

Ex. Tridodecahedral sulphureted antimonial silver.

Trioctahedral.

Ex. Trioctahedral sulphuret of lead.

Bigeminated, when it presents a combination of four forms, which, taken by twos, are of the same species.

Ex. Bigeminated carbonate of lime.

Amphihexahedral, i. e. *hexahedral* in two ways, when by taking the faces according to two different directions, we have two hexahedral contours.

Example. Amphihexahedral axinite.

Sexdecimal, when the faces which belong to the prism or to the middle part, and those which belong to the two summits, are the former six in number, and the latter ten in number, or *vice versâ*.

Ex. Sexdecimal feldspar.

In the same manner we say *octodecimal*.

Ex. Octodecimal feldspar.

Sexduodecimal.

Ex. Sexduodecimal carbonated lime.

Octoduodecimal.

Ex. Octoduodecimal sulphuret of copper.

Deciduodecimal.

Ex. Deciduodecimal feldspar.

Peripolygonal, when the prism has a great number of sides.

Example. Peripolygonal tourmaline.

Supercomposite, when the form is very much compounded.

Ex. Supercomposite tourmaline.

Antienneahedral, i. e. having nine faces on two opposite sides, is a name peculiar to a variety of the tourmaline, in which the two summits are of nine faces, and the prism of twelve sides; whereas, generally, the prism is enneahedral.

Prosenneahedral, i. e. having nine faces on two adjacent parts, is another variety of the tourmaline, in which the prism and one of the two summits have each nine faces.

Recurrent, when, on taking the faces of the crystal by annular rows, from one extremity to the other, we have two numbers, which succeed several times, as, four, eight, four, eight, four.

Ex. Recurrent oxid of tin.

Equidifferent, when the numbers which

designate the faces of the prism and those of the two summits, which in this case differ from each other, form the commencement of an arithmetical series, as, six, four, two.

Example. Equidifferent amphibole.

Convergent, when in the foregoing case the series is sensibly convergent, as, fifteen, nine, three.

Ex. Convergent tourmaline.

Unequal (impair), when the numbers which designate the panes of the prism and the faces of the two summits, considered as different from each other, are all three unequal, without being in other respects in progression.

Ex. Unequal tourmaline.

Hyper-oxidated, i. e. *acute to excess*, is a variety of carbonated lime, which contains the combination of two rhomboids; the one acute, which is the inverse; the other incomparably more acute.

Spheroidal, is said of the diamond with forty-eight bombated faces.

Plano-convex, is the diamond with some plane and some curvilinear faces.

3. *Secondary forms considered relatively to certain facets, or certain ridges, remarkable for their arrangement or position.*

The crystal is called,

Alternate, when it has on its two parts, the one superior and the other inferior, faces which alternate among each other, but which correspond on both sides.

Example. Alternate quartz.

Bisalternate, when in the foregoing case the alternation takes place, not only among the faces of one and the same part, but also among those of the two parts.

Ex. Bisalternate carbonate of lime, bisalternate quartz.

Bibisalternate, when there are on both sides two orders of bisalternate facets.

Ex. Bibisalternate sulphuret of mercury.

Annulary, when a hexahedral prism has six marginal facets ranged in form of a ring around each base.

Example. Annulary emerald.

We say the same of an octahedral prism with eight marginal facets around bases.

Ex. Annular oxide of tin.

Monostic, when a prism of any given number of panes has, in the contour of each base, a row of facets in number different from that of the sides, and which may be all marginal, or some marginal and others angular.

Ex. Monostic topaz.

Distic, when in the same case there are two rows of facets around each base.

Ex. Distic topaz.

Subdistic, when among the facets arranged on one and the same row around each base, two are surmounted each by a new facet, which is as it were the rudiment of a second row.

Example. Subdistic peridot.

Plagihedral, when the crystal has facets situated in a slanting direction.

Ex. Plagihedral quartz, plagihedral zircon.

Dissimilar, when two rows of facets, situated the one above the other, towards each summit, have a defect in symmetry.

Ex. Dissimilar topaz.

Squared (encadré), when it has facets which form kinds of squares around faces of a simpler form already existing in the same species.

Ex. Squared fluate of lime.

Slightly prominent (prominule), when it has ridges which form a very slight eminence.

Ex. Slightly prominent sulphate of lime.

Zonary, when it has around its middle

part a row of facets, which form a kind of zone.

Example. Zonary carbonate of lime.

Apophanous, i. e. *manifest*, when certain facets or certain ridges present some indication useful for ascertaining the position of the nucleus, which would otherwise be difficult to find out, or even to determine, either in point of direction or the measurement of the decrements.

Ex. Apophanous feldspar, apophanous sulphuret of antimoniated silver, apophanous gray copper.

Blunted (emoussé), when it has facets which intercept, and render as if blunted, some parts which would otherwise be sharper than the rest.

Ex. Blunted axinite, blunted carbonate of lime.

Contracted, is a dodecahedral variety of carbonated lime, in which the bases of the extreme pentagons undergo a kind of contraction, in consequence of the inclination of the lateral faces.

Dilated, is said of another dodecahedral variety of carbonated lime, in which the bases of the extreme pentagons undergo a kind of dilatation, in consequence of the inclination of the lateral faces.

Acuteangled, is a variety of carbonated lime in a hexahedral prism, the solid angles of which are intercepted by very sharp triangular facets.

Defective, is a variety of borated magnesia, in which four solid angles of the primitive cube are intercepted by facets, while the opposite angles remaining untouched, are subject to a kind of defect.

Superabundant, is another variety of borated magnesia, in which the solid angles which were untouched in the defective variety, are intercepted each by four facets, in such a way as to make a superabundance where there was a defect.

4. *Secondary forms considered relatively to the laws of decrement on which they depend.*

The crystal is called,

Unitary, when it undergoes only a single decrement by one row.

Example. Unitary telesia.

If there are two, three, four decrements by one row, we say bisunitary, triunitary, quadriunitary.

Ex. Triunitary peridot, bisunitary carbonate of lime.

Binary, bibinary, tribinary, &c. in the case of one, two, and three decrements by two rows.

Ex. Binary oligist or specular iron, bibinary feldspar.

Ternary, biternary, &c. in the case of one, two decrements, &c. by three rows.

Unibinary, if there are two decrements, the one by one row, the other by two; *uniternary*, if there is one by one row, and the other by three; *binoternary*, if there is one by two, and the other by three, &c.

Example. Uniternary carbonate of lime, binoternary carbonate of lime.

The nomenclature in all the foregoing expressions, as well as in those which follow, makes an abstraction of the faces parallel to those of the nucleus, which exist most frequently in the secondary crystal.

Among the forms in which the nucleus is entirely disguised, some have names borrowed from different considerations; and those which remain are so few in number, that I thought it unnecessary to complicate the language by employing a particular designation for them.

In order to avoid confounding the words which express the decrements with those which indicate the number of the faces, we may remark, that the former have their termination in *hedral*, as dodecahedral, or in *al*, as octodecagonal, whereas the others end in *ary*.

Equivalent, when the part visible *(exposant)* which indicates a decrement is equal to the sum of those which indicate the others.

Example. Equivalent sulphat of iron.

Subtractive, when the part visible relative to a decrement is less by unity than the sum of those which indicate the others.

Ex. Subtractive pyroxene.

Additive, when the part visible relative to a decrement exceeds by unity the sum of those which indicate the others.

Ex. Additive sulphat of copper.

Progressive, when the parts visible form a commencement of arithmetical progression; as one, two, three.

Ex. Progressive tourmaline.

Disjointed, when the decrements form an abrupt leap, as from one to four or four to six.

Example. Disjointed sulphuretted antimonial silver.

Partial, when there is some part which remains without decrements, while the other parts similarly situated undergo them.

Ex. Partial sulphuret of cobalt.

Subdouble, when the part visible relative to a decrement is the half of the sum of the other parts visible.

Ex. Subdouble topaz.

We say *subtriple*, *subquadruple*, &c. in the same way.

Ex. Subtriple sulphat of copper.

The three parts visible *(exposans)* which compose the indication of an intermediary decrement, count as one only, which is equal to their sum.

Doubling, *tripling*, *quadrupling*, when one of the visible parts is repeated twice, thrice, or four times in one series which would otherwise be regular.

Example. Doubling peridot, quadrupling peridot.

Identical, when the parts visible of the simple decrements, to the number of two, are equal to the terms of the fraction relative to a third decrement which is mixed.

Ex. Identical gray copper.

Isonomous, i. e. *equality of laws*, when the parts visible which indicate the decrements on the edges being equal, those which express the decrements on the angles are equal also.

Ex. Isonomous sulphat of copper.

Mixed, when the form results from a single mixed decrement.

Ex. Mixed telesia.

Pantogenous, i. e. *deriving its origin from all the parts*, when each ridge and each solid angle undergoes a decrement.

Example. Pantogenous sulphat of barytes.

Biferous, i. e. *which carries twice*, when every ridge and every solid angle undergoes two decrements.

Ex. Biferous gray copper.

Surrounded (entouré), when the decrements take place on all the ridges and on all the solid angles around the base of a prismatic nucleus.

Example. Surrounded sulphat of barytes.

Opposite, when a decrement is made by one row, and another is intermediary.

Ex. Opposite oxid of tin.

