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TEXT-BOOK

OF

DESCRIPTIVE MINERALOGY

BY

HILARY BAUERMAN, F.G.S.

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PREFACE.

IN THE PREPARATION of the present volume, owing to the large and constantly increasing stock of mineralogical literature, the chief difficulty has been the selection and compression of the material so as to give a fair general view of the subject within the space available. For this purpose and in order to carry out the general ideas of the series, only the more important species, whether from a natural history or an economic point of view, are described in much detail, the general relations of the individual species in each group being indicated in a preliminary statement at the commencement of each chapter. It was originally intended to illustrate the descriptions mainly by the figures in the 'Treatise on Systematic Mineralogy;' but during the progress of the work, the writer was fortunate enough to acquire the wood blocks used in the illustration of 'Brooke and Miller,' which have been generally regarded as the best examples of their class ever executed, and he has used a selection of these in preference to perspective projections.

As in the former volume, the double system of notation is followed—that of Miller according to Weiss's order, and the corresponding symbols of Naumann for forms, but the former is alone used for faces. In the figures of the oblique system it must be borne in mind that sometimes the slope of the oblique axis is to the right and sometimes to the left, and therefore to bring these into accordance with the assumption of a uniform forward slope the plane of projection is, in the former case, the positive, and in the latter the negative clinopinakoid, which will give a corresponding difference in the indices of the type faces, while Naumann's form-symbols are unchanged.

The writer, having been absent from England while a considerable number of sheets were in the printer's hands, is much indebted to his friend Mr. F. W. RUDLER, who has kindly undertaken the revision of these for publication.

LONDON : *April* 30, 1884.

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DESCRIPTIVE MINERALOGY.

CHAPTER I.

INTRODUCTORY.

In a preceding volume of this series, the methods followed in the systematic determination of the three principal properties of minerals, namely, their form, structure, and composition, have been considered, and the purpose of the present volume is to give a comprehensive view of the results of such investigations when applied to the whole range of the mineral kingdom by describing, with such detail as may be done within the space available, the more important species, and particularly those with which it is necessary that the student should become acquainted. Following the general practice, these descriptive elements will be arranged as much as possible in the same order according to the following scheme.

Form.—Crystallographic system and development. Elements of fundamental forms the angle ∞P of the unit prism facing the transverse lateral axis, the basal angle z, the front and lateral polar angles x and y of the unit pyramid, or the polar angle R of a rhombohedron, being given according to the system, together with the fundamental axial ratios determined from these, and in the clinometric systems the characteristic axial inclinations.

Crystallographic habit illustrated by one or more figures in plane projection, except in the cubic system, where per-

spective projections are used. In the hexagonal, tetragonal, and rhombic systems the plane of projection is the basal pinakoid, in the oblique the longitudinal or clinopinakoid, or plane of symmetry, and in the triclinic a plane perpendicular to the zone axis of the principal prism. In some cases the oblique forms are also projected on to the horizontal plane, but this is where the obliquity of the longitudinal axis is very small, and the form has previously been considered to belong to the rhombic system. Principal twin forms. Irregular groupings and aggregates of other kinds.

Structure.—Principal cleavages, character of fracture, hardness, specific gravity, degree of translucency, lustre, colour of mass and streak, optic constants, such as refractive indices, character and sign of double refraction, relation of optic to crystallographic axial planes, apparent and real optic axial angles.

Composition.—Generalised formulæ and corresponding percentage composition, principal chemical characteristics, particularly fusibility, flame colouration, reactions with vitrifiable fluxes, and behaviour with mineral acids.

Occurrence and distribution.—Principal localities and modes of occurrence, particularly associations with other minerals, economic value and applications.

One of the most important points in systematic description being the selection of appropriate names, it will be necessary to consider this somewhat more in detail.

Names of minerals.—The specific names applied to minerals are either old words forming part of the ordinary current language of the country, or, what is more commonly the case, new creations founded on the names of persons or localities, or upon some peculiarity of the substance, physical or chemical; the usual practice being to add the termination *ite* or *lite* to the selected word, from the analogy of the Greek λίθος. When the final letter of the word is a vowel, the termination *ne* is often used; thus the minerals dedicated to Sir H. Davy and the Abbé Haüy have been named

respectively Davyne and Haüyne, these forms being more euphonious than the corresponding words terminating in *ite*.

In France and Italy the same general practice prevails, but in Germany and Scandinavia the equivalent termination *it* or *ith* is used instead of *ite*.

The older names referred to as preceding the language of systematic mineralogy, are derived partly from classical antiquity, especially from the writings of Theophrastus and Pliny, and partly from the German writers of the fifteenth and sixteenth centuries. To the former we owe many of the names of minerals used as gems, such as diamond (adamas), sapphire (sapphirus), emerald (smaragdus), &c., as well as those of some of the commoner metallic ores, as pyrites, magnetite, and hematite; and to the latter the names of the more abundant rock-forming minerals, such as quartz, felspar, hornblende, schorl, &c., most of which are, however, only reproductions of the current miners' terms of the period. The use of complimentary names originated with Werner, the oldest example being Torberite, named after Torber Bergmann. Local names were among the earliest in use, e.g. magnetite, named after Magnesia in Asia Minor, where the loadstone was found; and copper, derived from the Latin *cuprum*, called after the island of Cyprus; but their principal development is due to the necessities of modern mineralogy. When properly selected they are very convenient, as serving to fix in the memory either the localities where minerals have been originally found, or where they are specially abundant, as, for example, Chessylite, applied to the blue hydrated carbonate of copper from Chessy, near Lyons, whence the finest examples have been derived; Anglesite, to sulphate of lead, from the original locality, Parys Mine, in Anglesea; Falunite, to a hydrated silicate, first observed at the mines of Falun, in Sweden; and many others. On the other hand, such names as Cornwallite, Erinite, and Piedmontite, are too vague to serve as useful reminders of the localities whence the minerals so designated have been derived; while Towanite

is an example of an inappropriate local name—that of a small Cornish harbour—for copper pyrites, which is of world-wide distribution : these may be regarded as models to be avoided.

Names founded on physical or chemical peculiarities are mostly of modern origin, and are generally compounded of Greek words with the systematic termination. Such are : Idocrase, from εἶδος, form, and κρᾶσις, mixture, referring to the great number of observed forms ; Sarcolite, from σαρκός, flesh, and λίθος, from its pale red or flesh-coloured tint ; and many others. As a rule, these names are among the most uncouth and inconvenient ; and as they are not unfrequently founded upon false analogies, some trivial character, or one that may be common to many other minerals, being selected, as a specific distinction, knowledge of their etymology is not always an advantage as an aid to the memory. Names of this kind are largely used in the class of silicates, and more particularly in the group known as Zeolites.

Owing to the great diversity of opinion as to the value of specific names as adopted by different authors, the use of synonyms becomes a necessity in descriptive mineralogy. This is especially the case in comparing works written in different languages, the particular name current in one country being often represented by a synonym of equal value in another. Thus the mineral known as Leucite in England and Germany, is generally called Amphigène by French and Italian mineralogists ; Idocrase, used in France and England, is equivalent to the German Vesuvian ; and so on. In other cases synonyms result from names independently given to particular varieties of minerals, which have afterwards been brought under the general name of pre-existing species. Such names are often very convenient when the varieties to which they are applied are well defined.

When a selection has to be made among many synonyms, it is generally preferable to use the oldest and best established name, rather than a new one, even although the latter may

be irreproachable in termination; and in the case of minerals worked as metallic ores, the ordinary commercial names should always be used where possible. Thus for all purposes copper pyrites, tinstone, and zinc blende, are preferable to chalcopyrite, cassiterite, and sphalerite.

Classification.—In the earlier systems of mineralogy the classification was, as a rule, arbitrary, some prominent species being adopted as types of classes, to which others were referred by the use of analogies, mostly founded on physical properties. Thus we have in Werner's systems of 1789–1816 classes of gems and stones, salifiable substances, pyrites, blendes, inflammable minerals, &c., giving an essentially incongruous grouping, though in many instances the associations were sufficiently natural. The same order was adopted by Mohs and Breithaupt, with the adoption of generic and specific nomenclature analogous to that of the biological sciences. This latter arrangement was tried by several authors in the interest of symmetry, but it has in all cases proved impracticable on the large scale; the objection of requiring two special names to indicate a mineral instead of one, being sufficient to condemn it for ordinary use. In the older chemical classifications, such as that of Berzelius, in 1816, the base or electro-positive element is adopted as the foundation of the group, all the compounds of one metal, such as calcium, lead, copper, magnesium, &c., whether sulphides, silicates, carbonates, &c., being classified together. This has the inconvenience of masking the isomorphous relations of the analogous compounds of different bases, and necessitates repetition where two or more bases of equal importance are present in the same substance, e.g. potassium and aluminium in felspar, &c. This is obviated in the second classification of Berzelius according to the electro-negative components, all sulphides being grouped together without regard to the nature of their bases, except that of their molecular quantivalence. In this way the isomorphous relations of form to constitution, which is the only natural

basis of classification, are brought out. In rare instances the formation of sub-groups, upon grounds that are mainly physical, becomes necessary, owing to the complication or uncertainty of the molecular constitution, these occurring mainly in the group of silicates.

The classification adopted in the following pages is in the main similar to that of the second edition of Rammelsberg's 'Mineral-Chemie;' but, in the chemical formulæ, the method of grouping analogous molecular compounds in parallel horizontal lines has generally been departed from, and a consecutive order adopted so as to economise space.

A few general remarks on the forms and relations to each other of the different species in the groups are given as introductory matter to each of the chapters.

CHAPTER II.

NATIVE ELEMENTS.

THE few elements occurring in the free state in minerals may be grouped in three well-marked series. The first of these includes the heavy malleable metals, gold, silver, copper, mercury, iron, and the platinum group, which are essentially electro-positive or basic elements when in combination: all crystallise in the cubical system, and in many instances combine with each other in every proportion without change of form. The second series includes the metals arsenic, antimony, and bismuth, and the metalloids sulphur, selenium, and tellurium, that are usually electro-negative when in combination with the members of the first series, but are electro-positive when in combination with the metalloids of the same series, especially sulphur, and also with oxygen or chlorine. Arsenic, antimony, bismuth, and tellurium, are isomorphous, crystallising in rhombohedral forms, whose crystallographic elements are very closely related. Sulphur is remarkable for its trimorphism, being known in two different crystalline series as well as in the amorphous state; but only one of the former is found in nature: similar properties also distinguish its analogue selenium, which is not, however, found in a free state.

The third group is represented by the single metalloid carbon, which is also trimorphous, being found crystallised in a cubical series of forms in diamond, in a rhombohedral or monosymmetric series in graphite, and amorphous in coal and other substances, resulting from the alteration of

carbohydrates, and, although standing alone in nature, is closely allied to silicon and boron, which may be prepared artificially and are similarly trimorphous.

GROUP I.

GOLD.—*Cubic holohedral.* Figs. 1–2. $o\{111\}O$, $d\{110\}\infty O$, $a\{100\}\infty O\infty$, $m\{311\}3O3$, $t\{421\}4\breve{O}2$. Twins common on 111, the structure when repeated producing striated surfaces. Crystals rarely of large size or developed on more than a few faces. Usually aggregated into acicular or arborescent forms and filaments, or massive in various forms

FIG. 1.

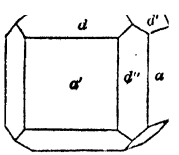
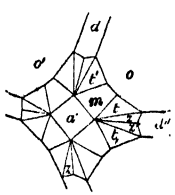


FIG. 2.



from minute scales (dust) up to irregular lumps of several pounds' weight (nuggets). Cleavage, none. Fracture, hackly to finely granular, but difficult to produce. Very malleable. Hardness, 2·5–3. Sp. gr. 15·6–19·5, according to composition; when chemically pure, melted, and not rolled, 19·4. Lustre, metallic. Colour, gold-yellow in purest varieties, but varying from pale straw-yellow to full orange-red in different samples.

Composition.—Gold, alloyed with silver. The amount of the latter may vary from 1 to 40 per cent. Copper and iron may also be present, but the total of foreign substances other than silver is usually under 1 per cent. The proportion of gold in 1,000 parts of the metal is called its millesimal fineness. This is tolerably constant on the large scale over particular districts, e.g. :

	Average fineness.	Extremes.	Silver.
California. . .	880	870–890	60–120
Australia . . .	925	900–960	35–60
Russia . . .	—	870–980	2–125

Silver diminishes the colour and density very rapidly: when present to the extent of 28 per cent. the colour is a very pale yellow. With 35 per cent. the distinctive gold colour entirely disappears. Alloys of this kind, of sp. gr. 14·5–15·7, are sometimes separated from gold under the name of *Electrum*.

Fusible without alteration, giving the reaction of copper and iron with borax in oxidising flame, and a yellow opaque bead due to silver with salt of phosphorus in reducing flame. Insoluble except in aqua regia or other compounds evolving chlorine, the silver remaining as an insoluble chloride. Precipitated from solution as a brown powder by ferrous sulphate, or by oxalic or sulphurous acid. Distinguished from other minerals of the same colour, such as copper or iron pyrites, by its malleability and streak, which is the same as that of the mass, the streak of iron pyrites and copper pyrites being black and greenish respectively. Golden-coloured mica scales are sometimes very similar to gold dust, but can be distinguished by their cleavage, the elasticity of the thin scales, and the colourless streak. More striking differences may be made out by the use of the blowpipe or wet reagents, but as a rule the simpler physical tests given above will be sufficient. For trying the streak the ordinary jeweller's touchstone is most convenient, the colour of the mark made by the specimen under examination being first compared with that of an alloy of known composition and afterwards touched with a drop of dilute nitric acid, when the mark of that of a base metal or low gold alloy will disappear or diminish visibly in brilliancy, while that produced by gold of high fineness is not sensibly altered in appearance.

Occurrence.—Gold is found in two principal forms—namely, in crystalline and irregular masses, in quartz veins traversing chloritic, talcose, and argillaceous schists; and in worn and rounded particles of all sizes, from the finest scales up to lumps or nuggets of several hundreds or even thousands of ounces in weight, in alluvial deposits—the former being usually distinguished as vein, quartz, or mill gold, and the latter as wash, stream, alluvial, or placer gold. When in veins, its usual associates are pyrites, galena, copper pyrites, magnetic pyrites, mispickel, magnetite, hematite, blende, bismuth, tetradymite, and other tellurium minerals, many of which are, as a rule, auriferous. In alluvial deposits, it accompanies the harder and heavier minerals resulting from the waste of the original matrix or rock whence it has been derived, the most abundant being magnetite, garnet, zircon, spinel, diamond, topaz, sapphire, platinum, osmiridium, chromic iron, and magnetite. The finer particles are distinguished as float gold or gold dust; those of medium sizes, from $\frac{1}{20}$ to $\frac{1}{2}$-ounce weight, as coarse gold; and all above that weight as pepites or nuggets. These are occasionally found in considerable size, having been discovered at different times exceeding 50 lbs. in weight, among which are one of 87 lbs. from Miask, another of 161 lbs. from California, the largest being the Welcome nugget of Ballarat in Australia, weighing 184 lbs. Such masses are, however, exceedingly rare, the bulk of the gold of the world being obtained by stamping and washing from quartz vein stuff, in which it is rarely visible, quartz with $\frac{1}{4}$ oz. troy of gold per ton, or 1 part in 130,000, and alluvial deposits with considerably less being worked on the large scale. Iron pyrites and galena almost invariably contain gold, which, when in sufficient quantity, may be extracted directly by amalgamation with mercury, or concentrated by the processes of smelting lead, and finally in silver, whence it is recovered by the process of parting, or solution in sulphuric acid. Native bismuth, especially that from South America,

often contains a considerable amount of gold, which may be recovered by treating it in the same manner as lead, by cupellation.

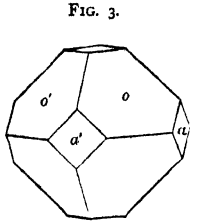
Gold is very widely distributed, being found in all the continents, although very unequally distributed. In the United Kingdom it has been found in alluvial deposits in Cornwall in association with tin ore, and in similar deposits in Wicklow, and at Helmsdale in Sutherlandshire; the principal localities of gold-bearing veins being in the vicinity of Dolgelly, and at Ogofau in Carmarthenshire. On the continent of Europe small quantities of alluvial gold are obtained from the sands of the Rhine and the Danube, and there are mines upon quartz veins in the Alps, at Zell and Gastein in Tyrol, and others of a more productive character at Pestarena in Italy. At Schemnitz in Hungary it is worked with galena and silver ores, and at Nagyag, Felsöbanya, Ofenbanya, and other places in Transylvania, in association with tellurium minerals. The largest production is, however, in Russia, the Pacific States of America, and Australia. The Russian mines, which are principally alluvial, extend along the eastern slope of the Ural and over a considerable part of Siberia, the most productive localities being Beresov, Nischne Tagilsk, and Miask. The principal American mines are those of California, extending along the whole valley of the Sacramento river northward to the Klamath and Columbia valleys, or generally along the western slope of the continent, the same conditions prevailing northward in the Fraser river basin in British Columbia. On the Atlantic side gold mines have been worked in Virginia, North and South Carolina, and Alabama, in the St. Lawrence valley, on the Chaudière river in Canada, and in Nova Scotia, but more important localities are in Colorado, Dakotah, and Montana. The Australian mines extend along the eastern slope of the continent, from Queensland through New South Wales and Victoria to Bass's Straits, the most productive areas being in the

neighbourhood of Ballarat, Castlemaine, and Sandhurst, in Victoria, where both alluvial deposits and quartz veins are extensively worked. There is also a considerable production in New Zealand.

In Africa the principal production is in the higher Nile valley in Abyssinia, but mines of enormous antiquity, which have been long abandoned, are known in Nubia between the Nile and the Red Sea. Coarse, nuggety gold has been brought from the Transvaal district. In Brazil the principal mines are in the district of Minas Geraes, the minerals worked being chiefly arsenical and magnetic pyrites, which yield gold by amalgamation, but rarely contain it in a visible form. *Palladium gold*, or *porpezite*, from Porpez in Brazil, contains 4 per cent. of silver and 10 per cent. of palladium. *Rhodium gold* contains rhodium in variable quantities up to 43 per cent.; sp. gr. 15–16.

SILVER.—*Cubic.* Fig. 3. $o\{111\}O$, $a\{100\}\infty C\infty$. Also $\{210\}\infty O2$, $\{520\}\infty O\frac{5}{2}$, $\{410\}\infty O4$, $\{311\}3O3$, $\{751\}7O\frac{7}{5}$.

FIG. 3.



Twins common on 111. Crystals often distorted by elongation on a dodecahedral axis. Dendritic aggregates common; also wires and thin sheets, and films. Cleavage, none. Fracture, hackly to fine-granular; very malleable. H. 2·5–3. Sp. gr. 10·51–11. Lustre, metallic. Colour and streak, silver-white. Tarnishes black.

Composition.—Silver sometimes pure, usually alloyed with copper, mercury, arsenic, antimony, or gold. When the latter is in quantity, it passes into electrum; maximum of copper about 10 per cent.; of mercury, 8 per cent.

Easily fusible to a bright metallic globule, which absorbs oxygen while melted, giving it out on solidification (spitting). Gives a yellow enamel with salt of phosphorus in oxidising

flame. Soluble in nitric acid ; solution colourless if pure ; usually blue from copper, or with black sediment of gold, and giving a dense curdy precipitate, with salt or hydrochloric acid of chloride of silver, which is soluble in excess of ammonia, and may be reduced to metallic silver by zinc.

Occurrence.—Usually in association with silver-glance, proustite, pyrargyrite, horn silver, and other argentiferous minerals, being very commonly a product of the alteration of these species, and found in pseudomorphs after them ; also with galena, iron pyrites, antimonial ores, and those of nickel and cobalt. The largest crystals, cubes about half-inch side, are from Kongsberg, in Norway. The commonest occurrence is, however, in wire-like dendritic masses, which are found in almost every silver-mining district of Europe and America, usually in druses with calcite. In the Lake Superior district it is irregularly interspersed through native copper, and in New Mexico and Utah in thin sheets, in slates, and grains in sandstone.

Filiform and crystalline aggregates, similar to natural ones, are sometimes found in the hearths of furnaces, smelting silver ores. These are supposed to originate from the action of steam upon sulphide of silver at a red heat.

COPPER.—*Cubic.* Figs. 4–6. $o\{111\}O$, $a\{100\}\infty O\infty$,

FIG. 4.

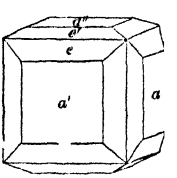
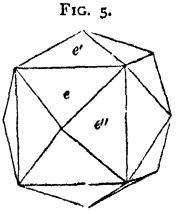


FIG. 5.



$d\{110\}\infty O$, $e\{210\}\infty O2$, $k\{520\}\infty O\frac{5}{2}$. Twin plane $\{111\}O$, fig. 7. Here the form is distorted by compression on the

twin axis, only one-fourth of the full number of faces being developed. Crystals rarely well formed, except when small, being usually distorted, or with curved faces. Usually in irregular aggregates, including dendritic, filiform, platy and solid masses, also interspersed in grains or flakes through other minerals; as encrusting pseudomorphs of quartz,

FIG. 6.

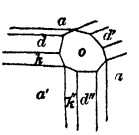
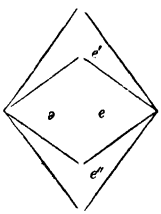


FIG. 7



calcite, and aragonite, and in the hollows of vesicular rocks. H. 2·5–3. Sp. gr. 8·5–8·9. Fracture, hackly, finely granular to silky; very malleable. Cleavage, none. Lustre, metallic. Colour, copper-red when fresh, usually of a lighter tint than commercial bar copper; generally tarnished to various shades of red or brown to black.

Composition.—Copper, often extremely pure, usually purer than the best-refined smelted copper. The observed impurities are chiefly iron, arsenic, silver, and mercury. Fusible at a strong red heat in reducing flame to a bead, having a green opalescence while melted. With fluxes, gives the characteristic reactions of copper. Soluble in nitric acid, giving a clear green solution, also slowly in ammonia when exposed to the air.

Occurrence.—Commonly as a product of the alteration of pyritic minerals in copper lodes, with red oxide, carbonates, and other oxidised copper ores, in Cornwall, Russia, South Australia, &c. At Coro Coro, in Bolivia, interspersed through sandstone (copper barilla). In basalt, dolerite, &c., on the Rhine, Antrim, the Faröe Islands, and Lake

Superior. In serpentine in the Lizard district, Cornwall. The largest European mass of copper was found at Mullion, Cornwall. It weighed about three tons ; one half has been preserved in the collection of the Royal School of Mines, London. In the Lake Superior mines masses of enormous size have been found. They are of irregular form, filling vein fissures, the largest having measured 45 to 60 feet deep, 20 to 35 feet long, and 5 to 8 feet thick ; the latter dimension being the most variable from the inclusion of masses of vein stuff. In one instance a druse of crystals {210}, about $1\frac{1}{2}$ inch across, was found in the centre of a mass $4\frac{1}{2}$ feet thick. From 200 to 500 tons of copper have been taken from single masses, and one was reputed to have cubed 800 tons. These are remarkable, not only as minerals, but as the largest masses of any single element known upon the earth's surface.

In addition to the large masses, the Lake Superior mines afford numerous other forms of native copper, often irregularly intermixed with native silver in porphyritic forms, but rarely alloyed ; the metal cut from the large masses being, as a rule, remarkably pure, and when tested electrically giving a higher conductivity even than that deposited by electrolysis. The bulk of the produce of the district is obtained from amygdaloidal dolerites, whose cavities are lined with shells of copper filled with calcite, zeolites, and other minerals, the rock being of such a character that it can be crushed by stamping, when the metal separates in malleable flakes and shots that may easily be recovered by washing. At the Calumet and Hecla Mine, one of the most productive copper mines in the world, about 15,000 tons of copper are smelted annually from a conglomerate of quartz and jasper pebbles which is in great part cemented by the metal. The entire district, which is about 200 miles in length, practically produces no other copper-bearing mineral than the native metal, sulphides and other ores being almost entirely absent, a condition which has not been observed in any

other area of the same size. Copper has been observed in pseudomorphs after quartz, calcite, and aragonite, but these are generally encrusting forms. Large crystals from Lake Superior, well developed externally, are often mere shells which are filled with calcite, zeolites, and orthoclase. When interspersed in minute films through crystals of calcite the latter have a peculiar pink tint. Very perfect replacements of aragonite are obtained from Chili. When exposed to air and water for a considerable time, the surfaces of masses of native copper are slowly covered with an earthy variety of malachite with an intermediate layer of red oxide. This change is commonly seen in ancient bronze and copper ornaments and coins that have been buried for a long time in the ground. By the action of water containing sulphides or alkaline sulphates and organic matter, copper may be converted into the disulphide, copper pyrites, and other sulphuretted copper ores.

Water containing sulphate of copper in solution often deposits metallic copper when left in contact with a reducing agent, such as metallic iron, wood, or carbonaceous substances. In this way very fine crystals are sometimes obtained in old mine works and waste heaps.

OSMIRIDIUM. Newjanskite. Light Osmiridium. — *Hexagonal.* Z 124°, $a : c = 1 : 1{\cdot}4105$. In small tabular crystals and flattened grains. Cleavage, {0001}(0*P*), tolerably perfect. Sp. gr. 19·5. Whiter and of a higher lustre than platinum.

Composition.—IrOs, or osmium 49·34, iridium 46·77, rhodium 3·15, and iron 0·74; the two latter metals being in partial replacement of iridium.

IRIDOSMIUM. Sisserskite. Dark Osmiridium.—*Hexagonal,* and similar to the preceding except that the sp. gr. is 21–21·2 and colour darker, approaching lead-grey.

Composition.—$IrOs_3$ and $IrOs_4$, with 25 and 30 per cent.

of iridium respectively, the remainder being osmium with some rhodium and ruthenium. The maximum amount of osmium is 77 per cent. Both varieties are infusible and insoluble in acids, including aqua regia, but are decomposed by fusion with nitre, giving off pungent vapours of osmic acid, leaving a saline mass, from which blue oxide of iridium may be extracted by water. The darker variety gives off osmium vapours when heated on charcoal.

Occurrence.—With platiniferous alluvial sands of the Ural, forming the residue when crude platinum is dissolved in aqua regia. Also with gold in California, Oregon, and British Columbia. The larger grains of the light-coloured variety are used for pointing the nibs of gold pens.

Gold dust containing osmiridium is usually melted with a quantity of silver or zinc sufficient to reduce its specific gravity to such an extent that the heavy suspended grains of the latter minerals fall to the bottom of the melting pot and are retained in the last bar of the cast, which is put aside for special treatment. If this is not done, and the grains remain diffused through the gold, the gold bars will be quite unfit for coinage.

PALLADIUM.—*Cubic.* Usually in grains like platinum and the allied minerals. Malleable. H. 4–5. Sp. gr. 11·8–12·2. Colour, light steel-grey.

Composition. — Palladium, with some platinum and iridium. Infusible; soluble in nitric acid, giving a red solution. Occurs with platinum in gold dust from Brazil; formerly obtained in some quantity, but is now exceedingly scarce.

Palladium is a metal somewhat whiter than platinum, but bluer than silver. It is chiefly remarkable for its capacity of absorbing hydrogen up to 800 times its volume, forming a presumed palladium-hydrogenium alloy.

PLATINUM.—*Cubic.* Rarely crystallised in small cubes, usually in grains and rough irregular masses or nuggets.

Cleavage, none. H. 4–4·5. Sp. gr. 16–19. When pure and melted, 21·45, which becomes 21·7 when forged. Lustre, metallic. Colour and streak, bright grey, or intermediate between silver and iron, being bluer than the first and whiter than the second. Fracture, hackly when suddenly, and finely granular when gradually broken; malleable but somewhat hard. Occasionally magneti-polar when containing iron.

Composition.—Essentially platinum (71 to 89 per cent.) and iron (4·8 to 19·66 per cent.), with smaller quantities of iridium (0·6 to 7 per cent.), osmium (0· to 1·8 per cent.), palladium (0·25 to 2·1 per cent.), rhodium (0·30 to 4·40 per cent.), and copper (0·2 to 5·2 per cent.).

Infusible before the blowpipe and insoluble in acids, except, when boiled, aqua regia, when a yellow solution, usually with some insoluble residue of osmiridium, is obtained. Sal ammoniac produces in the solution a precipitate, which when dried and heated to redness yields the metal as a dense black powder.

Occurs chiefly in grains and fragments, which are sometimes included in masses of chromic iron or serpentine, but generally loose, in alluvial deposits, accompanying gold, osmiridium, iridium, palladium, chromic iron ore, magnetite, zircon, corundum, and diamond. The principal localities are at Miask, Nischne Tagilsk, and Goroblagodat, among numerous others on both sides of the Ural, producing about 20 tons annually. In South America, in the provinces of Choco and Barbacoas, in the Republic of Columbia, and in Brazil, the associations are similar, though it is reported in one or two localities to occur in veins with gold, pyrites and brown iron ore. The largest known mass, weighing 23 lbs., is in the museum of the School of Mines in St. Petersburg.

IRIDIUM or platiniridium is another of the group of platinum metals found in crude Russian platinum. It occurs in grains, having the sp. gr. 22·65 to 23, and as such is re-

markable as being the heaviest substance known. Purified melted iridium has sp. gr. of 22·40. An alloy of platinum and iridium has been selected as the metal for the standard metre bars prepared by the International Metre Commission. The alloy is made by melting the metals in a lime crucible by the oxyhydrogen blowpipe, and casting into ingots, which are subsequently reduced to the proper shape for the standard bars by forging.

IRON.—*Cubic.* Observed forms (artificially produced) usually skeleton octahedra; generally massive in various forms, from minute interspersed grains in rocks up to irregular masses of several tons weight. Most of these are supposed to be of extra-terrestrial or meteoric origin, and are generally made up of an alloy of iron with nickel and cobalt, through which are interspersed phosphides of iron and nickel, sulphides of iron and magnesian silicates, such as enstatite and chrysolite. Polished plates of meteoric iron when etched often develop more or less regular patterns, due to crystalline structure. These are known as Widmannstätten's figures, and may also be observed in wrought iron that has been melted and allowed to cool slowly. Burnt iron, or wrought iron, that has been subjected for a long time to a very high temperature, but lower than its melting point, also develops a polyhedral structure analogous to crystalline form, breaking into fragments with brilliant faces, resembling those of cubes or octahedra. Cleavage, cubic, but rarely seen, owing to the tenacity and ductility of the metal; and for the same reason a hackly fracture can only be occasionally developed, that of a finely granular character being more common. H. 4–5. Sp. gr. 7–7·8. Opaque. Lustre, metallic. Colour, iron-grey or black, usually rusted on exposed surfaces; strongly magnetic.

Composition.—Iron, with more or less of nickel, 3 to 17 per cent., with traces of cobalt, copper, chromium, and

manganese. Native iron of reputed terrestrial origin is rare, and is usually found in small masses. As a probable constituent of the basalts of Antrim it has been noticed by Andrews, also in masses up to 25 tons weight in the basalt of Greenland. Meteoric iron masses, on the other hand, are often of enormous size, varying from a few pounds to 15 or 20 tons, and more. Many of these have been seen to fall, and when collected are found to be covered with a fine slag-like glaze of a melted vitreous substance, When broken, they are found to be either compact masses of metallic iron, or granular aggregates of silicates, usually with more or less of the metal scattered through them, but sometimes entirely free from it. Almost every large mass has been made the subject of elaborate chemical investigation, the subject forming a special branch of study which has no immediate connection with ordinary mineralogy. Among the most important researches in this field are those of Berzelius, Haidinger, Lawrence Smith, Maskelyne, and Flight. Daubrée has also published a series of investigations of great interest on the probable synthesis of meteorites.

MERCURY.—*Cubic*, crystallising in octahedra at −40° C., but liquid at all temperatures above the extreme cold of Arctic countries. Sp. gr. 13·59. Lustre, metallic. Colour, white, somewhat bluer than silver.

Composition.—Mercury usually pure, but may contain traces of silver and other metals in solution without losing its fluidity. In the closed tube sublimes, leaving a residue if any foreign metals are present. The sublimate deposits in the cooler part of the tube as a dew of finely divided globules, which may be made to coalesce by agitation. Soluble in nitric acid.

Occurs with cinnabar in globules, and occasionally in larger quantities, in the cavities and druses of the vein-stones at Idria in Carniola, Almaden in Spain, and other

mercury mines. Has also been found in alluvial deposits with chloride of mercury on the Tagus, and in Lüneberg, Hanover.

AMALGAM.—*Cubic* (fig. 8). Principal form $d\{110\}\infty O$, often with complex modifications (fig. 9), $o\{111\}O$, $a\{100\}\infty O\infty$, $p\{221\}2O2$, $n\{211\}2O$, also massive and granu-

FIG. 8.

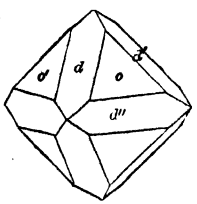
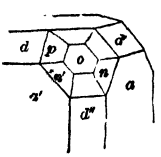


FIG. 9.



lar. Cleavage, 110 very imperfect. H. 3–3·5. Sp. gr. 13·7–14. Opaque. Lustre, metallic. Colour, somewhat whiter than tin. Fracture, granular to uneven, cuts with a grating noise.

Composition.—Mercury and silver in various proportions. The principal varieties are referred to the following types :

AgHg	containing silver	35	mercury	65	per cent.
Ag_2Hg_3	„	„	26·5	„	73·5	„

The principal localities are Moschellandsberg in Rhenish Bavaria, whence most of the finely crystallised specimens have been derived, Almaden, Allemont, Dauphiné, and Chañarcillo, Chili.

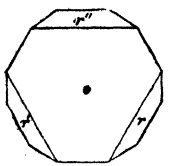
Arquerite is an amalgam of the composition $Ag_{12}Hg$ with 86·5 per cent. of silver from Arqueros, Chili.

Gold amalgam has been found in a few localities in South America with platinum metals, and at Mariposa and elsewhere in California. It contains about 75 per cent. of gold.

GROUP II.

ARSENIC. Scherbenkobalt.—*Hexagonal, rhombohedral.* $R = 85° 41'$, a $c = 1 : 1{\cdot}3779$ (fig. 10), $r\kappa\{10\bar{1}1\}R$, $o\{0001\}oR$. The crystallographic determinations are from crystals artificially prepared, which are of thin tabular habit. Cleavage, 0001 perfect, $01\bar{1}2$ imperfect. Usually in botryoidal, reniform, or spheroidal masses, with a fibrous or granular structure, also compact and interspersed. H. 3·5. Sp. gr. 5·75. Lustre, metallic. Colour, white, with a bluish cast, only to be seen in freshly broken specimens, as it tarnishes very rapidly to a dark brown or black, and becomes dull; streak, black, which may be burnished to a sub-metallic lustre like that of graphite when rubbed. Fracture, very finely granular to uneven. Essentially brittle, though slightly malleable when cut with a knife or crushed under a hammer.

FIG. 10.



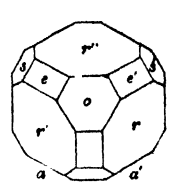
Composition.—Arsenic with traces of antimony, iron, nickel, cobalt, silver, or gold, from the associated ores of these metals. Volatilises without fusion on charcoal, giving the characteristic garlic-like odour. In the closed tube sublimes, forming a brilliant metallic mirror. Heated with access of air it is converted into arsenious acid As_2O_3, which deposits as a dense white crystalline sublimate. Soluble in nitric acid with formation of arsenious acid, and by complete oxidation, of arsenic acid As_2O_5. The solution when freed from nitric acid gives with sulphuretted hydrogen an orange-yellow precipitate, which is soluble in carbonate of ammonia.

Occurrence.—Native arsenic is a not very common associate of arsenical silver, lead, nickel, cobalt, and copper ores in the mines producing these minerals, more especially those of silver, nickel, and cobalt. The most productive

localities have been Andreasberg in the Harz, Freiberg, Marienberg, Joachimsthal, Schneeberg, and Annaberg, in Saxony and Bohemia, and the Münsterthal in Baden.

ANTIMONY. — *Hexagonal, rhombohedral.* $R = 87° 35'$, $a : c = 1 : 1{\cdot}3068$ (fig. 11), $r\kappa\{10\bar{1}1\}R$, $e\kappa\{01\bar{1}2\} -\frac{1}{2}R$, $s\{02\bar{2}1\} -2R$, $a\{11\bar{2}0\}\infty P2$, $o\{0001\}$ $o R$. Crystals rarely simply, usually repeated twins on $01\bar{1}2$. Cleavage, basal, very perfect, rhombohedral, $01\bar{1}2$ perfect, $02\bar{2}1$ imperfect. Usually massive in lamellar, botryoidal, and reniform aggregates, the latter of a granular texture. H. 3–3·5. Sp. gr. 6·65–6·72. Lustre, metallic. Colour and streak, white, a little bluer than tin. Brittle. Fracture, lamellar to finely granular, according to the structure of the crystalline plates, the surface of a broken mass consisting mostly of basal cleavages.

FIG. 11.



Composition.—Antimony, usually containing some iron, arsenic, or silver. Fuses on charcoal at 440° C., at a higher temperature burns, producing a dense white smoke of Sb_2O_3. In the closed tube gives a dark metallic sublimate like arsenic, but being less volatile the deposit takes place nearer to the assay. In the open tube gives a sublimate of antimonious acid Sb_2O_3. Soluble in nitric acid, being partly converted into insoluble Sb_2O_3, and partly into nitrate of antimony. Soluble in aqua regia; the solution when diluted with water becomes turbid from the separation of Sb_2Cl_3.

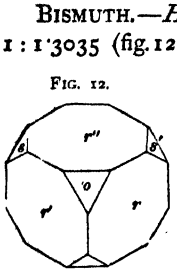
Occurrence.—Essentially rare, being found chiefly at Allemont in Dauphiné, in Borneo, with other antimonial minerals at Přibram and Andreasberg.

Allemontite is a natural alloy of arsenic and antimony, sp. gr. 6·203, approximating in composition to $SbAs_3$ = 37·85 Sb, 62·15 As per cent. Found at Allemont. Many

specimens of native arsenic from other localities are somewhat similar in composition.

BISMUTH.—*Hexagonal, rhombohedral.* $R=87° 40', a : c = 1 : 1·3035$ (fig. 12), $r\kappa\{10\bar{1}1\}R$, $s\kappa\{01\bar{1}2\} - 2R$, $o\{0001\}oR$.

FIG. 12.



The fundamental rhombohedron is easily obtained of large size by crystallisation from fusion. Twin face $-\frac{1}{2}R$. Cleavage, oR perfect, $-\frac{1}{2}R$ and $-2R$ imperfect. Generally massive in plates, interspersed grains, or plumose, and dendritic aggregates, basal surfaces commonly striated parallel to the edges of the rhombohedron. H. 2–2·5. Sp. gr. 9·73. Opaque. Lustre, metallic. Colour, white, with a reddish tinge; streak, grey, but taking the colour of the metal when burnished. Somewhat sectile, but breaks under the hammer. Fracture, highly crystalline.

Composition.—Bismuth, often with some sulphur, tellurium, or arsenic, the latter up to 30 per cent., and sometimes sufficient gold and silver to be worth extraction on the large scale. Melts at 268° C., volatilises on charcoal with the deposit of a lemon-yellow sublimate of BiO; when melted on bone ash in a muffle the oxide, as it forms, melts, and is absorbed, so that the metal can be examined for gold and silver by cupellation in the same manner as lead. Soluble in nitric acid, the solution when largely diluted with water giving a dense precipitate of basic subnitrate or *pearl white.*

Occurrence.—Most commonly in association with nickel and cobalt ores in the Schneeberg, Joachimsthal, and Altenberg mines, also in Bolivia, with tin ores at Botallack and other mines of the St. Just district, at Dolcoath, and Huel Sparnon also with cobalt ores. In Queensland in association with gold in masses coated with a crust of bismuthic oxide and carbonate. In South Australia with molybdenite.