Synoptic, when the laws of decrement present as it were the picture of those which take place with respect to the whole of the other crystals, or at least with respect to the greatest part.

Example. Synoptic feldspar.

Retrograde, is a variety of carbonat of lime, the expression of which contains two mixed decrements, which are such that the faces resulting from them seem to retrograde, by throwing themselves backward, on the side of the axis opposite to that which looks towards the face on which they originate.

Ascending, when all the laws of decrement have an ascending course, setting out from the angles or lower edges of a rhomboidal nucleus.

Ex. Ascending carbonat of lime.

5. *Secondary forms considered relatively to the geometrical properties which they present.*

The crystal is called,

Isogonous, i. e. *equality of angles*, when the faces which are on parts differently situated, form equal angles between each other.

Example. Isogonous cymophane.

Anamorphic, i. e. *form turned upside down*, when we cannot give it the position most natural to it, without that of the nucleus being as it were turned upside down.

Ex. Anamorphic stilbite.

Rhombiferous, when certain facets are true rhombuses, although, from the manner in which they are cut by the adjoining faces, they do not appear at the first glance to be of a symmetrical figure.

Ex. Rhombiferous quartz.

Equiaxis, when it has the form of a rhomboid the axis of which equals that of the primitive rhomboid.

Ex. Equiaxis carbonat of lime.

Inverse, when it has the form of a rhomboid the salient angles of which are equal to the plane angles of the primitive rhomboid, and *vice versâ*.

Example. Inverse carbonat of lime.

Metastatic, i. e. *transferred*, when it has plane angles and solid angles equal to those of the nucleus which are thus transferred to the secondary form.

Ex. Metastatic carbonat of lime.

Contrasting, when it has the form of a very acute rhomboid, in which an inversion of angles similar to that which takes place in the inverse presents a kind of contrast, in so far as it resembles in another part a very obtuse rhomboid.

Ex. Contrasting carbonat of lime.

Persisting, is a variety of carbonat of lime in which certain faces are cut by the adjoining faces, so that they preserve the same measurements of angles which they would have had without that, except that these angles have other respective positions.

Ex. Persisting carbonat of lime.

Analogic, when its form presents several remarkable analogies.

Example. Analogic carbonat of lime.

Paradoxal, when its structure presents singular and unexpected results.

Ex. Paradoxal carbonat of lime.

Complex, when its structure is complicated by laws not very common, as when it is produced by decrements some mixed and others intermediary.

Ex. Complex carbonat of lime.

6. *Secondary forms considered relatively to certain particular accidents.*

The crystal is called,

Transposed, when it is composed of two halves of an octahedron, or of two portions of another crystal, one of which seems to have turned upon the other in a quantity equal to a sixth of its circumference. See page 356. Model, No. 46.

Example. Transposed spinel, transposed sulphuret of zinc.

Hemi-trope, i. e. *one half reversed*, when it is composed of two halves of one and the same crystal, one of which seems to be reversed.

Ex. Hemi-trope feldspar. See page 232. Model, No. 45.

Rectangular, a particular name given to the staurotide or staurolite, composed of two prisms which cross at right angles. See page 242. Model, No. 50.

Obliqueangled, a particular name given to the staurotide, composed of two prisms which cross at an angle of sixty degrees. See page 242, Fig. 103.

Sexradiated, a name given to the staurotide, composed of three prisms which cross so as to represent the six radii of a regular hexagon.

Cruciform, a name given to the harmatome, composed of two crystals which form a kind of cross.

Triglyphous, when the striæ considered on three faces united around one and the same solid angle, are in three directions perpendicular to each other.

Example. Triglyphous sulphuret of iron.

Geniculated, when it is composed of two prisms which unite by one extremity, forming a kind of knee.

Ex. Geniculated oxid of titanium.

SECTION II.

AMORPHOUS OR CONFUSED CRYSTALLISATION—BASALTIC COLUMNS—STALACTITES—INCRUSTATIONS—TUFFAS—GEODES—SEPTARIUM—PSEUDOMORPHOSES—PETRIFACTIONS, &c.

When the crystalline moleculæ disseminated in a liquid experience obstacles which affect their tendency to re-unite in conformity to the laws of their mutual affinity, the forms which result from their aggregation have no longer that regularity which belongs to an exact and precise determination. Their edges are blunted, their faces are curved, their pyramids are obliterated. Hence the crystals called *lenticular*, or which imitate the form of a lentil; *cylindroids*, the prism of which is rounded off.

Scopiform, or *fascicular*, consisting of laterally aggregated needle-like and capilliform crystals, diverging from a common center. Thus we have scopiform aggregated crystals of red antimony ore, zeolite, striated red cobalt ore, and capilliform pyrites, &c.

Acicular, or similar to needles. Elongated equally thick prisms, adhering laterally, or in the direction of their length, present this appearance. It occurs often very distinctly in sulphate of barytes, and in the murio-carbonate, or white lead ore.

In a row, which is best characterized by comparing it to a string of pearls. The axis of all the crystals lying in one direction, so as to form a single series.

Globular. A casual aggregation consisting mostly of flattened prisms, which occurs sometimes in cubical or octahedral pyrites.

Rose-like consists of thin or flattened prisms, on whose lateral planes others are assembled, which, by crossing each other in different directions, give to the aggregation a rose-like appearance.

If a multitude of small indeterminable crystals are so intimately connected with each other that they form only one body, we then consider this body as a particular being, and hence the substances which we call *striated*, *fibrous*, &c. and which are formed by the junction of an infinite number of crystalline needles, sometimes parallel, sometimes divergent, and at other times crossing in different directions.

The appellation *amorphous* has been given to substances which present, as it were, the last degree of confused crystallisation, and the vague and indefinable form of which is, as it were, *mute* 'to the eye of the observer.

Basaltic Columns. The natural columns which form the giants' causeway in Ireland, and Fingal's cave in the isle of Staffa, together with the rock on which Edinburgh castle stands, and part of the hill, in the suburbs of that city, called Arthur's seat, are all a very compact variety of that class of rocks called basalt; this rock is in many instances separated into numerous distinct but irregularly shaped columns, consisting of from three to nine sides.*

The two most striking instances of this columnar structure are the giants' causeway in Ireland, and Fingal's cave in the isle of Staffa. The columns of the giant's causeway rarely consist of more than six sides, and are sometimes separated by veins of red ochre; the columns of Staffa often have eight or nine sides.

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* A similar appearance is observable in a mass of clay or starch that has been gradually dried; and in the interior of a mass of block tin: often also in common sand-stone that has been exposed to a sufficient degree of heat.

The separate columns of both places are articulated or disposed to separate transversely so as to form a flat concave and flat convex surface exactly corresponding with each other: and these articulations or transverse fractures sometimes occur so frequently in the same column, that the distance between two of them in many instances does not equal the diameter of the column.

The diameter of these basaltic columns varies from three inches to three feet.

In the general appearance of a mass of columnar basalt, there is great regularity; but the regularity of form in these instances is very different from the effect of crystallisation, it exhibits internally no symmetrical arrangement, the measure of no angle being fixed. Hence it seems that the symmetry is to be ascribed merely to the mutual separation occasioned by the contraction of the mass, and these columns cannot be classed among crystallised bodies.

Stalactites. The water which filters into the fissures of stones situated in the arched part of subterranean cavities, or which oozes through the lax and porous texture of these vaults, arrives at the surface, after dissolving certain stony molecules or becoming combined with it in various ways. The drops which remain suspended from the arch during a certain time, undergo a solidification, which commences on the external surface; and the stony molecules which the liquid gets rid of, exerting their attraction on each other, and attracted at the same time by the side of the vault which they adjoin, form in this place an initial tube, or kind of small ring. This rudiment of tube increases and grows longer by the addition of other drops, which succeed to the first, conducting new molecules which the orifice of the tube attracts in its turn. Sometimes this tube preserves the form of a hollow cylinder, similar to a quill. But frequently it increases in size, and is enveloped with concentric layers, the matter of which is furnished by the liquid which descends along the external surface. It then becomes a thick cylinder or cone ; and sometimes the molecules hollowed out by the drops which thus flow into the interior of its canal, finish by obstructing it entirely. These different modifications are peculiarly sensible in bodies which belong to carbonate of lime.

But a part of the liquid, on falling from the arch upon the ground, forms there other depositions composed of strata generally undulated, or protuberances, the figures of which vary ad infinitum. Lastly, the liquid which flows along the lateral partitions gives rise to bodies, the form of which we might compare to that of a drop of congealed water. Hence *Stalactites* are called those bodies which are formed in the arch of the vault ; and *stalagmites* those which originate from the falling of the liquid on the ground. It is, however, much more convenient to call both *stalactites*, as it is sometimes difficult to distinguish between the two kinds of formation, when the bodies under consideration have been removed from their original position.

Incrustations. In the preceding concretions, the aggregation of the molecules depends more especially on the evaporation and chemical changes of the liquid which has dissolved them. Other concretions, which have been called *tufas*, and *sinters*, proceed from similar causes, and sometimes likewise from a kind of precipitation only of the molecules originally suspended in the liquid. The latter are frequently deposited on the surface of different organized bodies, particularly on those which belong to the vegetable kingdom, and sometimes cover the inside of certain bodies, such as sewers or drains.