TELLURIUM.—*Hexagonal rhombohedral.* $R = 86° 57'$, $a : c$ 1 : 1·3302. Crystals rare, the largest from Colorado, hexagonal prisms with rhombohedral terminations; generally massive or in finely granular aggregates. Cleavage, ∞R perfect, oR imperfect. Brittle. H. 2–2·5. Sp. gr. 6·1–6·3. Lustre, metallic. Colour and streak, tin- to silver-white, tarnishing brown.

Composition.—Tellurium, usually with some gold. Fuses easily, and volatilises on charcoal, burning with a green flame. In the open tube gives a sublimate of Te_2O_3, which is colourless and transparent when melted, also oxidised by the action of nitric acid. Soluble without change in sulphuric acid, when not too strongly heated, giving a red solution, from which a blackish grey powder of tellurium is precipitated by dilution with water.

Occurrence.—Very rare, in association with tellurides of gold, silver, and other metals, in Transylvania and the mines near Gold Hill, Colorado.

TETRADYMITE.—*Hexagonal, rhombohedral.* In compound groups containing the combination $3R$, oR four times, repeated by twinning on $-R$, also massive in foliated and granular aggregates. Cleavage, oR perfect. H. 1·5–2. Sp. gr. 7·2–7·9. Lustre, metallic. Colour, tin-white to steel-grey, tarnishing quickly. Flexible in thin laminæ, marks paper like graphite.

Composition.—Contains bismuth and tellurium with or without sulphur. The former is represented by $Bi_2Te_2S = (2Bi_2Te_3 + Bi_2S_3)$, containing bismuth 59·09, tellurium 36·36, sulphur 4·55 per cent.; some American varieties without sulphur are Bi_2Te_3.

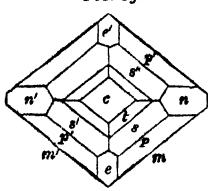
Fusible in the closed tube, giving a grey sublimate; when roasted gives off SO_2 and TeO_2; on charcoal, behaves like tellurium, leaving a button of metal (bismuth); sometimes the odour of selenium is apparent. Soluble in nitric acid, with separation of sulphur.

Occurrence.—With gold and tellurium ores in Merioneth-

shire, Hungary, and a few localities in Norway and Sweden; at Caldbeck Fells, Cumberland; in the United States, in North Carolina and Georgia, Colorado and Arizona; everywhere exceedingly rare.

SULPHUR.—*Rhombic.* $X = 106° 38'$, $Y = 84° 58'$, $Z = 143° 17'$, ∞P $101° 58'$, $a : b : c = 0{\cdot}813 : 1 : 1{\cdot}904$. Crystals pyramidal in habit, $P\{111\}$ predominating. Fig. 13 contains most of the commoner forms, $m\{110\}\infty P$, $p\{111\}$ P, $s\{113\}\frac{1}{3}P$, $t\{115\}\frac{1}{5}P$, $c\{001\}oP$, $e\{101\}\breve{P}\infty$, $n\{011\}\breve{P}\infty$. Twins: 1. on 101 with contact on 111, producing cruciform penetration groups; 2. on 110; 3. on 011; only the first kind common. Cleavage, 001 and 110 imperfect. Also in stalactitic, globular, reniform, and irregular masses, and in powdery incrustations, the latter known as flour or flowers of sulphur. H. 1·5–2·5. Sp. gr. 2·07. Brittle, somewhat sectile. Transparent, translucent, opaque. Lustre, adamantine, resinous. Colour, sulphur-yellow, passing through orange to brown, and through primrose- and straw-yellow to white.

FIG. 13.



Strong, positive, double refraction; indices for yellow light.

$\alpha = 1{\cdot}958$, $\beta = 2{\cdot}038$, $\gamma = 2{\cdot}240$. Optic axial plane 010, first median line axis c, $2V$ $69° 40'$.

Composition.—Sulphur, almost chemically pure in the lighter coloured crystals, those of orange or darker tints often contain selenium or arsenic. Some crystals from the solfatara of Naples with 18 per cent., As_2S_3. The compact varieties usually mixed with clay, bitumen, gypsum, or celestine.

Easily fusible and volatile; melts and sublimes at a low heat in the closed tube, giving the characteristic yellow ring when pure. In the open tube, or before a direct flame, gives off abundant fumes of sulphurous acid, in the latter

case burning with a blue flame. Insoluble in water or acids; soluble in turpentine and bisulphide of carbon.

Occurrence.—Common in volcanic districts, such as Iceland, Vesuvius, the Lipari and Sandwich Islands, &c., as a product of solfataras, as the emanations of steam in the vicinity of active or dormant volcanoes are termed. In such places a deposit of sulphur is formed among the stones of the crater by the steam jets, which, when removed, is renewed at short intervals. The most important deposits are not, however, directly connected with active volcanoes, but are found in tertiary strata in Sicily near Girgenti, where it occurs over a considerable area in white marls and clays associated with gypsum and celestine. Other important localities are in the Romagna, and Hellin and Conil in Spain, where the largest known crystals have been found. In Sicily the sulphur is extracted from the rock, of which it forms 6 to 16 per cent., by piling it in heaps or kilns, which are ignited at the bottom, the heat evolved by the combustion of a portion of the sulphur being employed to melt the remainder, which separates from the infusible earthy matters and collects in basins at the bottom. A less wasteful method, in which the rock is treated with bisulphide of carbon, and the dissolved sulphur subsequently recovered by distillation in retorts, has recently come into use to a small extent, as have also retorts or kilns, in which the rock is heated out of contact with the air.

SELENIUM.—*Oblique.* In thin lead-grey plates red by transmitted light. H. 2. Sp. gr. 4·3. Found only at Culebras, Mexico. Seleniferous sulphur occurs at the solfatara of Volcano in the Lipari Islands, and at Kilauea in Hawaii. It is of a deep orange colour.

GROUP III.

DIAMOND.—*Cubic.* Forms: {111} *O*, with brilliant faces; {100}, $\infty O\infty$, faces pitted; {110} ∞O, faces striated or curved; {211} $2O2$ in combination; {221} $2O$, various ∞On, including {201} {301} {302}; mOn probably {541} {651}. The latter as simple crystals, but invariably with rounded faces (fig. 14). Twins common on 111, usually shortened

FIG. 14.

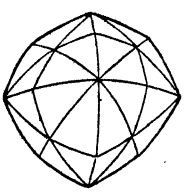
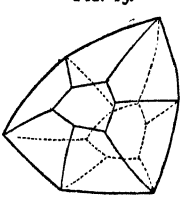


FIG. 15.



on the twin axis, producing with {111} triangular plates, and with {*hkl*} obtuse trigonotype pyramids (fig. 15). Cleavage, 111 very perfect. H. 10. Sp. gr. 3·44–3·52. Transparent, translucent. Lustre, adamantine. Colourless, or variously tints of grey, yellow, brown, pink, or blue, the latter being the rarest. Refractive. Indices of colourless crystals, 2·413 red, 2·419 yellow, 2·428 green; those of brown ones somewhat higher. Strong chromatic dispersion, causing a brilliant play of colours when facetted. Becomes positively electric by friction; is without electric conductivity; often phosphorescent after exposure to strong sunlight.

Composition.—Carbon, with minute traces of foreign substances. Infusible, darkens and becomes opaque, or transformed into graphite, when very strongly heated out of contact with air. In oxygen burns with the production of CO_2. Can also be oxidised by heating with sulphuric acid and potassic bichromate. The siliceous and ferruginous

residue after combustion sometimes shows a reticular arrangement, which may indicate vegetable cellular structure. Crystals often polarise light from irregular internal tension. In burning, triangular depressions parallel to faces of {311} are developed on the faces of {111}. These are common in South African crystals.

Occurrence.—Found in Brazil, the Ural, India, Australia, Borneo, and South Africa, the first and last localities, especially the latter, being the most productive at present. The rock called Itacolumite, a schistose and chloritic quartzite, is characteristic of the Brazilian diamond districts, the diamonds being found in a gravel of pebbles of quartz, chalcedony, and other siliceous substances, cemented by limonite and clay. In Australia few crystals have been found with zircon, garnet, and sapphire in gold-bearing alluvia or 'gem gravels.' In India the diamond gravels are similar to those of Brazil, containing quartz, agate, jasper, &c., upon sandstones of Devonian age. In South Africa the productive localities are the gravels of the Vaal and Orange rivers, and more particularly dykes or pipes of decomposing igneous rocks (probably an olivine basalt or enstatite rock) penetrating schists. This has now been worked several hundred feet below the surface without getting to undecomposed rock. The diamonds are found irregularly interspersed through it, and may be an original constituent, but the general opinion of local investigators is that they have been derived from older rocks below.

The South African crystals are mostly regularly formed octahedra, simple and in combination with {*hkl*}; the Brazilian, dodecahedra with curved faces, {*hkl*} approximating to {110} and tabular twins and octahedra. The Indian forms are mostly octahedra. The largest known diamond is said to be in Borneo, and to weigh 367 carats or 1284 troy grains. The Pitt, a cut brilliant, is of 136 carats. The Koh-i-Noor in the original Oriental shape was 186, but has been reduced to a brilliant of 124 carats. Many

large crystals have been discovered of late years in South Africa.

The chief use of diamond is for ornamental purposes, the crystals being reduced by cutting or grinding with diamond dust upon a lapidary's wheel to a double pyramidal form, unsymmetrical to the base, being pointed at one end, and with a large flat surface at the other, as in hemimorphic crystals. The pyramid is cut with the largest number of faces possible, to obtain a maximum of total reflecting surfaces; the stone is mounted with the flat surface uppermost. These are known as brilliants, and can only be obtained from well-shaped crystals. Those of less regular form are cut as roses, in which the surface is covered with triangular facets, and the thinnest twins or flat cleavage pieces are made into tables, having only a narrow band of facets on the sides. Diamonds that, from want of lustre or defects, cannot be cut, are called Bort. For glass-cutting the apex of an octahedral crystal is required, so as to have a solid point, a cleavage fragment or other splinter being only useful for writing or scratching.

Carbonado is a black amorphous diamond found in Brazil, often in masses of considerable size. It is intensely hard, and being uncleavable, cuts in any direction, being the most powerful abrading agent known. It is used in rock-boring and millstone-dressing machines.

The extreme hardness and lustre of diamond are usually sufficient to distinguish it when cut from other gems, such as topaz or white beryl, or imitations made in dense glass or paste. When uncut the crystalline form is the best guide. The specific gravity is sufficient to distinguish it from most gems except topaz.

GRAPHITE. Plumbago, Black Lead.—In six-sided prisms with flat ends and modified basal edges, which may be hexagonal or, according to Nordenskjold, oblique, basal planes, often striated parallel to the edges. Crystals usually

short, columnar, or tabular, also in columnar fibrous and radiated aggregates, plates, scales, and compact masses. Cleavage, basal, very perfect. H. 1–2. Sp. gr. 2–2·26. Sectile, flexible in thin laminæ. Opaque. Lustre, metallic. Colour and streak, iron-grey, black. Marks paper, the softer varieties giving the darker marks; unctuous to the touch, and feels cold in the hand from its comparatively high thermal conductivity; also a good electric conductor, which diamond is not.

Composition.—Carbon, with variable amounts of ash, mostly iron, silica, and earthy matters. The purest varieties contain 94 to 96 per cent. of carbon, while in those of inferior quality it may be as low as 35 per cent. Infusible, burns slowly in the air when finely divided, and more readily in oxygen, producing CO_2. Insoluble and unaffected by acids; but by continued heating, with a mixture of nitric or sulphuric acid and potassic bichromate or chlorate, may be partially oxidised to graphitic acid ($C_{11}H_4O_5$).

Occurrence.—Found chiefly interspersed in grains, scales, or small fragments in granite grains and crystalline limestones, and in larger irregular masses, which are more or less lenticular in shape. The finest quality for pencils, the amorphous kind, has been obtained from Borrowdale in Cumberland, where it occurs in 'sops' or irregular masses in a dyke of diorite. Another and much larger deposit is worked in granite at Alibert's Mine in Eastern Siberia. The largest commercial supply is obtained from Ceylon, whence it is exported in powder and lumps of various sizes, the latter being often well crystallised. Similar crystalline varieties are found with apatite and mica in crystalline limestones in Canada and in the State of New York. The largest deposits in Continental Europe are near Passau in Austria.

As an accidental product it is formed on the large scale in iron smelting, masses from two to three inches across being occasionally found in the slags of blast furnaces.

This product is highly crystalline and is known as *Kish.* The action of iron as a special solvent in this case is parallel to that of aluminium or zinc in the production of the crystallised varieties of the analogous elements boron and silicon.

The carbonaceous substance deposited in gas retorts resembles graphite in its refractory nature and high electric conductivity, but is very much harder.

Molybdenite and *micaceous hematite* are very similar in appearance to graphite ; the former is distinguished from it by the slightly green colour of its streak, and by giving the reaction of sulphur in the open tube. The latter is distinguished by its red streak, and by its giving reactions of iron with fluxes.

CHAPTER III.

ARSENIDES AND ANTIMONIDES.

THE natural compounds of antimony and arsenic with the heavy metals, silver, copper, lead, iron, nickel, &c., form two groups of dissimilar constitution. Of these the first or basic group includes a small number of species which may be represented by the general formula Rn(AsSb), where n is some large number, ranging from 3 to 18, and R=Cu or Ag. The second group includes an important series of minerals, which are represented by three types; namely, normal arsenides of the forms RAs, RSb, where R = Ni; bi-arsenides of the form RAs_2, where R may be either Fe, Ni, or Co, or any two or all three of these metals; and intermediate forms, such as R_3As_4 or R_5As_8. A portion of the arsenic may also be replaced by sulphur, or rather the molecule of arsenide may combine with the analogous molecule of sulphide, such as RAs with RS, and RAs_2 with RS_2, without change of form.

The normal and intermediate arsenides, like the corresponding sulphides, are generally hexagonal when crystallised. The biarsenides are both rhombic and cubic, in the same manner as FeS_2 is dimorphous in the same systems. The cubic forms of the biarsenides are, however, usually holohedral; while cubic FeS_2, iron pyrites, is remarkable for its pentagonal hemihedrism. This particular habit is, however, characteristic of one member of the group, namely, cobalt glance ($CoS_2 + CoAs_2$), in a very marked degree.

The minerals included in this group are essentially ores of arsenic, nickel, and cobalt, and form the principal commercial sources of supply of these metals. Although occasionally found pure in considerable masses, they are as a rule intimately mixed with iron pyrites and similar substances of small value, the nickel or cobalt forming but a very small proportion of the actual ore, so that their reduction involves considerable cost and labour.

BASIC SERIES, R (AsSbBi).

ARSENICAL COPPER.—Under this head are included various substances, which are essentially basic arsenides of copper. They are distinguished by different names, according to composition, as follows:

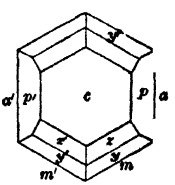
			per cent.		per cent.
DOMEYKITE	Cu_3As	containing	71·71	Cu and	28·29 As
ALGODONITE	Cu_6As	„	83·53	„	16·47 „
WHITNEYITE	Cu_9As	„	88·38	„	11·62 „

The last of these is an amorphous substance of a finely granular or conchoidal fracture; white with a reddish tinge, and metallic lustre very much resembling that of speculum metal when freshly broken, but it usually has a yellow tarnish. Brittle. H. 3–3·5. Sp. gr. 8·4–8·7. The species containing more arsenic are somewhat whiter and of a lower sp. gr.—domeykite 7·2–7·5, algodonite 6·9–7·6—but are otherwise similar. All are fusible on charcoal, giving off arsenical fumes and ultimately yielding a bead of malleable copper in the oxidising flame. Soluble in nitric, but not in hydrochloric, acid.

All these species are found in association with native copper at Houghton, Lake Superior, and with other copper ores near Copiapo and Coquimbo in Chili, but are not common in either locality.

DYSCRASITE. Antimonial Silver.—*Rhombic.* Y 92°, ∞P 119° 59′, $a : b : c = 0{\cdot}5775 : 1 : 0{\cdot}6718$ (fig. 16, or very close to a hexagonal form), $a\{010\}\infty\breve{P}\infty$, $p\{021\}\infty\breve{P}2$, $c\{001\}0P$, $m\{110\}\infty P$, $y\{111\}P$, $z\{112\}\frac{1}{2}P$. Twins common on 110. Crystals short columnar, generally massive or in granular aggregates. Cleavage, 001, 001. Fracture, uneven. Lustre, metallic. Colour, silver- to tin-white, tarnishing yellow and black. H. 3·5. Sp. gr. 9·7–10.

FIG. 16.



Composition.—Various isomorphous mixtures of silver and antimony, including $Ag_{18}Sb$, Ag_6Sb, Ag_3Sb, Ag_2Sb, the corresponding percentages of silver being 94·1, 84·2, 72·65, 63·9.

Fuses easily on charcoal, giving a white incrustation and a globule of silver. Soluble in nitric acid with a residue of antimoniate of silver ($Ag_2Sb_3O_8$). Occurs at Andreasberg, Alt Wolfach in Baden, Allemont, and Chañarcillo.

Arsenical silver is most probably a mixture of dyscrasite with arsenic and mispickel. It occurs in massive reniform aggregates in calcite, averages 9 per cent. of silver and 15·5 of antimony, and is of some importance as a silver ore, at Andreasberg.

NORMAL AND HIGHER ARSENIDES.

BREITHAUPTITE. Antimonial Nickel.—*Hexagonal.* Z 112° 10′, $a : c = 1 : 0{\cdot}8585$. Crystals short, prismatic, or combination of $\infty P.0P$, tabular, with hexagonal striations on base; also dendritic and granular. Fracture, fine conchoidal to uneven. Brittle. H. 5. Sp. gr. 7·54. Lustre, metallic. Colour, copper-red, tarnishing blue; streak, reddish brown.

Composition.—NiSb, with Ni 32·22 and Sb 67·78 per cent., a portion of the former being usually replaced by Fe. Upon charcoal gives a strong antimonial sublimate, leaving a difficultly fusible residue of metallic nickel, which gives

a brown bead with borax in oxidising flame. Completely soluble in aqua regia, giving a green solution (chloride of nickel). Found at Andreasberg in the Harz, with other nickel and cobalt and silver ores. A variety from Ar in the Pyrenees contains 11 per cent. of arsenic in partial replacement of antimony.

RED NICKEL ORE. Copper Nickel, Kupfernickel, Nickeline, Rothnickelkies.—*Hexagonal.* Z 86° 50′, $a : c = 1 : 0{\cdot}8194$. Crystals rare, usually massive, dendritic, or interspersed in grains. Fracture, conchoidal to uneven. Brittle. Opaque. Lustre, metallic. Colour, light copper-red, tarnishing grey and black; streak, brownish black. H. 5·5. Sp. gr. 7·33–7·67.

Composition.—NiAs, or Ni 43·6 and As 56·4 per cent., usually with traces of iron and sulphur. In some localities the arsenic is replaced by antimony in variable proportions up to a maximum of 28 per cent. Such varieties are represented by the general formula Ni(AsSb). These contain less nickel, or from 34 to 40 per cent.

Gives no sublimate in the closed tube. When melted and exposed to an oxidising flame, gives off arsenical vapour, when a brittle regulus of Ni_4As is obtained, which gives with borax the characteristic reactions of nickel and usually of cobalt.

Soluble in nitric acid, with a separation of arsenious acid, and more readily in aqua regia, giving a grass-green solution.

Occurrence.—With silver and lead ores at Freiberg and Andreasberg, but more abundantly with other nickel and cobalt ores and bismuth at Schneeberg, Annaberg, and Marienberg, in Saxony, also in Cornwall as a rarity with copper ores, and more abundantly in Newfoundland. The best crystallised specimens are from Sangerhausen in Thuringia, also with copper ores. The antimonial varieties are found chiefly at Allemont and in the Pyrenees. It is one

of the most valuable ores of nickel, being occasionally found in large masses; more generally, however, it forms part of the general mixture of ores which are treated by consecutive operations for the different metals—copper, lead, silver, nickel, and cobalt.

MISPICKEL. Arsenical Pyrites.—*Rhombic.* ∞P 111° 12′ (varies from 110° 49′ to 112° 17′),[1] $a : b : c$, 0·685 : 1 : 1·186

FIG. 17.

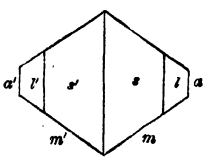
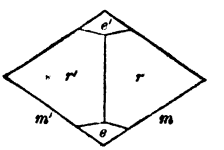


FIG. 18.



(figs. 17, 18), $m\{110\}\infty P$, $a\{010\}\infty \breve{P}\infty$, $e\{101\}\breve{P}\infty$, $l\{011\}\breve{P}\infty$, $s\{012\}\frac{1}{2}\breve{P}\infty$, $r\{014\}\frac{1}{4}\breve{P}\infty$. The last is generally the most prominent form, the faces being striated parallel to its axis. Crystals short columnar, or tabular. Twins on 110 and 101, both common, in the latter, with penetration, the vertical axes of the components crossing at 59° 12′. Also in radiating columnar groups, massive and granular interspersed. Cleavage, 110 perfect. Fracture, uneven. Brittle. H. 5·5–6. Sp. gr. 5·9–6·2. Opaque. Lustre, metallic. Colour, silver-white, steel-grey; streak, black.

Composition.—FeAsS=(FeS_2FeAs_2), iron 34·36, arsenic 46·01, sulphur 19·63 per cent. In some instances a portion of the arsenic is replaced by antimony (1 to 1½ per cent.), and in the varieties *Glaucodot* and *Danaite*, some of the iron by cobalt, the proportion of the latter metal ranging from 6 to 24 per cent. Also contains gold and silver, occasionally in workable quantity (a few ounces to the ton).

In the closed tube gives a red sublimate of sulphide of arsenic, followed by a darker one of metallic arsenic;

and in the open tube sulphurous and arsenious acids; on charcoal gives arsenic fumes, and melts to a black metallic globule, giving with borax the reaction of iron, and in the cobaltic varieties of cobalt. When powdered and roasted at a low heat, the whole of the sulphur and arsenic may be volatilised, leaving a residue of ferric oxide. Soluble in nitric acid, with separation of sulphur and arsenious acid. When finely powdered and boiled in water, is said to be partially decomposed with evolution of H_2S. The contents in precious metals, if any, can usually only be determined by the assay of a large quantity.

Occurrence.—A common associate of other sulphides, especially of iron pyrites and copper pyrites. In Devonshire and Cornwall it is found in large quantities with copper and tin ores; in Saxony, with lead and silver ores, at Freiberg; and with tin ores at the Saxon and Bohemian tin mines. The cobaltic varieties are most abundant in Chili, Sweden, and Norway, and those containing gold and silver in Brazil and Australia.

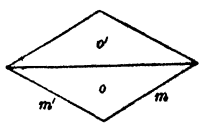
When pure it is not easily affected by the air, the crystals remaining brilliant even after long exposure; in which respect it differs from rhombic iron pyrites. Occurs as pseudomorphs after magnetic pyrites and Stephanite.

Arsenical pyrites is the principal source of the arsenious acid of commerce, which is obtained by calcining the mineral and collecting the vapour in large flues. This operation is usually carried on as one of the accessory processes of dressing tin and copper ores, which often contain arsenical pyrites in quantity. Such ores must be first calcined to get rid of the arsenic as a preliminary to the recovery of the more valuable metals. It is similarly obtained in the treatment of nickel and cobalt ores.

LÖLLINGITE. Arsenical Iron. Leucopyrite.—*Rhombic.* ∞P 122° 26′, $a : b : c = 0{\cdot}5494 : 1 : 1{\cdot}1432$ (fig. 19), $m\{110\}$ ∞P, $o\{101\}\breve{P}\infty$, generally massive, with a fibrous or

columnar structure. Cleavage, 001 tolerably perfect. Fracture, uneven. Brittle. H. 5·5. Sp. gr. 6·9–8·7. Opaque. Lustre, metallic. Colour, silver-white to steel-grey; streak, black.

FIG. 19.



Composition. — Includes various compounds of iron, arsenic, and sulphur, less sulphur than with mispickel, the maximum being about 6 per cent. The following analyses are of two extreme types, with their approximate formulæ:

	Sulphur	Arsenic	Antimony	Iron
Fe_5As_8, FeS_2 . .	6·07	58·94	1·37	32·92
$FeAs_2$ . . .	0·70	72·18	—	26·48

Usually some copper up to 4 per cent., and antimony, the latter in partial replacement of arsenic. Certain varieties are cobaltic, in one instance up to 15 per cent. When heated behaves similarly to arsenical pyrites, except that the varieties free from sulphur give a black sublimate of metallic arsenic instead of the red sulphide observed with the former. Soluble in nitric acid with separation of arsenious acid.

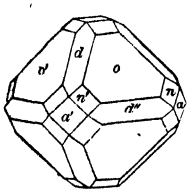
Occurrence.—Among other localities, at Lölling in Carinthia, Schladning in Styria, and Reichenstein in Silesia. At the latter place it is found in serpentine, and is used as an arsenical ore, the residues being subsequently treated for the recovery of a very minute proportion of gold.

BIARSENIDES OF NICKEL AND COBALT.—These occur both in cubic and rhombic forms, similar to those of bisulphide of iron, and, like the arsenides of iron, form numerous different minerals by association with varying proportions of the corresponding sulphides of the same metals. Nickel and cobalt, being very similar in properties, may replace each other in almost any proportion without affecting the form or appearance of the mineral. When free from or only

containing a small amount of sulphur, the cubic varieties in which cobalt predominates are known as Smaltine or Speiss Cobalt, and those containing principally nickel, as Chloanthite. The rhombic forms of similar constitution, rich in nickel, form the species Rammelsbergite. As these minerals have many properties in common, and are closely related, it will be convenient to consider them together.

SMALTINE. Speiss Cobalt, Grey Cobalt, Arsenical Cobalt.—CHLOANTHITE. White Arsenical Nickel.—*Cubic* (figs. 20 and 28). $o\{111\}O$, $a\{100\}\infty O\infty$, $d\{110\}\infty O$, $n\{211\}2O2$, 100, 111 often curved; also in dendritic and other crystalline aggregates and massive. Fracture, uneven. Brittle. Lustre, metallic. Colour, tin-white to steel-grey; exposed faces of crystals usually dulled to lead-grey. H. 5·5. Sp. gr.: smaltine, 6·3–7·2; chloanthite, 6·43–6·73.

FIG. 20.



RAMMELSBERGITE.—*Rhombic.* ∞P 123°. Sp. gr. 7·1–7·2. Usually massive. Otherwise similar to the cubic varieties.

Composition.—Essentially arsenides of nickel, cobalt, and iron, with or without some sulphide of the same bases, but subject to such variation that they cannot be represented by a single general formula. According to Rammelsberg, the following groups may be distinguished:

I. Those corresponding to RAs and R_2As_3, or some nearly similar ratios, such as R_5As_6, R_4As_5, R_3As_4, R_3As_5, and R_4As_7.

II. Those containing the higher arsenides, RAs_2 and R_2As_5.

In a very few cases sulphur is wanting, but as a rule it is present, and increases with the amount of nickel until the composition $\begin{pmatrix} RAs_2 \\ RS_2 \end{pmatrix}$ is reached in cobalt glance and

nickel glance, which are exactly isomorphous with iron pyrites.

The equivalents of iron, nickel, and cobalt being very nearly the same, the proportion of arsenic is nearly constant in those varieties that are free from sulphur. Thus the theoretical compounds—

$NiAs_2$	contains	27·88 Ni	and	72·12	As	per cent.
$CoAs_2$	„	28·20 Co	„	71·80	„	„
$FeAs_2$	„	26·48 Fe	„	72·18	„	„

While a mixture of all these in equal parts would contain—

(Co 9·4, Ni 9·5, Fe 9·0) and As 72·1.

The observed variations in the proportion of the different constituents are—

	Co	Ni	Fe	Cu	As	Sb	S
Minimum	?	?	?	?	55·85	—	0·08
Maximum	24·13	37·34	18·48	8·41	73·55	7·01	17·82

The varieties in which the proportion of nickel is greater than that of cobalt are the most common.

Heated in the closed tube gives a sublimate of arsenic; in the open tube, arsenious and sulphurous acids; on charcoal, gives off arsenic, and fuses to a globule of basic arsenides. This, when treated with borax in the oxidising flame, gives successively the reactions of iron, cobalt, and nickel, the metals being oxidised and removed in the order named. For this purpose, however, it is necessary that the first fusion should be effected in the reducing flame, so that no oxides may be formed except under the influence of the borax. The progress of the operation is determined by occasionally squeezing the melted borax between the forceps to a flat plate, in order to allow of its examination by transmitted light; or, if the colour is very deep, it may be diluted by melting up a fragment with fresh borax. The change of colour from dark green to

cobalt-blue is usually well seen, but the passage of the latter into the dark brown of nickel is not quite so easy to catch. If the mineral is calcined before fusion there will be a production of oxides of the different metals, which, dissolving up in the flux simultaneously, will give a mixed colour.

Soluble in nitric acid, depositing arsenious acid, the solution being either red or green according to the prevalence of cobalt or nickel. When moistened with water and exposed to the air, the surfaces of the crystals become rapidly covered with an efflorescence of hydrated arsenates of cobalt and nickel, forming the minerals cobalt- and nickel-bloom respectively. The former is pink and the latter green; so that according as one or other colour is developed, the mineral is classed either as smaltine or white nickel. Some crystals from Schneeberg, after a long exposure to the air, develop upon the fractured surfaces alternately bands of pink and green, showing that they are made up of parallel shells of nickel and cobalt arsenides; and it is very probable that the discrepancy in the analyses of different samples may be due to the prevalence of this class of structures in apparently homogeneous crystals.

Occurrence.—The most productive localities of these minerals are the mines in the neighbourhood of Schneeberg in Saxony, where crystals about half an inch side are not uncommon. Usually both the cobalt and nickel varieties are closely associated together with native bismuth and kupfernickel, and occasionally silver ores. In Cornwall formerly obtained with similar associations at Huel Sparnon and Dolcoath; also at Riechelsdorf in Hesse, Tunaberg in Sweden, and Bolivia; with native silver at Silver Islet, Lake Superior. They form the principal ores of cobalt and nickel, but are rarely found in sufficient quantity for direct treatment; usually, in the smelting of copper and lead ores, they become concentrated in an arsenical regulus, which by repeated fusion is enriched sufficiently to be treated specially for these metals, the cobalt being produced either as purified

oxide of cobalt, or a blue glass called smalt, while the nickel is reduced to the metallic state.

GLANCE COBALT. Cobaltine. Bright White Cobalt.—*Cubic with parallel hemihedrism.* Forms exactly similar to those of iron pyrites (figs. 37, 39), being very characteristic. Cleavage, cubic, perfect. Cube faces striated as in pyrites. Also massive, compact, or granular. H. 5·5. Sp. gr. 5·8–6·22. Lustre, brilliant metallic. Colour, silver-white with a reddish tinge, to iron-grey, the more ferriferous varieties being of the darker colour and lower densities; streak, greyish black. Fracture, lamellar. Brittle.

Composition. — (CoS_2CoAs_2) or S 19·28, As 45·18, cobalt 35·54 per cent. The average percentage of cobalt found by analysis is from 30 to 34 per cent. In the ferriferous variety from Siegen two-thirds of the cobalt is replaced by iron, the percentage of the former being reduced to 8·5–9·5.

Unaltered by heating in the closed tube ; in the open tube gives off arsenious and sulphurous acids. On charcoal fuses with difficulty to a grey bead. Soluble in nitric acid, depositing arsenious acid, but not sulphur; the solution is rose-red.

Occurrence.—The typical locality is Tunaberg in Sweden, where brilliant detached crystals, the largest about $\frac{3}{4}$ inch across, have been found, also at other Swedish cobalt mines with copper ores in mica schist. It is the most valuable cobalt ore, being free from nickel.

GERSDORFFITE. Nickel Glance. Arsenik-nickel-glance. Amoibite.—*Cubic, hemihedral*, similar to the preceding. Cleavage, cubic, perfect, also massive and granular. H. 5·5. Sp. gr. 5·6–5·9. Lustre, metallic. Colour, white, steel-grey, tarnishing grey or black ; streak, black. Fracture, uneven.

Composition.—(NiS_2NiAs_2) or sulphur 19·39, arsenic 45·45, nickel 35·15, or parallel to that of cobalt glance.

Usually contains some iron, cobalt, and antimony, in partial replacement of the normal constituents.

Heated in the closed tube, gives red and yellow sublimates of arsenic sulphide; and arsenious and sulphurous acids in the open tube. Fusible on charcoal; gives with borax the reactions of iron, cobalt, and nickel. Soluble in nitric acid with deposit of sulphur and arsenious acid; the latter subsequently dissolves.

Occurs at Müsen, Ems, Harzgerode, and Los in Sweden.

Ullmannite, or antimon-nickel-glance, is similar to the preceding, supposing the arsenic to be replaced by antimony, the composition being NiS_2, $NiSb_2$.

It occurs in Siegen and Carinthia.

Arsen-antimon-nickel-glance and *Wolfachite* are intermediate forms containing both arsenic and antimony; the latter is rhombic and isomorphous with Marcasite.

Skutterudite is essentially $CoAs_3$, containing As 79·23 and Co 20·77 per cent.; it occurs in small cubic crystals, similar to those of glance cobalt, at Skutterud in Norway.

CHAPTER IV.

SULPHIDES.

AMONG the natural metallic sulphides the most numerous are those of silver, copper, lead, zinc, antimony, and arsenic; which not only form the principal ores of these metals, but may be regarded as the chief sources whence the oxides and oxysalts found in nature have been derived. Sulphides of the lighter metals, on the other hand, are exceedingly rare in nature; that of calcium has been found in meteorites under conditions similar to those observed in the slags of iron furnaces; while sulphide of sodium is found in a single mineral, lapis lazuli, not alone, but in combination with silicates; and sulphide of manganese occurs similarly in Helvine, a sulpho-silicate. There are, however, two natural manganese sulphides, but they are of rare occurrence. Bisulphide of iron, FeS_2, is exceedingly abundant as an independent mineral, and other iron and sulphur compounds take part in the composition of numerous double sulphides, the constitution of which is in many cases doubtful.

For purposes of classification the sulphides may be divided into the following groups:

A. Simple sulphides, i.e. of one metal, or of two or more isomorphous ones of the forms $\overset{I}{R}_2S$ and $\overset{II}{R}S$. These are the so-called protosulphides, monosulphides, or anhydrides of the sulphur bases, and are analogous to the corresponding oxides.

The $\overset{I}{R}_2S$ group are either cubic, rhombic, or dimor-

phous in both systems; the RS_n group are cubic, hexagonal, and dimorphous in these systems.

B. A series intermediate in composition between RS and RS_2, represented by magnetic pyrites, Fe_nS_{n+2}, which for convenience may be called magnetic sulphides, being analogous to the magnetic oxides of the same metal. They are generally hexagonal when crystallised.

C. Bisulphides of the form RS_2, or pyrites series. Iron pyrites (FeS_2) is the principal and typical member of this series, which, as we have previously seen, is closely isomorphous with the corresponding arsenides, crystallising both in cubic and rhombic forms.

D. Sulphides of the metals of the arsenic group, i.e. antimony, arsenic, bismuth, and molybdenum. These include the anhydrides of the sulphur acids—sulphantimonic, sulpharsenic, and sulpho-bismuthic acids—and are either rhombic, hexagonal, or oblique in crystalline form.

E. Sulpho-salts, or combinations of members of the A series with those of D, which crystallise in the cubic, rhombohedral, rhombic, or oblique systems, the larger number being rhombic.

As a rule the sulphides crystallising in the cubic system are hemihedral in habit, appearing both in inclined and parallel forms. Copper pyrites, which is tetragonal in symmetry, appears in sphenoidal hemihedrons and allied forms, which differ but slightly from regular tetrahedra.

Metals of the monad and dyad group, being isomorphous, may replace each other in sulphides almost indefinitely without changing the form of the combination; so that substances of very variable composition may be of the same crystalline form and be represented by the same general formula. For this reason, and more particularly from the circumstance that the minerals are most valuable for the practical mineralogist when they appear in masses where the crystalline forms are not as a rule recognisable, it will be found that the physical characters other than

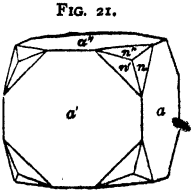
crystalline form, the blowpipe reactions, and study of the results of analyses rather than generalised formulæ will be the most valuable aids towards attaining a knowledge of these most important mineral substances. The extreme complexity that results from isomorphous replacement may best be illustrated by the species Tetrahedrite or Fahlerz, which is represented by the generalised formula $(\overset{I}{R}_2\overset{II}{R})_4R_2S_7$, under which expression is included a series of substances alike in crystalline forms, but varying in composition from low-class copper ores to others exceedingly valuable for their silver contents, and in the most complex instances including, besides sulphur, from 8 to 10 metallic elements.

The tellurides, selenides, arsenides, antimonides, and bismuthides of the heavy metals being for the most part isomorphous with the corresponding sulphides, should strictly be considered together, but as a matter of convenience they will be described after the simple sulphides and before the sulpho-salts.

GROUP A. NORMAL OR PROTOSULPHIDES, $\overset{I}{R}_2S$ $\overset{II}{R}S$.

SILVER GLANCE. Vitreous Silver Ore, Glaserz, Argentite, Argyrose.—*Cubic.* Usually in octahedra or cubes, variously combined with $\{110\}\infty O$, $\{221\}2O$, $n\{211\}2O2$ (fig. 21, also figs. 1 and 3). Also in piled octahedra, and various dendritic and capillary forms, massive, and in thin films encrusting. Also in pseudomorphs after ruby silver ore. In New Mexico replacing fossil shells. Cleavage, 100, 110 imperfect. Fracture, flat, conchoidal, uneven. H. 2–2·5. Sp. gr. 7·2–7·4. Malleable, sectile. Opaque. Lustre, metallic, usually dull. Colour, lead-grey when fresh, blackish grey when tarnished; streak, similar to the colour of the fresh mineral, shining.

FIG. 21.



Composition.—Sulphide of silver, Ag_2S. Silver 87·1,

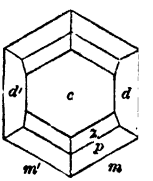
sulphur 12·9 per cent. Fusible on charcoal, giving off fumes of SO_2 and yielding a bead of silver, and occasionally a slag giving the reactions of iron and copper. The crystals as a rule are almost chemically pure, giving 85 to 87 per cent. of silver. Decomposed by nitric acid with separation of sulphur. The reduced silver bead often gives traces of gold when dissolved in nitric acid.

Occurrence.—In most localities producing the richer silver minerals in nests or bunches, often at the crossing of two veins. The finest crystals have been obtained from Kongsberg in Norway, Freiberg, the Saxon-Bohemian Erzgebirge, and the Harz. Very abundant in the mines of the Western Continent, Mexico, Peru, Chili, Nevada, Colorado, New Mexico, &c. Most commonly found in an amorphous state, interspersed through earthy vein stuff, forming the so-called dry or earthy silver ores (*metal azul*), or with pyritic minerals, galena, and antimonial sulphides, the so-called argentiferous lead ores. Another line of association, seen in Hungary, Peru, and Russia, is with copper pyrites, gold, and the manganese minerals, pyrolusite, diallogite, and rhodonite. Under ordinary conditions it is rarely recognisable by form or physical character, as much of the ore worked on the large scale containing from 25 to 100 ounces of silver per ton, differs from ordinary quartz only by its pale bluish grey tint, and argentiferous galena as a rule is indistinguishable from that containing no silver. In most cases, therefore, it is necessary to assay samples of a certain size to obtain a correct idea of their value. In the rare instances where the mineral is found crystallised, it may be recognised by its characteristic malleability and the ease with which it is reduced on charcoal.

Acanthite is a dimorphous variety of Ag_2S occurring in slender or thorn-like masses, which crystallise in the rhombic system, and are isomorphous with copper glance. In other physical and chemical characteristics resembles silver glance, with which it is found associated principally at and Joachimsthal.

COPPER GLANCE. Vitreous Copper, Kupferglanz, Chalcosine, Grey Copper Ore, Redruthite.—*Rhombic.* $Z=125°\ 22'$, $\infty P\ 119°\ 35'$ (approximately hexagonal), $a : b : c = 0{\cdot}582 : 1 : 0{\cdot}971$ (fig. 22), $a\{010\}\infty\breve{P}\infty$, $c\{001\}oP$, $p\{111\}P$, $z\{113\}\frac{1}{3}P$, $d\{021\}2\breve{P}\infty$, $m\{110\}\infty P$. Twins common on 110 producing hexagonal, and on 112 cruciform, groups. Also massive in nodules and other irregular shapes. Cleavage, {110} indistinct. Fracture, flat, conchoidal, uneven. Somewhat malleable and sectile, but less so than silver glance. H. 2·5–3. Sp. gr. 5·8. Opaque. Lustre, metallic. Colour and streak, bluish lead-grey, sometimes brownish, being brilliant when fresh, but becomes black and dull when continuously exposed to sunlight. Often tarnishes blue or iridescent.

FIG. 22.



Composition.—Cu_2S, disulphide of copper. Copper 79·85, sulphur 20·15 per cent. Iron may be present, FeS partially replacing Cu_2S, from 0·2 to 6·5 per cent., lead usually not exceeding 1½ to 2 per cent. Easily fusible on charcoal, giving a green flame to a bead which effervesces from the escape of SO_2, and may be ultimately reduced to metallic copper alone, or more easily with cyanide of potassium. Decomposed by nitric acid with separation of sulphur, giving a blue solution in which silver may sometimes be detected by hydrochloric acid. Some varieties contain a little silver.

Occurrence.—The finest crystallised specimens have been derived from the districts of Camborne, Redruth, and Saint Just in Cornwall, and from Bristol in Connecticut. The compact varieties are generally associated with the richer sulphides of copper and iron, erubescite and copper pyrites, and not with iron pyrites. Also with tin ore and hematite. Other localities are Ballycumisk, Ireland, and Monte Catini, Tuscany. In Nova Scotia in nodules in sandstone, and in Canada and Sweden in gneiss and mica schist.

It is among the most stable of the ores of copper, although it is sometimes altered superficially into melaconite or malachite. Has been found in pseudomorphs after galena and copper pyrites, and as a product of alteration incrusting native copper.

STROMEYERITE.—*Rhombic*, closely isomorphous with copper glance and acanthite. Crystals rare, usually massive. H. 2·5–3. Sp. gr. 6·3. Strong metallic lustre. Colour, dark lead-grey. In other respects similar to copper glance.

Composition.—($Ag_2S.Cu_2S$), silver 53·10, copper 31·17, sulphur 15·73 per cent. Easily reduced on charcoal to metal giving the reactions of copper and silver. Besides the pure mineral from Siberia, Silesia, and Chili, indefinite mixtures containing from 2 to 30 per cent. of silver have been found in Chili and Arizona, where it appears to be specially characteristic of many mines, notably in the Arivacca and Tombstone districts.

IALPITE.—*Cubic*, in octahedra with cubic cleavage. Malleable, and generally resembling silver glance, but with strong metallic lustre. H. 2·5. Sp. gr. 6·89.

Composition.—($3Ag_2SCu_2S$), silver 71·78, copper 14·04, sulphur 14·18 per cent. From Ialpa in Mexico, and Chili. It has also been obtained as a furnace product in smelting argentiferous copper ores in Colorado. The *fine metal* of the copper smelter, which is essentially Cu_2S, also crystallises in octahedra, thus establishing the complete dimorphism of the sulphides of the two metals, and their isomorphous mixture.

STERNBERGITE.—Flexible Silver Ore.—*Rhombic*, in thin tabular six-sided crystals, with perfect basal cleavage, also in fibrous divergent aggregates, and massive. H. 1–1·5. Sp. gr. 4·25. Flexible in thin laminæ. Colour, bronze-green or brown, to bluish black, tarnishing blue. Crystals resemble those of dark-coloured mica or graphite.

Composition.—$AgFe_2S_3$, or silver 33·2, iron 36, sulphur

30 per cent. The constitution is uncertain, a portion of the iron being present as FeS, and the remainder either in the condition of Fe_2S_3 or FeS_2. The crystalline form is related to that of copper glance, but it contains about 5 per cent. of sulphur in excess of the amount required by the formula (Ag_2SFeS). The percentage composition is nearly similar to that of copper pyrites, supposing silver to be substituted for copper. Does not give off sulphur in the closed tube, on charcoal fuses to a magnetic bead with partial separation of silver, with borax gives a silver bead and slag coloured by iron. Decomposed by aqua regia with separation of sulphur and chloride of silver, the solution is yellow from ferric chloride.

Occurrence at Jöhangeorgenstadt, Joachimsthal, Schneeberg, and Marienberg, but very rare.

Frieseite, *Silberkies*, and *Argyropyrite* are similar minerals, but contain less silver (27–30 per cent.).

OLDHAMITE.—Form undescribed.

Composition.—CaS, or calcium 55·56, sulphur 44·4 per cent. Found as a constituent of a meteorite from Busti in India.

MANGANESE GLANCE.—Alabandine Mangan-blende.—*Cubic.* In cubes and octahedra with perfect cubic cleavage, usually granular or massive. H. 3·5–4. Sp. gr. 4·014. Fracture, uneven. Lustre, semi-metallic when fresh, dull when tarnished. Dark grey to black, tarnishing brown, streak and powder, dirty green.

Composition.—MnS (manganous sulphide), or manganese 63·32, sulphur 36·7 per cent. When roasted gives off sulphurous acid, and changes colour to greenish grey, after which it may be fused at the edges in the reducing flame to a brown slag. In salt of phosphorus in the reducing flame, the fresh mineral dissolves with a kind of detonation, giving the characteristic reaction of manganese. Soluble in hydrochloric acid, evolving sulphuretted hydrogen.

Occurs in the Transylvanian gold mines with tellurium minerals, in Mexico and Brazil, and has been found as an artificial furnace product at Konigshütte in Upper Silesia.

TROILITE.—FeS, or iron 63·6, sulphur 36·4 per cent. Occurs in the Knoxville and other iron meteorites associated with magnetic pyrites, sometimes, but rarely, free from nickel. It is not known among minerals of terrestrial origin.

MILLERITE. Haarkies. — *Hexagonal, rhombohedral.* R 144° 08′, $a : c$, 1 : 0·3296. In very thin hair-like crystals and groups, also hemispherical and radiated aggregates of divergent fibres, sometimes forming thin layers. H. 3·35. Sp. gr. 4·6–5·6. Lustre, metallic. Colour, brass- to bronze-yellow, tarnishing with grey iridescence; streak, yellow, shining; powder, greenish black. Brittle.

Composition.—NiS, or nickel 64·45, sulphur 35·55 per cent.; usually contains some iron, copper, or cobalt. Fusible on charcoal, the bead effervescing and spitting, giving off sulphurous acid; after removal of the sulphur is difficultly reducible to an unmelted mass of metallic nickel, which is somewhat malleable and slightly magnetic. The roasted mineral gives the reaction of nickel with salt of phosphorus, and sometimes those of iron, copper, and cobalt. Soluble in nitric acid, giving a grass-green solution.

Occurs in most localities producing other nickel minerals. The most characteristic examples of the fibrous varieties are obtained from the hollows in nodules of clay iron ore or amorphous siderite in the coal measures of Staffordshire and South Wales, forming delicate single or grouped crystals. At Dowlais, in Glamorganshire, they are associated with Hatchettine, or natural paraffin. At Gap Mine, in Pennsylvania, the radiated variety forms plates $\frac{1}{8}$ inch thick and several inches square, which are very similar in appearance to iron pyrites. The fibrous variety has recently been in some quantity in carboniferous sandstone in Belgium.

EISENNICKELKIES. Nicopyrite. — *Cubic.* Massive in granular aggregates, having an octahedral cleavage. Fracture, uneven. Brittle. H. 3·5–4. Sp. gr. 4·6. Light bronze-brown; streak, darker brown, tarnishing greenish brown. Not magnetic.

Composition.—Variable. n(FeS)NiS. The original Norwegian variety is 2FeSNiS, corresponding to iron 36·09, nickel 21·81, sulphur 36·09 per cent., while that from Inverary containing only from 10 to 11 per cent. of nickel and proportionately more iron, is usually mixed with magnetic and copper pyrites, causing a still further diminution of the amount of nickel in the bulk of the ore.

When roasted and treated with borax in the oxidising flame gives the reaction of iron, and in the reducing flame a black opaque glass.

From Lillehammer in Norway, Inverary and Craigmuir in Scotland. The name originally given by Scheerer cannot be rendered into English as nickeliferous iron pyrites, as it is not a bisulphide.

SULPHIDE OF COBALT OR JEYPORITE is a steel-grey mineral found in masses of undeterminable form near Jeypore in Central India, which is essentially CoS, or cobalt 64·4, and sulphur 35·16 per cent. It is used by the local goldsmiths for colouring gold work. The name has been rectified to Jeyporite by Major Ross, from the former Syeoporite, which, he has pointed out, arises from a misspelling of the name Jeypore.

BLENDE. Zincblende, Sphalerite, Black Jack, Chumbe.—*Cubic, tetrahedral* (figs. 23–25). o, $\kappa\,\{111\}\ \frac{O}{2}$, $o'\kappa\,\{1\bar{1}1\}\ -\frac{O}{2}$, $d\{110\}\ \infty O$, $a\{100\}\ \infty O\infty$, $m\kappa\,\{311\}\ \frac{3O3}{2}$, $g\{320\}\ \infty O\,\frac{3}{2}$. Types of crystals octahedral and dodecahedral, the tetrahedra are distinguishable by differences of sur-

face, and the faces of κ {311} are usually striated parallel to the edges of {110}. Twins very common on 111, usually

FIG. 23.

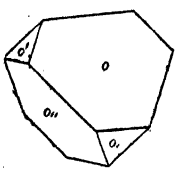


FIG. 24.

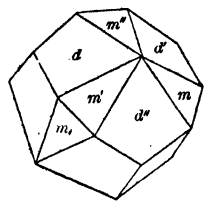
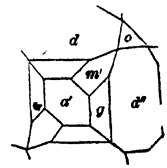


FIG. 25.



many times repeated and shortened, producing very distorted forms. Also in cleavable crystalline masses of various kinds, and massive, of a compact or finely granular texture in columnar, reniform, and other concretionary shapes. Cleavage, {110} very perfect. Brittle. H. 3·5–4. Sp. gr. 3·7–4·2. Transparent and translucent when light-coloured, opaque in dark and compact varieties. Lustre, adamantine or resinous, metallic in some dark-coloured crystals, waxy or horny in compact varieties. Colourless and transparent crystals rare, usually of some tint of yellow, brown, or black, the compact varieties white, flesh-coloured, light yellow or brown; streak, white, or generally lighter coloured than the mass. Plates of an inch thick of the light-coloured Spanish variety are as perfectly transparent as an equal thickness of polished plate glass; this is partly due to the very perfect cleavage. Refractive index for yellow light, 2·269.

Composition.—ZnS, zinc 67, sulphur 33 per cent., which fairly represents the purest varieties, but it more generally contains some iron, cadmium, and lead, and in some varieties traces of indium and gallium. The darker coloured varieties, the Black Jack of the English lead mines, are amorphous mixtures of the formula n(ZnS)FeS, the maximum amount of iron being about 20 per cent. Cadmium may amount to as much as 5 per cent., but is usually

considerably less, 0·35 to 0·58 per cent., in brown blende of the Harz. The rarer metals only in spectroscopic traces.

Decrepitates violently when heated; the edges of a sharp splinter may be slightly rounded if protected from oxidation, but otherwise infusible. Converted slowly by roasting into zinc oxide, which is yellow when hot and becomes whiter on cooling; when heated with soda on charcoal, the oxide is produced as an incrustation. If cadmium is present the incrustation has a brownish iridescence at the edges. Dark-coloured varieties give the iron reaction with borax. Decomposed by hydrochloric acid on boiling, giving off H_2S, also by nitric acid with separation of sulphur.

Occurrence.—Abundant in many countries. The purest transparent yellow kind is found in large irregular deposits in limestone caverns in the Picos de Europa, west of Santander, in Spain, associated with carbonate and silicates of zinc. In Sweden a large mass of a light brown variety is associated with green felspar, in gneiss at Åmmeberg on Lake Wettern. In Cornwall, Wales, Alston Moor and Teesdale, Derbyshire, and the Isle of Man, dark-coloured blende is commonly found in the lead-mining districts with galena, quartz, dolomite, and calcite. In Belgium, and on the Rhine, compact blende intimately mixed with galena and iron pyrites is a characteristic product of the lead mines, and requires a large amount of mechanical treatment to fit it for the smelter. The blue stone of Parys Mine, Anglesea, is an intimate mixture of the whole of these minerals in an almost impalpable form, which cannot be separated into its constituents mechanically. Honey-yellow or transparent crystals are obtained at Přibram and in Hungary. In America the principal deposits are in the State of Missouri.

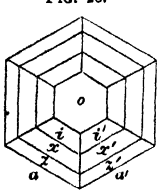
By slow oxidation blende may be converted into sulphate of zinc, and by the decomposition of the latter by alkaline carbonates and silicates into the hydrated carbonates and silicates, or the class of minerals called *Calamines*. When associated with pyrites, blende often takes an iridescent

tarnish, but otherwise it is very little liable to alteration, the crystals retaining their brilliancy for a very long period. The yellow Spanish blende contains cavities filled with fluid, in which chloride of sodium is dissolved; and in the capillary fissures formed by these when empty, the surfaces are often found crusted with calamine, and in some instances with cinnabar.

Blende is commonly known as *Black Jack* by English miners, and as *Chumbe* in Spanish South America. Formerly it was of very small value, but has now become the principal ore of zinc, the calamines and other oxidised ores having become scarce of late years. It is, however, more difficult and expensive to reduce, and produces a lower quality of metal, containing more iron, lead, and arsenic than that made from calamine. Cadmium when present passes off in the first portion of the distilled zinc, which if put aside may be utilised as a source of this metal.

GREENOCKITE. — *Hexagonal, hemimorphic.* $a : c = 1 : 0{\cdot}8252$ (fig. 26), $a\{10\bar{1}0\}\infty P$, $z\{20\bar{2}1\}2P$, $x\{10\bar{1}1\}P$, $i\{10\bar{1}2\}\frac{1}{2}P$, $o\{0001\}oP$. On the opposite side of the base, $\{10\bar{1}\bar{2}\}$ and $\{000\bar{1}\}$ only. Crystals short, prismatic or tabular, and very small, though well developed, also in thin earthy crusts. Cleavage, $10\bar{1}0$ perfect, 0001 imperfect. H. 3–3·5. Sp. gr. 4·8–5. Translucent. Lustre, adamantine. Colour of crystals, honey- to orange-yellow, and somewhat lighter in crusts; streak, orange-yellow to light red. Double refraction positive. Refractive index of ordinary ray, 2·688.

FIG. 26.



Composition.—CdS, or cadmium 77·8, sulphur 22·2 per cent. When heated in closed tube, becomes red and decrepitates, returning to the original colour on cooling; in open tube, gives off sulphuric acid; on charcoal with reducing flame,

either with or without soda, is reduced, volatilised, and gives a reddish-brown incrustation of cadmium oxide. Soluble in hydrochloric acid ; when heated evolving sulphuretted hydrogen. Unlike zinc, cadmium is precipitated as sulphide from solution containing free acid. In the crystallised form exceedingly rare, the chief locality being Bishoptown in Renfrewshire ; but it is present in zinc blende in quantities not recognisable except by analysis, or by working upon large quantities of the mineral. The principal cadmiferous blendes are those of Belgium and Silesia; the largest proportion of cadmium being in that of Engis in Belgium. The artificial sulphide is very similar in properties to the natural mineral, and is used as a pigment, being of a fine orange-yellow colour, and quite permanent.

WURTZITE.—*Hexagonal*, in combinations of {10$\bar{1}$0} {10$\bar{1}$1}. Cleavage, 10$\bar{1}$0. H. 3·5–4. Sp. gr. 3·98. Brownish black ; streak, brown. Lustre, vitreous.

Composition.—ZnS, the same as zinc blende. From Ovuro in Bolivia. The brown radiated blende of Přibram is cleavable into hexagonal forms, and the crystals formed accidentally in furnace products also belong to the hexagonal system, and like those of Greenockite are hemimorphic, so that the dimorphism of this substance is well established.

COVELLINE.—Indigo Copper, Kupferindig, Añilado.—*Hexagonal*. *Z* 155°, rarely in thin, small, tabular crystals ; usually massive, in flat and reniform aggregates of finely granular, conchoidal, or even fracture. Also in pseudomorphs, after copper pyrites and galena. Colour, indigo-blue to black ; streak, black. Opaque. Lustre, dull, imperfectly waxy. H. 1–1·15. Sp. gr. 4·59–4·64.

Composition.—CuS, sulphide of copper, or cupric disulphide, Cu_2S_2, or copper 66·46, sulphur 33·54 per cent. Fusible on charcoal, burning with a blue flame of sulphur ; gives off sulphur in closed tube, otherwise behaving like copper glance.

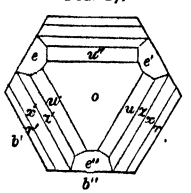
Occurs at Sangerhausen, in thin veins in the Kupfer-

schiefer, resembling massive copper glance, but distinguishable by its remarkable blue colour, which is exactly similar to that of indigo. Also in the lavas of Vesuvius, and in Chili, Australia, and other copper-producing countries, but not a very common copper ore.

Cantonite, from Canton in Georgia, is probably a pseudomorph of CuS, after galena.

CINNABAR. Zinnober.—*Hexagonal, trapezohedral, tetartohedral.* $R = 92° 36'$, $a : c = 1 : 1{\cdot}145$ (fig. 27), $e\ \kappa\ \{10\bar{1}1\}R$, $u\ \kappa\ \{01\bar{1}2\} - \frac{1}{2}R$, $z\ \kappa\ \{02\bar{2}3\} - \frac{2}{3}R$, $x\ \kappa\ \{04\bar{4}5\} - \frac{4}{5}R$, $r\ \kappa\ \{02\bar{2}1\} - 2R$, $b\ \{10\bar{1}0\}\ \infty R$, $o\ \{0001\}\ oR$. A crystal from Ripa in Tuscany has been described, in which $\{11\bar{2}0\}\ \infty P2$ appears as a trigonal prism, together with some hemiscalenohedra, proving the tetartohedrism previously announced on optical grounds by Descloizeaux. Also in crystalline concretions, massive, granular, and earthy. Twins common on 0001 with parallel axes. Cleavage, $\{10\bar{1}0\}$ perfect. H. 2–2·5. Sp. gr. 8·12–8·99, crystallised varieties the densest. Fracture, splintery, uneven, sectile. Transparent to translucent in crystals; opaque when compact and earthy. Lustre, metallic, or adamantine in crystals, shining to dull in granular varieties. Strong positive double refraction; indices for red light, $\omega = 2{\cdot}854$, $\epsilon = 3{\cdot}199$, being higher than those of any other transparent substance. Strong circular polarisation, the rotatory power being fifteen times that of a quartz plate of equal thickness. Colour, crimson or cochineal-red in crystals, scarlet in pure earthy varieties, brownish or orange-red in others; streak, scarlet.

FIG. 27.



Composition.—HgS, mercury 86·2, sulphur 13·8 per cent. When heated in the closed tube, volatilises without residue if pure, giving a black sublimate, or, with the addition of soda, a sublimate of mercury in fine globules. Soluble

in aqua regia, with separation of sulphur, is not acted on by nitric acid.

Occurrence.—With native mercury and amalgam at Moschellandsberg in Rhenish Bavaria; in large deposits in carbonaceous schists with various hydrocarbons at Idria in Carniola; in quartzite at Almaden de Azogue; and in limestone in the Sierra di Alpujarres in Spain. In California at Reddington Sulphur Banks, and New Almaden, in Mexico, and in Queensland. Idria, Spain, and California yield the chief commercial supply. The Almaden ore is essentially a quartzite permeated with cinnabar, the richest yielding about 16 per cent., which is completely volatilised in the furnace, leaving a residue of the same bulk as original rock. Crystals are comparatively rare; they are found in druses, often with considerable quantities of liquid mercury. The pure mineral occurs in large masses in the limestone deposits, but these are essentially irregular. From its great density it may often be collected from alluvial deposits by washing.

Cinnabar is readily distinguished from other red minerals, such as ruby silver ores or realgar, especially where massive or earthy, by its peculiarly brilliant colour, and its full red streak. The high density is also very characteristic.

Metacinnabar is an amorphous black variety of sulphide of mercury, similar to that produced in the first stage of the manufacture of vermilion. H. 3. Sp. gr. 7·75. *Composition* same as cinnabar. Found with cinnabar at Reddington Mine in California.

GALENA. Galenite, Bleiglanz, Soroche.—*Cubic.* tals of cubic types most frequent, octahedral less so (figs. 28–31). $a\{100\}\infty O\infty$, $o\{111\}O$, $d\{110\}\infty O$, $n\{211\}2O2$, $p\{122\}2O$, $9\{133\}3O$. Faces of {100} usually brighter than those of {111}. Twins common on 111; usually much compressed on the twin axis. Cleavage, 100 highly perfect; also massive in aggregates, with a distinct crystalline structure, or finely granular. Fracture, conchoidal,

but difficultly obtainable, owing to perfection of cleavage. Brittle; slightly sectile. H. 2·5. Sp. gr. 7·25–7·7. Opaque.

FIG. 28.

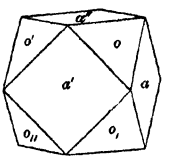
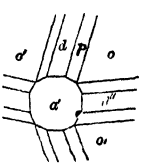


FIG. 29.



Lustre, metallic, very brilliant when fresh. Colour, lead-grey, tarnishing to a darker, tint; streak, similar. The finely

FIG. 30.

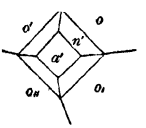
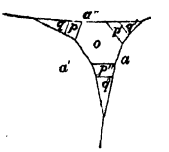


FIG. 31.



granular aggregates lighter in colour than the more coarsely crystalline ones.

Composition.—PbS, or lead 86·6, sulphur 13·4 per cent., invariably containing some silver, but usually considerably less than 1 per cent. Iron, zinc, antimony, copper, and gold are sometimes found, but it is not certain whether these are in chemical combination or due to very intimate mixture of other minerals. A very minute trace of gold seems to be invariably present. When heated on charcoal, decrepitates; fuses, emitting sulphurous acid vapour; gives a yellow incrustation, and is reduced to metallic lead, which if sufficiently argentiferous will give a visible bead of silver by cupellation. Partially soluble in nitric acid, depositing sulphur and sulphate of lead. Soluble in hydrochloric acid when hot, depositing chloride of lead on cooling.

Occurrence.—The most abundant ore of lead, and widely distributed both in stratified deposits and veins, but prin-

cipally in the latter. In England it occurs in veins, traversing the carboniferous limestone and millstone grit series in Alston Moor, Teesdale, Weardale, Swaledale, and Wensleydale; also in Derbyshire near Bakewell, and in the neighbourhood of Holywell and Wrexham in North Wales. In all these localities it is associated with blende, fluor, calcite, heavy spar, and quartz, and is, as a rule, poor in silver. In the Isle of Man it is associated with antimonial copper and silver ores and blende in Silurian strata. The Cardiganshire and Montgomeryshire mines and those of the Shelve district in Shropshire are also in slaty rocks of Silurian age. In Cornwall and Devon, and in the valleys of the Rhine and its tributaries, the Lahn and Sieg, the lead-bearing veins are in Devonian strata, and, as a rule, the ore is richer in silver than that of the carboniferous limestone veins, spathic iron ore being a common associate. The mines of Freiberg in gneiss, and of the Harz in Devonian slates, produce a highly argentiferous galena, which is, however, much mixed with copper, antimonial, and other minerals, so that the lead produced is of an inferior character unless carefully refined. The Silesian lead ores are principally found with those of zinc and iron in irregular deposits in the Muschelkalk, and similar deposits on a much larger scale are found in the island of Sardinia. In Spain the chief production is from veins. These occur in metamorphic Silurian strata in the neighbourhood of Almeria and Adra; in granite, in the Linares district near Cordova, and in various stratified and irregular deposits around Carthagena. Among the latter are some curious masses included in eruptive trachytes. The ores richest in silver are those of the Sierra de Almagrera. Very pure galena is found in liassic limestones at Bleiberg in Carinthia associated with molybdate of lead. Přibram, in Bohemia, also produces highly argentiferous galena; the veins, which are in Silurian strata, are remarkable for their persistence downwards, the mines being between 3,000 and 4,000 feet in depth. The

Schemnitz lead mines are in veins in a tertiary trachyte analogous to that of Carthagena, the lead ore being associated with native gold and silver ores. Among stratified deposits the most remarkable in Europe is that of Mechernich in the Eifel, where a thick bed of sandstone is in places filled with nodules formed of sand grains cemented together by galena. This is of Triassic age. At Mine Lamotte, in Missouri, galena occurs in large crystals and bands permeating a cellular dolomite of the Lower Silurian period, forming horizontal deposits of great value, though irregular in distribution. In Utah and the Western States large and irregular deposits of highly argentiferous lead ore have been found under somewhat similar conditions. There are other lead-bearing limestones of Silurian age on the Upper Mississippi, and a very finely crystallised variety of galena has been brought from the east main coast of Hudson's Bay, also from similar strata. In Northern Peru lead ores are found in gold- and silver-bearing veins in trachyte under conditions somewhat like those of Hungary.

The largest crystals recorded, cubes of about ten inches in the side, are from Laxey. Others, nearly as large, are not uncommon in the northern mines in Alston Moor. These very large individuals are rarely perfect, the faces being roughened with parallel impressions of similar smaller crystals, and they are often hollow internally, being made up of a shell of two inches or more in thickness, with a distinct fibrous structure in the fracture. Brilliant crystals of prevailing octahedral types are obtained at Neudorf in the Harz with spathic iron ore. Very large octahedra have also been found in Western Australia. There is also a considerable difference in the structure of individual crystals, some cleaving into smooth, mirror-like surfaces, while others break into small cubical steps, or even with a finely granular surface. The latter is known as steel-grained ore, and is sometimes held to indicate a large proportion of silver. This belief is, however, erroneous, as both coarse and fine

grain may exist with a high or low proportion of silver in different localities, and it is probably only true for the ore of any one locality in the sense that the finer-grained ore is more likely to be mixed with antimonial silver minerals of a similar texture than those of a coarser grain.

Galena, by atmospheric oxidation and percolating water, gives rise to sulphate (anglesite), phosphate (pyromorphite), and carbonate (white lead ore), and, in rarer instances, to chromates and molybdate of lead. Many of these are, however, easily reconverted into sulphide when exposed to the action of sulphides or sulphuretted hydrogen, so that we have instances of pseudomorphs of pyromorphite in galena. Anglesite and white lead ore are often found crystallised out on the faces of cubes of galena, and sometimes massive examples of the latter are found converted into one or other of these minerals, either completely or with only a small nucleus of unaltered galena.

As prepared for the lead smelter, the galena of different districts differs considerably in its lead and silver contents. As a rule, the proportion of the former diminishes as the latter increases, as it is not possible to push the mechanical concentration of ores containing much silver to as high a point as those which are poorer without large loss upon the more precious metal. Ores with calcareous vein-stuff are also more easily dressed than those with quartz or barytes, and when blende and pyrites are present the separation involves very considerable trouble and loss of metals. The following are some of the averages of by districts :

	Lead per cent.	Silver in ounces per ton of lead.
Northumberland and Durham	70–77	8
Cornwall	70	49
Isle of Man	75	20–60
Harz	62	30
Freiberg	55	45
Přibram	49	100
Linares, Spain . . .	77	10

COPPER PYRITES. Yellow Copper Ore, Kupferkies, Chalcopyrite. — *Tetragonal with sphenoidal hemihedrism.* $Z = 108°\ 40'$, $\frac{P}{2}\ 71°\ 20'$, approximating closely to the regular octahedron and tetrahedron, $a : c = 1 : 0{\cdot}9856$ (figs. 32, 33).

FIG. 32.

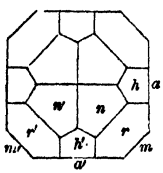
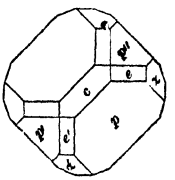


FIG. 33.



$a\{100\}\infty P\infty$, $m\{110\}\infty P$, $c\{001\}oP$, $p\,\kappa\{111\}\frac{P}{2}$, $p'\,\kappa\{1\bar{1}1\}\frac{1}{2}\frac{P}{2}$, $n'\,\kappa\{1\bar{1}2\}-\frac{1}{2}\frac{P}{2}$, $r\kappa\{332\}\frac{3}{2}\frac{P}{2}$, $r'\,\kappa\{\bar{3}\bar{3}2\}-\frac{3}{2}\frac{P}{2}$, $e\{101\}P\infty$, $z\{201\}2P\infty$. Twins common: 1, on 100

FIG. 34.

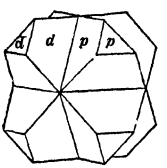
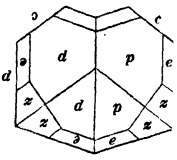


FIG. 35.



(fig. 34); 2, on 111 (fig. 35); 3, on 101. Twins usually repeated, the intermediate components being reduced to thin plates producing very distorted forms. Cleavage, 201 not very distinct. Usually compact, interspersed in granules or in reniform or botryoidal masses. Fracture, conchoidal. Brittle, slightly sectile. H. 3·5–4. Sp. gr. 4·1–4·3. Opaque. Lustre, sub-metallic. Colour, brass- to gold-yellow, the former when fresh, the latter when slightly tarnished;

when fully tarnished, irised in various colours (peacock ore), indigo-blue or black; streak, greenish black, shining.

Also in pseudomorphs after copper glance and Fahlerz.

Composition.—$CuFeS_2$, or copper 34·57, iron 30·54, sulphur 34·89 per cent., generally varying from the type in the massive varieties by increase of copper when associated with richer copper ores, or by increase of iron and sulphur when associated with iron pyrites. In the latter case, the two minerals are often intimately mixed, and pass by insensible gradations into the so-called coppery pyrites containing only 2–4 per cent. of copper. Traces of selenium and thallium sometimes observed.

Heated in closed tube decrepitates, sometimes giving a sublimate of sulphur (it is doubtful whether it does so when pure, i.e. free from FeS_2). On charcoal fuses with intumescence and scintillation to a rough magnetic globule. When powdered and roasted at a low heat is converted into a fritted mass, giving the reactions of copper and iron with fluxes. Slowly soluble in nitric acid with separation of sulphur.

The constitution of copper pyrites is uncertain, the formula being written either as (CuS.FeS) or ($Cu_2S.Fe_2S_3$), and there is no certain means of determining which view is the correct one. If the former is adopted, it becomes a member of the RS group; if the latter, of the group of magnetic sulphides. It might also be considered as of the form RS_2, where R = CuFe, or similar to iron pyrites. There is, however, no such compound as CuS_2 known to the chemist.

The crystalline form is remarkable, the parameters of the unit form differing but very slightly from those of the regular octahedron, while the combinations are very decided in tetragonal symmetry. Dana classifies this species as isomorphous with iron pyrites; but as it is tetrahedral it bears closer analogies to zinc blende, its relations with that species being of the kind distinguished by Scacchi as *polysymmetric.*

Occurrence.—Copper pyrites may be regarded as the standard ore of most copper-mining districts. It is generally found in Cornwall with quartz, chlorite, and iron pyrites, which are also its most usual associates in other places. In some of the deeper Cornish mines, Dolcoath, Carn Brea, &c., it has been found in zones alternating in depth with tin ore. When associated with the richer sulphides, erubescite, and copper glance, without iron pyrites, it is often accompanied by dolomite or calcite, as in the serpentinous rocks of Tuscany, or in hornblende, gneiss, and schist in Sweden and Canada. It rarely occurs in quantity with galena; when present in lead-mining districts, being usually confined to particular groups of veins which are not prominently lead-bearing. In small quantity it is very commonly present in spathic iron ores, especially in the more manganesiferous varieties, such as those of Siegen and Exmoor. In the former district the larger spathic ore veins pass into smaller ones containing sulphides which are worked as nickel and copper ores. The same association with nickel and cobalt ores, as well as with richer argentiferous sulphides, is seen in the Kupferschiefer of Mansfeld. Copper pyrites being essentially a soft and not very heavy mineral, cannot be easily separated by mechanical means from iron pyrites or quartz. The mixtures of these minerals, therefore, as delivered to the smelter are not usually very rich in copper, the average of the Cornish ores sold not containing more than 5–8 per cent. By a preliminary calcination a considerable proportion of the iron pyrites is converted into ferric oxide, which on subsequent fusion serves to flux the quartz, the result being a sulphide known as *coarse-metal* or *regulus* which is very similar in composition to copper pyrites. The richest deposits of pyritic copper ores at present worked are those of South Australia, Namaqualand in the Cape Colony, Chili, and Newfoundland.

The most productive English mines are Devon Consols, Mellanear, and South Caradon.

Breithaupt's *Cuban* is a variety of sulphide of iron and copper containing $\left.\begin{matrix}2Fe\bar{S}\\CuS\end{matrix}\right\}$ or only 21 per cent. of copper (two-thirds of the amount in copper pyrites), which occurs in masses having a cubic cleavage, but is otherwise similar to copper pyrites. In Cuba, Chili, and with glance cobalt in Sweden.

TIN PYRITES. Bell-metal Ore, Stannine.—*Cubic, tetrahedral.* Crystals $\infty O\infty . \frac{O}{2}$; exceedingly rare, usually massive, with imperfect cubical cleavage. Fracture, uneven. Brittle. H. 4. Sp. gr. 4·3–4·5. Colour, dark steel-grey; streak, black.

Composition. — Essentially a mixture of isomorphous sulphides of the form RS, where R = SnCuFe usually, but sometimes Zn is also present. One of the simplest varieties is represented by $FeCu_2SnS_4 = \left.\begin{matrix}2CuS\\SnS\\FeS\end{matrix}\right\}$ corresponding to tin 27·65, copper 29·24, iron 13·11, sulphur 30·00 per cent. When zinc is present it replaces a portion of the iron, the other constituents remaining unchanged. Heated on charcoal, fuses, giving off sulphurous acid, and depositing a white crust of stannic oxide; when roasted, gives the reactions of copper and iron, and by continued treatment with reducing fluxes, a somewhat brittle bead of copper. Soluble in nitric acid, with separation of sulphur and stannic acid, or in aqua regia, when only sulphur is deposited; the solution is either blue or green.

Occurrence.—In Cornwall with tin ore, copper pyrites, and wolfram at East Pool and other mines in the Camborne district, also in the Saxon and Peruvian tin districts, but not very common. As a tin ore it is useless, but is of a certain value as a copper ore, a portion of the tin being reduced and forming with the copper an alloy or mixed metal suitable for the production of sheathing nails.

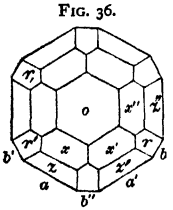
GROUP B. MAGNETIC SULPHIDES.

MAGNETIC PYRITES. Pyrrhotine, Magnetkies.—*Hexagonal.* Z 89° 44′, $a : c = 1 : 0{\cdot}862$ (fig. 36).

a	*z*	*x*	*o*	*r*	*b*
{10$\bar{1}$0}	{20$\bar{2}$1}	{10$\bar{1}$1}	{0001}	{11$\bar{2}$1}	{12$\bar{1}$0}.
∞P	$2P$	P	oP	$2P2$	$\infty P2$

Crystals rare, usually short columnar, or tabular. Twins on 10$\bar{1}$1, producing a nearly rectangular cross, rare. Usually massive or interspersed, or in granular or platy aggregates. Cleavage, {10$\bar{1}$0} imperfect. Fracture, flat, conchoidal, granular. H. 3·5–4·5. Sp. gr. 4·54–4·64. Opaque. Lustre, metallic. Colour, bronze-yellow to brown; tarnished specimens resemble dulled (not blackened) bronze castings; streak, grey or black. Slightly magnetic, rarely polar. Attracted by the magnet when powdered.

FIG. 36.



Composition.—Fe_nS_{n+1}, the analysed varieties ranging from Fe_6S_7 to $Fe_{11}S_{12}$, in which the sulphur varies from 38·4 to 40 and the iron from 61·6 to 60 per cent. These may be regarded as containing $\left.\begin{matrix} n\text{FeS} \\ Fe_2S_3 \end{matrix}\right\}$ or $\left.\begin{matrix} n\text{FeS} \\ FeS_2 \end{matrix}\right\}$. On the former view the composition will be analogous to that of the corresponding magnetic oxides of iron, while on the latter it will be essentially isomorphous with the sulphides of the RS group, crystallising in the hexagonal system. Some varieties contain from 3 to 6 per cent. of nickel, and others a small quantity of gold, discoverable only by assay of a large sample. Heated in closed tube gives no sublimate, and in open tube sulphurous acid fumes. Fusible on charcoal to a black metallic bead, and by continued roasting is converted into ferric oxide. When treated with gold and borax in the reducing flame after roasting, nickel may be detected

in those varieties that contain it. Soluble in hydrochloric acid, giving off sulphuretted hydrogen, and depositing sulphur.

Occurrence.—At Bodenmais, in Bavaria, in granite associated with Triphylline; the nickeliferous varieties are worked at Modum in Norway, and Gap Mine in Pennsylvania. At St. John del Rey, in Brazil, forms with iron and arsenical pyrites one of the gold-bearing minerals, and as a rule is of intermediate richness, being less auriferous than the former and more so than the latter; the total proportion being, however, very small. It is sometimes used as a sulphur ore in chemical works, but is of less value than common pyrites for this purpose.

ERUBESCITE. Bornite, Purple Copper Ore, Variegated Copper Ore, Buntkupfererz.—*Cubic.* Rarely crystallised, usually massive or granular. Cleavage, octahedral, very imperfect. Fracture, conchoidal, uneven. Opaque. Lustre, sub-metallic. Colour, copper-red, livid red ('horse-flesh ore') to bronze-brown; exposed surfaces usually tarnished in rainbow colours or in single colours, deep blue and red prevailing; streak, black.

Composition of crystallised varieties apparently $Cu_3Fe.S_3$, or copper 55·58, iron 16·36, sulphur 28·06 per cent., but the massive varieties often differ very sensibly from this, the amount of copper ranging from 44 to 70 per cent. And, as in the case of copper pyrites, there is also considerable difference as to the constitution, especially in regard to the state of combination of the iron, whether as FeS or Fe_2S_3. Rammelsberg adopts the former view, and gives the following four general types:

	I.	II.	III.	IV.
	Cu_2S CuS $2FeS$	Cu_2S CuS FeS	$2Cu_2S$ CuS FeS	$9Cu_2S$ CuS $2FeS$
Copper per cent.	44·21	55·58	63·27	70·83

Of these, No. II. representing the crystallised, and No. III.

the massive varieties, are most common. If the iron is taken to exist as Fe_2S_3, the whole of the copper is assumed to be as Cu_2S. There can be but little doubt, from its association, that the variations in composition in the massive varieties are due to admixtures of copper glance or copper pyrites in many instances, the three species being very commonly found together. Heated in the closed tube does not give a sublimate of sulphur, on charcoal fuses to a grey magnetic brittle bead of a coppery red fracture; with fluxes may be reduced after roasting to metallic copper; with acids behaves like copper pyrites.

Occurrence.—Common with the richer sulphides of copper, and less so when iron pyrites prevails. The largest quantities were obtained at Monte Catini in Tuscany in masses up to several tons; also in the mines near Redruth and Camborne, the Acton and Harvey Hill mines in Canada, Ballycumisk in Ireland, and a few other localities. The tendency of mixed ores containing this mineral to tarnish is very marked, the masses being generally variegated in brilliant colours, forming the so-called *peacock copper ore.* When the alteration has proceeded further, the external parts are sometimes covered with malachite or other hydrated copper minerals. As pseudomorphs it occurs after copper glance and copper pyrites. When in quantity forms one of the most valuable ores of copper.