Thus, if water impregnated with calcareous matter or other materials, remains long in contact with extraneous substances, an earthy incrustation takes place, that soon excludes the incrusted substance from view; which thus in common language, is said to be petrified: the shape, that is, remaining the same; but the substance in appearance converted into stone. In this manner are formed the so called incrustations or *petrifactions* of birds' nests, moss, leaves, branches of trees, &c. If the process be carried on for a sufficient length of time, and the incrusted body be of a perishable nature, as in the case of vegetable matter, the whole of this is removed by gradual decay, and the remaining mass is entirely earthy: but its form, and the circumstances of its situation, will generally serve to shew its origin.

The warm springs of St. Philippe in Tuscany contain a great proportion of calcareous matter, which they deposit so compactly round substances immersed in them as to be employed for the purpose of obtaining casts, and models, &c. With this view hollow moulds being suspended in the water, the earthy particles are deposited in them; and the deposition, when removed from the mould, preserves the exact impression of it. These incrustations are very delicately, but very firmly compacted; and of a whiteness equal to that of Carrara marble. It is said that there are springs of the same kind near Guanca-Velica in Peru; and that many vases and statues, &c. are placed in the Church of Lima, which have been formed from such depositions as those of St. Philippe.

Osteocolla. The substance so called by the earlier mineralogical writers, from its resemblance to a mass of agglutinated bones, is nothing more than a calcareous deposition that has taken place round small branches and twigs of trees. In many instances the vegetable substance has been removed, and its place supplied by the deposition of fresh earthy matter: seldom however entirely; for in making a transverse section of any of the branches of such a mass, there may be generally observed the trace of a longitudinal cylindrical cavity; which shews that the deposition originally took place on something that has been subsequently removed.

The beautiful mineral called *Flos Ferri* is a stalactite. It is met with at Schemnitz in Stiria in the clefts of sparry or white iron ore; from which circumstance, and the delicacy of its general appearance, it has received the above appellation: but it contains no iron. Count Bournon has conjectured that its form is the effect of sublimation; the direction of the coralloïd branches being too wavy and uncertain to have proceeded from stalactitic deposition. A transverse section of this substance shews a delicate instance of a fibrous radiated texture: the branches are often of a silky lustre externally, owing to an aggregation of very minute crystals, superficially investing them.

Local circumstances, and the degree of celerity with which stalactitic deposition takes place, vary the appearance of the effect produced; and hence those grotesque accumulations which have been described as representing the forms of various animate and inanimate substances: as the fancied figures of lions, &c., in some of the caverns near Buxton, and in other parts of Derbyshire. In the quarries of the island of Antiparos these depositions have been carried to a great extent: an account of the fantastic shapes of which is given in extravagant terms in a letter written to Kircher, inserted in his Mundus Subterraneus *. A passage in Pliny is applicable to this part of the subject:—" Inter plurima alia Italiæ miracula, ipsa marmora in lapicidinis crescere auctor est Papirius Fabianus, naturæ rerum peritissimus: exemptores quoque affirmant compleri sponte illa montium ulcera †." The latter circumstance is often affirmed of the quarries of Antiparos.

When water which has dissolved earthy

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* Vol. I. p. 122—130.

† Nat. Hist. lib. xxxvi.

substances is introduced into a subterranean cavity of small dimensions, where it can remain, the stony molecules incrust the sides of this cavity, which is generally of a round form, and sometimes end by studding it with crystals. This is what has been called *geode.* Some of these bodies contain a solid and moveable nucleus, or a pulverulent earthy matter*: of this description also are certain pieces of silex found in marl. Sometimes also the geode is entirely filled with a matter which may be distinguished by the naked eye from that of which it is itself composed.

The *Septarium* belongs to this class. This substance is an indurated marl, containing numerous veins of carbonate of lime, which divide it into distinct partitions; and hence the term *septarium*: some-

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* It is probably from this that the term *geode* is derived, i. e. a body which contains earth.

times the transverse sections of these partitions are nearly of a square form; and as they then resemble the surfaces of dice, the substance has been called in consequence *Ludus Helmontii;* Van-helmont having particularly described it.

The *septarium* occurs in distinct and flattened spheroidal nodules; sometimes in larger and irregularly shaped masses.

In the former instance the veins of calcareous carbonate are opaque and of a white colour; and so distributed as to be of the greatest dimensions at the centre, from whence they gradually diminish towards the circumference of the nodule, but terminate within it. From this distribution Mr. Playfair draws a very strong argument in support of Dr. Hutton's theory of geology; since, as in this case, "the matter with which the veins are filled could not have been introduced by infiltration from without, or in any other way; the only supposition left for explaining the singular structure of the fossil is, that the whole mass was originally fluid; and that in cooling the calcareous part separated from the rest, and afterwards crystallised*."

The argument is, I think, incontrovertible in the particular instance; but in many instances of the massive and irregularly shaped *Ludus*, the veins are neither disposed in the same manner, nor are they of the same colour and opacity: on the contrary, they possess that kind and degree of transparency and colour, which is characteristic of those varieties of carbonate of lime, that have unquestionably been deposited from water, as in stalagmites, &c.: and besides this, there are internal marks of a periodical formation of the vein, both from its stratified character, and the difference of colour in the different corresponding strata.

Water, impregnated with carbonic acid, in penetrating through marble, lime-stone, or

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* Playf. Illust. pp. 30, 31.

chalk strata, very commonly becomes impregnated in its passage with particles of the calcareous carbonate; which it subsequently deposits, either by simple exposure to air, or upon the surface of extraneous bodies with which it comes into contact: and thus forms stalactites.

Calcareous amorphous masses. The most familiar instance of the deposition of a calcareous matter from water is that, which takes place on the inner surface of vessels employed for the purpose of boiling water impregnated with a calcareous carbonate. The incrustation separated from the sides of Carfax conduit, in Oxford, (at the time of its removal, about twenty-five years since) was nearly an inch in thickness; and of a distinctly sparry structure. There is, in the Oxford collection, part of a wooden duct that served to convey the water from this conduit: the transverse section of it is of a square form, and it is worthy of observation that the calcareous incrustation, which is of a stratified appearance, is of equal thickness on every one of the four surfaces: by which it appears, that a deposition of this kind is not mechanical.

The substance called *Agaric Mineral* is a stalactitic deposition of carbonate of lime, frequently met with in the clefts of calcareous strata, particularly such as are of a porous texture; in some instances it adheres to the sides of the cleft with the resemblance of a fungus *(agaricum)*: and hence its name.

It may also happen that a substance may be incrusted with crystals of a different nature, by being as if moulded along with them. For instance, we are acquainted with crystals of metastatic carbonated lime incrusted with quartz, and sometimes the silicious envelope remains empty after being separated from the crystals which it concealed.

Pseudomorphoses. There exists another kind of concretions which we call pseudomorphoses, *i. e. bodies which have a false* *and deceitful figure*; because the substances which belong to this order present in a very remarkable manner foreign or strange forms, which they have in some measure obtained from other bodies which had received them from nature.

When the type of this apparent transformation is a shell, it happens frequently enough that the shell still covers in whole or in part the substance, which is as if moulded into its interior*, and then nothing appears simpler than the explanation of the fact, by the introduction of a liquid charged with stony molecules into the cavity of the shell; and this observation leads to a similar explanation of the formation of the kinds of nuclei modelled into shells, which we meet with isolated and stripped of every envelop.

Sometimes the shell itself has been penetrated by another matter generally siliceous, which has been substituted for the

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* De L'Isle Crystall, tome ii. p. 161.

cartilaginous substance of which this shell had been partly composed*; and it may happen in this very case that the interior of the shell has remained empty. It is no longer, properly speaking, a pseudomorphosis. It is a fossil which has merely become more stony than it was before.

This last kind of modification takes place equally with respect to the bones and to the other solid parts of animals which are found immured in the bowels of the earth; *i. e.*, they may pass to an almost entirely stony state, by the help of a substance which supplies the place of their cartilaginous part.

The case cannot be the same with vegetable productions as with shells. They

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* We know that shells, as well as the bones of animals, are formed of two substances; the one calcareous, which is not susceptible of putrefaction; the other cartilaginous, membranous, or fleshy, which may be destroyed by the joint action of air and water.

have no testudo, or envelope, which can exist after the destruction of the interior substance, and serve as a mould to a stony or other substance for receiving an impression of their form. If we supposed that one of these productions, such as a portion of the branch of a tree, were entirely destroyed, so that the cavity which it occupied in the bowels of the earth remained empty, we could conceive that a stony matter might afterwards fill this cavity and there be modelled to it. In this case the new body would resemble externally the branch of a tree; it would have the appearance of knots and wrinkles, but its inside would not present any trace of organization, and it would only be, as it were, the statue of the vegetable production, which it would have displaced.

What is generally called *petrified wood* is a much more faithful imitation of real wood. On a transverse section we distinguish the appearance of concentric layers, which in the living tree must have proceeded from its increasing in thickness; all the principal lineaments of organization are preserved to such a degree, that they sometimes serve to enable us to recognize the species to which the tree belonged which has undergone petrifaction.

Among the different explanations which have been given of this phænomenon, that which seems to be most generally admitted, although not exempt from objections, consists in supposing that the stony matter is substituted for the vegetable in proportion as the latter is decomposed; and because the substitution takes place successively, and as it were molecule by molecule, the stony particles, in arranging themselves in the places rendered empty by the disappearance of the ligneous particles, and by moulding themselves into the same cavities, take the impression of the vegetable organization, and copy the traits of it precisely.

The mineral kingdom also has its pseudomorphoses. We find some substances of this kingdom under crystalline forms, which are only borrowed; and it is probable that, in some cases at least, the new substance has been substituted gradually for that which has ceded its place to it, as we suppose takes place with respect to petrified wood.

The various pseudomorphic bodies imprint their form on the matter which surrounds them, and frequently also the impression serves as a cell for an organic substance which is simply in a fossil state, or which has received a certain degree of alteration only. This takes place in particular with respect to the ferns and other plants of the same family, the form of which is moulded on a schistous matter, as we shall afterwards more fully detail.

Petrifactions.—We generally denominate *petrifactions* all the variously modified substances which we have mentioned, even those which only present impressions of animal or vegetable productions. Daubenton applies this term only to bodies which, in their natural state, being partly stony and partly cartilaginous, such as shells, have become entirely stony.

As we merely purpose to mention a few examples of the modifications in question, and not to unite them methodically under one and the same point of view as several authors have done, we shall confine ourselves to the enunciation of some of them in speaking of the substances which have formed their secondary matter, and shall adopt the nomenclature to this method of classifying.

We ought not to omit that there are also pseudomorphoses, which arise from the substitution of a metal in the room of an organic body. Sulphuret of iron presents several examples of this kind of metallization.

By referring to all that has preceded, we may define in the following manner the different concretions of which we have given the description:—

Stalactite.—The term *stalactite* is applied particularly to those calcareous concretions which are formed on the roofs of natural caverns, and which resemble in their shape the common icicle.

The matter of the stalactite, as has been already stated, is conveyed by water that has penetrated the contiguous strata; and in its deposition assumes various appearances according to accidental circumstances.

If the water oozes through very slowly, some time elapses before a drop is formed of sufficient size to fall by its own weight; and, in this interval, some of the calcareous particles are separated from the water, and adhere to the roof. In this manner successive particles are separated and attached to each other, until a stalactite is formed.

When the formation is rapid, the texture is comparatively loose, and of an earthy appearance: and this is particularly the case with those stalactites that are formed from recently constructed arched buildings, as bridges, or cellars; where the stalactite is made up of thin concentric cylinders, like a roll of fine cinnamon. In other instances the substance is completely sparry: and, often, very closely resembles the transparent part of the quill of a bird's wing; and not unfrequently terminates in a spherical assemblage of small pointed crystals. If the percolation of water containing calcareous matter is too rapid to allow time for the formation of a stalactite, the earthy matter is deposited from it after it has fallen from the roof upon the floor of the cavern; and in this case the deposition is by some called a stalagmite: an unnecessary verbal distinction adopted by some writers merely for the convenience of description. Stalagmites are commonly, at least in the early stage of their formation, of a mamillary shape: by gradual accumulation they become conical.

In some instances the separation of the calcareous matter takes place both at the roof and on the floor of the cavern; and, in the course of time the substance of each deposition increasing, they both meet; and form an irregular but continued pillar.

The *incrustation* is a concretion in the form of a crust applied to the surface or to the interior of a body. To this we may refer the *geode*, which is a concretion in the form of an envelop, spherical or nearly so, sometimes empty and sometimes containing a nucleus.

The *pseudomorphosis* is a concretion endowed with a form foreign to its substance, and for which it is indebted to its molecules filling a space formerly occupied by a body of the same form.

With petrifactions Mineralogy has no farther concern than as far as minerals appear in extraneous forms, having by a substitution of particles assumed the figure of animal and vegetables substances.

In a geological view, these bodies are

highly interesting. They are justly considered as the medals of antiquities which serve to form the history of our globe They are not mere geological curiosities thinly scattered here and there. The most internal parts of continents, now many hundred miles from the sea, and mountains of the greatest height equally distant, not only contain such bodies as are exclusively the inhabitants of the sea, but seem even composed of them: immense mineral strata are to be found in most parts of Europe full of them; and other remains of life and vegetation are not less abundant in others.

Though most organized bodies that are found buried in the soil, or in strata, are commonly called petrifactions; yet those only ought to receive this appellation which have by some chemical process changed their animal or vegetable natures, and acquired that which is peculiar to the mineral kingdom.

Besides the difference in respect to the various kinds of organic bodies, which are now found imbedded in strata, they differ greatly with respect to the state which they are in; some being still in their natural and original state, as most of the osseous remains of hot-blooded animals; the remains of some of the crustaceous creatures, and some shells. Others are charred, or converted into coal, as most vegetable substances found in the strata accompanying pit-coal. Some are changed into calcareous spar, or carbonate of lime, as most shells. Others into different kinds of agate and flint, as most woods; and others again are changed into pyrites, or sulphuretted metals.

No part of mineralogy, it must be confessed, is less understood than this. The greater part of what pass under the name of petrifactions, are either merely impressions, or nuclei, or incrustations, so that any general doctrines, founded upon common observations, would be very liable to be erroneous. We do not recollect having seen any osseous remains of hot-blooded animals, that had lost their natural structure and assumed a lapideous texture; their cells and pores are filled with stony and pyritical matter: but in general they are either in their natural and original state, or they have lost the connecting medium of the calcareous matter, and are decomposed. But shells, crustaceous animals, and lithophyta, the common productions of the sea, though often found in their natural state or decomposed, are generally real petrifactions. They are usually calcareous, though their moulds and impressions are often siliceous, and likewise their perforations and vacuities. The siliceous, we venture to affirm, are the inverse of the calcareous. Thus the entrochites in a calcareous state are what mechanics call *female screws*, having the worm within a hollow cylinder; whilst those that are siliceous are *male screws*, having the worm round the outside of a solid cylinder. The first is the real shell converted into carbonate of lime, commonly called spar, or with a spathous texture; the latter, the mould formed within the cavity of it.

Vegetables are found merely charred, or penetrated with bitumen, or else wholly or partially changed into coal; often likewise so completely penetrated with siliceous matter as to form a solid siliceous mass; but we believe they are never converted into a calcareous body.

There are two things further to be considered relative to organic remains, which, as far as petrifactions are to be consulted as the records of past events, are worthy of deep attention. First, that of a far greater part there are now no similar species existing; and secondly, that of those which do, the greater part do not now exist in the countries in which they are found. If we go back to a remoter period than that when the alluvial and superficial covering of the earth was deposited, to that period at which the greater part of our stratified rocks were formed, we shall find that almost another creation then existed, of which our present strata have been the cemeteries.

Of the myriads of belemnites, cornua ammonis, encrinites, &c. &c. which are to be seen in them, none now are ever found in our seas, or the seas of other parts of the world.

Some naturalists so far extend the opinion, of most of the inhabitants of the seas of that remote period being now extinct, that they will hardly admit there is a *single fossil shell* which will bear a strict comparison with any species now living. It is the same with the vegetable world. Though there are many fossil species very similar to species still in existence, yet few we believe will bear a nice examination. In the same argillaceous and sand-stone strata, in which we find some plants of the filix tribe, very similar to those now growing near the spot where these lie buried, we find others, of whose original we cannot form the smallest idea, which we are certain cannot be found in the neighbourhood, and which most resemble some plants of the tropics.

If we descend to times which approach nearer our own, and examine the alluvial strata, we find the remains of animals in in their natural state, which likewise are not, and most probably never were, inhabitants of the countries in which they are now met with.

There is still another general and very interesting observation to be made with regard to these substances, namely, that they are generally found in the middle and lower heights of the earth. In the middle heights of our globe petrifactions are still very rare; but they increase in variety and number, as we approach the lower places, and are at length accumulated in immense quantities in the lowest parts of Secondary or Stratified Mountains.

We also observe, that the organic remains found in the middle heights of mountains are totally changed into stone; but the more we descend into the lower places, the more these bodies appear unaltered, or approach to their original state. It is likewise observed, that the higher places afford different genera and species of petrifactions from those found in the lower strata.

SECTION III.

TABLE

OF

CRYSTALLINE FORMS OF MINERALS*.

1. *Substances which have a common Primitive Form, with the same Dimensions.*

I. CUBE.

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
GOLD	Cube.
Silver	
Copper	
Borat of magnesia	
Muriat of soda	
Sulphuret of lead	

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* Copied from Lucas's Tableau Méthodique des Especes Minerals, and corrected according to the latest researches of Haüy's and Brongniart's Mineralogy.

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
Sulphuret of iron	Cube.
Arseniate of iron	
Oxid of tin	
Gray cobalt	
Phosphate of manganese	
Aplome	
Amphigene or Leucite	Irregular tetrahedron.

II. REGULAR OCTAHEDRON.

Fluat of lime	Regular tetrahedron.
Muriat of ammonia	
Alum or sulphat of alumine	
Spinelle	
Muriate of copper	
Diamond	
Native amalgam	
Ruby, or red oxide of copper	
Magnetic, or oxidulated iron	
Native bismuth	
Native antimony	Irregular tetrahedron.