LINNÆITE. Kobaltnickelkies.—*Cubic.* Crystals octahedral, with cubical replacements, usually small and well-defined twins on 111, also compact. Cleavage, cubic, imperfect. Fracture, conchoidal, granular. Brittle. Colour, yellowish or reddish white, tarnishing yellow. Lustre, metallic; streak, dark grey or black.

Composition.—$R_3S_4 = \left.\begin{matrix} {}^{2}RS \\ RS_2 \end{matrix}\right\}$ where R = CoNiFe. A typical specimen from Müsen contained: nickel 33·64, cobalt 22·09, iron 2·29, sulphur 41·98 per cent. The

proportion of the first two metals, or Ni : Co, varies considerably from 4 Ni : Co to 2 Co : Ni; the maximum amount of iron is below 5 per cent. Heated in closed tube gives a sulphur sublimate; in open tube sulphurous acid, and occasionally fumes of arsenic. Fusible on charcoal to a bead, which covers with a magnetic crust. When roasted and heated with borax, gives a dull violet glass, which becomes of a pure cobalt blue when heated in the reducing flame with gold. This gold alloy gives nickel reaction with salt of phosphorus. Soluble in nitric acid, depositing sulphur, and giving a red solution.

Occurrence.—At Müsen, in Westphalia, in small brilliant crystals, with Fahlerz and copper pyrites; also in Maryland and Missouri. Valuable as a cobalt and nickel ore, but not very common. Resembles cobalt glance, but is not quite so brilliant, and the crystals do not show faces of the pentagonal dodecahedron.

GROUP C. BISULPHIDES.

IRON PYRITES. Schwefelkies, Mundic, Bronce.—*Cubic with parallel hemihedrism.* Commonest form *a* {100} $\infty O \infty$

FIG. 37.

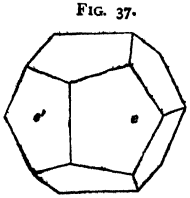


FIG. 38.

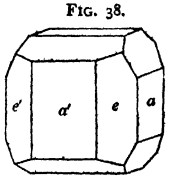
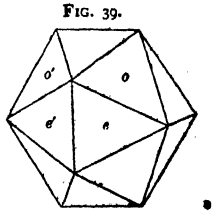


FIG. 39.



either alone or variously combined, also *o* {111} O rarely alone, $e\pi$ {210} $\left[\frac{\infty O 2}{1}\right]$ often alone (fig. 37), $s\pi$ {321} $\left[\frac{3 O \frac{3}{2}}{2}\right]$, $\left[\frac{\infty O 2}{\frac{1}{2}}\right]$, n {211} $2O2$ (figs. 37–42, also fig. 28). {110} $\infty \bar{O}$ is comparatively rare. Faces of {100} usually striated parallel to their edges of combination with π {210}.

Penetration twins of π 210 on a face of 110 common (fig. 270 Syst.); also penetration cubes on 111. Crystals often of large size (3 inches across). Also massive and in various crystalline aggregates, stalactitic, globular, botryoidal, reniform, usually of a radiated structure, and interspersed in dendritic patches and grains in rocks and fossils. In pseudomorphs, after magnetic pyrites, mispickel, copper pyrites, silver glance, the sulpho-salts of silver, quartz,

FIG. 40.

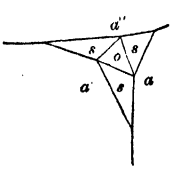


FIG. 41.

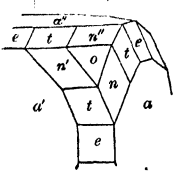
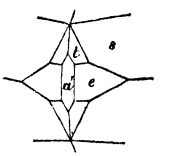


FIG. 42.



barytes, fluor, Aragonite, calcite, and dolomite, and replacing organic remains, both vegetable and animal. Cleavage, cubic, very imperfect, fracture conchoidal. Brittle. H. 6–6·5. Sp. gr. 4·9–5·2. Opaque. Lustre, metallic. Colour, pale to full brass-yellow, passing to gold-yellow and brown, the deeper colour due to tarnish; streak, black. Thermo-electric, the crystals being either positive or negative, according to the prevalence of one or other hemihedral form. Combinations of the former class usually contain faces of the cube, and of the latter those of the octahedron.

Composition.—FeS_2, or iron 46·7, sulphur 53·3 per cent., often containing some copper, cobalt, or arsenic, and in smaller quantity gold, silver, selenium, and thallium.

Heated in the closed tube gives a sulphur sublimate. On charcoal the sulphur burns with a blue flame, the residue in either case being similar to magnetic pyrites. Decomposed by nitric acid, with a considerable deposit of sulphur.

Pyrites is the most abundant of metallic sulphides, and is found in rocks of all ages, variously interspersed from isolated crystals and grains to actual rock masses. In

mineral veins it commonly accompanies the sulphides of the other heavy metals, especially arsenical and copper pyrites, and silver ores. As a rule it is more common in rocks that are impermeable to water, or contain carbonaceous substances, such as clay, slate, and coal, than in those that are freely permeable, like sandstone.

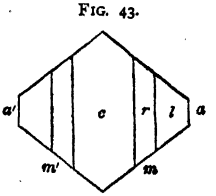
Crystals with well-developed smooth faces, and some of the hard massive may be preserved without alteration for a considerable period, and are sometimes used in jewellery under the name of Marcasite; but the granular varieties, especially when mixed with coaly matter, readily oxidise in damp air, producing ferrous sulphate, sulphuric acid, and the whole series of basic sulphates, the ultimate result being limonite, $Fe_2H_6O_9$.

Pyrites in which these changes are in progress is said to be *vitriolescent.*

The finest crystals are obtained from Traversella and Brosso in Piedmont with magnetite and copper pyrites, and from the iron mines of Elba, most of the described combinations being from these localities. In Cornwall the crystallised specimens have been principally obtained from the mines in the neighbourhood of Liskeard, and in Devonshire from about Tavistock.

MARCASITE. White Iron Pyrites, Strahlkies, Wasserkies. —*Rhombic.* ∞P 106° 05′, $\breve{P}\infty$ basal 99·40 $a : b : c =$ 0·752 : 1 : 1·185 (fig. 43), $m\{110\}$ ∞P, $a\{010\}$ $\infty \breve{P}\infty$, $l\{011\}$ $\breve{P}\infty$ $r\{014\}$ $\frac{1}{4}\breve{P}\infty$. Crystals usually tabular to the base and elongated on axis *a*. Twins on 110, which by repetition produces a five-sided rosette, *spear* or *cockscomb pyrites*, also on 101, also massive in aggregates like those of pyrites, the nodules often having a radiated crystalline structure. Cleavage, 110 imperfect. Fracture, uneven.

FIG. 43.



Brittle. H. 6–6·5. Sp. gr. 4·65–4·88. Colour, brass-yellow, lighter than pyrites, tarnishing to brown; streak, black.

Composition.—FeS_2, the same as pyrites, and with the same chemical properties. It is, however, more liable to change by vitriolescence under ordinary atmospheric conditions.

Pyrites is very largely used in the production of sulphuric acid; when heated to redness with access of air, it takes fire and burns until nearly the whole of the sulphur is consumed, leaving a residue consisting mainly of ferric oxide, in which any copper that may be present is retained as a sulphide. The extraction of the copper from the burnt residues is now effected on the large scale by means of calcination with salt, the copper being removed in the soluble form as chloride, the ultimate residue being nearly pure ferric oxide. Very large deposits of pyrites of this kind, containing from 2 to 4 per cent. of copper in the form of interspersed copper pyrites, are worked at Buitron and Pomarron in South-West Portugal, and at Tharsis and Rio Tinto in Spain. The presence of copper in pyrites is indicated by the black colour of a tarnished surface.

Gold is usually present in the pyrites of all gold-bearing districts, and often in larger proportion than in the accompanying quartz vein stuff. Traces of gold may also be found in pyrites from many other localities, but it does not seem to be so generally present as it is in galena.

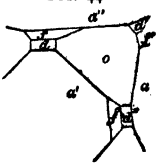
Selenium and thallium are commonly present in pyrites, though not in recognisable quantity, being found in some of the less volatile products, flue dust &c. of the furnaces used in the production of sulphuric acid.

By the decomposition on the large scale of masses of pyrites near the surface of the ground, deposits of brown iron ore may be produced. This change is concerned in the production of the so-called gozzans, or rusty masses of quartz filling mineral veins, the original pyritic substance being converted to brown iron ore, while associated sulphides

of lead, copper, and silver are converted into carbonates, or reduced to the metallic state. The iron ores of Wicklow and the neighbourhood of Santander are of this class, and probably also some of those of Elba. In the latter island the ore is often coloured by a beautiful rainbow-coloured film, due to the oxidation of a thin film of pyrites. White iron pyrites is common in stratified rocks, the lower chalk near Dover being an abundant locality for star-like groups of crystals, often well developed, and nodular masses of a radiated structure. In the coal measures flattened nodules of pyrites are often found in the shales, and, in some cases, in the coal itself; these are known as *Coal Brasses*, a term analogous to the *Bronce* of the Spanish American miner. In Cornwall the common term is Mundick, the varieties being distinguished as sulphur, copper, or arsenical mundic, according to the prevailing constituents.

HAUERITE.—*Cubic with parallel hemihedrism* (fig. 44). $\infty O\frac{3}{2}$ In detached single crystals or groups in clay and gypsum, also radiated fibrous masses. Cleavage, 100 perfect. H. 4. Sp. gr. 3·463. Colour, dark reddish brown to black; streak, brownish red. Lustre, adamantine when fresh, slightly translucent in thin fragments.

FIG. 44.



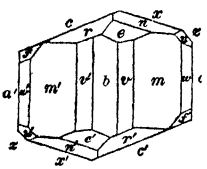
Composition.—MnS_2, or manganese 45·8, sulphur 54·2 per cent.; a portion of the metal replaced by iron (up to 1·5 per cent.). Heated in the closed tube gives off sulphur; the residue is green, and soluble in hydrochloric acid. Gives manganese reaction with soda in platinum; soluble in hot hydrochloric acid, giving off sulphuretted hydrogen, and depositing sulphur.

Found at Kalinka, near Neusohl in Hungary, with native sulphur, in crystals up to half an inch across; although rare, it is of great interest from its isomorphism with iron pyrites.

GROUP D. ANHYDRIDES OF THE SULPHUR ACIDS.

REALGAR.—*Oblique.* $a : b : c = 1{\cdot}440 : 1 : 0{\cdot}973$, $\beta = 66° 05'$, ∞P 74° 26′ (fig. 45), $a'\{100\}\infty\breve{P}\infty$, $b\{010\}\infty\breve{P}\infty$, $c\{001\}0P$, $m'\{110\}\infty P$, $e\{\bar{1}11\}P$, $n\{\bar{2}12\}\breve{P}2$, $v\{230\}\infty\breve{P}\frac{3}{2}$, $w\{430\}\infty\breve{P}\frac{4}{3}$, $r\{012\}\frac{1}{2}\breve{P}\infty$, $x\{101\}\breve{P}\infty$, $z\{201\}2\breve{P}\infty$, $u\{421\}4\breve{P}2$, $f\{212\}-\breve{P}2$. Crystals often completely developed, short columnar, with prominent basal and numerous prismatic faces, also massive, granular, and incrusting. Cleavage, 010, 001 tolerably perfect, 110 imperfect. Fracture, conchoidal. Sectile. H. 1·5–2. Sp. gr. 3·4–3·6. Translucent. Lustre, adamantine. Colour, hyacinth-red; streak, orange-yellow. Double refraction negative. Optic axial plane, 010. Apparent axial angle, 93° (yellow), strong inclined dispersion. First median line inclined 103° to axis *a* and 11° to *c*. Approximate mean refractive index, 2·549.

FIG. 45.



Composition.—AsS, or arsenic 79·1, sulphur 20·9 per cent. Heated in the closed tube, melts, volatilises, and sublimes, keeping the same colour; with cyanide of potassium and soda gives a black ring of metallic arsenic. In the open tube gives sulphurous acid, and a white crystalline sublimate of arsenious acid. On charcoal burns with a brilliant blue light, and dense smoke of arsenious acid. Soluble in nitric acid with deposit of sulphur, and partially so in caustic potash, leaving a brown residue.

The finest crystals are from Kapnik in Hungary; other localities are Felsobanya, Schneeberg, Andreasberg, the solfatara near Naples, and Peru. In China the massive variety is sometimes carved into ornaments, which somewhat resemble dark-coloured amber, but are of a higher lustre. These, as well as the crystals, must be kept in the dark, as by continued exposure to sunlight they lose colour and lustre, and finally break up into a yellowish red powder.

The stability of crystals even from the same locality is very unequal in this respect.

ORPIMENT.—*Rhombic.* ∞P 117° 49′, $a : b : c =$ 0·603 : 1 : 0·674. Crystals rare, usually massive, in platy or broad columnar aggregates. Cleavage, 010 very perfect, the cleavage planes being striated vertically. Sectile, and slightly flexible in thin laminæ. H. 1·5–2·0. Sp. gr. 3·4–3·5. Colour, lemon- to orange-yellow; streak, similar. Lustre, resinous, nacreous, on cleavage surfaces, translucent to opaque, thin laminæ transparent.

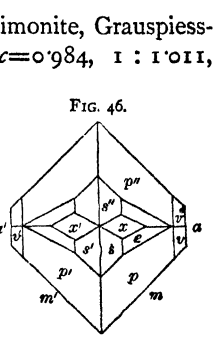
Composition.—As_2S_3, or arsenic 60·98, sulphur 39·02 per cent. The reactions are similar to those of realgar, except that it is completely soluble in caustic alkalis and the sublimate in the closed tube is yellow.

Occurs with realgar in the same localities, the two minerals being often mixed together, producing a variegated red and yellow mass.

Dimorphine is a mineral of similar composition, found at the solfatara of Naples, in minute crystals which are referred to two different types, both of which are rhombic. In other respects it is very similar to orpiment.

ANTIMONY GLANCE. Stibnite, Antimonite, Grauspiessglanz.—*Rhombic.* ∞P 90° 54′, $a : b : c$=0·984, 1 : 1·011, a {010} $\infty \breve{P}\infty$, m {110} ∞P, p {111} P, x {012} $\frac{1}{2}\breve{P}\infty$, v {121} $2\breve{P}2$, e {213} $\frac{2}{3}\breve{P}2$, s {113} $\frac{1}{3}P$. Crystals usually long columnar, or acicular, rarely well terminated, pyramidal faces usually curved or otherwise distorted, and prismatic faces vertically striated. Generally in radiated or divergent bunches. Also massive, with columnar or fibrous structure. Cleavages, 010 very perfect, and 001, 100, 110 less perfect. H. 2. Sp. gr. 4·6–4·7. Colour, lead-grey; streak, similar,

FIG. 46.



weathering black or with rainbow tarnish. Lustre, metallic, very brilliant on cleavage surfaces.

Composition.—Sb_2S_3, or antimony 71·77, sulphur 21·83 per cent., usually with traces of lead and copper. Heated in the open tube, gives, in addition to sulphurous acid, a sublimate consisting partly of Sb_2O_3, which is fusible and volatile, and partly of SbO_2, which is neither fusible nor volatile. On charcoal melts easily, giving a greenish tinge to the flame, gives off copious fumes, and volatilises, leaving in some instances a residue containing lead, copper, and iron.

Soluble in hydrochloric acid, giving a slight crystalline precipitate of PbCl if lead be present. The solution gives a precipitate of oxychloride when diluted with water. Nitric acid converts it into Sb_2O_3 and S, both insoluble. With caustic potash lye changes to an orange colour, and dissolves in great part when heated, orange-yellow sulphide of antimony being precipitated from the alkaline solution on the addition of an acid.

Occurrence.—With lead and silver ores at Neudorff and Wolfsberg in the Harz, Přibram, Bohemia, Kremnitz and Schemnitz in Hungary, in Borneo, and at a few Cornish localities, being most abundant in Borneo. At Kremnitz, fine acicular forms are found, piercing crystals of heavy spar.

Antimony glance is the chief ore of antimony. When freed from earthy matters by fusion or liquation, it forms the *antimonium crudum* of commerce. This, when treated with iron and alkaline fluxes, gives metallic antimony or *star regulus*, so called from the star-like pattern formed by the crystals on the surfaces of the ingots.

BISMUTH GLANCE.—*Rhombic.* ∞P 91° 30′. Crystals long columnar, or acicular, analogous to those of antimony glance, and rarely with developed ends ; usually in radiating or irregularly intersecting bundles, also granular and massive, or with a platy or fibrous structure. Cleavage, $\infty \breve{P} \infty$ perfect, less so parallel to the other pinakoids, and to the

prism imperfect. H. 2–2·5. Sp. gr. 6·4–67. Lustre, metallic. Colour, pale lead-grey (lighter than antimony glance), usually tarnished to yellow and rainbow colours.

Composition.—Bi_2S_3, or bismuth 81·25, sulphur 18·75 per cent. The analyses of Cornish specimens show from 2 to 3 per cent. of iron and copper. Very easily fusible. In the open tube gives off sulphurous acid, melts, and a white sublimate which melts to brown or yellow drops (BiO). On charcoal melts and boils, giving a yellow incrustation and a bead of bismuth, which by continued heating may be entirely volatilised if pure, otherwise the residue will contain copper and iron. Soluble in nitric acid, depositing sulphur. The solution when cooled and diluted with water deposits subnitrate of bismuth (pearl-white).

Occurrence.—With other bismuth minerals, at Carrock Fell, Cumberland, in the Saint Just and Gwennap districts in Cornwall, at Johangeorgenstadt, Altenberg, and Joachimstahl, and in Bolivia.

MOLYBDENITE.—*Hexagonal or oblique.* In tabular or short columnar crystals, which are not sufficiently perfect for exact determination. Usually in six-sided thin plates, or in curved foliated aggregates. Cleavage, basal, very perfect, flexible in thin laminæ. Sectile and unctuous to the touch. H. 1–1·5 (can be marked by the finger nail, and soils paper). Sp. gr. 4·6–4·9. Colour, lead-grey, with a blue or red tinge. Lustre, metallic; streak, bluish-grey on paper and somewhat greenish on porcelain.

Composition.—MbS_2, or molybdenum 58·97, sulphur 41·03 per cent. Heated in the open tube, gives off sulphurous acid; in the forceps, colours the outer flame yellowish green; on charcoal, in oxidising flame, gives a yellow coating of molybdic oxide, becoming white on cooling; close to the assay the coating is copper-red. When roasted, gives with borax a bead, yellow in oxidising, and nearly black in reducing flame. Nitric acid converts it to molybdic acid, an

insoluble white powder; with sulphuric acid it gives a blue solution.

Occurrence.—Interspersed in granite, gneiss, and other crystalline rocks, in many parts of the world, but rarely in large quantity; in mineral veins with quartz and copper ores in Cumberland, Cornwall, the West Indies, &c., and with native bismuth in South Australia.

Remarkable for its great similarity to graphite, from which it may be most readily distinguished by its blowpipe behaviour.

SELENIDES.—The number of natural compounds of selenium is very small, and being rare, and as a rule massive, their crystallographic characters are not very well defined. As far as is known, however, they are isomorphous with the corresponding sulphides of the same bases.

CLAUSTHALITE. Selenblei.—*Cubic*, in masses and granular aggregates, having a cubic cleavage, like galena. H. 2·5. Sp. gr. 8·2–8·8. Opaque. Lustre, metallic. Colour, lead-grey; streak, grey.

Composition.—PbSe, lead 72·38, selenium 27·62 per cent. Part of the lead may be replaced by silver up to 11·67 per cent. Sometimes contains cobalt up to 3 per cent. In the closed tube, decrepitates, but is not otherwise changed; on charcoal, gives the odour of selenium, and an incrustation which is first grey, then red, and finally yellow. In the open tube gives a red sublimate of selenium. With soda on charcoal reduced to metallic lead.

Occurs at Clausthal, Zorge, and Tilkerode, in the Harz, Freiberg, and Mendoza in Chili.

Several selenides, containing both lead and copper in variable proportions, have been described, principally from Tilkerode and Zorge, Harz; the latter locality giving the specific name of *Zorgite*. According to the prevalence of one or other metal, they are also distinguished as Selenbleikupfer (plumbo-cuprous selenide), Selenkupferblei (cuproplumbic selenide). The following are the principal types of composition:

Sp. gr.	5·6	Copper	15·77	Lead	48·43	Selenium	35 p. c.
„	—	„	46·64	„	16·58	„	36·59 „
„	7·0	„	9·00	„	60·00	„	30·00 „
„	7·5	„	4·00	„	65·00	„	30·00 „

These are soft lead-grey substances, usually tarnished blue or black, without definable forms, usually in granular or other small masses, interspersed in calcite; easily fusible upon charcoal to a grey mass, which may be fluxed to a bead of copper.

Berzeline or *Berzelianite* occurs at Skikerum, in Norway, in dendritic aggregates included in calcite, which are brown or black on the surface, but silver-white on a fresh fracture.

Composition.—Cu_2Se, copper 61·6, selenium 38·4.

Crookesite, from the same locality, in brittle lead-grey masses without crystalline structure. H. 2·5. Sp. gr. 6·9. Contains copper 45·67, silver 3·71, thallium 17·25, selenium 33·25 per cent. Fuses easily to a greenish black enamel, colouring the flame strongly green. This is remarkable as being the only mineral in which thallium has as yet been found in quantity. Probably minute quantities of this or some similar selenide, interspersed in copper and iron pyrites in the same manner as sulphide of cadmium is in blende, are the source of the deposit in sulphuric acid chambers from which thallium has hitherto been derived.

Eucairite, also from Skikerum, is (Cu_2SeAg_2Se), copper 25·32, silver 43·13, selenium 31·53 per cent., or analogous to Stromeyerite or Ialpaite.

Naumannite, Ag_2Se, silver 73, selenium 27 per cent., is an iron-black strongly lustrous mineral (H. 2·5. Sp. gr. 8), occurring at Tilkerode, in granular or platy masses, with definite cubic cleavage, or apparently isomorphous with silver glance.

Tiemannite. Massive, in finely granular aggregates. Fracture, conchoidal or uneven. H. 2·5. Sp. gr. 7·10–7·37. Colour, dark lead-grey.

Composition.—HgSe or Hg_6Se_5, mercury 75, selenium 25 per cent. In *Lerbachite*, which has a cubic cleavage, the mercury varies from 17 to 45 per cent., and may be partly replaced by lead. Both are found at Lerbach, Clausthal, and Tilkerode.

Onofrite is a massive sulpho-selenide of mercury, similar in character to metacinnabar, originally found at San Onofre, Mexico, and latterly in a palæozoic limestone at Marysvale, Utah. Specimens from the latter locality (H. 2·5. Sp. gr. 7·63) contain mercury 82, selenium 4·6, and sulphur 11·7, besides minute quantities of zinc and manganese. It is essentially (4HgSHgSe). In the open tube gives sulphurous acid fumes, sublimates of mercury, and sulpho-selenide of mercury, and a residue yellow while hot (zinc oxide). On charcoal the selenium odour is recognisable.

TELLURIDES.—These minerals form a small but interesting group, which occur under similar conditions of association in a few widely separated localities; the more abundant ones being of great economic value, as containing a large proportion of gold and silver.

HESSITE. Tellursilberglanz.—*Cubic*, crystals rarely well defined, usually compact, in masses of fine-grained texture. H. 2–2·5. Sp. gr. 8·31–8·45. Opaque. Lustre, metallic, lead- to steel-grey. Sectile.

Composition.—Ag_2Te, silver 62·8, tellurium 37·2 per cent. Easily fusible to a dark bead covered with dendritic crystals of silver, reducible to a silver bead with soda. In strong sulphuric acid gives a deep red solution (characteristic of tellurium). Rezbanya in Transylvania and Sawodinski in the Altai are the chief localities.

Petzite is similar in constitution to Hessite, the silver being partly replaced by gold, and resembles it in most physical characters, but is much denser. That from Nagyag, with 18 per cent. of gold, has sp. gr. 8·83; while

the Californian and Colorado varieties, with 24–26 per cent. of gold, range in sp. gr. from 9 to 9·4. In the Gold Hill district, Colorado, it forms one of the principal minerals in a group of quartz veins in porphyries traversing very coarse granites, and occurs in rounded masses, sometimes implanted on iron pyrites and irregular crystalline aggregates, which are occasionally coated with encrusting pseudomorphs of gold.

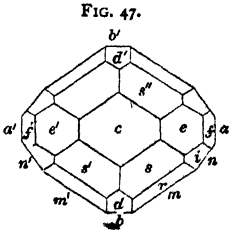
COLORADOITE, HgTe, mercury 60·98, tellurium 39·02, has also been found in the Gold Hill mines. It occurs in granular or fibrous columnar masses, without crystalline structure or cleavage, with uneven or imperfectly conchoidal fracture. H. 3. Sp. gr. 8·627. Opaque. Lustre, metallic, iron-grey to black, with iris or purple tarnish. It is intimately mixed with quartz, gold, and native tellurium. Most analyses vary considerably from the theoretical composition.

Stutzite, Ag_4Te, has been described by Schrauf as occurring with other tellurides at Nagyag. It is apparently hexagonal, but may be isomorphous with the analogous species copper glance and discrasite.

Altaite, PbTe, lead 61·79, tellurium 38·21, has been found in the Altai and in Colorado, but is extremely rare.

SYLVANITE. Graphic Tellurium. Weisstellur.—*Oblique.* P 117° 08′, $a : b : c = 1·634 : 1 : 1·265$, β 89° 35′, $r\{\bar{1}1\bar{1}\} -P$, $s\{\bar{1}2\bar{1}\} -2P2$, $a\{100\} \infty P\infty$, $b'\{001\} oP$, $c\{010\} \infty P\infty$, $e'\{110\} \infty P$, $f'\{210\} \infty P2$, $i\{\bar{3}2\bar{1}\} -3P\frac{3}{2}$, $n\{\bar{2}0\bar{1}\} -2P\infty$, $m\{\bar{1}0\bar{1}\} -P\infty$, $d\{011\} P\infty$. (Schrauf's notation of Miller's rhombic figure.) Crystals often with hollow faces and other irregularities. Twins common on 101, the lamellar individuals crossing at right angles or obliquely, forming the so-called graphic tellurium, from their resemblance to Hebrew letters. Also

FIG. 47.



interspersed in quartz in lamellar or granular aggregates. Cleavage, 010 very perfect. H. 1·5–2. Sp. gr. 7·99–8·33. Sectile, brittle, in thin laminæ. Opaque. Lustre, metallic. Colour, bright steel-grey to silver-white.

Composition.—$(AuAg)Te_2$. The proportion of gold to silver varies.

	Au:Ag	Gold	Silver	Tellurium	
Nagyag	4 : 3	26·97	11·47	59·97	PbSbCu traces.
Colorado	1 : 1	24·83	13·05	56·31	

Easily fusible, giving in the open tube a sublimate of tellurous acid which melts to a transparent glass. On charcoal, colours the flame blue, giving a white incrustation and a dark grey bead, which can be reduced alone, or easier with soda, to a bead of silvery gold. Soluble in aqua regia, with separation of chloride of silver; and in nitric and sulphuric acids, with separation of gold. With the latter the solution is dark red.

Occurs in Transylvania, California, and Colorado, in the localities given for native tellurium and other tellurides.

Weisstellur or *Krennerite* is a closely allied species which appears to be rhombic, and also differs from sylvanite by containing lead up to 14·5 and antimony to 8·5 per cent. The composition is, however, not very definite.

NAGYAGITE. Foliated or Black Tellurium. Elasmose.—*Tetragonal* (Miller) or *rhombic* (Schrauf). Crystals, mostly small and imperfect, are eight-sided striated plates. Usually in granular or foliated masses, with a perfect cleavage, sectile and flexible in thin laminæ. H. 1–1·5. Sp. gr. 6·85–7·20. Opaque. Lustre, metallic. Colour, dark lead-grey.

Composition.—$(PbAu)(TeS)_2$, usually with some Sb and Cu. A typical specimen contained: lead 50·95, gold 9·10, silver 0·53, copper 0·99, tellurium 30·09, sulphur 9·70 per cent. Antimony may be present up to 4·5 per cent.

Gives the reactions of lead and sulphur, in addition to those of the constituents of other tellurides. Decomposed by hydrochloric acid, evolving sulphuretted hydrogen, and leaving a residue of tellurium and gold. Soluble in nitric acid with separation of gold, and in aqua regia with separation of sulphur, sulphate and chloride of lead.

Occurs at Nagyag and Offenbanya, where it forms a valuable gold ore.

CALAVERITE.—Crystalline form undetermined, probably oblique or rhombic, with an imperfect cleavage and massive, granular. Fracture, uneven, brittle. H. 2·5. Sp. gr. 9·043. Colour, light brass-yellow.

Composition.—(AuAg) Te_2, Au : Ag = 7 : 1 ; gold 39, silver 33, tellurium 58 per cent. Described by Genth from Stanislaus Mine, California, and since found in some quantity in the Gold Hill district, Colorado. A 'pure crystallised gold telluride' has also been described by Krenner, from Nagyag.

MELONITE, which occurs in minute six-sided crystals with perfect basal cleavage at Stanislaus Mine, is essentially Ni_2Te, with nickel 23·5, tellurium 76·5 per cent.

CHAPTER V.

SULPHOSALTS.

THIS group includes those sulphides that contain arsenic, antimony, or bismuth, in addition to one or more of the electro-positive metals. The constitution of theoretical sulphantimonious acid being unsettled—it may be written either as $HSbS_2$ or H_3SbS_3, according as it is supposed to be constructed on the type of nitrous or phosphorous acid—it is not possible to assign constitutional formulæ to them, as the same compound may be regarded either as a basic or normal salt, or as a normal or acid salt, as one or other kind of formula is adopted for the acid. It is therefore convenient to regard the minerals of this class as made up of molecules of the simple sulphides $\overset{I}{R}_2S$ or $\overset{II}{R}S$ and Sb_2S_3, As_2S_3 or Bi_2S_3, combined in very variable proportions. In the larger number of instances the acid sulphide is that of antimony, which combines with every sulphur base entering into the group, while the least abundant are the sulpho-bismuthic compounds, which chiefly contain copper as a base.

The simplest forms are those consisting of $\overset{I}{R}_2S+Sb_2S_3$ and $\overset{II}{R}S+Sb_2S_3$, i.e. normal sulphosalts. Of these the following are known as independent minerals :

A		B	
Miargyrite	$Ag_2S+Sb_2S_3$	Zinckenite	$PbS+Sb_2S_3$
Wolfsbergite	$Cu_2S+Sb_2S_3$	Scleroclase	$PbS+As_2S_3$
Emplectite	$Cu_2S+Bi_2S_3$	Berthierite	$FeS+Sb_2S_3$

Next in order of complexity are those containing two or more atoms of basic to one of acid sulphide, or basic sulphosalts.

A_2		B_2	
Polyargite	$12Ag_2S+Sb_2S_3$	Geocronite	$5PbS+r_2S_3$
Polybasite	$8R_2S+r_2S_3$		r=SbAs
R=AgCu r=SbAs		Boulangerite	$3PbS+Sb_2S_3$
Stephanite	$5Ag_2S+Sb_2S_3$	Meneghinite	$4PbS+Sb_2S_3$
Pyrargyrite	$3Ag_2S+Sb_2S_3$	Kobellite	$3PbS+r_2S_3$
Proustite	$3Ag_2S+As_2S_3$	r=SbBi	
Wittichenite	$3Cu_2S+Bi_2S_3$	Jamesonite	$2PbS+Sb_2S_3$
		Dufrenoysite	$2PbS+As_2S_3$

Lastly, by combination of members of the A_2 and B_2 groups and analogous compounds we arrive at the following more complex series:

Freislebenite $(3Ag_2S+Sb_2S_3)+2(2PbS+Sb_2S_3)$.
Bournonite $(3Cu_2S+Sb_2S_3)+2(PbS+Sb_2S_3)$.
Patrinite $(3Cu_2S+Bi_2S_3)+2(3PbS+Bi_2S_3)$.
Fahlerz $m(4\overset{I}{R}_2S+r_2S_3)+n(4\overset{II}{R}S+r_2S_3)$.
$\overset{I}{R}_2=Ag_2Cu_2$ $\overset{II}{R}=PbFeZnHg$ $r_2=As_2Bi_2Sb_2$.
Enargite $(5Cu_2S+As_2S_3)+4(5CuS+As_2S_3)$.

The different members of these groups are of very unequal values mineralogically considered. The most important, as regards abundance and perfection of their crystalline series, are amongst the most complex, namely Bournonite, Fahlerz, and Freislebenite, and the silver minerals of the A_2 series, Proustite, Pyrargyrite, and Stephanite, while those which are simpler in composition are for the most part rare and imperfectly crystallised. The larger number, including Bournonite, crystallise in the rhombic system, but Freislebenite is oblique, Fahlerz cubic, and Proustite and Pyrargyrite are rhombohedral, so that there is no very obvious relation between form and com-

position. The two species last mentioned are closely isomorphous both in form and habit. The crystallographic affinities of Fahlerz are with the sulphides of the RS series, the cubic symmetry and tetrahedral habit recalling the forms of blende and copper pyrites. As a mere aid to the memory, the silver ores of the A and A_2 series may be considered as intermediate terms between silver glance or acanthite and antimony glance, and in like manner the lead series of B, B_2, as terms of a series whose limits are galena and antimony glance.

Economically considered, the minerals are essentially silver, copper, and lead ores, and as a rule occur with other ores of the same metals and those of antimony and arsenic in mineral veins. They are valuable as being generally argentiferous, but as sources of copper and lead are to be regarded as of an inferior quality to the simple sulphides, the resulting metals being mostly reduced in value by the presence of antimony or arsenic.

FAHLERZ. Antimonial Grey Copper Ore.—Tetrahedrite, Panabase, Weissgültigerz, Schwatzite, Pavonado.

TENNANTITE. Arsenical Grey Copper Ore. — *Cubic with inclined hemihedrism* (figs. 48–51). $a\{001\}\infty O\infty$,

FIG. 48.

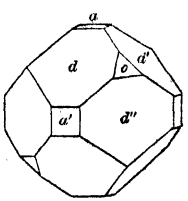
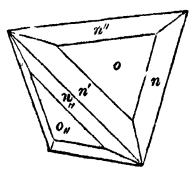


FIG. 49.



$d\{110\}\infty O$, $o\kappa\{111\}\frac{O}{2}$, $n\kappa\{211\}\frac{2O2}{2}$, $y\kappa\{233\}\frac{\frac{3}{4}O}{2}$. Faces of 110 often rough, and those of $\kappa\{211\}$ striated parallel to edges of $\kappa\{111\}$. Twins on 111 producing

with individuals of different sizes penetration groups of irregular shape, also massive and granular. Cleavage, 111 imperfect. Fracture, conchoidal, uneven. Brittle. H. 3–4. Sp. gr. 4·3–5·2. Colour, steel-, lead-grey, iron-black; streak,

FIG. 50.

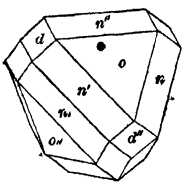
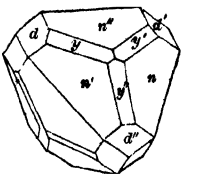


FIG. 51.



black to dark red. Opaque. Lustre, metallic, sometimes slightly translucent, in thin fragments, transmitting deep red light; tarnishes black.

Composition.—Sulphantimonides and sulpharsenides of all the sulphur bases. The most generalised formulæ that can be given are:

$$\left\{\begin{matrix} m\overset{\text{I}}{\dot{\text{R}}}_8\text{X}_2\text{S}_7 \\ n\overset{\text{II}}{\dot{\text{R}}}_4\text{X}_2\text{S}_7 \end{matrix}\right\} = \left\{\begin{matrix} m(4\text{R}_2\text{S}\ \text{XS}_3 \\ n(4\text{RS}\ \ \text{XS}_3 \end{matrix}\right\}$$

$\dot{\text{R}} = \text{CuAg}$, $\overset{\text{II}}{\dot{\text{R}}} = \text{FeZnHg}$, $X = \text{SbAs}$; $m : n$ usually about 2 : 1. Qualitatively they are divisible into:

I. *Antimonial series*, containing no arsenic, with silver, copper, iron, and zinc as bases. These are the most argentiferous.

II. *Mixed series*, containing both antimony and arsenic, the former usually predominating; the bases are chiefly copper, iron, zinc, and mercury, the latter often in considerable proportion, but that of silver is usually small.

III. *Arsenical series*, containing no antimony; the bases are almost exclusively copper and iron (Tennantite), and less commonly zinc, silver, and mercury are entirely absent.

The diversity of composition due to isomorphous replacement in both sulphur-acids and bases, is seen by the

following analyses, which are so selected that each shows a maximum of one constituent:

	I.	II.	III.	IV.	V.
Sulphur	21·17	26·61	24·17	22·53	29·18
Antimony	24·63	—	27·47	19·34	—
Arsenic	—	19·03	—	2·94	19·01
Bismuth	—	—	—	0·81	—
Mercury	—	—	2·70	17·27	—
Silver	31·29	—	—	—	—
Copper	14·81	51·62	36·13	35·55	42·60
Iron	5·98	1·95	1·89	0·87	9·21
Zinc	0·99	—	6·05	0·69	—
Total	98·87	99·21	98·41	100	100

Localities.
I. Freiberg.
II. Tresavean, Cornwall.
III. Val di Castello, Tuscany.
IV. Iglo, Hungary.
V. Skutterud, Norway.

Argentiferous varieties such as No. I. are known as Polytelite or by the old German miner's name of Weissgültigerz, and often contain some lead. More generally the silver is less, between 1 and 17 per cent. No. II., which contains no antimony, is also called Tennantite. No. IV. is a mercurial variety known as Schwatzite. Pavonado is the Spanish miner's term.

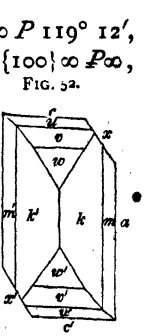
The blowpipe behaviour varies with the composition. All kinds fuse in the closed tube, giving a red sublimate of sulphide of antimony, preceded in the mercurial varieties by a dark grey one, which appears only at a very low heat, and in those containing arsenic by one of sulphide of arsenic. In the open tube the corresponding oxides of arsenic and antimony, and metallic mercury, are formed. On charcoal, the oxides of zinc and lead may be detected by their characteristic incrustations, and iron and copper in the residue, either by vitreous fluxes or by reduction with soda. Mercury can be best found by fusing a portion of the pulverised mineral in a closed tube with soda, when the reduced metal sublimes, and silver by cupellation. Soluble in nitric acid, arsenious and antimonious acids separating. The solution becomes blue from copper by adding ammonia

in excess, and cloudy with hydrochloric acid when silver is present.

Occurrence.—With other silver, lead, and copper ores, in many mining districts. The argentiferous varieties are chiefly from South America, Freiberg, with diallogite, and the Isle of Man (Foxdale Mine with galena). Tennantite is the arsenical kind from the neighbourhood of Redruth. The mercurial varieties are from Tuscany, Rhenish Bavaria, Schwatz, Tyrol, and Schmölnitz, Hungary. At Müsen, with Linnæite and copper pyrites; at Herodsfoot Mine, Liskeard, with Bournonite in fine crystals, which are often covered with a thin film of copper pyrites. Very fine crystals associated with transparent diallogite have been obtained at Buckskin Gulch, Colorado. The mercurial varieties are darker, and those containing much silver lighter in colour than the ordinary kinds containing copper and antimony only. A portion of the mercury is usually recovered in the smelting of the former and the bulk of the silver; but as copper ores they are of a low class, from the large proportion of antimony. This is indicated in the name Fahl=faul, rotten, from the inferior quality of the copper derived from it.