III. REGULAR TETRAHEDRON.

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
Copper pyrites	Regular tetrahedron.
Gray copper	

IV. RHOMBOIDAL DODECAHEDRON.

Garnet	*Tetrahedron with isosceles triangular faces, all equal and similar.*
Sulphuret of zinc or Blond	

II. *Substances, the Primitive Forms of which only are of the same Kind, with Dimensions respectively peculiar to each.*

I. RHOMBOID.

1. *With obtuse summits.*

Carbonat of lime	Rhomboid.
Tourmaline	Irregular tetrahedron.
Rock crystal or quartz	

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
Chabasie	Rhomboidal.
Dioptase	
Sulphuret or red silver ore	

2. *With acute summits.*

Corundum	Rhomboid.
Oligist or specular iron	
Sulphate of iron	

II. OCTAHEDRON.

1. *Pyramids with square bases.*

Zircon	Irregular tetrahedron.
Harmatome	
Anatase	
Molybdate of lead	
Mellite	
Tungstate of lime	
Oxid of tin	

2. *Pyramids with Rectangular bases.*

Nitrate of potash	Irregular tetrahedron.
Carbonate of lead	
Sulphate of lead	

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
Oxid of zinc	Irregular tetrahedron.
Arseniate of copper	
Macle or Chiastolite	
Arragonite	
Shorlaceous Beril	

3. *Pyramids with rhombic bases.*

Sulphur	Irregular tetrahedron.
Red sulphuret of arsenic	
Blue carbonat of copper	
Siliceo alcareous tianite	
Carbonate of soda	
Sphene	

III. RIGHT QUADRANGULAR PRISM.

I. RIGHT OR QUADRANGULAR PRISM.

1. *With square bases.*

Sulphate of magnesia	Isosceles-rectangle-triangular prism.
Vesuvian or Idocrase	
Mesotype	
Chromat of lead	
Oxid of titanium	
Paranthene	

2. *With rectangular bases.*

NAMES OF THE SUBSTANCES.	FORMS OF THE INTEGRANT MOLECULE.
Crysoberil or cymophane	Prism with rectangular bases.
Euclase	
Peridot	
Prehnite	
Stilbite	
Feruginated tungsten	
Apophilite	
Anhydrous sulphate of lime	Isosceles rectangle triangular prism.
Calcareous tungsten	

3. *With rhombic bases.*

Sulphat of barytes	Scalene-rectangle-triangular prism.
Sulphat of strontian	
Staurotide	Isosceles-rectangle-triangular prism.
Hyperstene	
Triphane	
Topaz	Prism with rhombic bases.
Mica	
Talc	
Arsenical iron	
Sulphuret of molybdena	
Diaspore	Isosceles triangular prism.

4. *With oblique-angled parallelogram bases.*

NAMES OF THE SUBSTANCES.	FORM OF THE INTEGRANT MOLECULE.
Sulphat of lime	Prism with oblique-angled parallelogram bases.
Epidote	
Axinite	

IV. OBLIQUE QUADRANGULAR PRISM.

1. *With rectangled bases.*

Borat of soda	Prism with rectangled bases.

2. *With rhombic bases.*

Hornblende	Prism with rhombic bases.
Actinolite	
Grammatite	
Augite	Oblique triangular prism.

3. *With oblique-angled parallelogram bases.*

Feldspar	Prism with oblique-angled parallelogram bases.
Disthene	
Sulphat of copper	

V. REGULAR HEXAHEDRAL PRISM.

NAMES OF THE SUBSTANCES.	FORM OF THE INTEGRANT MOLECULE.
Phosphat of lime	Equilateral triangular prism.
Telesie	
Emerald	
Nepheline	
Pycnite	
Dipyre	
Sulphuret of mercury	
Carbonate of strontia	
Pinite	
Sulphuret of copper	

VI. PYRAMIDAL DODECAHEDRON.

Phosphat of lead	Irregular tetrahedron.
Carbonate of barytes	

III. *Forms which are found to be secondary in different species.*

I. CUBE.

NAMES OF THE SUBSTANCES.	PRIMITIVE FORMS.
Fluate of lime	Regular octahedron.
Native bismuth	
Muriate of ammonia	

II. REGULAR OCTAHEDRON.

NAMES OF THE SUBSTANCES.	PRIMITIVE FORMS.
Muriat of soda	Cube.
Sulphuret of lead	
Sulphuret of iron	
Gray cobalt	

III. REGULAR HEXAHEDRAL PRISM.

NAMES OF THE SUBSTANCES.	PRIMITIVE FORMS.
Carbonat of lime	Obtuse rhomboid.
Sulphuretted antimoniated silver	
Corundum	Acute rhomboid.
Phosphat of lead	Pyramidal dodecahedron.
Mica	Straight prism with rhombic bases.
Sulphuret of molybdena	

IV. RHOMBOIDAL DODECAHEDRON.

NAMES OF THE SUBSTANCES.	PRIMITIVE FORMS.
Fluat of lime	Regular octahedron.
Oxidulated iron	
Spinel	

V. SOLID WITH TWENTY-FOUR EQUAL AND SIMILAR TRAPEZOIDS.

NAMES OF THE SUBSTANCES.	PRIMITIVE FORMS.
Muriate of ammonia	Regular octahedron.
Garnet	Rhomboidal dodecahedron.
Amphigene	Cube.
Analcime	
Sulphuret of iron	

General Observations, and Reflections, on the Statements, comprehending the Theory of Crystallography.

Since the printing of the preceding sheets, Dr. Wollaston, in a paper read before the Royal Society, has endeavoured to shew, that the original moleculæ of crystallisable matter are probably spherical.

Assuming this statement, the constitution of those crystalline solids which yield by mechanical dissection, solids of two kinds, namely, tetrahedrons and octahedrons, (see page 146), may be more satisfactorily explained, than if we imagine, that the original moleculæ of those substances are tetrahedron; because the former solids can arrange themselves into tetrahedrons or octahedrons, and the vacuities they leave are of a much smaller bulk than when the former crystalline solids are formed of tetrahedral or octahedral moleculæ.

Dr. Wollaston has extended this idea, which he stated, as originally in part pointed out by Dr. Hooke, to the formation of crystalline bodies, and endeavoured to show the laws of arrangements, according to which crystalline forms would be produced of spherical moleculæ, or sometimes of flat spheroids. The above statement Dr. Wollaston observed is perfectly gratuitous. It would not become us to anticipate the summary detail of this hypothesis. The paper to which we allude, no doubt, will be laid before the public by Dr. Wollaston himself, through the medium of the Philosophical Transactions.

We have now made a hasty tour through the fertile field of crystallography. It is a rich field, the cultivation is merely commenced, and which waits for more favourable times, and a greater number of labourers to reap from it an abundant harvest.

We have seen to what all the different metamorphoses of crystals belong under which the primitive form is presented in secondary crystals, whether simple or compound. Sometimes the decrements are performed at once on all the edges, as in the dodecahedron with rhombic planes, or on all the angles, as in the octahedron originating from the cube. At some times, take place only on certain edges or certain angles. At others there is an uniformity between them, so that there is only a single law of decrement by one, two, three ranges or more, and which acts on different edges or on different angles. Sometimes the law varies from one edge to another, or from one angle to another; and this is what happens in particular when the nucleus has not a symmetrical form, as when it is a parallelopipedon, the faces of which differ by their respective inclinations, or by the measurements of their angles. In some cases the decrements on the edges correspond with the decrements on the angles to produce the same crystalline form. It also happens sometimes that the same edge, or the same angle, undergoes successively several laws of decrement which succeed each other; and even further, there is a multitude of cases in which the secondary crystal has faces parallel to those of the primitive form, and which are combined with the faces produced by the decrements, and give rise to new, in order to modifications.

With such diversity of laws, sometimes

solitary, and sometimes marching as it were by groups round the same primitive form, the number of ranges subtracted was in itself very variable; if, for example, there were decrements by twenty, thirty, forty, or more ranges, as may be imagined, the multitude of forms which might exist in each species of mineral would be capable to overwhelm the imagination, and the study of crystallography would present an immense labyrinth, which, in spite of the clue furnished by theory, could with difficulty be unravelled. But the power which produces the subtractions seems to have a very limited action. These subtractions are most frequently formed by one or two ranges of moleculæ. Haüy found none which went beyond six ranges; but such is the fertility which is united with this simplicity, that, by confining ourselves to decrements by one, two, three, and four ranges, and abstracting those which are mixed or intermediate, we find that the rhomboid is susceptible of eight millions three hundred and eighty-eight thousand six hundred and four possible forms of the same substance, and even this number may be much extended in consequence either of intermediary or mixed decrements being taken into account.

In order to have a still more accurate idea of the power of crystallisation, we must add to this facility of producing so many different forms, in commencing with a single figure, that of attaining one and the same form by different structures. The rhomboidal dodecahedron, for instance, which we obtained by combining cubical molecules, exists in the garnet, with a structure composed of small tetrahedrons with triangular isoscele faces, as we shall find under the head of this mineral substance; and Haüy has found it in a species of fluate of lime, where it is also an assemblage of tetrahedrons, but regular, and the faces of which are equilateral triangles. Some attempts at the dissection of primitive crystals seem to announce, that the tetrahedron, with triangular faces, is the most frequent primitive form of the particles; to these may also be joined, in thought, the triangular prism and the parallelopipedon. Tetrahedrons, arranged in a great many different manners, give every possible form, as may be seen by the artificial generation of parallelopipedons, from laminæ by every kind of superposition, of octahedrons, of dodecahedrons, of rhomboids, &c. It is evident then, that the tetrahedron may be supposed the only primitive form of the particles, generating every other form, as well in the nuclei as in the secondary and external crystallisations. In this probable hypothesis, which is consistent with the simplicity and economy of nature, the constant and given forms, both of the nuclei and in the secondary crystals of the same substance, depend only on the respective disposition, or the particular arrangement of the primitive particles among themselves. It is in the disposition, and the arrangement of these particles, which always takes place in the same manner in the same substance, that the geometric character of each substance consists; and this character, or that limited disposition of particles, depends on the proper or chemical nature of bodies.