FREISLEBENITE. Schilfglaserz.—*Oblique.* ∞P 119° 12′, $a : b : c = 0{\cdot}587 : 1 : 0{\cdot}928$, $\beta = 87°46'$ (fig. 52), $a\{100\}\infty\breve{P}\infty$, $x\{101\}\breve{P}\infty$, $m\{1\bar{1}0\}\infty P$, $k\{1\bar{2}0\}2\breve{P}\infty$, $c\{001\}oP$, $u\{o\bar{1}2\}\frac{1}{2}\breve{P}\infty$, $v\{o\frac{3}{2}2\}\frac{3}{2}\breve{P}\infty$, $w\{o\bar{2}1\}2\breve{P}\infty$. Crystals chiefly combinations of prisms and clinodomes, the former predominating and striated longitudinally. Cleavage, 110. Fracture, granular, uneven. Colour, pale to dark lead-grey, near that of graphite; streak, brownish black. H. 2. Sp. gr. 6–6·4. Lustre, metallic.

FIG. 52.



Composition.—$Ag_6Pb_4Sb_6S_{13} = (3Ag_2S, 4PbS, 3Sb_2S_3)$ is the nearest generalised expression, which contains silver

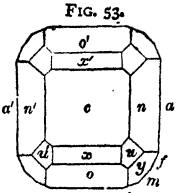
23·83, lead 30·44, antimony 26·91, sulphur 18·82 per cent., but sometimes copper and iron are found in small quantity. Heated in the open tube, gives a white antimonial sublimate. On charcoal fuses, gives a white and yellow incrustation of antimony and lead, and finally a bead of argentiferous lead.

Occurrence.—With other antimonial silver ores at Freiberg, Kapnik, Přibram, and Felsobanya, and more abundantly at Hiendalaencina in Spain. At the latter place, where it formed for some time a very productive silver ore, it was found in a vein in gneiss, associated with most of the antimonial silver ores of the same class, galena, quartz, and barytes. The German name, Schilfglaserz, refers to the striations of the crystals, which resemble the markings on the stems of reeds.

DIAPHORITE.—A mineral of almost identical composition with Freislebenite, and found with it at Přibram and Freiberg, but rhombic in crystallisation, the forms being in many respects analogous to those of antimony glance.

BOURNONITE. Rädelerz, Cog-Wheel Ore. — *Rhombic.* $\infty P\, 93° 40'$, $a : b : c = 0{\cdot}938 : 1 : 0{\cdot}897$ (fig. 53), $a\{010\}$ $\infty \breve{P}\infty$, $b\{100\}$ $\infty \bar{P}\infty$, $c\{001\}$ $o P$, $m\{110\}$ ∞P, $f\{120\}$ $\infty \breve{P}2$, $e\{210\}$ $\infty \bar{P}2$, $y\{111\}$ P, $u\{112\}$ $\frac{1}{2}P$, $o\{101\}$ $\bar{P}\infty$, $x\{102\}$ $\frac{1}{2}\bar{P}\infty$. Crystals usually thick tabular combinations of the three pinakoids and the unit prism, with subordinate development of domes and pyramids. The lateral parameters being nearly equal, some of the forms have a general resemblance to those of the tetragonal system. Twins very common on 110, forming by repetition four-armed nearly right-angled crosses, and cog-wheel and star-like forms similar to those of Aragonite, also massive. Cleavage, 010 imper-

FIG. 53.



fect. Fracture, conchoidal, uneven, brittle. H. 2·5–3. Sp. gr. 5·7–5·9. Lustre, metallic. Colour, lead-grey to black; streak, similar.

Composition.—$CuPbSbS_3 = \begin{pmatrix} 2(3PbS + Sb_2S_3) \\ (3Cu_2S + Sb_2S_3) \end{pmatrix}$, corresponding to lead 42·38, copper 12·98, antimony 24·98, sulphur 19·66 per cent. The pure mineral is free from silver, which when found is due to an admixture of fahlerz. Heated in the closed tube, gives a sublimate of sulphide of antimony. When roasted, gives a sublimate of antimonious acid and an infusible residue of antimoniate of lead. On charcoal fuses easily, gives off antimonial vapours, and, at a stronger heat, oxide of lead and a slag containing copper. With nitric acid gives a blue solution, and deposits sulphur and a white powder containing antimony and lead. Caustic potash dissolves out the sulphide of antimony.

Occurrence.—With fahlerz and similar antimonial minerals and other ores of lead and copper in the Harz, Freiberg, Hungary, Mexico, Peru, and Bolivia. Two of the best localities for crystals are Kapnik in Hungary, where it is found with quartz and yellow blende, and Herodsfoot near Liskeard, where it is intimately associated with fahlerz and pyrites.

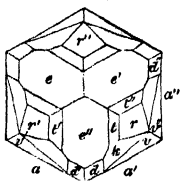
Needle ore or *Patrinite*, from Beresov, and *Kobellite*, from Hvena, Sweden, are minerals analogous in constitution to Bournonite, but containing bismuth, wholly or partly replacing antimony. The former is $CuPbBiS_3$, with 36 per cent. of bismuth, and the latter $Pb_3BiSbSb$ with 18 per cent.

Wittichenite, or bismuthic copper ore, is Cu_3BiS_3, or $\begin{pmatrix} 3Cu_2S \\ Bi_2S_3 \end{pmatrix}$, with copper 38·48, bismuth 42·09, and sulphur 19·43 per cent., from Wittichen, Baden.

These are all rare, but of interest, as establishing the isomorphism between the sulph-bismuthites and the corresponding sulphantimonites.

PYRARGYRITE. Antimonsilberblende, Dunkelesrothgültigerz, Dark Red Ruby Silver Ore, Rosicler.—*Hexagonal, rhombohedral, hemimorphic.* $R108°42'$, $a : c = 1 : 0{\cdot}788$ (fig. 54), $a\{11\bar{2}0\}\infty P2$, $v\kappa\{21\bar{3}1\}R^3$, $k\kappa\{10\bar{5}\bar{1}8\}\frac{5}{8}R^3$, $t\kappa\{21\bar{3}4\}\frac{1}{4}R^3$, $r\kappa\{10\bar{1}1\}R$, $e\kappa\{01\bar{1}2\}-\frac{1}{2}R$, $d\kappa\{12\bar{3}2\}-\frac{1}{2}R^3$. Crystals columnar, with flat ends, or combinations of rhombohedra and scalenohedra; faces often rounded. The opposite ends are often dissimilar; the hemimorphism is also seen in $\{10\bar{1}0\}$, which appears as a trigonal prism. Twin planes: 1. 0001; 2. $01\bar{1}2$; 3. $10\bar{1}4$. The last is most common, three individuals being grouped about a fourth central one. Also in dendritic aggregates, massive, granular, and in thin films. Cleavage, $10\bar{1}1$ not very distinct. Fracture, conchoidal, brittle, slightly sectile. H. 2–2·5. Sp. gr. 5·7–5·9. Translucent. Lustre, metallic, adamantine. Colour, deep cochineal-red; apparent in thin crystals or fragments; larger masses being nearly black; streak, purplish or brownish red. Double refraction negative; indices for red light, $\omega=3{\cdot}084$, $\epsilon=2{\cdot}881$.

FIG. 54.

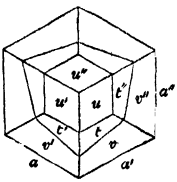


Composition. — $Ag_3SbS_3 = 3Ag_2SSb_2S_3$, silver 59·78, antimony 22·51, 22·51, sulphur 17·71 per cent. Heated in closed tube, Sb_2S_3 sublimes; in open tube, gives off SO_2 and Sb_2O_3. On charcoal fuses with spirting, giving a white incrustation, and ultimately a bead of silver. Decomposed by nitric acid, depositing sulphur and Sb_2O_3. Caustic potash or sulphide of potassium dissolves out Sb_2S_3.

Occurrence.—In most silver-producing districts, especially in the Harz, Freiberg, Joachimsthal, Mexico, and Chili, generally in association with native silver, silver glance, and the other rich or noble silver ores, and with arsenical pyrites at Irwin, Colorado. The finest crystallised specimens have been obtained from Andreasberg, Joachimsthal, and Mexico, and the largest masses from Idaho and Freiberg. In England it has been found in small quantity at Dolcoath, Huel Ludcott, and the lead mines in the Callington district.

PROUSTITE. Arsensilberblende. Light-red Ruby Silver Ore. Lichtesrothgültigerz.—*Hexagonal, rhombohedral, hemimorphic.* R 107° 48′, $a : c = 1 : 0{\cdot}785$ (fig. 55), a $\{11\bar{2}0\} \infty P2$, $v \kappa$ $\{21\bar{3}1\}$ R^3, $t \kappa$ $\{21\bar{3}4\}$ $\frac{1}{4}R^3$, $u \kappa$ $\{10\bar{1}4\}$ $\frac{1}{4}R$. Crystals generally similar to those of pyrargyrite, but scalenohedral forms more common, especially R^3, having X 105° 22′, Y 144° 43′. Cleavage, imperfect. Fracture, conchoidal, uneven; also massive, and in thin films. H. 2–2·5. Sp. gr. 5·5–5·6. Colour, between hyacinth- and cochineal-red, or deeper than realgar and lighter than cinnabar; streak, similar to the colour of realgar crystals. Lustre, metallic, adamantine, very brilliant when fresh (being the most highly lustrous of known minerals), but becomes dull when kept for a length of time exposed to sunlight.

FIG. 55.



Heated in the closed tube, gives sublimate of As_2S_3. On charcoal fuses easily, gives off arsenical fumes, and is reduced to a bead of silver.

Composition.—$Ag_3AsS_3 = \left\{\begin{matrix} 3Ag_2S \\ As_2S_3 \end{matrix}\right\}$, corresponding to silver 65·45, arsenic 15·16, sulphur 19·39. Decomposed by nitric acid, depositing sulphur and arsenious acid. Caustic potash dissolves out As_2S_3. Double refraction negative; indices for red light, $\omega = 2{\cdot}979$, $\epsilon = 2{\cdot}711$.

Occurrence.—In association with pyrargyrite and other silver ores at Freiberg, Joachimsthal, the Harz, and other silver mines. The finest crystals have been derived from Andreasberg, and more particularly from Chañarcillo in Chili, where they are found singly of considerable size, up to two or three inches in length, and in aggregates of great beauty. One of the finest examples of these groups has recently been added to the collection in the British Museum. At Joachimsthal it is found in scalenohedra on the ends of crystals of pyrargyrite. In the massive forms it is easily distinguished from the latter by its greater liveliness of colour.

Xanthocone.—An orange-yellow rhombohedral mineral, which differs from Proustite by containing a portion of the arsenic as $As_2S_5 = \begin{pmatrix} 3Ag_2S\ As_2S_3 \\ 3Ag_2S\ As_2S_5 \end{pmatrix}$. It is found in small brilliant crystals at Freiberg, generally resembling Proustite, except in colour.

MIARGYRITE.—*Oblique.* In short columnar or tabular crystals. H. 2·5. Sp. gr. 5·3. Lustre, metallic. Colour, black, very deep red by transmitted light.

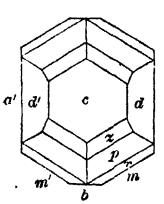
Composition.—$Ag_2SSb_2S_3$, or silver 36·7, antimony 41·5, sulphur 21·8. Reactions similar to those of Proustite. Found at Freiberg and several other silver-producing localities, but rare.

ENARGITE.—*Rhombic.* ∞P 97° 53′. Usually in granular or columnar aggregates. Cleavage, 110, 101, 010. H. 3. Sp. gr. 4·36–4·47. Lustre, metallic. Colour, iron-black; streak, dark grey.

Composition.—Cu_3AsS_4, which may be considered either as $(4CuS)Cu_2S\ As_2S_3$ or $3Cu_2S\ As_2S_3$, with copper 48·4, sulphur 32·5, arsenic 48·4 per cent. Fusible in charcoal, giving off arsenic and leaving an arsenical copper bead. Caustic potash dissolves out As_2S_3.

Occurrence.—With copper ores at Morococha, Peru; with gold and tin ores at Brewer Mine, South Carolina.

FIG. 56.



STEPHANITE. Sprödglaserz, Melanglanz, Psaturose.—*Rhombic.* ∞P 115° 39′, $a : b : c = 0{\cdot}631 : 1 : 0{\cdot}689$ (fig. 56), a {010} $\infty \breve{P}\infty$, b {100} $\infty \bar{P}\infty$, c {001} oP, d {021} $2\breve{P}\infty$, m {110} ∞P, r {221} $2P$, p {111} P, z {112} $\frac{1}{2}P$. Crystals usually tabular or short, prismatic, sometimes terminated at both ends. Twins on 110, when repeated forming star-like groups similar to those of Aragonite. Cleavage, 010 and

Huel L.

021 imperfect. Fracture, conchoidal. Opaque. Lustre, metallic. Colour, iron-black. Brittle. H. 2·5. Sp. gr. 6·2–6·3.

Composition. — $Ag_5SbS_4 = 5Ag_2S.Sb_2S_3$; silver 68·36, antimony 15·44, sulphur 16·20 per cent. usually with a little copper. Heated in closed tube decrepitates, fuses, and, after long heating, sulphide of antimony sublimes. Fuses easily on charcoal, giving off antimonial vapours, and with soda a bead of silver. The whole deposit of oxide of antimony after a time is reddened by oxide of silver. Soluble in nitric acid, depositing sulphur and sesquioxide of antimony.

Occurrence.—With native silver, silver glance, and other silver ores in the mines of Freiberg, Přibram, Schemnitz, Nevada, and Mexico. The finest crystals are from Braünsdorf near Freiberg, associated with quartz and red silver ores. A very large example has been found at Huel Newton.

POLYBASITE. Eugenglanz.— *Rhombic.* ∞P nearly 120°. Crystals resemble flat hexagonal pyramids with triangular groups of striations on 001. Cleavage, basal, imperfect. Lustre, metallic. Colour, iron-black, thin splinters deep red by transmitted light. H. 2·0–2·5. Sp. gr. 6·0–6·25.

Composition.—$(AgCu)_9$ $(SbAs)$ $S_6 = 9R_2SR_2S_3$. The most argentiferous kind contains silver 72·01, copper 3·36, antimony 5·46, arsenic 3·41, sulphur 15·87 per cent. Behaviour before the blowpipe, and with nitric acid, similar to that of Stephanite or fahlerz, except that no sublimate of antimonial or arsenical sulphide forms in closed tube. The silver bead obtained on charcoal generally contains copper. Occurs with other silver ores, copper, and iron pyrites, at Freiberg, Přibram, and in Chili, Mexico, Idaho, and Nevada.

GEOCRONITE.—*Rhombic.* Crystals rare, usually compact, in masses, having a fibrous or granular structure. Opaque. Lustre, semi-metallic. Colour, lead-grey, weathering black. H. 2·5–3. Sp. gr. 5·8–6·5.

Composition.—$Pb_5(SbAs)_2S_8 = 5PbS + (SbAs)_2S_3$. An analysis by Svanberg gave: lead 66·45, antimony 9·58, arsenic 4·69, copper 1·51, iron 0·42, zinc 0·11, sulphur 16·26 per cent. Easily fusible on charcoal, giving the reactions of lead, antimony, sulphur, and sometimes of arsenic.

Occurs at Sala in Sweden with zinc blende, argentiferous galena, and Salite augite, in an irregular mineral deposit in limestone; also at Meredo in N.W. Spain and in Tuscany.

BOULANGERITE.—In fine fibrous or plumose masses of indeterminate crystalline form, also granular and compact. H. 3. Sp. gr. 5·8–6·0. Colour, bluish lead-grey; streak, a little darker in tint. Opaque. Silky to metallic lustre. Often coloured with yellow spots by oxidation.

Composition.—$3PbS.Sb_2S_3$, or lead 59·0, antimony 22·8, sulphur 18·2 per cent., but varying in the proportion of the two sulphides in different samples. Blowpipe reactions similar to those of Zinckenite.

Found chiefly at Molières, Département du Gard, France, Wolfsberg in the Harz, and Bottino, Tuscany.

ZINCKENITE.—*Rhombic.* ∞P 120°39′, usually in twinned six-sided prisms, with a low terminal pyramid; prismatic faces generally striated. Fracture, uneven. H. 3–3·5. Sp. gr. 5·30–5·35. Colour and streak, steel- to lead-grey, sometimes with rainbow tarnish. Lustre, metallic.

Composition.—$PbS.Sb_2S_3$, or lead 35·75, antimony 42·14, sulphur 22·11 per cent., usually with some copper and iron.

Decrepitates when heated, and fuses readily; gives slight sublimates of sulphur and sulphide of antimony in closed tube; in open tube, sulphurous acid and oxide of antimony. On charcoal may be almost completely volatilised with incrustations white at the outer and yellow at the inner edge; with soda may be reduced to antimonial lead. Decomposed by hydrochloric acid with evolution of sulphuretted hydrogen; the solution deposits crystals of

chloride of lead on cooling. When finely powdered, caustic potash dissolves out sulphide of antimony.

Found at Wolfsberg in the Harz, accompanying antimony glance.

Plagionite is a similar mineral from the same place, containing a larger proportion of lead, the composition being either $4PbS3Sb_2S_3$ or $9PbS7Sb_2S_3$.

JAMESONITE. Heteromorphite, Federerz.—*Rhombic.* ∞P 101° 20′. Crystals imperfect, in radial or parallel columnar aggregates, generally massive (Jamesonite), or in fibrous, felted masses (Heteromorphite). Cleavage, basal, perfect. H. 2–3. Sp. gr. 5·56–5·72. Colour, steel- to dark lead-grey; streak, grey.

Composition.—$Pb_2Sb_2S_5 = 2PbS.Sb_2S_3$. A portion of the lead is generally replaced by iron, or in some cases silver. A sample from Arany Idka, Hungary, contained, lead 40·82, iron 2·99, copper 1·78, silver 1·48, antimony 33·10, bismuth 0·22, sulphur 18·59. The fibrous varieties are generally without silver. Blowpipe reactions similar to those of Zinckenite.

Occurrence.—In the neighbourhood of Padstow and Port Isaac in north-east Cornwall, also in Spain and the Ural. A highly argentiferous variety from Nevada contained 6 per cent. of silver. Heteromorphite is principally found in the Harz and Freiberg mines.

BERTHIERITE. — In columnar or fibrous crystalline masses of undetermined form. H. 2–3. Sp. gr. 4·0–4·3. Colour, dark steel-grey with a yellow or reddish tint, tarnishing in rainbow colours.

Composition.—$mFeS\ nSb_2S_3$ with iron 9·8–16·0, antimony 52·6–61·3, sulphur 28·8–31·3 per cent. A portion of the iron is sometimes replaced by manganese up to 3 per cent.

Fuses at a low heat on charcoal, giving off antimonial vapours and leaving a black magnetic slag, which gives reactions of iron and in some cases of zinc and manganese. Soluble in boiling hydrochloric acid.

Found at Chazelles in Auvergne, Braünsdorf in Saxony, and Arany Idka in Hungary.

CHAPTER VI.

OXIDES.—The oxides occurring as minerals may be divided into two classes, according to their behaviour when heated in the closed tube, when some give off water, while others do not. The former are termed *hydrous* or *hydrated oxides*, and the latter *anhydrous oxides* or *anhydrides*. The degree of heat required to effect the change in the former class varies very considerably, and in some instances a compound may by careful heating be obtained which is stable at a particular temperature, but gives off a further quantity of water when subjected to a greater heat. Such compounds may be regarded either as containing one or more molecules of the anhydrous oxides, combined with one or more molecules of water, or as containing hydrogen combined in the same manner as any other metal, or the hydrogen may be supposed to exist in both states, the water produced by a gentle heat being considered as present in combination, and that formed at higher temperatures as due to the decomposition of a complex oxide containing hydrogen. For the purposes of classification the second hypothesis gives the more symmetrical formulæ, and may therefore be adopted with advantage.

The number of minerals in this class is comparatively small, as out of the numerous oxides that have been made known by chemical research a few only are sufficiently stable to maintain an independent existence in nature. These may be classified into series, whose typical formulæ and crystalline symmetry are as follows :

I. Protoxide series, $H_2O\ \overset{I}{R}_2O\ \overset{II}{R}O\ H_2\overset{II}{R}O_2$. Cubic and hexagonal.

II. Sesquioxide series, $\overset{VI}{R}_2O_3$. Hexagonal, cubic?

III. Magnetite, or Spinel series, $\overset{II\ VI}{R}R_2O_4 = (\overset{II}{R}O + \overset{VI}{R}_2O_3)$. Cubic.

IV. Chrysoberyl, or Göthite series, $\overset{V}{R}R_2O_4$ and $H_2\overset{VI}{R}_2O_4$. Rhombic and oblique.

V. Arsenious acid series, $\overset{III}{R}_2O_3$. Cubic and rhombic.

VI. Silica, Titanic acid series, $\overset{IV}{R}O_2$. Tetragonal, hexagonal, rhombic, oblique.

VII. Molybdic acid series, RO_3. Undetermined.

Series VI. is remarkable for the great diversity of symmetry under which individual members appear, SiO_2 and TiO_2 having each three series of crystalline forms, the former being also found in an amorphous state. This series also includes a large proportion of the small number of minerals that crystallise in the tetragonal system.

I. Protoxide Series.

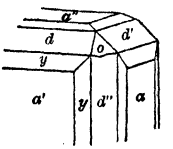
Ice.—*Hexagonal, rhombohedral.* The axial ratio has not been satisfactorily determined. Usually in hexagonal plates or short columnar prisms aggregated by a prismatic plane into forms resembling those of pyrargyrite; also in six-rayed stellar groups in snow; also massive, fibrous, and granular.

H. 1·5. Sp. gr. 0·92. Brittle, or slightly sectile. Fracture, conchoidal. Colourless and transparent. Lustre, vitreous. Double refraction positive. Mean refractive index, 1·309 for yellow light. The optic axis is perpendicular to the natural surfaces of plates.

Composition.—H_2O, or hydrogen 11·1, oxygen 88·9 per cent.

RUBY COPPER ORE. Cuprite, Rothkupfererz, Cuivre Oxidulé, Zigueline. — *Cubic.* (Fig. 57.) $a\{100\}\infty O\infty$, $o\{111\}O$, $d\{110\}\infty O$, $y\{510\}\infty O5$; also figs. 1, 3, 20, 29. Crystals sometimes completely developed and isolated; but generally aggregated in groups in druses. Also fibrous, massive, and earthy. Cleavage, octahedral, tolerably perfect, brittle. H. 3·5–4. Sp. gr. 5·7–6. Colour, very deep crimson or cherry-red, in most cases only visible when the crystals are fractured so as to give thin edges, or against a strong light, under which condition they are translucent; ordinarily opaque, with very brilliant reflection; streak, brownish red. Lustre, metallic—adamantine. Refractive index, 2·849 for lithia red light.

FIG. 57.



Composition.—Cu_2O, suboxide of copper, cuprous oxide, or copper 88·8, oxygen 11·2 per cent. Heated on charcoal blackens, melts, colouring the flame green, and is reduced to a bead of copper. In the forceps, colours the flame green, or if moistened with hydrochloric acid, blue. Dissolves in hydrochloric acid, giving a brown solution, which when diluted with water deposits white insoluble Cu_2Cl. Also soluble in nitric acid. Sulphuric acid decomposes it into CuO and metallic copper, the former passing into solution as cupric sulphate, while the latter is undissolved.

Occurrence. — Common in copper-producing localities, especially in the gozzans or portions of veins that have been subjected to atmospheric action; being often formed by the oxidation of native copper, and liable to change into malachite or azurite. The largest crystals, those from Chessy near Lyons, which are perfectly developed and occasionally $\frac{1}{2}$ to $\frac{3}{4}$ inch across, are generally found to be altered either completely or partially into malachite. Old bronze and copper articles that have been buried for a long period often present the same succession of minerals. Fine crystals have been produced at different times from most of the principal mines

in Cornwall; at the present time the South Australian mines are the most productive.

The massive variety, also known by the miner's name of *Ziegelerz*, tile ore or brick ore, is a mixture of Cu_2O with limonite.

The fibrous variety is sometimes separated as a distinct species under the name of *Chalcotrichite* or *Plush Copper Ore*, and has been considered to be rhombic; but this view is now generally abandoned, the fibres being held to be elongated cubes. It occurs in fine fibres, occasionally matted together into a kind of felt, the colour being brighter, or nearer scarlet than that of the octahehral crystals; some of the Lake Superior specimens are nearly orange coloured. The chemical composition and properties are similar to those given for cuprite.

Occurrence.—At Phœnix mines and other localities in Cornwall, at Rhenbreitbach, in the copper conglomerates of Lake Superior, &c.

Cuprite is one of the most valuable copper ores from its high percentage of metal, but is rarely found in quantity except in newly opened mines such as those of Australia and Chili.

TENORITE. Black Oxide of Copper.—*Rhombic*, in thin tabular crystals, also in fine scales and earthy. Cleavage, prismatic in two directions making an angle of 72° with each other. Colour, dark steel-grey to blackish brown, opaque but translucent, in thin laminæ.

Composition.—CuO, or copper 79·85, oxygen 20·15 per cent.

Occurs in cracks and hollows of lavas at Vesuvius.

Melaconite is another variety of CuO, found in some quantity at Copper Harbour, Lake Superior, in forms which are apparently cubic; probably pseudomorphs after Erubescite, also massive of a dark grey or iron-black colour and feeble lustre associated with chrysocolla. A powdery form

of the same substance is common as a deposit upon the surface of masses of copper pyrites. Cupric oxide is a valuable copper ore, but difficult to collect if the ore is subjected to dressing by water.

RED ZINC ORE. Zincite. Spartalite.—*Hexagonal.* Z 123° 46′, $a : c = 1 : 0{\cdot}621$. Crystals resembling those of quartz with truncated summits, rare, usually in large-grained and lamellar aggregates. Cleavage, ·0001 very perfect, ·10$\bar{1}$0 less so. H. 4–4·5. Sp. gr. 5·43–5·7. Colour, hyacinth-red to brownish red; streak, orange-red. Translucent in plates $\frac{1}{20}$ inch thick. Lustre, adamantine. Double refraction positive.

Composition.—ZnO, or zinc oxide with zinc 80·25, oxygen 19·75 per cent., usually with some manganese in partial replacement of zinc. Infusible when heated alone; with soda on charcoal gives a zinc incrustation, and with borax the reaction of manganese. Soluble in hydrochloric acid, giving off chlorine, if containing much manganese.

Occurrence.—In intimate association with Franklinite and Willemite at Franklin, Stirling, and Sparta, New Jersey, forming large deposits in metamorphic limestones which are extensively worked as zinc ores.

The metal produced from it is of high quality, being free from lead and arsenic; it is chiefly used in the preparation of white zinc paint.

The colour has been variously attributed to interspersed scales of hematite or to combined manganese.

Oxide of zinc is often found in the fume produced from iron furnaces smelting zinciferous iron ores, in the form of colourless or bright yellow hexagonal crystals.

PERICLASE.—*Cubic.* {100}, {111}, alone and in combination. Cleavage, 100 perfect. H. 6. Sp. gr. 3·67–3·75. Colour, dark green. Lustre, vitreous. Transparent.

Composition.—MgO (magnesia or magnesium oxide), partially replaced by ferrous oxide, which occurs to the

extent of 6 to 8½ per cent. and is the cause of the green colour. When prepared artificially by heating magnesia in dry hydrochloric acid gas, the crystals are white or colourless.

Infusible by the mouth blowpipe flame, soluble in acids when powdered. Found in hollows in blocks of dolomite at Monte Somma, Vesuvius.

BRUCITE. — *Hexagonal, rhombohedral.* $R=82°\ 22\frac{1}{2}'$, $a : c = 1 : 1{\cdot}521$. Crystals tabular combinations of several rhombohedra with the base. Cleavage, basal highly perfect, splitting nearly as easily as gypsum. Also in foliated, massive, and fibrous aggregates.

H. 2·5. Sp. gr. 2·35 – 2·45. Sectile and flexible, in thin laminæ, fibres elastic. Colour, white inclining to blue, green, or yellow; streak, white. Translucent. Double refraction positive.

Composition. — $H_2MgO_2 = H_2OMgO$, or magnesia 69, water 31 per cent. Usually contains the isomorphous oxides MnO and FeO, from about 1 to 5 per cent. in partial replacement of magnesia, and in the fibrous varieties a notable proportion of carbonates.

Heated in the closed tube, gives off water, turning brown if containing much iron. When strongly ignited becomes alkaline to test paper, and if moistened with cobalt nitrate gives the pale red frit characteristic of magnesia. Soluble in hydrochloric acid with or without effervescence according to the presence or absence of carbonates.

Occurrence.—With other magnesian minerals in serpentine in the Shetland Islands, Filipstad in Sweden, the Ural, Hoboken, New Jersey, &c. The latter place is the most productive locality, and also produces the fibrous variety which is known as Nemalite.

Crystals of Brucite have been found in deposits in steam boilers fed with water containing $MgCl_2$.

PYROCHROITE is a mineral similar in appearance to Brucite when freshly broken, but becoming dark-coloured

and ultimately black when exposed to the air. The composition is: $H_2MnO_2=H_2OMnO$, usually containing some magnesium in partial replacement of manganese. Occurs with Brucite at Filipstad in Sweden.

The following metallic protoxides are also known as mineralogical rarities:

Bunsenite, NiO, cubic. Johangeorgenstadt.

Manganosite, MnO, cubic. Långbanshytta.

Hydrargyrite, HgO. Los Bordos, Chili.

Litharge, PbO, has been found in several places, but its natural origin is doubtful.

II. SESQUIOXIDE SERIES.

CORUNDUM. Sapphire Emery, Ruby.—*Hexagonal, rhombohedral.* $R=86°\ 04'$, $a:c=1:1{\cdot}363$.

FIG. 58.

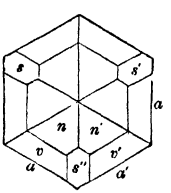


FIG. 59.

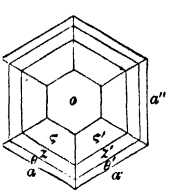


Fig. 58, 59. $a\{11\bar{2}0\}\infty P2$, $o\{0001\}o P$, $n\{22\bar{4}3\}\frac{4}{3}P2$, $s\{99\bar{1}\bar{8}7\}\frac{14}{9}P2$, $v\{44\bar{8}3\}\frac{8}{3}P2$, $z\{22\bar{4}1\}4P2$, $\theta\{88\bar{1}\bar{6}3\}\frac{16}{3}P2$, $s\kappa\{01\bar{1}2\}-\frac{1}{2}R$.

Crystals, chiefly combinations of the prism and acute pyramids of the second order. When the prism is absent or much reduced, the pyramids and basal plane give crystals of a tub-shaped outline; $\{22\bar{4}3\}$ often occurs as a simple form. Crystals often loose or rolled, also in massive and granular aggregates. Twins on $10\bar{1}1$ usually producing lamellar forms by repetition. Cleavage, rhombohedral, but mostly interrupted and better developed in one direction than the other two.

Fracture, conchoidal, uneven, or splintery. When massive, exceedingly tough. H. 9. Sp. gr. 3·6–4·1. Transparent, translucent. Lustre, vitreous, sometimes pearly on basal plane. Colour, variable, sometimes transparent and colourless, but usually some shade of blue, red, or yellow in the precious varieties, or brown to black when massive. Double refraction, negative. Refractive indices, $\omega = 1{\cdot}768$, $\epsilon = 1{\cdot}760$ for red light.

Composition.—Al_2O_3, alumina or aluminium oxide, with aluminium 53·2 and oxygen 46·8 per cent., usually with some ferrous oxide, amounting in ruby and sapphire to between 1 and 4 per cent., and in emery to 8 per cent. and upwards. In the latter the iron is often due to intermixed magnetite.

Infusible and unalterable by heat, and only very slightly acted on by borax or salt of phosphorus, giving a clear colourless bead when free from iron. When finely powdered and heated with cobalt solution gives a fine blue colour. Insoluble in acids, but may be rendered soluble by fusion with caustic alkalis or alkaline bisulphates.

The following varieties are distinguished by special names :

Sapphire and Ruby include the more brilliantly coloured and translucent crystals, suitable for jewellery, the former being blue and the latter various tints of pure red. The yellow kinds are called Oriental Topaz; green, Oriental Emerald; and purple, Oriental Amethyst. Sapphires are somewhat harder than rubies, and are more readily obtained of a good size and fine quality than the latter. Fine large rubies are among the rarest of gems.

The colour in sapphires is often unequally distributed in the crystal, and advantage is taken of this in making what are known as doublets, in which a thin coloured plate of sapphire is cemented to a piece of rock crystal, and the whole facetted as one stone. This when seen from the front appears to be of a deep blue throughout, the difference

being only discovered when the combination is looked at sideways.

Star sapphires are translucent crystals, which show an opalescent blue star of six rays in the direction of the principal axis. For ornamental purposes they are used *en cabochon*, i.e. ground to a spheroidal surface instead of being cut with facets.

Corundum and adamantine spar are dull and irregularly coloured crystals that are not fit for jewellery, but form the best kind of polishing material. Emery includes the fine-grained massive and dark-coloured varieties.

Occurs in crystalline and metamorphic rocks, such as granite, gneiss, crystalline limestone, dolomite, and chloritic schist, the finer crystals being usually found loose in the detritus of river valleys with other hard spinel magnetite minerals. The finest rubies are brought from Burmah. Sapphires come principally from Ceylon. In North Carolina corundum crystals, often of large size, are found in serpentine. Emery is chiefly brought from the island of Naxos, in the Greek archipelago, where it occurs in irregular deposits in crystalline limestone.

The principal use of this species, apart from ornamental application, is for polishing and grinding metals, glass, and other hard substances. For this purpose the emery stone is crushed and ground to as fine a powder as possible, the various sizes of grain or flour being separated by very careful levigation. Solid emery wheels, made by cementing coarsely crushed emery with siliceous or bituminous cement, are now manufactured on the large scale for the use of mechanical engineers, and are used instead of files in finishing metal work.

HEMATITE. Red Iron Ore, Iron Glance, Oligiste, Specular Iron, Blodsten.—*Hexagonal, rhombohedral.* $R = 86° 10'$, $a : c = 1 : 1{\cdot}359$ (figs. 60, 61), r κ $\{10\bar{1}1\}$ R, e κ $\{01\bar{1}2\}$ $-\frac{1}{2}R$, u κ $\{10\bar{1}4\}$ $\frac{1}{4}R$, n $\{22\bar{4}3\}$ $\frac{4}{3}P2$, o $\{0001\}$ o R.

Crystals mainly combinations of rhombohedra and scalenohedra, with or without the basal plane forming three different types, rhombohedral, pyramidal, and tabular, according to the prevalence of $\{10\bar{1}1\}$, $\{22\bar{4}3\}$, or $\{0001\}$ respectively. The combination R, oR, when equally developed, has triangular faces, and somewhat resembles an octahedron.

FIG. 60.

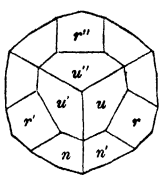
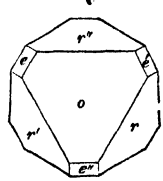


FIG. 61.



The tabular crystals are principally found in volcanic districts. Twins on 0001 and $10\bar{1}1$, the former being most common, giving complete penetration groups (fig. 278, 'Syst.' p. 174). Massive, and in radiated fibrous aggregates, forming spheroidal reniform and botryoidal masses, very common; also pseudomorphous after calcite, spathic iron ore, barytes, fluor spar, and less commonly after other minerals. Cleavage, *R* and o*R*, imperfect. Fracture, conchoidal—fibrous—uneven. Brittle. H. 5·5–6·5 in specular iron, 3–5 in hematite. Sp. gr. 4·5–5·3—the purest being the densest. Opaque, except in microscopic crystals, which transmit a brownish red light. Colour, bluish iron-black in crystals; fibrous and earthy varieties, various shades of brown and bronze-red, and when wet often nearly vermilion-red; streak, purplish to brown-red. Lustre of crystals, metallic; surfaces of crystalline spheroids often show a pearly bloom, but the fractured surfaces are dull or shining, resembling wood. Sometimes the crystals are iridescent, with brilliant colours.

Composition.—Fe_2O_3, or ferric oxide with iron 70 and oxygen 30 per cent., usually containing some ferrous oxide or magnesia, even in the purest crystals, and in the fibrous

varieties silica or titanic acid. Infusible, but reduced to a magnetic oxide by the reducing flame on charcoal; with borax and salt of phosphorus gives the reaction of iron; yellow in oxidising, dark green in reducing flame. When titaniferous the bead, with salt of phosphorus, after having been exposed to the outer flame and flattened between the forceps, shows minute square-based crystals of anatase under the microscope. These may be made more apparent by adding a few drops of water, when the vitrified salt dissolves freeing the crystals which move about in the liquid. Soluble in hydrochloric acid; the earthy varieties more readily than the crystals.

The hard, brilliant, well-crystallised forms are known as *Specular Iron*. The fibrous and dense crystalline varieties as *Hematite*, *Red Hematite*, *Kidney Hematite*, *Rother Glaskopf*; and the softer kinds as *Micaceous Iron Ore*, *Puddler's Ore*, and *Ruddle*. *Bloodstone* is a hard, fibrous variety, in pebbles or rounded fragments, having very smooth surfaces, which are used as burnishers for gold and other metals. *Blodsten* (bloodstone) and *Rodmalm* (red ore) are the Swedish miner's names for specular hematite.

Occurrence.—In large deposits, both in beds and veins, and also as a constituent of rocks; under the latter condition, the micaceous variety forms with quartz and chlorite, in the gold districts of Brazil, the rocks known as Jacotinga and Itabirite, which localities yield brilliant mirror-like crystals, two or three inches across. The finest crystals of specular iron are from the volcanic districts of Ascension Island, and the south coast of Arabia. Smaller brilliant examples are found in the lavas of Etna and Vesuvius. The more complex combinations are from Elba, St. Gothard, and the Tavetschthal. In the first-named locality the crystals are usually brilliantly irised and associated with iron pyrites. Specular and micaceous iron are found with tin ores in the Saint Just district in Cornwall, at Altenberg in Saxony, and with copper pyrites at Berehaven in Ireland. The principal

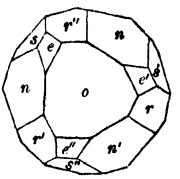
deposits of massive or slaty hematite (also called specular schist) are in the district of Marquette, Lake Superior, where it is found in beds of great thickness, interstratified with quartzite or jasper, and in the Norberg, near Nora, in Sweden. Fibrous or kidney hematite is exceedingly abundant in the district of Furness in North Lancashire, and about Ulverston and Cleator Moor in Cumberland. The most important of these deposits fill hollows in the carboniferous limestone in large irregular masses of nearly pure hematite, with occasional crystals of quartz, fluor spar, barytes, and Aragonite. The produce is distinguished as *hard* or *blast ore*, and *soft* or *puddler's ore*, the latter being soft and greasy to the touch. Hematite forms one of the most valuable ores of iron, both from its high proportional yield and its general purity from phosphorus and sulphur, in which respect it is only equalled by the allied species magnetite, the highest position being taken by the ores of Elba, Cumberland, and Central Sweden. The purer earthy or ochry kinds are sometimes used as paint for covering ironwork, and the fibrous varieties receive a special application in the manufacture of pencils for masons, to be used in setting out work upon stone.

MARTITE.—*Cubic*, in octahedra and combinations with ∞O and $\infty O\infty$. H. 6. Sp. gr. 5·16–5·24. Black, with imperfect metallic lustre; streak, brownish red. Not magnetic. Of the same composition as hematite Fe_2O_3, but it is doubtful whether it is an independent species, in which case Fe_2O_3 would be dimorphous, or merely pseudomorphous after magnetite. Found in Brazil, Vesuvius, and the Lake Superior iron district.