SECTION IV.

TABULAR VIEW OF THE METHODICAL DISTRIBUTION OF MINERALS ACCORDING TO THE SYSTEM OF HAÜY.

Preliminary Observations.

THERE is no one who has seriously attended to the study of mineralogy, without feeling at the same time the necessity of establishing divisions among the substances of this department of nature, so as to remove the numberless difficulties which would otherwise oppose the acquisition of knowledge. The aim of these arrangements consists in such a disposition of bodies as places those nearest each other which have similar properties, and others remoter, as their habitudes differ.

The first notions which men adopted from necessity concerning the different properties of mineral substances may be regarded as the early sketches of arrangement. In the time of Pliny, stones were even then distinguished from salts, from bitumens, and from metals, and a division into four classes already existed. The electric property of amber, the combustibility of bitumen, and the attraction of iron by the magnet, were known: already the stones formed distinct groups. The marbles and gems were separated, the heavy and the light, the hard and the soft minerals were divided. Antiquity however did not possess one single true notion, nor one positive idea of the methods, or classification of natural history, their advantages, and their necessity.

It was in the eighteenth century alone, that the denominations of kingdoms in natural bodies were adopted, that the mineral kingdom was particularly admitted, that mineralogical methods were imagined, and the distinctive properties or characters examined with a view to class and distinguish these different kinds of bodies.

It was natural, at first, to take for the characters of classification such properties as are the *most apparent*, the *most sensible*, and the *most easy* observed by the senses; or at least such of them as are most characteristic of the substances to which they belong; and that mineralogical methods in particular should be founded on what are called *external characters*, that is to say, on the striking properties only which minerals present to our senses, and which may be observed without causing them to undergo any material alteration.

In running over the different arrangements proposed successively, and which have been more or less established on the external or obvious characters, which the senses could discover, it was observed that the distinctions admitted would be insufficient to discriminate the substances of the mineral kingdom, and that they were more adapted to appropriate and to separate similar bodies from each other, or to confound for a long time the art of regularly and unequivocally characterising minerals, with the mere routine of knowing them at sight.

This singular pretension, which has done much injury to the progress of mineralogical science, is exhibited more particularly in some systems, which consider minerals only with regard to *some* of their properties. The authors, in framing their systems, have wished to draw, from a few single considerations, an order and distribution which they pretend is natural for the relative disposition, and a classification which they assert is easy to distinguish mineral substances from each other.

Instructed by the insufficiency of this proceeding, and guided by a light less deceitful and uncertain, again others have happily perceived that no single collection of external properties can be of use to establish *real* distinctions, that it is necessary to discriminate carefully the system, which by common characters only seeks to arrange these compounds with each other, from that artificial method, of which the aim is to teach the *means* of distinguishing them unequivocally and without error. They have associated and compared not only the obvious or striking characters, but all the individual apparent or sensible properties, and in opposing and contrasting the totallity of them with each other, they have established characters, proper to distinguish these bodies with more success. They have given a kind of portrait, by decomposing in some measure all the features of their physiognomy, and those outlines which have the strongest resemblance are then considered as answering the intended purpose.

However advantageous such a proceeding may be, it is nevertheless evidently reducible to a clear analysis of the external properties of minerals only; whatever may be the facility it affords of distinguishing each kind of mineral by reducing it to its just value, we must by no means forget that it cannot be applied for disposing these bodies in a natural order, that it can never serve to indicate their intimate nature or composition, and that it is not capable of answering its own peculiar object, unless a faithful enumeration of all the properties of each individual be given, and that otherwise we should constantly be in danger of confounding the mineral compound; and hence the method pursued can only be considered as an approximation to truth. It is indeed an excellent table, by the help of which we may find the object intended to be studied, but which can never dispense us from the necessity of investigating their properties and internal nature. If we are desirous of knowing the bodies we examine, and particularly determine the *uses to which they may be successfully applied*, recourse must be had to their chemical habitudes, that is to say, to the relations which they bear to other substances, on or from which they are capable of producing or receiving some peculiar observable changes.

It was undoubtedly because the study of the external characters of minerals soon convinced mineralogists that the mode of proceeding just stated was far from conducing to the exact knowledge of minerals, and that it was only capable of giving false ideas and producing errors respecting their nature, that the project was adopted of classing mineral substances according to their chemical composition or intimate nature. This happy thought, which forms the *only* real foundation and solid basis of the science, which, from the mere art or routine of distinguishing and naming these bodies, elevates it to a true science, has much engaged the attention of chemical mineralogists, who have successively laboured to extend, to improve, and to complete it. And this great object is not yet terminated, notwithstanding the numerous researches which have been made, and are daily making, without intermission, in this department of knowledge.

The chemical examination of minerals, that is to say, the nature of their composition, it is true does not yet enable us to compare the nature and characters of *all the minerals* hitherto known, so as to arrange them in a discriminate series, by the order of their composition, or so as to form a chemical arrangement, perfect in its structure. Each individual has not, and cannot be analyzed; this would be impracticable, and were it not, it would be without utility, but when the analysis of a mineral has been effected, we have reason to presume that a similarity of composition will exist in other specimens which agree with it closely in its external properties or characters.

It must be obvious, that the methodical distributions of minerals, whatever steps may be taken, cannot be so absolute and determinate as those which belong to animals and vegetables. Minerals, not being organic bodies produced by eggs or seeds, are not themselves so determinate and constant, and thus the great and essential difference of arranging them into classes, genera and species, so useful in the vegetable and animal kingdom, strictly speaking, is lost in mineralogy. And although mineralogists do by no means agree concerning the best modes of arranging minerals, even those who have most decidedly rejected the chemical system of classification, have admitted that the *class* and *genus* in mineralogy can be founded only on chemical principles, hence the ores, the stones, the salts, and the inflammable fossils, form distinct classes; and each metal and each earth gives rise to a genus. No other principle, no other character, or set of characters, can be substituted without rendering mineralogy an assemblage of the most vague, arbitrary, and fluctuating science; and hence this proceeding of fixing the higher divisions is well founded, and universally admitted.

The chief difficulty which offers itself affects what is called the *species*. In the animal and vegetable kingdom, the species is fixed by an invariable character. A certain organization and form are transmitted from one individual to another, with the combining the same succession, each plant and animal constitutes a whole, possessing a determinate form; each individual exhibits an essential difference capable of definition, and on this the species of the plant or animal is founded, and permanently fixed. In the general assemblage of properties there is no such thing as an imperceptible gradation from one to another. The individual of each, not liable to be placed under variations of circumstances at their formation, when the characters are fixed, are not liable to be much disguised in structure or form, and any alteration, when produced, being absolutely confined to the individual, is soon lost.

In the mineral kingdom each substance cannot thus be considered as an individual, and the species therefore cannot be determinate, arising from chemical combination, and that combination being liable to be influenced by various circumstances, while there is a power counteracting these and preserving uniformity, the individuals are liable to be almost indefinitely diversified in their properties, and must pass invariable into each other.

In the system of Haüy, the chemical composition of minerals is said to be professedly taken into view, in forming the arrangement, the species is determined from one character, namely, the integrant molecule; and hence Haüy defines the species, " A collection of bodies, of which the integrant moleculæ are alike, and composed of the same elements united in the same proportion." This latter condition being added, he generalizes the definition, and extends it to substances which, having their integral moleculæ of the same form, differ essentially in the principles of which these moleculæ are composed*; the form

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* Traité de Mineralogie, tom. I. p. 162.

of the integrant particle therefore being the basis of the specific distinction.

But as it is impossible to extend the system of the integral molecule to all minerals, there are mineralogists who reproach it with the difficulty of finding the directions of the cleavage, in many cases, the trouble of calculating them, &c. We should no longer* use the microscope, the telescope, nor the chronometer, for they also are very difficult to execute. Let us content ourselves with dressing, sleeping, and eating, convinced that without the pendulum and the telescope the stars will continue their course, and bring back the hours of sleep and the restoration of our powers.

The last objection which has been made against the system of Haüy, says this philosopher, and to which I shall pay any attention is that which is stated thus: "We

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* Chenevix. In the Philosophical Magazine, vol. 36.

must abandon the French system for that of the external characters, as the integral molecule cannot be observed in *all* minerals." One of the great advantages of the system of M. Haüy, one of its principal beauties, is to follow nature, and to speak as she does. Where she has finished her work in the highest manner of which it is susceptible, M. Haüy does the same; and if she produces a mineral endowed with all the characters which, according to us, compose the most perfect state, it is classed and defined as such. If she has been sometimes less rigorous in impressing her mark of perfection, the system follows the same course; while the method of external characters renders equally the honours of rigorous classification to sapphire and to the alumina of Halle. To say that we should make no use of an excellent system, because cases occur where it is unavailable, is to say to a patient, Lie not on a feather bed; for, if you are deprived of it, you will be reduced to the necessity of sleeping on a board. It is to tell a man in health not to take nourishment, for if the provisions become deficient he could no longer eat.

The following is the methodical distribution of Minerals adopted in the French School of Mineralogy.

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,

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

Emerald,
Euclase,
Amphigene,
Idocrase,
Meïonite,
Feldspar,
Corundum,
Pleonaste,
Axinite,
Turmaline,
Amphibole,
Actiite,
Pyroxene,
Staurotide,
Epidote,
Garnet,
Sphène,
Wernerite,
Diallage,
Anatase,
Dioptase,
Gadoleite,
Lazulite,
Mesotype,
Stilbite,

Phrenite,
Chabasie,
Analcime,
Nèpheline,
Harmatome,
Pèridot,
Mica,
Disthène,
Grammatite,
Pycnite,
Dypyre,
Asbestus,
Talc,
Macle.

CLASS III.

COMBUSTIBLE SUBSTANCES.

ORDER I.

Simple combustible substances.

SPECIES.

Sulphur,
Diamond,
Anthracite.

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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,
Antimonial-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,
Murio-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 or specular 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.

Chromeate of lead,
Chromate of iron.

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,
Koupolite,
Lèpidolithe,
Lime, sulphate anhydrous,

Lime, sulphate quartziferous,
Madreporite,
Malacolithe,
Micarella,
Petrosilex,
Scapolite,
Radiant spar,
Schistous spar,
Spinthere,
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 plaster 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 alumineferous 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.

Obsidean 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,
Muriate of ammonia,
Sulphuret of arsenic,
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,
Chabasie,
Carbonate of lime,
Sulphuret of iron.

CLASS VII.

II. NOT VOLCANIC PRODUCTS,

Substances modified by subterranean fires.

VARIETIES.

Porcelain thermantide,
Tripolian thermantide.

FINIS.

Mineralogical Chests, Chemical Preparations and Apparatus,

MANUFACTURED AND SOLD

BY ACCUM AND GARDEN,

OPERATIVE CHEMISTS, COMPTON-STREET, SOHO, LONDON.

MINERALOGICAL AND CHEMICAL CHESTS.

The Chemical Apparatus and Bottles contained in the following Chests are arranged in such a manner, that they may be seen at one View when the Chest and Drawers are open; they are besides so packed that they can readily be taken out, and when replaced fit in such a way, that the whole, when the Chest is locked, may be turned upside down without Risk of receiving injury.

Pocket Mineralogical Blowpipe Apparatus......£3. *to* £4.

This small mineralogical case contains Dr. Wollaston's blowpipe, a double magnifier, platina foil, a blowpipe forceps, two bottles of fluxes, a steel graver, test tubes, and the most essential re-agents necessary for the immediate examination of minerals. In the study of mineralogy, the pocket blowpipe apparatus, which joins to the convenience of a small size, and the facility of being easily transportable, is of singular advantage. It enables the mineralogist to expose instantly, to the action of a most violent heat, the substances he may meet with in his travels, &c.

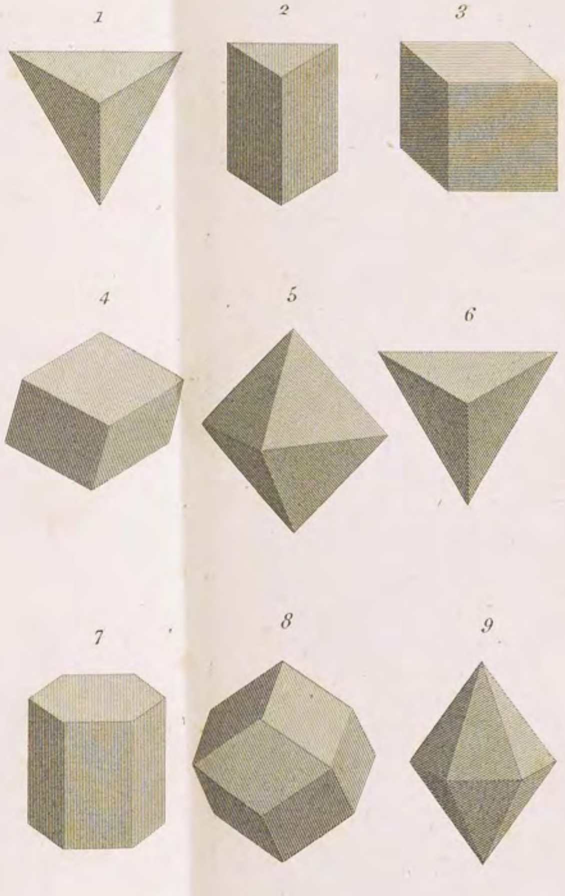
Mineralogical Travelling Chests.......£7. 7*s.* *to* £13. 13*s.*

Though the blowpipe assay is usually sufficient to furnish general notions concerning the substances of the mineral kingdom, those who study mineralogy as a science, are not content with this kind of analysis, because it does not afford the summary information they require. By always operating on small fragments, the results obtained are too minute to enable the operator to determine quantities with accuracy. By the application of the re-agents contained in this chest the general nature of any mineral may be easily and quickly ascertained.

Mineralogical Laboratories............£16. 16*s.* *to* £25.

This portable laboratory contains a complete collection of the most approved apparatus and instruments necessary for carrying on the analysis of mineral substances of all kinds. *It forms a companion to Accum's Manual of Analytical Mineralogy, intended to facilitate the practical analysis of metallic ores,* Pl. II.

Accum's Crystallography.



Lowry Sculp.

Accum's Crystallography. *Pl. III.*

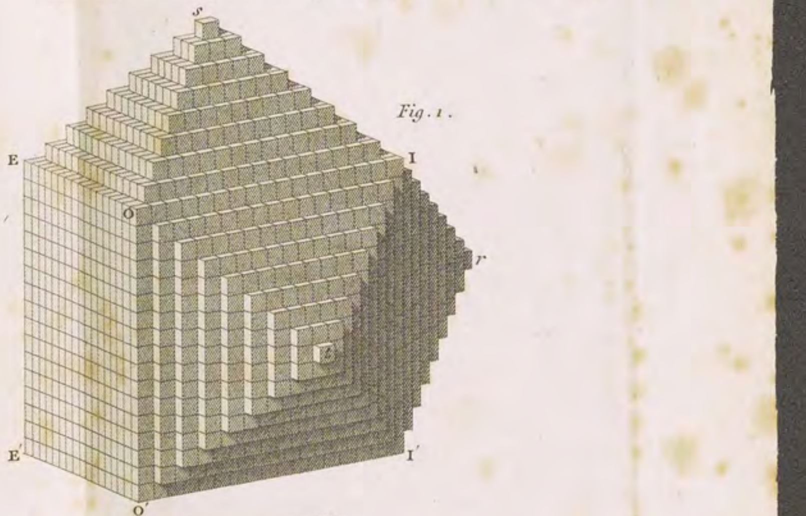


Fig. 1.

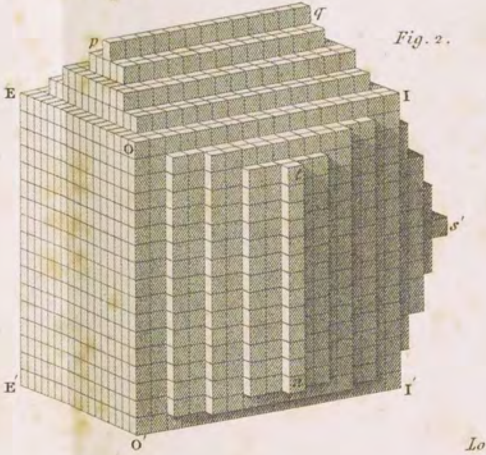
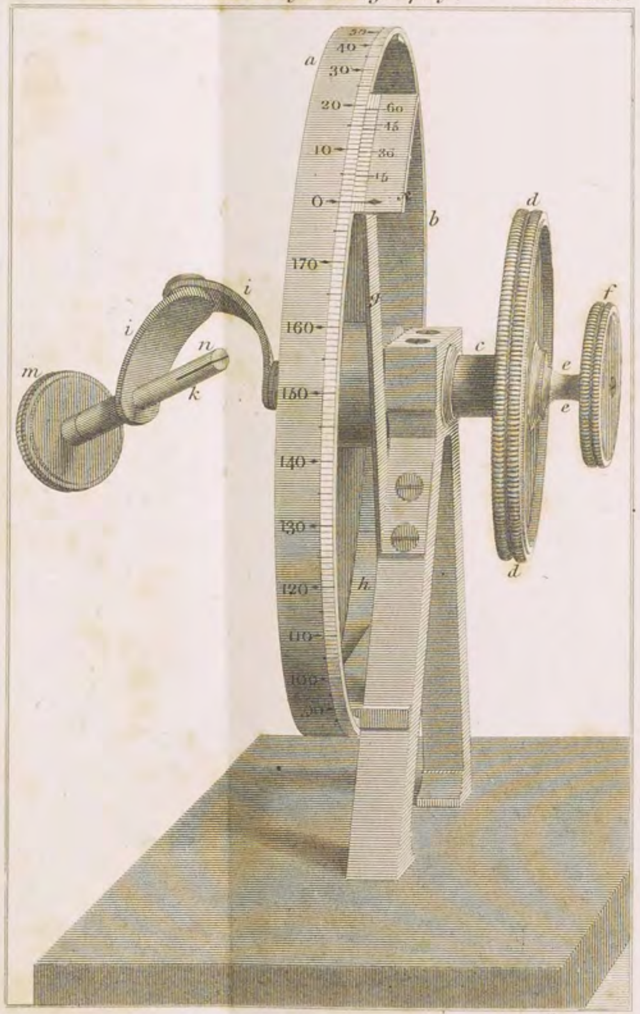


Fig. 2.