ILMENITE. Titanic Iron Ore.—*Hexagonal with rhombohedral tetartohedrism.* $R=86°$, $a : c = 1 : 1·385$ (fig. 62), r κ $\{10\bar{1}1\}$ R, e κ $\{01\bar{1}2\}$ $-\frac{1}{2}R$, s κ $\{02\bar{2}1\}$ $-2R$, n' κ π $\{4\bar{2}\bar{2}3\}$ $\frac{1}{4}(\frac{4}{3}P2)$, o $\{0001\}$ o P. Combinations very

similar to those of hematite, but differing in the scalenohedra and pyramids of the second order, which appear with only half their full number of faces, producing forms of a very unsymmetrical appearance. Crystals generally tabular, and at times aggregated in rosette-like groups, forming the so-called iron roses. Also massive and in loose blocks and grains. Cleavage, 0001, $10\bar{1}1$, both imperfect. Fracture, conchoidal, uneven. H. 5–6. Sp. gr. 4·30–5·21. Lustre, semi-metallic, almost vitreous on the fracture in some instances. Opaque. Colour, black, inclining to brown, or dark grey ; streak, black. Sometimes magnetic.

FIG. 62.



Composition.—Contains iron, magnesium, titanium, and oxygen, in variable proportions, two views being prevalent as to the probable constitution. The first of these, proposed by H. Rose and Scheerer, supposes it to consist of variable mixtures of the isomorphous sesquioxides, Fe_2O_3 and Ti_2O_3, or $x\ Ti_2O_3, y\ Fe_2O_3$; while the second, originally proposed by Mosander, and adopted by Rammelsberg, supposes it to be a ferrous or magnesian titanate, combined with variable proportions of Fe_2O_3, the principal varieties being represented by the following types :

I.	II.	III. *a*	III. *b*
$FeTiO_3$	$\left\{\begin{matrix}FeTiO_3\\MgTiO_3\end{matrix}\right\}$	$\{\ Fe_2O_3$	$\left\{\begin{matrix}FeTiO_3\\nFe_2O_3\end{matrix}\right\}$

The second hypothesis has the advantage of accounting for the somewhat considerable proportion of magnesia found in some varieties, which on Rose's view would have to be assumed to be present as Mg_2O_3, a combination which has not been shown to exist. The percentage composition, corresponding to the second series of formulæ, is as follows :

I. Ferrous oxide, 47·37. Titanic acid, 52·63.
II. „ 26·47. „ 58·32. Magnesia, 15·01.
III*a*. *m* varying from 9–1. „ 51–22. Iron, 37–55.
III*b*. *n* „ „ 2–12. „ 17–3·5. „ 59–68.

Magnesia usually below 3 per cent., and manganous oxide 0·2 to 4·0 per cent. Infusible in oxidising, but edges may be slightly rounded in reducing flame. With salt of phosphorus, the more titaniferous varieties give a red bead in reducing flame, which is rendered violet by touching it with tin, and reheating. With soda and saltpetre some varieties give a manganese reaction. Difficultly soluble in acids, hydrochloric acid sometimes leaving a residue of TiO_2; the solution when filtered and boiled with tinfoil becomes deep blue or violet. The powdered mineral heated with sulphuric acid gives a similar colour, which disappears on the addition of water. The best method of decomposing this class of minerals is by fusion with an alkaline bisulphate.

Occurrence.—Common as a constituent of crystalline and igneous rocks in many parts of the world, and occasionally in large deposits, usually with quartz, rutile, felspar, garnet, and other silicates. The most important localities are at Egersund, Arendal, and Tvedestrand, in Norway, and Bay St. Paul in Canada. On the coast of the Labrador from Quebec to Hudson's Straits, titaniferous iron sand is more or less prevalent along the beaches, being derived from the waste of the Labradorite, or Norite rock, which is the prevalent formation. Sometimes, in addition to the sand, boulders of considerable size are found. Similar beach sands are found at Taranaki, in New Zealand; on the Red Sea, and in the Bay of Naples. At Unkel, on the Rhine, a variety of a glassy aspect is found in basalt. At Taberg, in Sweden, titaniferous magnetite is found in a series of reticulating veins in serpentine. The crystallised groups called iron roses of St. Gothard occur in connection with adularia.

Titaniferous iron ores are, as a rule, pure ; that is, free from sulphur and phosphorus, and therefore yield a good quality of iron, but being exceedingly refractory and difficult to flux, are wasteful of fuel, so that they cannot be smelted to advantage if the titanic acid exceeds about 8 per cent. The chief use of the more titaniferous varieties is in fettling or lining puddling furnaces. Titaniferous iron sands are usually mixtures of Ilmenite with magnetite, and may be separated by means of the magnet into magnetic and non-magnetic portions, the former being proportionally richer in iron and poorer in titanic acid than the latter. A process founded upon this property has been used for the purpose of obtaining workable iron ore from the sand on the Labrador beaches.

BRAUNITE.—*Tetragonal.* $P = 108° 39'$, near a regular octahedron : crystals small, pyramids, with or without 001. Cleavage, pyramidal, perfect. H. 6–6·5. Sp. gr. 4·7–4·9. Opaque. Lustre, sub-metallic or greasy. Colour, brownish black ; streak, black.

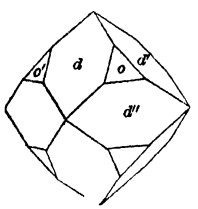
Composition.—$\left\{\begin{matrix}MnSiO_3\\3Mn_2O_3\end{matrix}\right\}$, or MnO 11·73, Mn_2O_3 78·35, SiO_2 9·92 per cent. Sometimes contains baryta up to about 2 per cent., and lime 1 to 1½ per cent. Heated in the closed tube gives off oxygen ; on charcoal infusible, giving the ordinary reactions of manganese with a borax bead and with soda on platinum foil. Soluble in hydrochloric acid, evolving chlorine and leaving a siliceous residue. Occurs with other manganese minerals at Ilfeld in Thuringia, and San Marcel in Piedmont.

The constitution given above is that adopted by Rammelsberg, and is analogous to his formulæ for titanic iron ores, but it may also be considered as $\left\{\begin{matrix}MnO\\MnO_2\end{matrix}\right\}$, or Mn_2O_3, the silica being supposed to be mechanically mixed.

III. MAGNETITE-SPINEL SERIES.

MAGNETITE. Magnetic Iron Ore, Magneteisen, Fer Oxidulé, Svartmalm.—*Cubic* (fig. 63). $o\{111\}O$, $d\{110\}\infty O$ prevailing forms, with {100}, {131}, {121}, {221}, mostly as subordinate modifications. Faces of {110} usually striated parallel to their longer diagonal; twin face 111. Crystals are sometimes found completely developed, embedded in slaty or aqueous rocks, but more usually grouped; also compact, massive, granular, and earthy, often in veins and beds of great size. Cleavage, octahedral. Fracture, conchoidal or granular, rather brittle. H. 5·5–6·5. Lustre, metallic; opaque, except when in films between other minerals, when it transmits a pale brown light. Colour, black; streak, similar. Strongly magnetic, and at times polar.

FIG. 63.



Composition. — $Fe_3O_4 = \left\{\begin{matrix} FeO \\ Fe_2O_3 \end{matrix}\right\}$, or iron 72·4, oxygen 27·6; otherwise ferrous oxide 31·03, ferric oxide 68·97 per cent. Sometimes contains magnesia or titanic acid. The finest crystallised varieties, as a rule, approximate very closely to the theoretical composition given above; some, however, are more nearly represented by $\left\{\begin{matrix} 3FeO \\ \text{—} \\ \text{—} \end{matrix}\right.$

The purest massive magnetite from Sweden sometimes shows an excess of FeO, and sometimes of Fe_2O_3, over the quantity required by the theoretical formula. This may possibly be due to isomorphism between FeO and F_2O_3 if the latter be truly dimorphous in Martite. The magnetic scale formed by heating iron to redness in the air is of an indefinite composition of this kind, the layer nearest the metal approximating to FeO, while that in contact with the

air is nearly or quite Fe_2O_3. In a non-oxidising flame magnetite may be melted with difficulty; in an oxidising atmosphere it is infusible, but is converted into Fe_2O_3, losing its magnetism and giving a red streak when subsequently powdered. With fluxes reacts like hematite. Soluble in hydrochloric acid; when completely dissolved the solution contains both FeCl and Fe_2Cl_3 in proportion corresponding to that of the two oxides.

Occurrence.—Abundant in the older crystalline rocks of Norway, Sweden, and Russia, the larger deposits being usually found in crystalline limestone, chlorite schist, hornblende schist, serpentine, and less commonly in quartzite or mica schist, which, under similar conditions, usually carry deposits of specular or micaceous hematite. As a constant though not very large constituent it appears in igneous rocks, particularly those of a low percentage of silica, such as basalt, diorite, &c.; being usually interspersed in minute crystals or granular masses: these are often titaniferous and vitreous or slaggy in aspect. These fine grains or crystals, when set free by the disintegration of the rocks containing them, form the black magnetic sands with which gold and other heavy minerals are associated in alluvial deposits. The finest crystallised specimens are obtained from Ala and Traversella in Piedmont, usually in association with copper pyrites, iron pyrites, garnet, diopside, augite, chlorite, &c. Perfect isolated octahedra are common in chloritic and hornblendic schists in the Tyrol and elsewhere. The Haytor iron mine in Devonshire is worked on a series of parallel bands of hornblendic and quartzose schists, containing crystals of magnetite and garnet, on the flanks of the Dartmoor granite. Near Dolgelly a bed of impure magnetite of an oolitic structure is found in the Silurian rocks; ore of somewhat like character occurs at Rosedale Abbey, in Yorkshire. The oolitic ironstone of Cleveland is similarly charged.

The purest magnetites, such as those of Dannemora, Persberg, and other places in Sweden, are among the best

qualities of iron ore, being almost absolutely free from minerals containing sulphur and phosphorus; but there is considerable variation in this respect. Some of the largest deposits, such as those of Gelivará in Lapland, contain so much phosphorus from intermixed crystals of apatite as to be unfit for making high-class iron. Others contain iron pyrites, which can only be destroyed with great difficulty by calcination. Quartz and titaniferous minerals also tend to reduce their value. The latter are tolerably abundant in some Norwegian and North American magnetites.

Magnetite is the most stable of iron compounds at high temperatures, being produced even from ferric oxide by partial dissociation of oxygen when the latter is heated to an extremely high degree. At ordinary temperatures it is, however, liable to change from the alteration of its ferrous oxide into limonite, and it is common to find octahedral crystals, especially those of microscopic size, in rocks that have been so altered. When in large masses, as in the Swedish mines, it is very slightly alterable in the air even when exposed for a long period.

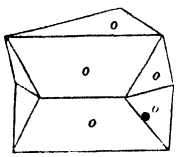
The Swedish miner's name, Svartmalm, signifies black ore, as distinguished from Rodmalm, red ore, or bloodstone = hematite. An earthy variety of magnetite, called Eisenmalm, iron containing manganese, has been described as a product of the alteration of manganiferous spathic iron ore in the Siegen district.

MAGNOFERRITE.—*Cubic*, in small shining black octahedra deposited from fumaroles upon the lavas of Vesuvius. Sp. gr. 4·6–5, strongly magnetic.

Composition.—Either $\left\{\begin{matrix}MgO\\Fe_2O_3\end{matrix}\right\}$ or $\left\{\begin{matrix}3MgO\\4Fe_2O_3\end{matrix}\right\}$, i.e. magnetite in which FeO is entirely replaced by MgO. The magnetic character is remarkable, and corresponds to that of the artificial compound of lime and ferric oxide, which does not, however, crystallise in the cubic system.

SPINEL.[1]—*Cubic*. In octahedra, also with subordinate modifications of 110 and 131. Twins on 111, usually much compressed (fig. 64) and often many times repeated, very common. In isolated crystals, and in rounded grains and fragments. Cleavage, octahedral, imperfect; fracture, conchoidal. H. 8. Sp. gr. 3·5–4·6. Lustre, vitreous. Colour, various shades of red, brown, blue, and green, also black, dull white, and occasionally colourless. Transparent in every degree to opaque.

FIG. 64.



Composition.—$\overset{II}{R}\overset{VI}{R}_2O_4$ or $\left\{\begin{matrix}RO\\R_2O_3\end{matrix}\right\}$, under which expression several proto-sesquioxide compounds are included. The simplest of these, containing $\left\{\begin{matrix}MgO\\Al_2O_3\end{matrix}\right\}$, or magnesia (MgO) 28, and alumina (Al_2O_3) 72 per cent., includes the transparent red varieties known as *spinel* and *Balas ruby*, which are used as gems, and whose colour is attributed to a trace of chromic oxide. They are of low sp. gr., 3·5–3·6. *Pleonast* or *Ceylonite* has more or less of the magnesia replaced by ferrous oxide, and of the alumina by ferric oxide, and varies from dark green to brown or black. When the proportion of iron to magnesia is small, the crystals are blue. *Picotite* is a black variety in which Al_2O_3 is partially replaced by Cr_2O_3; and *chlorospinel*, a grass-green one containing Fe_2O_3 in small quantity, is free from FeO, besides a small amount, 0·3–0·6 per cent., of CuO.

All the varieties are infusible. Red spinel changes colour by heat, being brownish black and nearly opaque while hot, and on cooling successively green and colourless, returning to the original red when cold. In borax and salt of phosphorus gives a bead reddish while hot and faint chrome-

[1] The variations in this twin form caused by repetition and distortion have been described very fully by Struver, Groth's *Zeitschrift für Crystallographie*, vol. ii. p. 480.

green when cold. The darker coloured varieties give the reactions of iron. When powdered gives a blue colour with cobalt. Insoluble in acids, but can be decomposed by fusion with an alkaline bisulphate. Spinel rubies are usually of a somewhat bluer red than true or Oriental (alumina) rubies, and, although very beautiful as gems, are of considerably less value than the latter. When cut they may be distinguished by their inferior hardness and specific gravity, and the absence of dichroism, which latter property is strongly marked in the real ruby.

Occurrence.—In granular limestone, serpentine, gneiss, and other metamorphic rocks. The black varieties are found in the limestone blocks of Monte Somma, Vesuvius. The red kinds are mostly brought from Ceylon as rolled pebbles and loose crystals, which are associated with sapphire and other varieties of corundum, garnet, and other minerals in the so-called gem sands.

Gahnite, *automolite*, *dysluite*, and *kreittonite* are minerals of similar constitution to spinel, but having the magnesia wholly or in part replaced by zinc or manganous oxide, and which are represented by the following generalised formulæ:

Automolite . .	Sp. gr. 4·1 –4·6	$\left\{\begin{matrix}(ZnMg)O \\ Al_2O_3\end{matrix}\right\}$
Dysluite . .	„ 4·0 –4·46	$\left\{\begin{matrix}(ZnFeMn)O \\ (Al_2Fe_2)O_3\end{matrix}\right\}$
Kreittonite . .	„ 4·48–4·89	$\left\{\begin{matrix}(ZnFeMg)O \\ (Al_2Fe_2)O_3\end{matrix}\right\}$

These are generally octahedral in habit and similar in character to the magnesian spinels, but give the reaction of zinc when heated with soda on charcoal. In colour they are usually dull grey, brown, green, or black, opaque, and inferior in lustre to the precious spinel.

FRANKLINITE.—*Cubic.* In octahedra with rounded and modified edges and angles, also massive, granular, or

compact. Cleavage, octahedral, imperfect; fracture, conchoidal or uneven. H. 6. Sp. gr. 5·1. Colour, black; streak, reddish brown. Opaque. Lustre, sub-metallic, sometimes feebly magnetic.

Composition.—$(FeZnMn)(Fe_2Mn_2)O_4 = \begin{Bmatrix}(FeZnMn)O\\(Fe_2Mn_2)O_3\end{Bmatrix}$

The proportion of the different metals varies considerably. The following is an average analysis: iron 45·53, manganese 10·29, zinc 18·70, oxygen (diff.) 25·48 per cent. Infusible, but glows and gives off sparks when strongly heated in the forceps. With borax gives at first a manganese colouration, but when more nearly saturated the reactions of iron. With soda or platinum gives manganese reaction, and on charcoal a zinc incrustation. Soluble in hydrochloric acid with evolution of a small quantity of chlorine, due either to the presence of Mn_2O_3 or partial peroxidation of some MnO.

Occurrence.—With red zinc ore, spinel, Willemite, and calcite, at Stirling and Franklin, New Jersey; the crystals, which are often of considerable size up to two inches across, being embedded in the other minerals. It is used as a zinc ore in the production of zinc-white, the residue, containing iron and manganese, being afterwards smelted as an iron ore.

CHROMIC IRON ORE. Chromite.—*Cubic, octahedral.* Crystals rare, usually in granular or compact masses, or interspersed in grains in rocks. Cleavage, 111 imperfect. Fracture, granular or uneven. H. 5·5. Sp. gr. 4·3–4·6. Opaque. Lustre, sub-metallic to vitreous or greasy. Colour, black or brownish black; streak, brown. Brittle, but rather difficult to powder. Partially magnetic at times.

Composition. — $(MgFe)(Cr_2Al_2)O_4 = \begin{Bmatrix}(MgFe)O\\(Cr_2Al_2)O_3\end{Bmatrix}$,

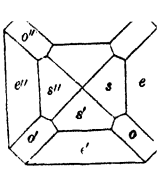
sometimes with Fe_2O_3. As in other minerals of the spinel class, the composition varies within wide limits. Thus Cr_2O_3 ranges from 40 to 64; MgO, 6 to 18; FeO, 15 to 36; Al_2O_3, 5 to 30; and Fe_2O_3, 0 to 21 per cent.

Infusible; may be rendered magnetic by heating in reducing flame. With borax and salt of phosphorus gives beads showing an iron colouration while hot, and on cooling the bright green of chromium, especially when treated on charcoal with tin. Insoluble in acids, but gives a yellow mass by fusion with soda and saltpetre on platinum, from which water dissolves out chromate of sodium.

Occurrence.—In serpentine, interspersed in small grains or in irregular masses and veins. The principal localities are Unst in Shetland; Bare Hills, Baltimore; Saranowsk in the Ural; Orsova on the Danube; the island of Eubœa in the Greek Archipelago; and Dun Mountain, New Zealand. It is principally used for the production of bichromate of potassium. The ore mixed with lime and calcined in a reverberatory furnace produces chromate of calcium, which is afterwards decomposed by carbonate of potassium and sulphuric acid. Other applications are in the manufacture of chromium and iron alloys, from which steel of remarkable hardness and tenacity is produced, and as a refractory substance to resist the highest possible temperatures, in the same manner as alumina, lime, and magnesia.

HAUSMANNITE.—*Tetragonal.* P 117° 54′, $a : c = 1 : 1{\cdot}174$ (fig. 65), $e\{111\}P$, $o\{011\}P\infty$, $s\{113\}\frac{1}{3}P$. In pyramidal crystals, single or twinned on 111; also massive, and in pseudomorphs after manganite and calcite. Cleavage, 001 tolerably perfect. H. 5·5. Sp. gr. 4·87. Opaque. Lustre, metallic. Colour, black; streak, brown.

FIG. 65.



Composition. — $Mn_3O_4 = MnOMn_2O_3$, or $2MnO.MnO_2$ with manganese 72, oxygen 28 per cent. = MnO 31, Mn_2O_3 69 per cent. = MnO 93, oxygen 7 per cent. Infusible, giving manganese reaction with borax; but, unlike pyrolusite, it does not give off oxygen when heated. Soluble in hydrochloric acid, evolving chlorine.

Occurrence.—With other oxides of manganese and barytes, at Ilmenau and Ilfeld in Thuringia, and Pajsberg and Långban in Sweden. Valuable chiefly for its manganese; the small amount of disposable oxygen, only 7 per cent., rendering it unfit for use in the production of chlorine. This species, though related to the spinel group by composition, differs markedly from them in crystalline form.

IV. CHRYSOBERYL SERIES.

CHRYSOBERYL. Cymophane.—*Rhombic.* X 139° 53′, Y 86° 16′, Z 106° 29′, $a : b : c$, 0·470 : 1 : 0·580 (fig. 66). $i\{011\}\ \breve{P}\infty$, $m\{110\}\ \infty P$, $r\{130\}\ \infty \breve{P}3$, $a\{010\}\ \infty \breve{P}\infty$, $b\{100\}\ \infty \breve{P}\infty$, $o\{111\}\ P$, $n\{121\}\ 2\breve{P}2$, faces of {100} striated vertically. In short columnar or thick tabular combinations, also twinned on 011 (fig. 67), producing by repetition six-armed crosses, or, when the re-entering angle at n is filled, double six-faced pyramids with basal truncations, whose composite character is shown by the contrasted striations (parallel to the dotted lines in fig. 67) on the apparent hexagonal base b. Cleavage faces, 100, 010 imperfect. Fracture, conchoidal, uneven. H. 8·5. Sp. gr. 3·6–3·8. Lustre, vitreous to greasy. Transparent, translucent. Colour, greyish or greenish white, asparagus-, emerald-, or oil-green. Strongly pleochroic, the variety Alexandrite deep red by reflected light. Double refraction positive. Indices for yellow light, $\alpha = 1{\cdot}747$, $\beta = 1{\cdot}7484$, $\gamma = 1{\cdot}7565$ in Brazilian cymophane. Plane of optic axes 010, first median line c, $2E = 42°\ 50'$, $\rho > v$.

FIG. 66.

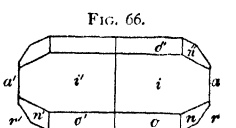
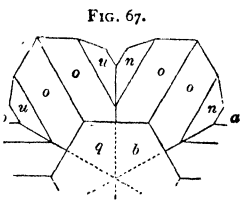


FIG. 67.



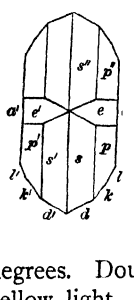
Composition.—$BeAl_2O_4 = BeOAl_2O_3$, or glucina 19·8, alumina 80·2 per cent. Usually with from 3 to 5 per cent.

of Fe_2O_3, and 1 to 3 per cent. of TiO_2. Infusible and unalterable by heat, but slowly dissolves by fluxes to a clear glass; with cobalt solution gives the blue of alumina. Not attacked by acids.

The fine green pleochroic variety called Alexandrite from the Ural is cut as a gem, as is also the opalescent kind known as Cymophane, from Ceylon. Other localities are the Mourne Mountains in Ireland, and Haddam, Connecticut.

DIASPORE.—*Rhombic.* ∞P, 93° 52′, $a : b : c = 0{\cdot}935 : 1 : 0{\cdot}935$ (fig. 68). $a\{010\}\infty\breve{P}\infty$, $e\{011\}\breve{P}\infty$, $p\{111\}P$, $s\{212\}\breve{P}2$, $l\{120\}\infty\breve{P}2$, $k\{230\}\infty\breve{P}\frac{3}{2}$, $d\{210\}\infty\bar{P}2$. In short columnar crystals, with rounded terminations (faces of P), also in fibrous and lamellar aggregates. Cleavage, perfect on $\infty\breve{P}\infty$, prismatic less so, very brittle. H. 5·5. Sp. gr. 3·3–3·46. Colourless, yellowish or greenish white, or violet-blue rusting to brown on exposure. Lustre, vitreous, nacreous on cleavage surface. Transparent and translucent in various degrees. Double refraction, positive; mean index 1·722 for yellow light. Optic axial plane 010, a first median line. Apparent axial angle large. Strongly pleochroic (trichroic).

FIG. 68.



Composition.—$H_2Al_2O_4 = H_2OAl_2O_3$, or water 14·82, alumina 85·12 per cent. In the open tube gives off water at 450° Cent., but can only be completely dehydrated at a strong red heat. Some kinds decrepitate, others do not. Infusible, and gives alumina reaction with cobalt solution. Insoluble in acids, except in sulphuric acid after previous calcination.

The crystallised varieties are from Dillen near Schemnitz, where they occur in a white compact clay (Dillnite), and the Ural; the fibrous and massive kinds are found with emery in Asia Minor and the United States.

HYDRARGILLITE. Gibbsite.—*Oblique.* In small six-sided tabular crystals, with basal cleavage, also in fibrous and spheroidal radiating masses like those of Wavellite. H. 2·5–3. Sp. gr. 2–3·4. Colourless, white, or variously tinted with grey, light green, or pink. The plane of the optic axes sometimes parallel, sometimes normal, to the plane of symmetry 010.

Composition.—$H_6Al_2O_6 = 3H_2O\ Al_2O_3$, or water 34·5, alumina 65·5 per cent. Some varieties contain a little phosphoric acid.

In the closed tube gives off water at a low temperature. Two-thirds of the water is driven off at 200° Cent., and the remainder behaves like diaspore. When strongly heated exfoliates, and glows with a bright light. Gives blue colour with cobalt solution. Difficultly soluble in hydrochloric and sulphuric acids.

From the Ural, Richmond and Lennox in Massachusetts, and Villa Rica in Brazil.

BAUXITE.—Amorphous in pisolitic granules or compact masses. Colour, white, grey, yellow, rusty brown or red, earthy and dull.

Composition.—Essentially a mixture of hydrates of alumina and ferric oxide. The original mineral contained alumina 52, ferric oxide 27·6, water 20·4 per cent. The Carniola variety contains 64 per cent. of alumina, and titanic acid is commonly present in small quantity.

Occurs at Les Beaux in France, Wochein in Carniola, and with the iron ore in the Antrim basalt. The alumina, being in the soluble form, it has been used as a cheap source of chloride of aluminium in the manufacture of the metal, as a flux for siliceous iron ores in the blast furnaces, and as a refractory lining for steel furnaces, as when subjected to a strong and long-continued heat it is altered to a hard infusible substance, strongly resembling emery.

GÖTHITE. Nadeleisenerz, Wood Iron Ore.—*Rhombic.*

X 126° 18′, Y 121° 05′, ∞P 94° 53′, $a : b : c = 0{\cdot}918 : 1 : 0{\cdot}606$. Crystals, usually slender prisms terminated by a pyramid, or thin tabular lamellæ. Commonly aggregated in druses in divergent radiating groups, reniform or botryoidal like hematite, sometimes isolated in quartz crystals, massive, or in pseudomorphs after pyrites, calcite, and barytes. Cleavage, 010 very perfect. Fracture, usually fibrous, radiated, rather brittle. H. 5·5. Sp. gr. 3·8–4·4. Colour, yellowish brown, dark brown, reddish brown, or nearly black. Lustre, adamantine, silky in the fibrous varieties, which are often variegated in colour (wood iron). Streak, brown or reddish brown, deeper than in limonite and not so red as in hematite. Opaque in mass, but small crystals are translucent and appear yellowish, brownish red, or blood-red by transmitted light, according to thickness. Feebly magnetic in some instances.

Composition.—$H_2Fe_2O_4 = H_2OFe_2O_3$, or water 10, ferric oxide 90 per cent. = metallic iron 63 per cent. Usually contains some manganese.

In the closed tube gives water and turns red; the other reactions are similar to those of hematite.

Occurrence.—As a secondary product in many iron ore deposits, especially in those producing spathic ores. The finest crystals have been derived from Restormel in Cornwall, where it formed the principal ore of a large iron mine in association with pyrolusite and other manganese ores and lithomarge. At Perran in Cornwall it formed beautiful encrusting pseudomorphs upon quartz crystals.

TURGITE. Hydrohematite.—Massive or fibrous, radiated, H. 5. Sp. gr. 3·74. Colour, reddish brown; streak, bright red. Lustre, metallic.

Composition.— $H_2Fe_4O_7 = H_2O_2Fe_2O_3$, or water 5·3, ferric oxide 94·7 per cent. The most characteristic variety decrepitates violently when heated, otherwise it behaves like hematite, which it very closely resembles in every particular. The principal localities are Bogoslowsk in the Ural, and

Salisbury in Connecticut, but probably much of the radiated hematite containing a little water and giving a red streak may be assigned to this species. The fact of an iron ore giving a red streak is not sufficient to establish its identity with hematite.

LEPIDOCROCITE.—*Microcrystalline* in aggregates of scaly or micaceous structure. Colour, reddish or clove-brown; streak, yellowish brown. H. 3·5. Sp. gr. 3·8.

Composition.—Similar to Göthite, but containing 2 to 5 per cent. of Mn_2O_3.

STILPNOSIDERITE.—Pitchy iron ore, or Schwarzer Glaskopf, is another variety of Göthite, either massive or similar in structure to kidney hematite, usually containing some silica and phosphoric acid.

The black brush iron ore of the Forest of Dean is a stalactitic variety. Occurs also in pseudomorphs after Vivianite, dolomite, calamine, and ruby copper ore.

Pitchy copper ore is a similar ferric hydrate containing cupric oxide, occurring in amorphous masses and pseudomorphs after copper pyrites and similar minerals.

LIMONITE. Brown Iron Ore, Brown Hematite, Bog Iron Ore.—*Amorphous*, or in undefined cryptocrystalline forms. In fibrous, granular, compact, and earthy masses, and in concretionary forms of all kinds; also pseudomorphous after pyrites, siderite, and many other minerals.

Lustre of fibrous kinds silky; nearly glassy or resinous when compact, and dull and earthy in granular or pulverulent kinds. Colour, brown in all shades, from nearly black to yellow, including the various ochres and ambers, raw and burnt sienna, and iron rust; streak, yellowish brown, and generally lighter than the mass.

Composition.—$H_6Fe_4O_9 = 3H_2O.3H_2O.2Fe_2O_3$, or water 14·4, ferric oxide 85·6 per cent. = 60 per cent. metallic iron.

Usually contains silica and manganese to some extent in combination, besides various mechanical impurities, such as quartz, sand, clay, carbonate of calcium, &c. Certain varieties of bog iron ore contain humic acid, and similar substances of organic origin.

Heated in the closed tube gives off water readily, sometimes with an empyreumatic odour, due to organic matter. With fluxes, behaves like hematite or Göthite, sometimes giving the colour of manganese or cobalt. Soluble in hydrochloric acid, the manganiferous kinds evolving chlorine, and leaving more or less of insoluble residue. When containing silica in combination the residue is slimy or gelatinous.

Limonite is an exceedingly common iron ore, and may be of almost any quality, according to the proportion and character of the foreign materials associated with it. The best kinds are those formed by the oxidation of spathic ore; and the worst, bog ores which commonly contain a large proportion of sand and phosphoric acid, and are better suited for making foundry pig iron than for conversion into wrought iron. It is a common product of the alteration of minerals containing iron or ferrous oxide, such as pyrites, siderite, ferrous sulphates, and silicates, &c., the whole of which are liable to change when exposed to damp air. The nature of this alteration has already been discussed. As pseudomorphs it is commonly observed after calcite, siderite, and pyrites, and less frequently after garnet, augite, cube ore, quartz, fluor, gypsum, barytes, dolomite, pyromorphite, white lead ore, ruby copper ore, galena, and blende.

The lake ore of Sweden is a limonite found in small pisolitic or money-like concretions which are dredged up from the bottom of lakes, and are reproduced in workable quantities at intervals of twenty or twenty-five years.

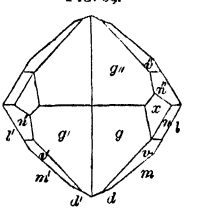
The bean ore (Bohnerz) of Germany is a dark-coloured glossy variety, in concretions resembling beans, which are

found in a matrix of clay, filling pipes and hollows in the oolitic limestones of Bavaria and Würtemberg.

Ochre, *Umber*, and *Sienna Earth* are intimate mixtures of limonite and clay, which by careful heating may be made to assume various shades of brown and yellow, and are among the most permanent of painters' colours.

MANGANITE. Grey Manganese Ore, Graubraunstein, Acerdèse. — *Rhombic.* ∞P, 99° 40′, $a : b : c = 0{\cdot}844 : 1 : 0{\cdot}545$, $m\{110\}\ \infty P$, $v\{221\}\ 2P$, $g\{313\}\ \breve{P}3$, $d\{210\}\ \infty \breve{P}2$, $l\{120\}\ \infty \breve{P}2$, $n\{121\}\ 2\breve{P}2$, $x\{365\}\ \frac{6}{5}\breve{P}2$.[1] Twin plane, 011 giving geniculated groups. Crystals usually columnar, terminated by {331} or {001}, or grouped parallel to 010, giving prisms with deeply striated faces or parallel bundles of fibres. Cleavage, 010 perfect, 110 less perfect, 001 imperfect. Fracture, uneven. H. 3·5–4. Sp. gr. 4·3 (fresh), 4·8 (weathered). Rather brittle. Opaque; slightly translucent in very thin particles. Lustre, semi-metallic. Colour, dark grey to black, weathering greenish or brownish, sometimes iridescent: streak, brown (fresh) or black (weathered).

FIG. 69.



Composition.—$H_2Mn_2O_4 = H_2OMn_2O_3$, or water 10·1, Mn_2O_3 89·9 per cent. Heated in closed tube gives off water at 200° C., and at higher temperature some oxygen (Mn_2O_3 becoming Mn_3O_4); with fluxes gives reactions of manganese. Soluble in hydrochloric acid giving off chlorine.

Occurrence.—With other manganese ores and barytes at Ilfeld in the Harz, Ilmenau in Thuringia, a few localities in Sweden, and recently in the Lake Superior iron district. Of little value as a bleach manganese ore on account of

[1] This form appears as a rhombic sphenoid; but as none of the other known pyramids are similarly developed, the hemihedrism of the species seems doubtful. Groth considers it to be holohedral, and exactly isomorphous with the similarly constituted species, Goethite and diaspore.

the small amount of disposable oxygen. The French name Acerdèse (from ἀκερδής = unprofitable) alludes to this circumstance.

V. Arsenious Acid Series.

Arsenolite. Arsenic Bloom, Arsenious Acid.—*Cubic.* In octahedra, usually in crystalline fibrous or powdery incrustations (artificial crystals of considerable size and brilliancy) are often obtained by sublimation. Transparent crystals of large size may be obtained from a hot saturated solution in ammonia by slow cooling. Cleavage, octahedral. H. 1·5. Sp. gr. 3·7. Colourless and transparent, or white and opaque. Lustre, under certain conditions vitreous to adamantine, but usually lower; translucent. Refractive index for yellow light, 1·755. Slightly soluble and sweet astringent to the taste.

Composition.—Arsenious acid (anhydride) As_2O_3, or arsenic 75·76, oxygen 24·24 per cent. Volatilises when heated in the closed tube giving a crystalline sublimate. On charcoal with soda gives the garlic odour of arsenic. Soluble in hydrochloric acid; the solution deposits metallic arsenic when boiled with copper.

Occurs as a secondary product in the Harz, Freiberg, and other Saxon and Bohemian localities where arsenical, nickel, cobalt, and silver ores are found.

Claudetite is a dimorphous variety of arsenious acid, crystallising in the rhombic system and isomorphous with Valentinite. The sp. gr. is 4·2, or somewhat higher than that of arsenolite. It is found in minute mica-like crystals in furnace flues and similar places, where it has presumably been sublimed at a high temperature.

Senarmontite.—*Cubic.* In octahedra, also massive with druses of crystals. Cleavage, octahedral, imperfect. Fracture, uneven. Colourless, white, or grey. Transparent or translucent in various degrees. Lustre, adamantine or

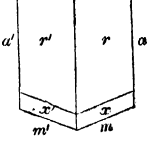
resinous. H. 2·5–3. Sp. gr. 5·2–5·3. In polarised light gives anomalous coloured rings analogous to those of a biaxial mineral. Mallard supposes that the crystals are not truly octahedral, but built up of individuals belonging to the oblique system.

Composition.—Antimonious acid (anhydride) Sb_2O_3, or antimony 83·56, oxygen 16·44 per cent. Turns yellow when heated, melts easily, and sublimes in the closed tube. On charcoal gives a white incrustation, and with soda in the reducing flame is reduced to metallic antimony. Soluble in hydrochloric acid, the solution depositing a white precipitate when diluted with water.

Occurrence.—Found near Constantine in Algeria, at Pernek in Hungary, and in Borneo. Also artificially formed as a furnace product.

VALENTINITE. Antimony Bloom, Exitèle.—*Rhombic.* ∞P, 136° 58′, $a : b : c = 0{\cdot}394 : 1 : 0{\cdot}707$, $a\{010\}\infty\breve{P}\infty$, (fig. 70), $m\{110\}\infty P$, $r\{011\}P\infty$, $x\{121\}2\breve{P}2$. In broad columnar and elongated tabular crystals, usually grouped in parallel or diverging series or star-like forms; also massive and in pseudomorphs after antimony, antimony glance, and kermesite. Cleavage, 110 perfect. H. 2·5–3. Sp. gr. 5·6. Semi-transparent, translucent. Colour, white, yellowish, or grey. Lustre, pearly on 010, adamantine on other faces. Double refraction strong. The optic axes for red lie in 001, those for blue in 010, making small angles with *a* as first median line, while for yellow they are approximately united. In specimens from Přibram and Algeria the axes for red are nearly united.

FIG. 70.



Composition.—Sb_2O_3, the same as Senarmontite, the chemical properties being also similar.

Found at Braünsdorf in Saxony, Wolfsberg in the Harz; Allemont in Dauphiny; in Algeria; Borneo, and other localities producing antimony ores, being essentially a product of their alteration.

VI. Dioxide Series.

This includes the dioxides of silicon, titanium, zirconium, tin, and manganese, which are of well-defined form, and those of carbon and sulphur, which, however, are not known in the crystalline condition, being permanent gases under ordinary atmospheric conditions.

A. Silica Series.

Silica, dioxide of silicon, or anhydride of silicic acid, occurs in at least three different conditions, each of which is marked by distinct physical and crystallographic characters. These are:

1. Hexagonal tetartohedral in quartz.
2. Rhombic or asymmetric in Asmanite and tridymite.
3. Amorphous in hyalite and opal.

Quartz.—*Hexagonal, trapezohedral, tetartohedral.* $R = 94° 15'$, $a : c = 1 : 1{\cdot}0999$ (figs. 71, 73); $r \kappa \{10\bar{1}1\} R$,

Fig. 71.

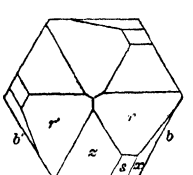


Fig. 72.

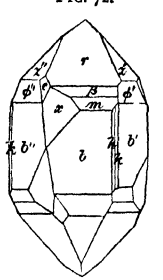
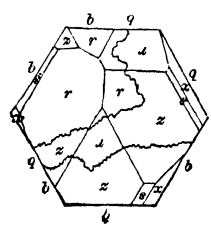


Fig. 73.



$\beta \kappa \{50\bar{5}3\} \frac{5}{3}R$, $m \kappa \{30\bar{3}1\} 3R$, $z \kappa \{01\bar{1}1\} -R$, $\phi \kappa \{07\bar{7}1\} -7R$, $b \{10\bar{1}0\} \infty P$, $k \kappa \kappa' \{15\bar{6}0\} \frac{1}{4}(\infty P\frac{6}{5})r$,

$s\ \kappa\ \kappa'\ \{22\bar{4}1\}\ \frac{1}{4}(2P2)r$, $x\ \kappa\ \kappa'\ \{15\bar{6}1\}\ \frac{1}{4}(6P\frac{6}{5})r$, $e\ \kappa\ \kappa'\ \{1\bar{3}21\}$ $-\frac{1}{4}(3P\frac{3}{2})l$ (other rhombohedra often seen are $4R$ and $7R$). Crystals of several different types. 1. *Holohedral, hexagonal.* When both unit rhombohedra are equally developed, giving the unit pyramid with the angles $Z=$ 103° 54′, $X=$ 133° 44′, which occurs both in a simple form or in combination with the hexagonal prism. 2. *Rhombohedral.* When the faces of one rhombohedron are prominently larger and more brilliant than those of its inverse form. These are the commonest kind; they are almost always in combination with the prism which is striated horizontally by rudimentary faces of more acute rhombohedra. When these latter are appreciably developed the inverse forms are usually different from the direct ones (fig. 72). 3. *Plagihedral.* When the combination includes 'rhomb' faces of a trigonal pyramid *s*, with or without those of trapezohedra *x*, as in fig. 71. The trapezohedra derived from $\{15\bar{6}1\}$ are the best developed, but appear

FIG. 74.