Lowry sculp.t

Accum's Crystallography. *Plate IV.*



Lowry Sc.

earths, stones, and other subjects of the mineral kingdoms; in 2 vols. A drawing and full description of the mineralogical laboratory may be seen in the Philosophical Magazine, No. clvii. 1811.

Portable Chemical Laboratories, for carrying on a general Course of Chemical Experiments .... £30. *to* £80.

Since chemistry has changed its appearance; since its instruments of experiments have been perfected, and acquired new forms, new paths for exploring the productions of nature have also been opened, the art of experimenting has been simplified, and become more familiar and easy. Experience has thus shown, that however varied the objects of research may be, and however numerous and different the products to be obtained may appear, the operator is now enabled to perform, at a trifling expence, his processes in the closet with more precision and perspicuity than could formerly be done in the regular laboratory fitted up with costly instruments. The numerous processes of degestions, the sublimation of salts, the solution of earthy, metallic, and other bodies, the concentration of saline liquids, the desulphuration of metallic ores, the processes of distillation by the naked fire or the sand-bath, and even the production of gases, and fusion of earthy fossils with alcalies, may be accomplished, at a trifling expence, by the help of the portable laboratory.

Packed Goniometer, described page 86.

Wollaston's Reflective Goniometer, described page 90.

Mineralogical Electrometers, described page 246.

Pocked Magnifiers for examining Minerals.

Improved Lamp Furnaces, £3. 3*s. to* £5. 5*s.*

The lamp-furnace, as it is perhaps not very properly called, is one of the most convenient means of applying the brilliant flame of an Argan's lamp to the purposes of experimental chemistry. By means of it a vast number of chemical operations may be performed with great speed, precision, and perspicuity. Indeed the lamp-furnace may be used for almost every one of the operations of chemistry in the small way, which require a temperature not exceeding a *dull red heat.* The processes of digestion, the sublimation of salts, the solution of earthy and metallic bodies, the concentration of liquids, all the multifarious processes of distillations by the sand-bath, and by the naked fire, the production of gases with the pneumatic apparatus, may commodiously be accomplished, at a trifling expence, on the table, with the help of this instrument.

Moveable Universal Furnace.............£3. 16*s.* *to* £8. 8*s.*

Among the whole group of apparatus designed for applying heat to bodies, this furnace undoubtedly is for the purposes of experimental chemistry the most useful, however numerous and different the operations to be performed may be. It may be used with perfect safety in a room, and is therefore well calculated, not only for those operators who have no access to the laboratory, but also for lecturers on chemistry. A very large number of chemical processes may be carried on in this furnace commodiously and at a cheap rate.

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Universal Furnace—Table Lamp Furnaces—Chemical Lamps—Spirit Lamps—Blowpipes with Platina Jets, Platina Spoon, Forceps, and Foil—Chemical Thermometers—Pneumatic Tables with Assortments of Bell-Glasses, Cylindrical Receivers, and Deflagerating Jars—Detonating Tubes—Bell-Glasses mounted with Stop-Cocks, Bladders, &c.—Glass Retorts with long Necks for procuring Gases—Eudiometers—Graduated Cylindrical Jars, divided into Cubic Inches and Decimal Parts—various sized Gas Bottles, plain and tubulated—Cast-Iron and Wrought-Iron Retorts, with Conducting Tubes—large Bladders, with Stop-Cocks—Air-Holders—Apparatus for impregnating Fluids with Gases—Pneumatic Mercurial Troughs, Nests of Cylindrical Air-jars adapted for the Mercurial Trough, plain and graduated—Glass and Earthenware Retorts, plain and tubulated, with corresponding Glass Receivers—Balloon Receivers—Small Copper Stills and Refrigerators—Glass Alembics—ditto of pure Silver, with Glass Capital—Earthenware and Black-lead Crucibles, round, triangular, and Skittle-shaped, with Stands and Covers for ditto—Specific Gravity Bottles—Steam Baths for drying Precipitates—Delicate Scales, and corresponding Weights—Common Hand-scales, and Piles of Weights for ditto—Galvanic Batteries, with Apparatus, for the Decomposition of Water—Glass, Porcelain, Earthen, and Stoneware Funnels, plain and ribbed—Glass Funnels, with long Necks, for charging Retorts—Glass Jars, in Sizes, plain and with Lips, for decanting or precipitating fluid, and for stirring mixtures—Iron Standards, with Sliding Rings for supporting Retorts, Flasks, Basons, and other Vessels—Filtering Stands and Filtering Frames—Test Tubes and Stand—Earthenware Basons, with Spouts, in Sizes—Flasks, Assay Jars, Matrasses, and Bolt-heads—Hand-mortars of Porcelain Biscuit—Iron Mortars, in Sizes—Graduated Glass Measures, from two Ounces to one Pint Capacity—Florence Flasks, and Stands for ditto—various sized Iron Boilers and Pans—Adopters of Glass and Earthenware—Steel Spatulas—a small Silver Spatula—a ditto of Platina—Glass and Enamel Rods, for stirring Acid and corrosive Mixtures—Capillary Tubes—Metal and Glass Syphons—Steel Anvils—Iron Ladles—Glass, Silver, and Earthenware Spoons—Sockets and Joints, for connecting Stop-Cocks, &c.—Tubes of Safety, and Hydrostatic Funnels—circular Pieces of Metal, and Plates of Glass, for covering deflagerating Jars, &c.—Copper Deflagerating Ladles—Writing Diamonds—Masks, to defend the Eye against Accidents in Chemical Operations—Barometers—Electrical Machines—Double-barrelled Table Air-Pumps—Hidrostatic Balances, and Nicholson's Hidrometers—Burning Lenses—Gazometers—Portable forge and Blowpipe Tables, with double Bellows—Freezing Apparatus—Flasks and Globes, for weighing Gases—Calorimeters—Leslie's Differential Thermometer—Metal Reflectors—Agate and Steel Mortars—Blast Furnaces—very delicate Balances and corresponding Weights, &c.

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Sulphuric Acid, pure and common—Nitric Acid, pure and common—Nitroas Acid—Muriatic Acid, pure and common—Oximuriatic Acid—Tartaric Acid, and all the rest of the Known Acids.

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Iron Filings and Wire—Copper, pure and common, and Copper Clippings—Granulated Zinc—Lead Foil—Silver Leaf and Wire—Gold Leaf and Wire—Tin Foil and Filings—Platina Foil and Wire—Qucksilver—Bismuth.

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Red Cabbage Tincture—Litmus Tincture—Turmeric Tincture—Brazil Wood Tincture—Tincture of Galls—Papers stained with these Tinctures—Alcohol, pure and common—Solution of Oxid Arsenic—Solution of Acetate Barytes—Solution of Sulphate Silver—Barytic Water—Hidrosulphuret Lime—Lime Water—Solution of Acetate Lead—Solution of Muriate Bismuth—Solution of Muriate Barytes—Solution of Muriate Gold—Solution of Muriate Tin—Solution of Muriate Lime—Solution of Muriate Platina—Solution of Nitrate Lead—Solution of Nitrate Barytes—Solution of Nitrate Silver—Solution of Oxalic Acid—Solution of Oxalate Ammonia—Solution of Prussiate Potash—Solution of Prussiate Lime—Solution of Prussiate Mercury—Solution of Soap in Alcohol—Solution of Sulphate Silver—Solution of Succinate Soda—Polished Plates of Copper, Iron, and Zinc—Sulphate of Iron—Strontia Water.

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Sulphuret Iron—Sulphuret Ammonia—Sulphuret Lime—Sulphuret Potash.

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White Marble—Phosphorus—Sulphuric Ether—Sulphur—Naptha—Oil of Turpentine—boiled Lint-seed Oil—Spirit Varnish—Paris Plaster—Windsor Loam—Stourbridge Clay—Lint-seed Meal—Slips of Bladder—Common Lute, for closing Glass Vessels, in preparing all common distilled Liquors—Lute for confining Acid and corrosive Vapours—Fire Lute to join the Covers of Crucibles, so as to keep them Air-tight, at a strong Heat—Fire Lutes for coating Glass and Earthenware Retorts—Cement for stopping Cracks in Iron Vessels intended to bear a Red Heat—Resinous Cement for fixing Tubes, &c. into Glass Vessels, to be Air and Water tight—Varnish for closely fitting Bladders and Bags to Stop-Cocks, and for rendering the joinings of small Glass Apparatus Air-tight, and every other Article employed in the Pursuits of Operative and Experimental Chemistry.

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