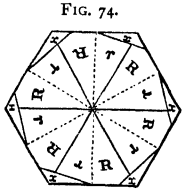
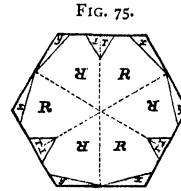


FIG. 75.



only as positive right and left forms, while those derived from $(13\bar{4}1\}$ are known in all four positions; trigonal and ditrigonal prisms are occasionally but rarely found. *Twins.* 1. On a face of $\{20\bar{2}1\}$, the vertical axes of the two constituents making an angle of 84° 33′ with each other. 2. On $\{0001\}$, with contact on a plane or an irregular surface. In the latter case (fig. 73) the group resembles a single crystal, the twinning being shown by the character of the rhombohedral faces, which are made up of bright (direct) and dull or pitted (inverse) portions irregularly intermixed

in the same surface. When there is complete penetration, both components being of similar rotation, plagihedral faces of the same direction may appear on all the basal solid angles, producing the effect of plagihedral hemihedrism, as in the scheme, fig. 74. 3. On {11$\bar{2}$0}. This applies to components with trapezohedra of opposite rotation, which produce an apparent scalenohedron (fig. 75), whose compound nature is no longer apparent in the quality of the faces, but when a section parallel to the base is examined optically, the crystal is seen to be made up of alternate right- and left-handed sectors.

The crystallographic development, whether in single or twinned crystals, is as a rule exceedingly irregular, one or two faces of one rhombohedron being often prominently larger than the others. In the tetartohedral forms the rhomb and plagihedral faces are rarely uniform in size, or present in the full number required by regular single or twinned crystals. The plagihedra especially are often represented by only a single face. Doubly terminated crystals are often found, but less frequently than those with only one end developed. Aggregates radiated in druses with the points free are common, also fibrous, granular, cryptocrystalline, massive, and compact aggregates.

Cleavage, 10$\bar{1}$1 in rare cases fairly perfect, 10$\bar{1}$0 imperfect. Fracture, conchoidal, parallel, splintery in crystals of lamellar structure. H. 7. Sp. gr. 2·65–2·66. Transparent and colourless in the purest varieties, translucent in various degrees, opaque in quartzite. Colour, white, grey, yellow, brown, red, blue, violet, green, and black. Lustre, vitreous. Double refraction positive; dispersion very small. Refractive indices for yellow light, ω=1·5442, ϵ=1·5534. Circular polarisation apparent in sections of all crystals parallel to the base, the direction of rotation corresponding to that of the plagihedral faces. In compound crystals made up of parts of different rotations, the lines of demarcation are marked by neutral bands in parallel polarised

light, due to the overlapping of equal thicknesses of plates of opposite rotations.

Composition.—SiO_2. Silicon dioxide, anhydride of silicic acid. Silicon 46·67, oxygen 53·33. Infusible except at the highest temperatures attained by special means, such as the oxyhydrogen blowpipe and the regenerative gas furnace, when it may be melted to glass. With soda fuses with effervescence to a clear bead, which is soluble in water. In salt of phosphorus gives a bead, opalescent with finely divided insoluble particles, the so-called silica skeleton. These are microcrystalline scales of tridymite. Insoluble in acids. Decomposed by hydrofluoric acid, producing gaseous fluoride of silicon. Slightly soluble in heated caustic alkaline liquors.

The other crystallised kinds of silica are:

TRIDYMITE. — *Triclinic*, approximating to hexagonal. $a : b : c$, 0·5822 : 1 : 1·1040. $\alpha\ \beta\ \gamma$ nearly 90°. Prism varies only 20′ from 60°. In minute six-sided crystals and wedge-like groups of three individuals. Cleavage, 001 imperfect. Fracture, conchoidal. Colourless and transparent white. Translucent to opaque. Double refraction positive. H. 7. Sp. gr. 2·28-2·33.

Composition.—SiO_2, properties similar to those of quartz, except that it is completely soluble in a boiling solution of carbonate of soda.

ASMANITE.—*Rhombic.* $a : b : c = 1·7437 : 1 : 3·3120$, is a variety of silica found in the meteorite of Breitenbrunn, Moravia, of sp. gr. 2·24, and otherwise very similar to tridymite. If, as is not improbable, these two species should be identical, the name Asmanite should have preference as the older.

OPAL and *Hyalite* are amorphous forms of silica, with variable quantities of water (5 to 12 per cent.), though probably not true hydrates. H. 5·5. Sp. gr. 1·9–2·3. Fracture, conchoidal. Brittle. Colourless and transparent,

but more generally coloured variously. Translucent and milky, often with a rich internal iridescence. Lustre, vitreous to greasy. When heated decrepitates, giving off water, but is not fused. More readily acted on by hydrofluoric acid than quartz, and when free from foreign substances dissolves completely in solution of caustic potash.

Varieties.—Crystals of quartz when perfectly limpid and colourless are known as rock crystal, or popularly as Cornish, Bristol, or Irish diamonds.

The names applied to the principal coloured varieties are *Amethyst*, when purple and dark blue; *Cairngorm* and *Smoke Topaz*, yellowish red and brown; and *Morion*, dark-brown and black.

Common quartz includes all the varieties, whether crystallised or massive, that are not transparent.

Rose quartz is a massive variety of a more or less pink or reddish colour.

Milky quartz, also massive, is compact, milk-white, semi-translucent.

Cat's eye. A greenish or bluish grey, or brown quartz, filled with fine parallel fibres of asbestos, which produce a peculiar silky lustre when cut in a rounded or cabochon form.

Avanturine. Massive reddish or brown quartz filled with small scales of mica, or penetrated by minute fissures causing a play of light. The above four kinds have the characteristic vitreous lustre. Of the duller varieties the more important are the following:

Hornstone. Compact, slightly translucent in thin fragments, or opaque. Various shades of grey, yellow, green, red, or brown, of a characteristic horny lustre, and flat conchoidal fracture. It is also called *chert.*

Quartzite. Compact, white, opaque quartz, often forming large rock masses, and more or less granular or slaty in structure. A black shining variety is known as *Lydian stone.*

Jasper is a compact quartz, coloured with limonite,

usually yellowish brown (*Egyptian jasper*) or sealing-wax red, also green banded with white or red (*riband jasper*), or spotted with red (*bloodstone* or *heliotrope*). Opaque quartz crystals when coloured yellow or red by included hematite or limonite are known as *Eisenkiesel.*

Chalcedony is essentially a mixture of quartz and amorphous silica, forming botryoidal, reniform, or stalactitic masses generally greyish or yellowish white, blue, rarely brown or red, and from translucent to nearly opaque. The clear reddish kinds are called *Carnelian. Sard* is a reddish brown; *Plasma*, olive-green; and *chrysoprase*, pale or apple-green.

Agate is a mixture of crystalline and amorphous silica in concentric layers, forming concretionary masses often of considerable size, which frequently contain hollows in the centre in which crystals of quartz or amethyst are developed. Fortification agate is called from the angular character of the bands, which correspond to the angles of the prism, and resemble the plan of a polygonal fortress.

Onyx has the bands regularly and sharply defined by difference of colour.

Flint is a dull grey or black amorphous substance, occurring in nodular masses in chalk and other limestones, and remarkable for the ease with which very perfect conical fractures can be developed in it; also gives sharp-edged fragments used for striking fire with steel.

The most important kinds of amorphous silica are:

Hyalite. A glassy substance occurring in small irregular masses resembling gum arabic. Colourless and transparent, with a highly vitreous lustre.

Fire opal. Transparent or translucent, of a reddish yellow or brown, with brilliant red reflections.

Precious opal. Translucent, of a bluish, yellowish, or milky blue colour, with various kinds of irised reflections, but usually one colour prevailing, either green or blue being the most common.

Common opal and *Semi-opal* are semi-translucent or

opaque, of a greasy lustre, usually white or yellowish brown; when forming the fossilising material and reproducing the structure of plant stems, it is called *wood opal.*

Hydrophane is an opal that has become dull by dehydration, but partially recovers its translucency when soaked in water for a time.

Pearl sinter, *siliceous sinter*, or *Geyserite* are pearly enamel-like substances, found as deposits from the waters of hot springs or geysers.

Occurrence.—Silica in its various forms is the most abundant of all minerals; quartz forms one of the principal components of granite, gneiss, and mica schist, an accessory component of many other rocks, and the mass of all quartzites and sandstones. The finest crystals are usually found in hollows in granitic rocks where the component minerals have had room to develop. The largest known individual exceeds three feet in length, is about 1½ foot across the basal section, and weighs about 7 cwt. Several tons of enormous crystals have been taken from a single cavern in Switzerland. Rock crystal is principally brought from Brazil, Uruguay, and Madagascar, amethyst from Brazil and India, cairngorm from the mountain of that name in Aberdeenshire, jasper and agate from the Palatinate, Hungary, the Ural, Brazil, and India. Opal from Hungary and Central America; the finest varieties are from the former country, the latter yielding more transparent kinds. Opal, of fine colour, is found also in Queensland. The fire opal comes from Honduras and Mexico.

Some localities for specimens of crystallographic interest are the marble quarries of Carrara, and Herkimer County, New York, which produce well-developed single crystals; the Dauphiné and Central Swiss Alps; Littlerock, Arkansas, for 'rhomb' faces; Pike's Peak, Colorado, for smoke topaz; and Brazil for twins of opposite rotation.

Quartz is very common in mineral veins associated with galena, blende, pyrites, and other metallic minerals. It also

occurs in pseudomorphs of many minerals, among which are gypsum, anhydrite, barytes, apatite, calcite, dolomite, siderite, calamine, hematite, fluor, pyrites, and galena, and as a fossilising material of plants and animal remains. Haytorite is a chalcedonic pseudomorph of datholite found at Haytor in Devonshire. Polishing slate or tripoli, which consists chiefly of the siliceous coatings of diatomaceous plants, is a chalcedonic or amorphous variety of silica.

Inclosures of foreign substances are frequently observed in quartz crystals. Among these are anthracite in the crystals of Herkimer County, New York, brown hair-like fibres of rutile, green fibres of actinolite, and scales of chlorite from many Alpine localities. Cavities containing fluids and gas bubbles are very common in quartz from granitic rocks, and often of such size as to be visible to the naked eye. The fluids are chiefly water and liquefied carbonic acid (anhydride). The quartz of Branchville, Connecticut, contains so much of the latter that it detonates and flies to pieces when struck or heated, often developing a perfect rhombohedral cleavage.

Hyalite is found in cavities in basaltic and similar igneous rocks, as are also agates and chalcedony. The Hungarian opals occur in trachytic rocks. The whole of these substances are evidently of secondary origin and deposits from solution in water. Deville found that silica melted before the oxyhydrogen flame was of the sp. gr. 2·3; and quartz when slowly heated is, according to Rose, reduced from 2·6 to the same density as that of tridymite and Asmanite, which are only found in volcanic rocks and meteorites. The alternation of compact quartz with amorphous silica in agates is rendered apparent by the action of weak hydrofluoric acid, the amorphous being more readily soluble than the crystalline bands.

Quartz or rock crystal is used chiefly for optical purposes, spectacle glasses, prisms, &c. Amethyst is largely employed for jewellery, being cut with facets and set clear. The finest

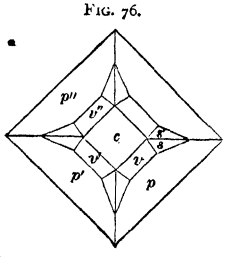
stones are those of Brazil. Cairngorm and smoky topaz form the basis of Scotch jewellery. Mortars and pestles made of agate and chalcedony are used in chemical laboratories in pulverising minerals for analysis, and the same substances are utilised for numerous minor ornamental purposes. When the coloured bands in an agate are not sufficiently well marked, they are brought out by heating the stone in sugar-syrup, and then treating it with sulphuric acid, when, owing to the difference in absorptive capacity of the different layers, the liquid will be unequally taken up, and bands of black or brown will be developed. If red colours are desired, the agate is caused to absorb a solution of ferrous sulphate, and is then heated.

Chert is used largely as a grinding stone in potters' flint mills, where flints that have been previously heated to redness and quenched in water are ground to a pulp or slip for porcelain making.

Lydian stone, a black variety of siliceous schist, is used as a gold touchstone, or for trying the colour of gold alloys against others of known composition. Tripoli polishing slate or infusorial earth, besides being used for polishing glass and metals, has received a new application of late years as an absorptive material for nitro-glycerine in the explosive substance known as dynamite.

ANATASE.—*Tetragonal.* Z 136° 36′, $a : c = 1 : 1{\cdot}77$, $p\{111\}P$, $v\{117\}\frac{1}{7}P$, $s\{1\,5\,19\}\frac{5}{19}P5$, $c\{001\}oP$. Crystals mostly of pyramidal, sometimes of tabular, habit. Cleavage, 111 and 001 both perfect. H. 6. Sp. gr. 3·8–3·9. Fracture, conchoidal, brittle. Imperfectly transparent, translucent. Lustre, metallic, adamantine. Colour, indigo-blue, hyacinth-red, brown, honey-yellow; transmitted light, greenish yellow. Double refraction negative. Indices for yellow light,

FIG. 76.



$\omega = 2{\cdot}554$, $\epsilon = 2{\cdot}493$. Interference rings in convergent polarised light usually irregular.

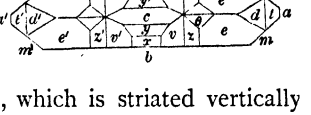
Composition.—TiO_2. Titanium dioxide, anhydride of titanic acid. Titanium 60, oxygen 40. Sometimes containing traces of Fe_2O_3 and SnO_2.

Infusible, dissolves to a nearly colourless glass in borax, which turns violet in the reducing flame. The same result is more readily obtained with salt of phosphorus. When much iron is present, tin may be necessary to effect the reduction. Insoluble in acids, but may be rendered soluble by fusion with alkaline hydrates, carbonates, or bisulphates.

Found in small brilliant crystals at Oisans in Dauphiné, St. Gothard, in the Ural, and in Brazil.

BROOKITE. Arkansite. — *Rhombic.* ∞P, 99° 50′, $\breve{P}\infty$ 94° 17′, $a : b : c = 0{\cdot}8416 : 1 : 0{\cdot}9444$, $a\{010\}\infty\breve{P}\infty$, $b\{100\}\infty\bar{P}\infty$, $c\{001\}\,0P$, $d\{043\}\frac{4}{3}\bar{P}\infty$, $t\{021\}2\bar{P}\infty$, $x\{102\}\frac{1}{2}\bar{P}\infty$, $y\{104\}\frac{1}{4}\bar{P}\infty$, $e\{122\}\bar{P}2$, $\theta\{5\,14\,18\}\frac{7}{9}\breve{P}\frac{14}{5}$, $z\{112\}\frac{1}{2}P$, $v\{326\}\frac{1}{3}\bar{P}\frac{3}{2}$.

FIG. 77.



Crystals thin, tabular to {100}, which is striated vertically in Brookite; and pyramidal, {122} predominating, in Arkansite. Cleavage, {010} imperfect. Fracture, uneven. H. 5·5–6·0. Sp. gr. 3·85–3·95 (Arkansite), 4·12–4·23 (Brookite). Translucent, opaque. Lustre, metallic, adamantine. Colour, yellowish, greenish, or reddish brown, hyacinth-red, Arkansite black; streak, pale yellow. Double refraction positive. The optic axes for red lie in {001} $2E = 65°$, and those for green in {010} $2E = 10°$. Axis *a* is the first mediar line for all colours.

Composition. — TiO_2, similar to anatase and rutile, having similar chemical characters. Usually some iron = 3–4·5 per cent., Fe_2O_3.

Found in small brilliant crystals with quartz and albite in diorite and felstone near Tremadoc, Carnarvonshire, and

Trefgaron, Pembrokeshire. Also at Oisans, St. Gothard, and Ellenville, New York, at the latter place with very brilliant quartz crystals. Arkansite is from Magnet Cove, Arkansas.

RUTILE.—*Tetragonal.* Z 84° 40′, X 123° 08′, $a : c =$ 1 : 0·644, $s\{111\}P$, $e\{101\}P\infty$, $m\{110\}\infty P$, $a\{100\}\infty P\infty$, $x\{410\}\infty P_4$. Twins common on 101 as in fig. 79,

FIG. 78.

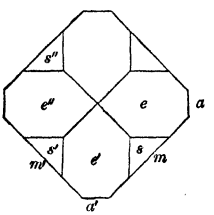
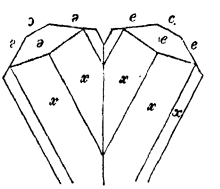


FIG. 79.



the principal axes of the individuals cross at 114° 25′ and 65° 53′; also on 301, producing by repetition nearly closed rings. Faces of prisms usually striated vertically. Crystals, short columnar, like those of tinstone; also in slender acicular and fibrous aggregates. Cleavage, 110 and 101 both imperfect. Fracture, conchoidal, uneven. H. 6·5. Sp. gr. 4·2–4·3. Translucent, opaque. Lustre, metallic, adamantine. Colour, reddish brown, hyacinth-red, also violet, yellow, and nearly black (nigrine). Double refraction positive.

Composition.—TiO_2, the same as anatase and Brookite, giving similar reactions with fluxes.

Occurrence.—In isolated, usually twin-grouped, crystals, in gneiss, granite, and crystalline schists at St. Gothard and elsewhere in Switzerland and Tyrol; St. Yrieux, near Limoges; Keller, Perthshire; Graves Mountain, Georgia, which has yielded the largest and finest crystals; Bay St. Paul, Quebec, in Ilmenite; Minas Geraes, Brazil, &c. At Oisans and other Alpine localities fine hair-like fibres of a bright brown colour

are found penetrating quartz crystals. At Cavradi in Tyrol, and in Australia, entire crystals of specular iron ore are found with flat columnar crystals of rutile lying symmetrically upon them, the principal axes of the latter being parallel to the lateral interaxes of the former.

TINSTONE. Cassiterite, Black Tin. — *Tetragonal.* $Z=87° 7'$, $a : c = 1 : 0{\cdot}6724$ (figs. 80, 81), $a\{010\}\infty P\infty$,

FIG. 80.

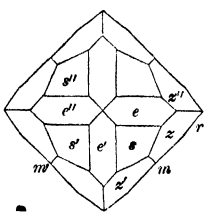
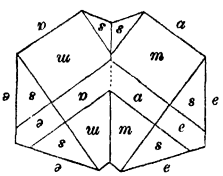


FIG. 81.



$m\{110\}\infty P$, $s\{111\}P$, $e\{011\}P\infty$, $z\{321\}3P_2^3$, $r\{320\}\infty P_2^3$. Twins on $\{111\}$ common, the principal axes of the individuals meeting at 112° 10′ and 67° 50′ (fig. 81). Prisms often striated vertically. Crystals of short columnar or slender pyramidal types, the former known as 'diamond-pointed,' the latter as 'sparrable tin.' As in quartz, the basal pinakoid exceedingly rare, but has been found in crystals from Pittkaranda, Finland. Also in reniform and spheroidal masses of a radiating fibrous structure, known as *wood tin* and *toad's-eye tin*, and massive interspersed in grains or as pebbles (stream tin). Cleavage, 110, 010, both imperfect. Fracture, small—conchoidal uneven. H. 6–7. Sp. gr. 6·8–7·0 crystals, 6–4 wood tin. Translucent, opaque. Lustre, adamantine, resinous, or horny. Sometimes colourless or grey, but more generally some shade of yellow, brown, or black; streak, white. Double refraction positive.

Composition.—Stannic dioxide (anhydride of stannic acid) SnO_2, or tin 78·6, oxygen 21·4 per cent. Usually

contains some iron, 1·5 to 2·5 per cent. Fe_2O_3, in pure transparent crystals, from Bolivia, up to 9 per cent. in wood tin. Occasionally silica and tantalic acid. Infusible and unchangeable by heat alone, but when mixed with soda and cyanide of potassium is readily reduced to metallic tin in the reducing flame. With fluxes sometimes gives the reactions of iron and manganese.

Tinstone occurs in intimate association with quartz, mica, topaz, tourmaline, wolfram, chlorite; iron, copper, and arsenical pyrites; and specular iron, and less frequently with bismuth minerals. In Cornwall it is found in veins traversing granite and argillaceous schists; and in Saxony, at Zinnwald, in minute reticulated veins in gneissic schists. At Villeder, in Brittany, it occurs under similar conditions to those of Cornwall. At Campiglia, in Tuscany, it is found in a tertiary limestone. Large crystals are obtained at Schlaggenwald and Graupen in Bohemia, and in Galicia (N.W. Spain). Wood tin, associated with small bright crystals of topaz, is brought from Darango, in Mexico.

Stream tin, the detritus formed from the waste of tin-bearing veins, occurs in the gravels and alluvial deposits of rivers, and as such is usually the first source of the metal before vein-mining commences in a district. In Cornwall the stream works are substantially exhausted, but large deposits of this kind of tin ore have been discovered along the eastern side of Australia with native gold in disintegrated quartzite, and in Perak in the Malay peninsula. A nearly colourless variety occurs at the Brewer Mine, South Carolina.

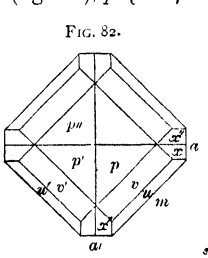
The tin-stuff or tin-bearing rock as raised from the mines in Cornwall, is an intimate mixture of the minerals mentioned, in which the tinstone rarely exceeds about 1 per cent. or 22 lbs. to the ton, and is often less, so that it is practically invisible. The dressing processes are very complicated, as the specific gravity, although high, is insufficient to permit of a separation of the constituent minerals by water alone; the first operation, after the rock

has been crushed to a very fine powder, having for its object the concentration of tinstone and pyritic minerals. The latter are then destroyed by calcination, producing ferric oxide, which is easily washed away, and the tin ore is brought up nearly to a state of purity, forming what is known as black tin. The operation is, in some cases, further complicated by the presence of wolfram, which, from its great density, cannot be separated by water or altered by calcination. In such cases fusion with carbonate or sulphate of sodium is sometimes used, which produces tungstate of sodium, a compound soluble in water.

The most important tin-producing districts are Cornwall; Banca, and other localities in the Malay peninsula and islands; Australia, and Tasmania. In America it is comparatively rare; the principal localities being Durango in Mexico, and Peru and Bolivia. The crystals from the latter country are nearly colourless and almost chemically pure.

ZIRCON. Hyacinth, Jacinth, Jargoon. — *Tetragonal.* Z 84° 20′, X 123° 19′, $a : c = 1 : 0{\cdot}640$ (fig. 82), p {111} P, v {221} $2P$, u {331} $3P$, x {311} $3P3$, m {110} ∞P, a {100} $\infty P\infty$. Usually in single crystals. Twins like those of rutile or tinstone (fig. 79). Of large size, but rare. Cleavage, 110 and 111 both imperfect. Fracture, conchoidal. H. 7·5. Sp. gr. 4·4—4·7. Transparent, translucent, opaque. Lustre, adamantine, vitreous, greasy on fracture. Sometimes colourless, usually orange or brownish red (hyacinth-red), also grey, green, and white. Strong positive double refraction. Indices for red light, $\omega = 1{\cdot}92$, $\varepsilon = 1{\cdot}97$. The interference figure in convergent and the coloured field in parallel polarised light usually very irregular, whence it is considered by Mallard and others to be of lower than tetragonal symmetry.

FIG. 82.



Composition.—$ZrSiO_4 = ZrO_2 + SiO_2$, or zirconia 66·3, silica 33·7 per cent. Accessory constituents are: lime 0·8 to 3·5, Fe_2O_3 0·6 to 2·2, alumina 0· to 2·5 per cent. As the relation of Si : Zr = 1 : 1 is uniform in all the analyses, Groth suggests that zircon, rutile, and tinstone are isomeric, having the molecule double that of Brookite, anatase, and quartz, and that their formulæ should be written, Ti_2O_4 and Sn_2O_4.

Infusible. The coloured varieties become white when strongly heated, and sometimes phosphorescent, the specific gravity being slightly increased. Very slightly acted upon by borax, giving a clear glass, not affected by salt of phosphorus or soda. Very slightly soluble when finely powdered in sulphuric acid. Decomposed by hydrofluoric acid, or by fusion with bisulphate of potassium or carbonate and hydrate of sodium in the same manner as a silicate. The solution of a zirconium compound when containing free acid reddens turmeric paper, which is the only peculiar reaction of ready application.

The colourless, light-coloured, and transparent varieties are cut as gems, and known as jargon or hyacinth, the latter name being applied to the red and yellow kinds. These are brought principally from Ceylon and India. At Frederiksvärn in Norway, Expailly in Central France, Esquimaux Bay, Labrador, Miask in the Ural, and other localities, zircon forms one of a curious group of minerals making up the rock known as zircon syenite, which is generally distinguished by the prevalence of an opalescent felspar.

Malacone is a partially hydrated form of zircon found in dull yellow-white or grey tetragonal crystals, containing from 1 to 9 per cent. of water. It gives off water in the closed tube, and is decomposed by hydrochloric acid. When strongly heated behaves similarly to zircon.

Found at Hitteröe in Norway, near Dresden, Miask in Siberia, and Chanteloup in France.

Auerbachite is a variety of zircon containing less zirconia than the normal mineral, being $2ZrO_2+3SiO_2$, from Mariopol in Russia. It is also tetragonal, $Z=85° 21'$.

THORITE.—*Tetragonal* or *cubical.* Usually in opaque black masses, with a dark brown streak. Fracture, conchoidal, hard, and brittle. Sp. gr. 4·6–4·8.

Composition.—Probably $ThO_2+SiO_2+H_2O$, or thoria 77·32, silica 17·44, water 18 per cent. Mostly contains lime, manganese, iron, and lead as impurities. A yellow variety called Orangeite is generally purer. It is the principal mineral containing thorium, but the blowpipe characters are not sufficient for its recognition, the most apparent reactions being those of the iron, manganese, and other accidental constituents. The principal locality is Brevig in Norway, where it is associated with zircon, the two species being probably isomorphous.

PYROLUSITE. Soft Manganese Ore, Braunstein.—*Rhombic.* ∞P 93° 40′, $a:b:c=0·938:1:0·728$. Crystals usually short columnar, with either flat (001) or domical (101) ends, and very commonly mere parallel bundles of fibres terminating in separate points, and more or less radially grouped; also massive and granular, in reniform, stalactitic, and other aggregated forms, compact and earthy In pseudomorphs after calcite and other carbonates, manganite, and Polianite. Cleavage, prismatic, dividing readily into fibres which are not very brittle. H. 2, when crystallised : 1–1·5 in fibrous and earthy kinds which mark paper like graphite. Sp. gr. 4·8–4·9. Lustre, imperfectly metallic in clean crystals, but usually lower; fibrous varieties being at most silky. Opaque. Colour, dark grey to black; streak, black.

Composition.—Manganese dioxide (peroxide of manganese), MnO_2, or manganese 63·22, oxygen 36·78 per cent. =MnO 81·6 and O 18·4, the latter representing the amount

of oxygen available for producing chlorine by the decomposition of hydrochloric acid, or Mn_3O_4 87·75, and O 12·25, which is the maximum amount of oxygen liberated from the pure mineral by heating it to redness. Usually contains a little water (under 2 per cent.) and at times 0·5–0·7 per cent. of baryta.

Infusible, but sometimes gives off water in the closed tube, and oxygen at a red heat. The brown residue is Mn_3O_4. With borax gives the violet bead of manganese. Soluble in hydrochloric acid, evolving chlorine in larger quantity than the other oxides of manganese, sometimes leaving a residue of baryta, silica, &c.

Occurrence.—Pyrolusite is the most important ore of manganese, and occurs either alone or with psilomelane, wad, manganite, Göthite, siderite, and other iron and manganese minerals, the deposits consisting mostly of irregular masses or bunches separated more or less perfectly from the associated minerals. The largest supply is obtained from the south-west of Portugal and the adjacent parts of Spain. It is also worked to some extent in Devonshire, near Ashburton, in veins in clay slate, and is in all cases probably the result of the decomposition either of mixed carbonates of manganese, iron, calcium, and magnesium, or of similar silicates.

In the Cantabrian mountains of Spain it is found in large veins traversing limestone with hematite, and various sized nodules are obtained from the adjacent superficial deposits. A similar class of superficial deposits has been worked very extensively in Nassau, where it is found in concretions with hematite and phosphorite in the alluvial soil covering Devonian limestones.

Pyrolusite is employed both for its manganese and oxygen. The purest kinds are used by glass-makers, as a means of masking the colour of iron in the sand, FeO being oxidised to Fe_2O_3 by the oxygen set free at a red heat, while the resulting MnO has no colouring power on

the glass. For bleaching-powder makers the ore is valued according to its power of decomposing hydrochloric acid and liberating chlorine, and should therefore be free from iron and lime compounds, which would simply waste acid by producing soluble chloride, but silica or other insoluble impurities are of less consequence. Such ores are therefore sold in the proportion of MnO_2 contained, 70 per cent. being the standard quality, and a deduction or increase of price is made for each unit per cent. indicated by any below or above that proportion. For the production of alloys of manganese and iron the lower qualities that are not fit for chemical manufactures, especially those containing much iron, are used, and in such cases the presence of lime is an advantage, and silica objectionable. The ores used for this purpose contain about 25 per cent. of manganese and an equal quantity of iron, and are brought principally from the neighbourhood of Carthagena in Spain.

POLIANITE is another variety of MnO_2, nearly similar in crystalline characters, but much harder and lighter in colour than pyrolusite ∞P 92° 52′, the crystals forming short columnar or fibrous aggregates. H. 6·5–7. Sp. gr. 4·8–5·1. Colour, light steel-grey. Lustre, feebly metallic. In composition it is nearly chemically pure, MnO_2.

PSILOMELANE. Hard Manganese Ore.—Amorphous; in botryoidal, reniform, fibrous, and stalactitic forms, often with a smooth surface and a curved scaly structure, like that of native arsenic or hematite; also in pseudomorphs (principally of calcite and fluor) or encrusting quartz and other minerals. Fracture, conchoidal, fibrous, or even. H. 5–6. Sp. gr. 4·1–4·7. Opaque. Colour, black, bluish or brownish black; streak, brownish black. Lustre, silky or dull.

Composition.—$\left\{ \begin{matrix} RO \\ nMnO_2 \end{matrix} \right\}$, R=$K_2$, Ba, Mn, either with

or without water. According to the prevalence of one or other alkaline metal, two classes are distinguished, known as potash- and baryta-psilomelanes. The former contains from 2 to 5 per cent. K_2O, and 76 to 81 per cent. MnO; and the latter, 12 to 17 per cent. BaO, and 63 to 70 per cent. MnO. The average amount of water may be from 3 to 5 per cent.

Infusible, giving off water in most instances, and oxygen invariably in the closed tube, the residue behaving like pyrolusite. In the potassic variety the alkali is soluble in water after the ignition of the mineral.

Wad is a brown earthy substance of indefinite composition, but probably a hydrated oxide of manganese, similar to psilomelane, but with more water, 10 to 15 per cent. Very soft, marking paper with a black or brown streak similar to the colour, which is often of a bright brown. It is also called Bog Manganese Ore.

Earthy cobalt ore, cobaltic manganese, or asbolan, are varieties represented by the same formula in which R=Cu and Co, containing CoO 20, CuO 4, MnO 40–42, H_2O 21 per cent.; but being only products of the alteration of other minerals, they vary considerably in composition, sometimes containing arseniates and arsenious acid. When the copper is in large proportion the mineral is termed Cuprous Manganese Ore.

All these substances are soluble in hydrochloric acid with evolution of chlorine; the cobaltic kinds giving a blue solution, which becomes red on dilution.

Occurrence.—Psilomelane and wad are common associates of pyrolusite and other manganese ores. The varieties containing cobalt are mostly from Saalfeld in Thuringia and Riechelsdorf in Hesse.

PITCHBLENDE. Uranpecherz, Uraninite.—*Cubic.* Crystals 100, 110, rare, usually in masses of irregular or concentric curved structure. Fracture, smooth or flat—con-

choidal. H. 3–6. Sp. gr. 5–9·2, according to purity, the heaviest being the purest. Pitchy black, greenish or brownish black; streak, greenish or brown. Lustre, greasy or horny.

Composition.—$U_3O_8 = UO_2 + 2UO_3$, or uranium 84·79, oxygen 15·21 per cent. The theoretical composition differs from that actually observed, as the proportion of U_3O_8 rarely exceeds 80 per cent., and is usually considerably less, the remainder being made up of iron, manganese, lead, bismuth, silica, arsenic, &c., from 8 to 10 additional constituents being returned in the analyses.

Infusible, sometimes giving water in the closed tube. With borax and salt of phosphorus gives beads that are yellow in oxidising and green in reducing flame; usually some lead is separated, and arsenical fumes are evolved in the reduction. Not acted upon by hydrochloric acid, except that the impurities, carbonates and sulphides, are dissolved. Soluble in nitric acid, the solution giving a bright yellow precipitate with ammonia.

Occurrence.—With silver ores in the Erzgebirge and at Přibram, and with tin ores in Cornwall; East Pool, Camborne, and Wheal Owles, Saint Just, being the principal mines now producing it. It is best distinguished by its peculiar horny lustre and great weight, and by the bright yellow incrustation of uranium ochre (a hydrated sulphate of indeterminate composition) which is commonly seen spotted over the surface.

Pitchblende is used for the preparation of uranium oxide and uranium yellow (uranate of soda), which are employed as enamel colours and for producing a glass that appears yellow by transmitted and bright green by reflected light. It is a very valuable mineral.

An exceedingly pure crystallised variety from Branchville, Connecticut, contained UO_3 40·08, UO_2 54·41, PbO 4·27, FeO 0·49, H_2O 0·88, total 100·23, or 81·5 per cent. of uranium.

CARBONIC ACID, CO_2, and SULPHUROUS ACID, SO_2 (or rather, in modern nomenclature, their *anhydrides*), are other members of the RO_2 group. Their crystalline forms are undetermined, so that it is not known whether they are isomorphous with silica or with titanic acid. Carbonic acid is given off in quantity, both in the gaseous state and in solution in mineral matters, in various localities adjacent to active or dormant volcanoes, a notable example being furnished by the great line of thermal and cold mineral springs on the flanks of the Eifel volcanic region which extends from the neighbourhood of Liege, in Belgium, across the Eifel, the Rhine, and Lahn Valleys to the Taunus, and includes many of the most famous mineral springs in Europe, such as Spa, Selters, Schwalbach, Apollinaris, &c.

Sulphurous acid is a common constituent of the gases or steam of volcanoes in the so-called suffioni and solfataras.

VII. MOLYBDIC ACID SERIES.

This includes only two species, neither of which is known in a definite crystalline condition.

MOLYBDIC OCHRE.—Amorphous in powdery incrustation upon sulphide of molybdenum. Pale yellow to orange-colour. Earthy and dull.

Composition.—MoO_3, or molybdenum 65·71, oxygen 34·29 per cent., sometimes containing oxide of uranium. Fusible on charcoal, giving an incrustation yellow while hot and white when cold. The bead with borax is colourless in oxidising, and nearly black in reducing flame. Soluble in hydrochloric acid and caustic alkalies, the solution turning blue when heated with metallic iron.

TUNGSTIC OCHRE. Wolfram Ochre.—An earthy, soft, greenish grey or yellow substance, incrusting wolfram. It is essentially WO_3 (tungstic acid), or tungsten 79·3, oxygen

20·7 per cent. Infusible. Soluble in caustic alkalies, but not in acids, and otherwise resembles artificially prepared tungstic acid.

OXYSULPHIDES.

There are very few representatives of this class of combinations among minerals, and only one of these is found in any quantity, namely, the oxysulphide of antimony, which is a secondary product derived from the alteration of antimony glance.

KERMESITE. Antimonblende.—Probably oblique. In fine acicular, silky, or hair-like fibres, usually in radiating tufts or sheaves, having one perfect cleavage parallel to the length of the fibre: also in pseudomorphs after antimony glance and plagionite. H. 1–1·5. Sp. gr. 4·6. Colour, cherry-red; streak, similar or somewhat lighter. Lustre, adamantine, slightly translucent.

Composition.—$Sb_2S_2O = \left\{\begin{matrix} 2Sb_2S_3 \\ Sb_2O_3 \end{matrix}\right\}$, or approximately antimony 75, sulphur 20, oxygen 5 per cent.

Blowpipe characters similar to those of antimony glance. When treated with solution of caustic potash, turns yellow and dissolves.

Occurs at Braünsdorf near Freiberg, with antimony glance in druses in quartzose schist, the fibres being sometimes nearly an inch long: also at Allemont, Přibram, and other localities producing antimony ores.

VOLTZITE or *Voltzine* is an oxysulphide of zinc, of the composition $\left\{\begin{matrix} 4ZnS \\ ZnO \end{matrix}\right\}$, found at Pontgibaud and Joachimsthal. In characters it is very similar to zincblende.

CHAPTER VII.

SILICATES.

THE classification of these, the largest and most important groups of natural minerals, is attended with some difficulty, as the real constitution of silicic acid is not known. Upon the hypothesis of the two definite compounds, metasilicic acid, H_2SiO_3, and orthosilicic acid, H_4SiO_4, a general division may be made into metasilicates and orthosilicates, according as the anhydride of one or other acid is supposed to be present. The normal metasilicates will then be represented by $\overset{II}{R}SiO_3$, and the normal orthosilicates by $\overset{II}{R}_2SiO_4$, the corresponding ratios R : Si being in the first case 1 : 2 and in the second 1 : 1. From either of these, basic and acid compounds are obtained by the addition of metallic oxide in the former and silica in the latter case. This is the method followed by Groth, who makes parallel and similarly classified series for the hydrated silicates. It is also followed by Dana, who calls the normal orthosilicates Unisilicates, and the normal metasilicates Bisilicates.

Rammelsberg's classification is based upon the analogy of the carbonates, and considers the three types, $\overset{I}{R}_2SiO_3$, $\overset{II}{R}SiO_3$, and $\overset{VI}{R}Si_3O_9$, as normal or neutral salts, basic and acid salts being obtained as in the preceding method. This gives the following series, which includes the principal types of composition.

Class	R : Si	Monads	Dyads	Hexads
Quadri-basic	2 : 1	$\overset{I}{R_4}SiO_6$ $\begin{cases} =\overset{I}{R_2}SiO_3 \\ +3\overset{I}{(R_2O)} \end{cases}$	$\overset{II}{R_4}SiO_6$ $\begin{cases} =\overset{II}{R}SiO_3 \\ +3\overset{II}{(RO)} \end{cases}$	$\overset{VI}{\mathfrak{R}_4}Si_3O_{18}$ $\begin{cases} =\overset{VI}{\mathfrak{R}}Si_3O_9 \\ +3\overset{VI}{(\mathfrak{R}O_3)} \end{cases}$
Tribasic	3 : 2	$\overset{I}{R_6}SiO_5$ $\begin{cases} =\overset{I}{R_2}SiO_3 \\ +2\overset{I}{(R_2O)} \end{cases}$	$\overset{II}{R_3}SiO_5$ $\begin{cases} =\overset{II}{R}SiO_3 \\ +2\overset{II}{(RO)} \end{cases}$	$\overset{VI}{\mathfrak{R}_3}Si_3O_{15}$ $(\mathfrak{R}\,Si\,O_5)$ $\begin{cases} =\overset{VI}{\mathfrak{R}}Si_3O_9 \\ +2\overset{VI}{(\mathfrak{R}O_3)} \end{cases}$
Dibasic (semi-silicates) (singulo-silicates)	1 : 1	$\overset{I}{R_4}SiO_4$ $\begin{cases} =\overset{I}{R_2}SiO_3 \\ +\overset{I}{(R_2O)} \end{cases}$	$\overset{II}{R_2}SiO_4$ $\begin{cases} =\overset{II}{R}SiO_3 \\ +RO \end{cases}$	$\overset{VI}{\mathfrak{R}_2}Si_3O_{12}$ $\begin{cases} =\overset{VI}{\mathfrak{R}}Si_3O_9 \\ +\mathfrak{R}O_3 \end{cases}$
Normal (bisilicates)	1 : 2	$\overset{I}{R_2}SiO_3$	$\overset{II}{R}SiO_3$	$\overset{VI}{\mathfrak{R}}Si_3O_9$
Sesqui-silicates	1 : 3	$\overset{I}{R_4}Si_3O_8$ $\begin{cases} 2(=\overset{I}{R_2}SiO_3) \\ +SiO_2 \end{cases}$	$\overset{II}{R_2}Si_3O_8$ $\begin{cases} =2(\overset{II}{R}SiO_3) \\ +SiO_2 \end{cases}$	$\overset{VI}{\mathfrak{R}}Si_9O_{24}$ $\begin{cases} =2(\overset{VI}{\mathfrak{R}}Si_3O_9 \\ +3SiO_2 \end{cases}$
Bisilicates (quadri-silicates)	1 : 4	$\overset{I}{R_2}Si_2O_5$ $\begin{cases} =\overset{I}{R_2}SiO_3 \\ +SiO_2 \end{cases}$	$\overset{II}{R}Si_2O_5$ $\begin{cases} =\overset{I}{R_2}SiO_3 \\ +SiO_2 \end{cases}$	$\overset{VI}{\mathfrak{R}}Si_6O_{15}$ $\begin{cases} =\overset{VI}{\mathfrak{R}}Si_3O_9 \\ +3SiO_2 \end{cases}$

The quantivalent ratios in the second column are the same as the oxygen ratios of the older notation, and the oxygen quotients of Scheerer are their reciprocals.

The compounds represented by the formulæ in the above table may either occur independently or may combine with others of the same class, giving minerals with more complex molecular formulæ. In such cases the quantivalent ratio is found by comparing the sum of the basic atoms $(\overset{II}{R}+\overset{VI}{\mathfrak{R}})$ with that of the silicon in both molecules. For instance, the simplest expression for the composition of Scapolite is $Ca_6Si_9O_{36}$, giving the quantivalent ratio $\overset{II}{R}+\overset{VI}{\mathfrak{R}} : Si = 12+24 : 36$, or 1 : 1, the same as that of a simple dibasic silicate. In addition to the groups in the table there are numerous silicates in which the ratio R : Si is of a less simple character, which may be considered as combinations of molecular groups of different classes, and in such cases the formulæ become very complex. An example of this kind is given in idocrase, $\overset{I}{R_6}\overset{II}{R_{44}}\mathfrak{R}_{10}Si_{35}O_{147}$, where R : Si =

11 : 10, which may be considered as $4(\overset{I}{R}_4SiO_4)+\overset{I}{R}_6SiO_5$, or 4 molecules of dibasic to one of tribasic silicate.

The number of metallic elements occurring as silicates is comparatively few, those most frequently observed being : among monads, potassium, sodium, and lithium ; of dyads, magnesium, calcium, strontium, barium, glucinum, manganese, and (*ferrous*) iron ; and of hexads, aluminium, and (*ferric*) iron. Zinc, copper, and bismuth are the only other heavy metals forming natural silicates, and these are comparatively rare.

Although the greater number of silicates are anhydrous, many of them are represented by more or less definite hydrated forms, which give off water when heated a little above the boiling point, or even in some cases spontaneously in a dry atmosphere. These are considered as hydrated silicates proper, while a third class, which do not become dehydrated below a red heat, are considered as containing hydrogen as a monad basic element—a view which in many cases leads to the simplification of the formula, and exhibits relations between the form and composition of allied species which are not apparent when the water is considered to be present as such.

The quantitative diversity in composition of silicates is in strong contrast with their comparative simplicity qualitatively ; and as this diversity often exists in species which are linked by similarity or identity of form or structure, these latter properties are often of more value for purposes of classification than the chemical composition. By far the larger number crystallise in the systems of lower symmetry, rhombic, oblique, and triclinic, some being dimorphous or trimorphous in these systems. The most striking examples of isomorphous groups among them are furnished by garnet in the cubic and tourmaline in the rhombohedral systems, which exhibit extreme qualitative variations in composition, while conforming closely to general quantitative type, and even to particular crystallographic form and habit.

The behaviour of silicates, when heated in the blow-pipe flame, often furnishes information of value as to their composition. Those hydrates that contain water of crystallisation, the so-called zeolites, mostly froth up when heated and fuse to white enamels, while others, such as chlorite and pyrophyllite, exfoliate or swell up to many times their original bulk, but do not fuse. As regards the fusibility of the anhydrous species for similarity of bases, those of normal or acid types are, as a rule, less refractory than the more basic kinds; and for similarity of constitution those of monad or dyad are more fusible than those of hexad bases. When two or more bases of the same kind are present, the fusibility is usually greater than when there is only one. For instance, simple magnesian silicates, such as Forsterite, Mg_2SiO_4, Enstatite, $MgSiO_3$, and the hydrated ones, serpentine and steatite, are infusible, the latter being one of the most refractory of natural substances; and the aluminium silicates, staurolite, topaz, and clay, are similarly infusible, but any of these may be readily fused by an addition of lime or ferrous oxide, ferrous silicates being the least refractory members of the series. The compound silicates of aluminium, calcium, and the alkali metals, forming the felspar group, are also fusible, and those containing sodium and calcium most readily so. Leucite, the richest alkaline silicate, is infusible, but this is to be attributed to the large amount of aluminium present.

When subjected to the action of hydrochloric or sulphuric acids, the more basic silicates, especially when containing calcium, such as Wollastonite, or aluminium, calcium, and water, as in the zeolite class, are usually decomposed with a separation of hydrated silica, which may be either gelatinous or granular; the former being especially characteristic of the zeolite type, which are decomposed by dilute acid at low temperatures. When the absolute amount of silica is low it may go into solution, and only separate after a time, or when the liquor is heated.

Some silicates which are not decomposible by acids under ordinary conditions are rendered wholly or partially so after being strongly heated or fused; garnet and idocrase are of this kind. The hydrated silicates of magnesium, serpentine, and meerschaum are readily decomposed by either hydrochloric or sulphuric acid, but talc is not, neither are the anhydrous magnesian silicates, or the more magnesian varieties of augite or hornblende. Micas of any kind are but slightly acted on by acids, sulphuric acid being the most effective. This, however, may be due to the difficulty of reducing them to a sufficiently fine state of division, as in all cases it is essential that the substances under examination should be reduced to the finest possible powder, unless the experiment is to be continued for a lengthened period. Of the felspar group, only those containing calcium and sodium are decomposed by strong hydrochloric acid, and then only very slowly. Clays and other hydrated aluminium silicates are decomposed when digested with strong sulphuric acid, and in some cases by caustic alkaline solutions.

The action of carbonic acid upon silicates in nature is generally similar in its results to that of the stronger acids in the laboratory. Calcium and the alkaline metals contained in silicates are readily converted into carbonates, and iron into ferric hydrates, while magnesium and aluminium are but slightly affected, being generally changed into hydrated silicates, such as serpentine, steatite, and clay. Speaking generally, therefore, a magnesian silicate, if not containing any other base, is but slightly affected by atmospheric vicissitudes, but if broken up by the peroxidation of ferric oxide it will probably be changed into serpentine or steatite; and similarly one containing aluminium and alkalies may give rise to a china clay.

The methods of occurrence and association of silicates introduce us substantially to the study of rocks or petrology, which, forming the subject of a special treatise in this series, will not be further enlarged upon here. Suffice it to say,

that those rich in silica, such as orthoclase, albite, hornblende, and mica, are, as a rule, associated with quartz in the so-called acid series of rocks, granite, trachyte, &c., while olivine, augite, Labradorite, and anorthite are more especially characteristic of the rocks of lower silication, basalt, dolerite, &c. Hypersthene and diallage augite are especially characteristic of the rocks known as gabbro ; and garnet of granulite, a fine-grained granite, and eclogite, being also common in isolated crystals, in crystalline schists, and metamorphic limestones.

Meconite, idocrase, and nepheline are common associates in the limestone blocks of Somma on Vesuvius, the latter being also a constituent of the lava known as phonolite. Leucite is entirely a volcanic product, forming a principal constituent of most of the recent lavas of Vesuvius and other Italian volcanic districts. The felspar group are probably the most abundant minerals of their class, orthoclase being found as a common constituent of granites and of the older gneiss of Scandinavia and North America ; and Labradorite, besides being abundant in most of the older igneous rocks, forms great mountain masses in a nearly pure form in the Labrador peninsula and in Lower Canada. Serpentine affords another instance of a single mineral being developed into great rock masses ; these, however, are supposed upon good evidence to be products of the hydration of olivine and similar magnesian silicates. The zeolite group are essentially products of the alteration of volcanic rocks, being found filling hollows in such rocks, together with opal and chalcedony. They are also found at times in mineral veins, especially in the silver mines of the Harz, but more particularly in the native-copper bearing dolerites of Lake Superior. Enstatite and bronzite are among the most characteristic associates of native iron in meteoric masses.

In the detailed description of the more important species in the following pages, precedence is given to the normal silicates, as these are numerically the most important.

AUGITE-HORNBLENDE GROUP.

The normal silicates of lime, magnesia and manganese, whether containing only one base or isomorphous mixtures of several, may be conveniently included under this head. They form several species, crystallising in the rhombic, oblique, and triclinic systems, but those belonging to the first and last systems approximate closely (or are polysymmetric) in dimensions with one or other of two types of oblique forms, which will therefore be first considered.

AUGITE. Pyroxene.—*Oblique.* ∞P, 87° 06′, $a : b : c$ = 1·094 : 1 : 0·591, $\beta = 74°$ (figs. 83, 84), $a\{100\}\infty\breve{P}\infty$, $b\{010\}\infty\breve{P}\infty$, $c\{001\}0P$, $m\{110\}\infty P$, $s\{\bar{1}11\}P$, $o\{\bar{2}21\}2P$, $\lambda\{\bar{3}31\}3P$, $z\{021\}2\breve{P}\infty$, $p\{\bar{1}01\}.\breve{P}\infty$. Crystals mostly short or long columnar, rarely tabular. Also in granular irregular masses. Twins common on 100, producing apparent rhombic forms when only one end of the crystal is seen. Cleavage, 110 perfect but interrupted, 010 and 100 imperfect. H. 5–6. Sp. gr. 2·9–3·5. Translucent—opaque. Colour, white, grey, green, brown, or black; streak, white or grey. Lustre, vitreous—pearly. Double refraction positive; indices for D line, $\alpha = 1{\cdot}673$, $\beta = 1{\cdot}679$, $\gamma = 1{\cdot}703$. Optic axes lie in 010. $2E$ 110°–113°. 1st median line is inclined 51° 6′ to the normal of 100, and 22° 5′ to that of 001. Darker varieties feebly pleochroic.

FIG. 83.

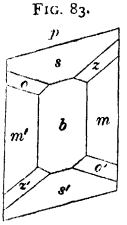
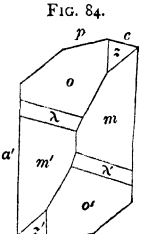


FIG. 84.



Composition.—$RSiO_2$; R = Mg, Ca, Fe or Mn, the first being most plentiful, or may be partially replaced by K_2 or Na_2, or by ~~Al~~ or ~~Fe~~, or any combina-

tion of these metals. The different varieties are distinguished by particular names as follows:

Diopside, *Alaite*, *Salite*, *White Coccolite* are colourless or light-coloured varieties, transparent to feebly translucent, consisting essentially of lime and magnesia silicates, entirely or nearly free from iron and alumina; FeO not exceeding 5 per cent.

Green Diopside, *Malacolite*, *Coccolite*, and *Diallage* contain 5 to 15 per cent. FeO, the proportion being highest in the dark green or black varieties, and lowest in those that are grey, pale, or bright green.

Coccolite is the term applied to the dark grey or black granular crystalline aggregates found in crystalline rocks. *Diallage* is a thin foliated variety, having a very distinct cleavage parallel to 100, and a pearly or sub-metallic lustre on the cleavage faces, in which respect, and the colour, greyish green, grass-green, or bronze-brown, it resembles hypersthene and bronzite, but is distinguished from them by its optical properties. The composition is not constant, some varieties containing alumina. From the almost uniform presence of water (0·5 to 2·2 per cent.) Diallage is held by Roth and others to be an altered mineral, produced from ordinary augite by hydration.

Hedenbergite is essentially lime-iron augite ($CaSiO_3 + FeSiO_3$), with 26–27 per cent. FeO, and either free from or with 2–3 per cent. of magnesia.

Jeffersonite contains both Zn (ZnO 10) and Mn (MnO 7–10) in addition to Ca or Fe.

The aluminous augites include most of the crystallised green, brown, and black varieties found in volcanic and crystalline rocks, and are in no way distinguishable externally from the non-aluminous varieties. The principal kinds are *Fassaite*, *Omphacite*, *Pyrgom*, and *Augite* proper. The amount of Al_2O_3 may vary from 2 to 8 per cent., the colour being determined by the proportion of iron, as in the previous instances.

Chrome diopside, a green augite, occurring with bronzite and olivine in olivine rocks, contains 4–7 per cent Al_2O_3 and 1·5–2·5 per cent. Cr_2O_3. These are referred to the normal silicate type by supposing Al to be present as AlO_3, and not combined as a silicate.

Achmite and *Ægirine*, which contain Na as well as Fe and Fe, are nearly allied crystallographically to augite. The former is remarkable for the long pointed character of its crystals.

The following are examples of complete analyses of types of the several varieties:

	SiO_2	Al_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	H_2O
Salite	55·11	—	0·54	—	25·63	18·39	—	—	—
Green Diopside	48·02	2·67	13·57	1·21	25·34	9·74	—	—	—
Diallage	53·60	1·99	8·95	0 28	21·06	13·08	—	—	0·86
Hedenbergite	49·01	—	26·43	—	20·87	2·98	—	—	—
Aluminous Diopside	51·50	6·15	0·35	—	23·80	17·69	—	—	1·10
Augite (Fassaite)	49·40	6·70	7·83	—	21·88	13·06	—	0·74	0·50
Achmite	51·16	28·28	5·23	0·69	—	—	0·43	12 46	0·39
Ægirine	50·03	28·68	1·98	1·52	1·42	1·33	—	12·20	1·05

(Fassaite): Fe_2O_3 6·70

Breislakite is a fibrous variety occurring in single hair-like fibres or felted masses in cavities in the older lavas of Etna. It fuses to a black slag. The exact composition is undetermined. *Mountain cork* is a fibrous felted variety analogous to asbestus.

The fusibility of augite varies very considerably. The varieties that melt easily in the forceps are Achmite and Ægirine, which give a yellow soda flame. Hedenbergite, common augite, Jeffersonite, salite and diopside represent a series in diminishing order of fusibility, diallage being almost infusible. The fusibility is obviously conditioned by the nature of the bases, those containing alkalies and ferrous oxide being the least, and those with alumina and magnesia the most refractory. According to composition, reactions of

iron and manganese are obtained with fluxes. Jeffersonite gives a zinc incrustation with soda on charcoal. The lighter coloured varieties often give the magnesia reaction with cobalt solution. None of the varieties are sensibly affected by acids at a moderate heat, those containing alumina being decomposed with difficulty by sulphuric acid at 250° C.

Occurrence.—The typical associations of the augite group are with garnet and other basic silicates in crystalline limestones, and with Labradorite and leucite, nepheline, olivine, and magnetite in the doleritic class of lavas. Diopside in nearly transparent white crystals is found at Ala and Traversella in Piedmont. Salite with galena and geocronite at Sala in Sweden. Fassaite is a bright green and crystallised variety from Fassathal in Tyrol. Black augite in small brilliant and perfect crystals is common among the ejecta of Vesuvius and Etna, and also occurs in the tertiary volcanic districts of Bohemia and Auvergne. Diallage is found in serpentines, and with plagioclase felspars in the rock known as gabbro. By partial hydration augite may be altered into serpentine or steatitic substances, and with the accession of alkalies into green earth, the latter being usually attended with the formation of calcite. By the action of sulphurous acid vapours in volcanic fumaroles, crystals are sometimes converted into nighly siliceous pseudomorphs, the greater part of the alumina and other bases being removed as sulphates.

The terms *augite* and *pyroxene*, and the corresponding adjectives *augitic* and *pyroxenic*, as general terms cover all varieties. The first is most generally used in England and Germany, and the latter in France and Southern Europe.

WOLLASTONITE. Tabular Spar.—*Oblique.* ∞P, 87° 28′, β=69° 48′, $a : b : c$=1·137 : 1 : 4831. In complex crystals, tabular to 100, or twinned on the same plane, which are not very common, usually in cleavable or fibrous masses. Cleavage, 100 and 001 perfect, 101 and $\bar{1}01$ interrupted. H. 4·5–5. Sp. gr. 2·78, 2·90. Colour, white, grey, or slightly tinted with

red, yellow, or brown. Lustre, vitreous, pearly on cleavage face. Sub-transparent, translucent. Fracture, uneven. Tough. Double refraction negative. Plane of optic axes, 010. $2E = 70° 40'$ (red), median line makes an angle of 32° 10′ with the clino-diagonal in front.

Composition.—$CaSiO_3$, or lime 48·3, silica 51·7 per cent. Usually contains MgO and FeO in small quantities (under 1 per cent.).

Fusible to a clear glass by a strong heat, and more readily with a small addition of soda, but with a larger quantity forms an infusible scoriaceous mass. Decomposed by hydrochloric acid with separation of gelatinous silica. Usually effervesces slightly from a partial decomposition and conversion into carbonate.

Occurrence.—Chiefly in granitic rocks and crystalline limestones, especially near the contact with igneous and volcanic rocks; in the Laurentian limestones of Grenville in Canada; Cziklowa in the Banat; the Cliff Mine, Lake Superior; and the Mourne Mountains, Donegal, are other well-known localities, but it is very widely distributed in other places.

PECTOLITE is a hydrated silicate, analogous in form to Wollastonite, usually found in parallel or radiated fibrous aggregates, several inches, or in some cases two or three feet, long. H. 5. Sp. gr. 2·78. Lustre, silky. Colour, snow-white. Opaque. Very tough.

Composition.—Probably $HNaCa_2Si_3O_9 = H_2SiO_3 + Na_2SiO_3 + 4(CaSiO_3)$, or water 2·71, soda 9·33, lime 33·74, silica 54·22 per cent. This makes the composition similar to that of Wollastonite. If the water is assumed to be uncombined, the formula becomes less simple. Heated in the closed tube yields water, and in the forceps fuses readily to a white enamel, except the weathered varieties, which are often infusible. Decomposed by hydrochloric acid with separation of flocculent silica; but when previously heated, it gelatinises.

Occurrence.—In cavities and fissures in volcanic and other igneous (trappean) rocks at Ratho near Edinburgh; Ballantrae, Ayrshire; in Skye; and Bergen Hill, New Jersey, associated with prehnite and zeolites.

SPODUMENE. Hiddenite.—*Oblique.* ∞P 87°, $a : b : c =$ 1·124 : 1 : 0·635, $\beta = 69° 40'$. Crystals usually tabular to 100, and elongated vertically. Twins on 100 common. Cleavages, 100 and 110 perfect, 011 imperfect. Also in masses with broad cleavage planes (100). H. 6·5–7. Sp. gr. 3·16–3·20. Transparent, translucent, opaque. Lustre, vitreous, pearly. Colour, emerald-green, amethystine, pink, grey or white; streak, white.

Composition. — $Li_2Al_2Si_4O_{12}$, corresponding to lithia 8·05, alumina 27·54, silica 64·41 per cent., closely represents the purest kinds, in which Li_2O varies from 6·75 to 7·62 per cent. Usually some Na_2O, CaO, or FeO present. Cr_2O_3 has been found in the green variety.

When heated, melts; colours flame red, and melts to a nearly colourless glass. The lithia flame colouration may be intensified by fusion with fluor spar and bisulphate of potash. Not acted on by acids.

Occurrence.—A rare mineral, but found in considerable quantity in some of the few known localities. Hiddenite, the emerald-green variety, is a recent discovery from Alexander County, North Carolina; occurs with emerald in gneiss in perfectly transparent crystals, which have been cut as gems. Spodumene proper is found in granite veins at Uto Island, Sweden; Sterzing, Tyrol; Killiney Bay, Dublin; Norwich, Goshen, and Chesterfield, Massachusetts; and Branchville, Connecticut. At the latter place it occurs in crystals up to four feet long and one foot broad, which are dull white and opaque externally, with a nucleus of the unaltered mineral, of a pale amethyst tint, cleavable into translucent slabs. The next layer, so called, *β* spodumene, contains only one-half of the original proportion of lithia,

3·5 per cent., and is shown by Brush and Dana to be a microscopic mixture of fibrous albite and a new compound called Eucryptite, a dibasic lithia silicate. The exterior opaque mass, called Cymatolite, shows a further transformation into fibrous albite and potash mica or granular microcline. Another transformation is into Killinite.

PETALITE is another silicate of lithia and alumina, cleavable to a prism of 87° (H. 6·5. Sp. gr. 2·4–2·56), which, while resembling spodumene in form, is very dissimilar in composition, being the highest silicate known, a bi- or quadri-silicate, of the composition $3Li_2Si_2O_5 + 4Al_2Si_6O_{15}$, with about silica 78, alumina 18, and lithia 3·5 per cent. Principally from Uto, Sweden, in glassy cleavable masses, and in minute crystals—*Castor* or *Castorite*—from Elba. The relation of petalite to spodumene is somewhat analogous to that of the triclinic alkali felspars albite and microcline to anorthite.

ENSTATITE. Bronzite. — *Rhombic.* ∞P, 88° 16′, $a : b : c = 0·97 : 1·0 : 0·585$. Usual combination columnar, {110} {010} {100}, with numerous brachydomes. Cleavage, 110 perfect, 010 and 100 less so. Also in granular or lamellar interspersed masses. H. 5·5. Sp. gr. 3·10–3·30. Colourless, grey, various shades of yellow, green, or brown; streak, white, with a grey or brown cast. Semi-translucent, opaque. Lustre, vitreous, pearly on cleavage surfaces. Semi-metallic or silky, with iridescence in bronzite. Double refraction positive. Plane of optic axes, 010; first median fine axis, *c*; axes very divergent.

Composition.—$MgSiO_3$, or magnesia 40, silica 60 per cent. in enstatite. In bronzite a portion of the MgO is replaced by FeO, 5 to 14 per cent., and CaO up to 2–3 per cent., and in some varieties by Al_2O_3 up to about 5 per cent. The purely magnesian varieties are infusible, and those containing iron nearly so. Neither kind is sensibly attacked by acids.

Occurrence.—Enstatite is found in meteoric stones, in the

olivine bombs of the Eifel volcanoes, and as a constituent of serpentine rocks in Cornwall, and at Lherz in the Pyrenees. At Bamle in Norway crystals of very large size are found with apatite. Bronzite is found under similar conditions, being common in meteorites. A bright green variety occurs in large cleavable fragments in the diamond-bearing detritus of Colesberg Koppje in the Transvaal.

HYPERSTHENE.—*Rhombic.* Approximating in dimensions and forms to bronzite, but differing in the optical characteristics, axis *a* being the first median line of the optic axes instead of *c*. Cleavage, 010 perfect, 110 and 100 imperfect or interrupted. Usually in foliated masses. H. 5–6. Sp. gr. 3·15–3·39. Lustre, pearly or semi-metallic, often with a characteristic iridescence due to symmetrically arranged, minute, interspersed foreign crystals. Colour, dark green, brown, black, to nearly copper-red; streak, grey or brownish grey. Translucent, opaque, brittle.

Composition.—$m(MgSiO_3) + n(FeSiO_3)$. m : n varies from 5 : 1 to 1 : 1. For 2 : 1 the percentage composition is MgO 24·01, FeO 21·7, SiO_2 54·2. Most varieties, however, contain alumina and lime in partial substitution of Mg and Fe.

The more ferruginous varieties are difficultly fusible to a black enamel, yield a magnetic mass on charcoal, and are partially decomposed by hydrochloric acid.

The principal localities are on the Atlantic coast of Labrador, the Isle of Skye, Greenland, Bamle in Norway (in very large crystals with apatite), and the volcanic districts of Auvergne and the Eifel. With Labradorite it forms the rock Hypersthenite and Norite. The dark brown iridescent varieties are sometimes cut and polished for ornamental purposes.

RHODONITE. Kieselmangan, Horn Manganese.—*Triclinic*, but closely approximating in form to augite. Crystals rare, usually massive. Cleavage, 110 perfect, 001 less so. The

angle between the cleavage faces is 87° 38′. H. 5·5–6·5. Sp. gr. 3·4–3·68. Lustre, vitreous, horny or pearly. Colour, flesh-red or pink, passing into yellowish red, green, or black; becomes brown by exposure, and is often blackened externally; streak, white. Transparent, mostly sub-translucent or opaque. Fracture, conchoidal, uneven. Very tough.

Composition.—$MnSiO_3$, or manganous oxide 54·2, silica 45·8 per cent. theoretical, but in all cases the silica is in excess, through partial replacement of manganese by calcium. The more highly calciferous kind is called Bustamite, and that with zinc, Fowlerite.

	SiO_2	MnO	FeO	CaO	MgO	(ZnO)
Rhodonite, Langbanshytta .	48·00	49·04	—	3·12	0·22	—
Bustamite, Mexico . . .	50·67	30·73	1·31	16·45	0·73	—
Fowlerite, Franklin, N.J. .	46·70	31·20	8·35	6·30	2·81	5·10

When heated, blackens and fuses with slight intumescence, about as readily as lime, iron, augite, giving manganese reaction with borax. The more calciferous varieties are imperfectly decomposed by hydrochloric acid, and sometimes effervesce, showing partial atmospheric alteration into calcite.

Occurrence.—The principal localities are at Långban and Pajsberg in Sweden; Přibram; Kapnik; and Schatrowa in the Ural. At the latter place it occurs in masses of a delicately shaded red, variegated with black veins (pyrolusite), which are cut into vases and other ornamental objects. At S. Marcel it is associated with braunite, manganese-epidote, and garnet. Pajsbergite and the associated manganiferous garnet Knebelite are used as manganese ores in the production of Spiegeleisen. Fowlerite occurs with Franklinite, and other zinc and manganese minerals, at Franklin, New Jersey. The siliceous variety *horn manganese*, a very intimate mixture of rhodonite and compact quartz, occurs as the vein stuff of silver- and gold-bearing veins in Transylvania, Hungary, and at Salpito in Northern Peru. At the latter places the ores

are very rich, but the vein material is extremely hard and tough.

HORNBLENDE. Amphibole.—*Oblique.* ∞P 124° 30′, $a : b : c = 0{\cdot}5318 : 1 : 0{\cdot}2936$, $\beta = 75°\ 02'$, $b\{010\}\infty\breve{P}\infty$, $c\{001\}\ 0P$, $m\{110\}\ \infty P$, $r\{\bar{1}11\}P$, $o\{\bar{2}21\}2P$, $i\{\bar{1}31\}3\breve{P}3$, $k\{111\}\ -P$, $v\{131\}\ -3P3$, $z\{021\}2\breve{P}\infty$. Twins common on 100. Fig. 85 is the common simple crystal of the type known as basaltic hornblende, and fig. 86 a twin having posi-

FIG. 85.

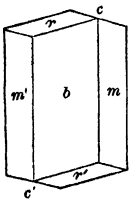
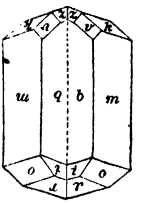


FIG. 86.



ni-pyramids at one end and negative ones at the other, giving an apparent rhombic symmetry when only one end is apparent. Also in elongated prismatic and acicular forms, and fibrous and granular aggregates. Cleavage, 110 perfect; 100 and 010 usually imperfect. Fracture, sub-conchoidal, uneven, rather brittle. H. 5–6. Sp. gr. 2·9–3·5. Colour, white, passing by various shades of green to black. Lustre, vitreous, pearly (cleavages), silky (fibres). Translucent, opaque. Double refraction negative. Index $\beta = 1{\cdot}64$ (approx. for yellow). Optic axes lie in 010, first median line inclined from 1° to 18° to axis c, $2V = 80°$–$85°$. Strongly pleochroic; transmitting green light parallel to maximum, and brown to minimum axis of elasticity.

Composition.—$RSiO_3$, similar to that of augite, and subject to the like qualitative diversity, the isomorphous substitution of different bases providing numerous varieties, which are distinguished by different names, of which the following are the more important.

Tremolite and *Grammatite*, essentially silicates of magnesium and calcium, are white or colourless, affecting columnar or fibrous forms. *Actinolite* in bright green columnar forms, usually in radiated groups, is the type of the non-aluminous hornblendes containing lime and iron in notable quantity. *Smaragdite*, *Pargasite*, and common hornblende, which contain alumina in considerable proportion in addition to dyad bases, range from emerald or bluish green to dark green and black. *Arfvedsonite* is an iron soda hornblende parallel to Achmite and Aegirine in augites. *Asbestus*, *amianthus*, *mountain cork*, and *mountain leather* are fibrous or felted varieties of the lighter coloured and usually non-aluminous kinds. The following are analyses of a few of the leading varieties:

	SiO_2	Al_2O_3	MgO	CaO	FeO	H_2O	Na_2O
Tremolite .	57·62	0·32	26·12	14·90	0·84	1·20	—
Actinolite .	55·50	—	22·56	13·46	6·25	1·29	—
Asbestus .	61·51	0·83	30·93	3·70	0·12	2·84	—
Smaragdite .	52·34	4·32	16·43	14·88	7·39	1·16	2·21
Hornblende .	40·91	13·68	13·19	13·34	17·48	0·85	—
Pargasite .	46·26	11·48	19·13	13·96	3·48	3·47	—
		Fe_2O_3					
Arfvedsonite.	51·22	23·75	0·90	2·08	9·92	—	10·58

Fluorine is sometimes present in considerable quantity, up to 2·86 per cent. in Pargasite.

Chemical characteristics similar to those of augite, the darker varieties being more readily fusible than the lighter ones. With bisulphate of potash in the closed tube a fluorine reaction may often be obtained. The fibrous varieties usually contain a notable quantity of water.

Occurrence.—Hornblende is a common constituent of crystalline rocks, being more particularly associated with the more highly silicated felspars, quartz, chlorite, magnetite, and pyrites. Tremolite is essentially an associate of crystalline limestones and dolomites. It is a principal component of hornblende- and actinolite-schists, the latter being very common in the Swiss and Tyrolese Alps. With the felspar

group it forms the rocks known as diorites and syenites; and with these and quartz, hornblendic granites and trachytes. Asbestus is commonly associated with serpentine.

Uralite is of the form of augite, but has the fibrous structure and cleavages of hornblende; internally the crystals often contain nuclei of augite, showing it to be a product of the alteration of the latter. It occurs in the porphyries of the Ural, of Predazzo in Tyrol, and of North Wales.

Nephrite is probably a compact variety of Tremolite. H. 6·5. Sp. gr. 2·97–3·00. Colour, white, grey, or green. Translucent. Lustre, greasy. It is remarkable for its toughness and hardness, the small number of localities in which it occurs, China, Tibet, Turkestan, and New Zealand, and also for its wide diffusion over Europe in prehistoric times, when it was used, as it still is, for ornamental carvings.

Pseudomorphs after hornblende have been observed in jasper, chlorite, steatite, and serpentine, the first being a case of complete substitution, and the others of partial transformation by hydration and removal of lime.

The only variety of hornblende directly of economic value is asbestus, which can be carded and spun like flax or cotton, and is largely used for steam-engine packings, fireproof cloth, and mill-boards, and as a filtering material for chemical purposes, it being unchanged by heat or mineral acids. The supply is chiefly derived from Italy and Canada. The hornblendic granites are generally tough, strong, and durable as building or paving materials.

The term *hornblende* is generally adopted by English, German, and Scandinavian writers, while in France and Italy *amphibole* is mostly used.

The crystallographic series of augite and hornblende are linked by a common form, the prism of 124° 30′, which is {110} in the latter and {210} in the former species, and in this sense they are isomorphous. The dimorphism is, however, apparent from the great diversity in physical characteristics, and also from differences in composition.

These differences, which are of value in discriminating between the species microscopically, are as follows. *Augite* shows prominently the nearly rectangular prism of 87° and 93°, and cleavages parallel to it. The crystals are usually short columnar, and rarely elongated or fibrous. It commonly contains lime in all varieties. For similarity of bases the density is about 10 per cent. greater than that of the corresponding kind of hornblende.

Hornblende is essentially a magnesian silicate, being sometimes free from lime, and when of similar composition is of lower density than augite. It affects the acute rhombic prism and cleavages of 124° and 56°, is very commonly elongated, columnar, or fibrous in habit, and is strongly pleochroic.

For any section of augite elongated parallel to the vertical axis the direction of maximum extinction in parallel polarised light may be inclined from 0° to 39° to its length, while in similar sections of hornblende the range is from 0° to 15° only.

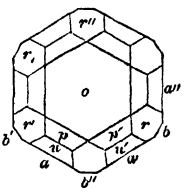
ANTHOPHYLLITE.—*Rhombic.* ∞P 125°, having the same polysymmetric relation to hornblende that Enstatite has to augite. Cleavages, 100, 110, and 010, the first most and the last least perfect. H. 5·5. Sp. gr. 3·19–3·23. Colour, brown or yellowish grey. Optically distinguishable from hornblende by the fact that the first median line of the optic axes which lie in 010 is the vertical axis.

Composition.—$nM_9SiO_3 + FeSiO_3$; n = 2, 3, or 7. From Kongsberg and Modum, in Norway.

BERYL. Emerald, Smaragd.—*Hexagonal.* Z=59° 53′, $a : c$=1 : 0·499 (fig. 87), a {10$\bar{1}$0} ∞P, b {11$\bar{2}$0} $\infty P2$, p {10$\bar{1}$1} P, u {20$\bar{2}$1} $2P$, r {11$\bar{2}$1} $2P2$, o {0001} oP. Crystals long columnar, flat-ended, prism faces usually striated vertically, and the pyramids, though numerous, being very subordinate in development, {12$\bar{3}$1} sometimes present with full

hexagonal symmetry. Cleavage, 0001 and 10$\bar{1}$0; neither very perfect. Fracture, conchoidal. H. 7·5–8. Sp. gr. 2·63–2·76. Lustre, vitreous. Colourless and transparent, pale green, blue, or yellowish, translucent to opaque, in beryl and aquamarine, transparent and bright grass-green in emerald. Double refraction negative and feeble. Indices for yellow, $\omega = 1{\cdot}5703, \epsilon = 1{\cdot}5659$, requiring thick sections to show interference figures, which are often distorted, producing pseudo-biaxial figures. In parallel polarised light the structure is very unhomogeneous, resembling that of strained glass.

FIG. 87.



Composition.—$3(BeSiO_3) + Al_2Si_3O_9$, or glucina (BeO) 14·11, Al_2O_3 19·05, SiO_2 66·84 per cent. Usually some lime and ferric oxide, and in emerald traces of chromic oxide are present.

Almost infusible; the edges of a thin splinter may be rounded by long-continued heating, transparent and colourless varieties becoming opaque by heat. With borax, beryl gives colourless and emerald-green (chromium) beads. Becomes opalescent in salt of phosphorus. Fumes with soda to a slaggy mass, in some cases a minute quantity of tin being reduced. Not acted on by acids.

Occurrence.—Beryl is tolerably widely distributed in granite and crystalline rocks, principal localities being Miask and Nertschinsk in Russia; the Mourne Mountains, Ireland; Limoges; Elba; and Grafton, New Hampshire. At the latter place enormous crystals, 2 feet over the base and 4 feet long, estimated at 2½ tons weight, have been observed in the rock. Fine emeralds for jewellery are chiefly got from Muzo near Bogota in Ecuador, where they are found in nests and druses with Parisite and calcite in a black limestone of Jurassic age. A famous ancient locality is Jebel Zabara in the Nubian desert, between Syene and Berenice.

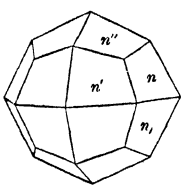
The colour of emerald has been attributed by different

observers to an organic compound analogous to chlorophyll, and to chromic oxide; the latter is the more probable.

The pale coloured and colourless crystals are cut into gems under the name of *aquamarine* and *beryl*, but are much inferior in value to emeralds. The coarse opaque crystalline masses are used as a source of glucina in chemical laboratories.

LEUCITE. Amphigène.—In forms closely approximating to {211} of the cubic system, which are considered by Vom Rath as tetragonal, $X=130°\ 03'$, $a:c=1:0{\cdot}5264$, $n''\{111\}P$, $n'n\{421\}4P2$; and by Weisbach and Mallard as rhombic, with $Z=70°\ 49'$, $X=130°\ 43'$, $Y=132°\ 33'$, $a:b:c=0{\cdot}9650:1:0{\cdot}4936$, $n''\{111\}P$, $n'\{421\}4\breve{P}2$, $n\{241\}4\breve{P}2$. Cleavage, parallel to (apparent) cube faces, imperfect. Fracture, conchoidal. H. 5·5–6. Sp. gr. 2·45–2·50. Lustre, vitreous to greasy, semi-transparent, translucent on edges. Opaque. Colour, white, ash-grey, yellowish and reddish white. Double refraction positive, very weak. $\omega=1{\cdot}508$, $\epsilon=1{\cdot}509$. In parallel polarised light, sections show a tesselated or lattice-like structure; and the substance is rarely homogeneous, layers of augite crystals and other foreign substances being symmetrically included.

FIG. 88.



Composition.—$K_2SiO_3+Al_2Si_3O_9$, or K_2O 21·53, Al_2O_3 23·50, SiO_2 54·97 per cent. Usually some of the alkali is soda, 1 to 6 per cent., the actual contents of potash varying from 12·5 to 20·5 per cent.

Infusible, giving the alumina frit with cobalt solution, and transparent glasses with borax and soda. Completely decomposed by hydrochloric acid, with separation of granular silica.

Occurrence.—A characteristic constituent of the lavas of Vesuvius, and the dormant volcanoes of the neighbourhood

of Rome and the Eifel, also found in loose crystals among volcanic ashes. Owing to the large proportion of alkaline silicate it is not very stable, and may be found in various stages of alteration; the principal change being hydration, with the removal of potash and substitution of soda, giving a substance analogous to analcime. By mere hydration and loss of potash it is convertible into orthoclase and china clay. The interpretation of the form as tetragonal is now commonly though not universally accepted; the principal evidence in its favour is in the occurrence of twin striations parallel to the (apparent) rhombic dodecahedron, which is an impossible twin face in the cubic system.

DIBASIC SILICATES, ORTHO-SILICATES, UNI-SILICATES.

The type of composition R_2SiO_4 is represented in its simplest form by two groups of minerals with well-marked crystallographic characters, the first, represented by Olivine, being rhombic, and the second, which are hexagonal with rhombohedral tetartohedrism, by Dioptase.

OLIVINE GROUP—RHOMBIC DIBASIC SILICATES.

OLIVINE. Peridot, Chrysolite.—*Rhombic.* ∞P 94° 03′, $a : b : c = 0{\cdot}932 : 1 : 1{\cdot}1733$ (figs. 89-92). $a\{010\}\ \infty \breve{P}\infty$, $b\{100\}\ \infty \bar{P}\infty$, $c\{001\}\ oP$, $d\{101\}\ \breve{P}\infty$, $e\{212\}\ \breve{P}2$, $f\{111\}\ P$, $l\{232\}\ \frac{3}{2}\breve{P}\frac{3}{2}$, $k\{011\}\ \bar{P}\infty$, $i\{021\}\ 2\bar{P}\infty$, $h\{012\}\ \frac{1}{2}\bar{P}\infty$, $s\{110\}\ \infty P$, $r\{230\}\ \infty \breve{P}\frac{3}{2}$, $n\{210\}\ \infty \bar{P}2$. Crystals short columnar, or

FIG. 89.

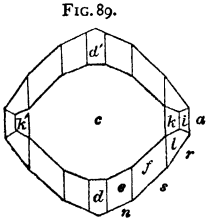
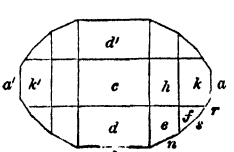


FIG. 90.



rounded from equal development in three principal zones, or chisel-edged by predominance of 021. Usually in irregular

granular masses. Cleavage, 010 and 100 imperfect. Fracture, conchoidal. H. 6–7. Sp. gr. 3·23–3·56. Transparent, translucent. Lustre, vitreous. Colour, white, yellowish, brown,

FIG. 91.

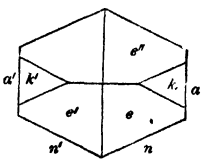
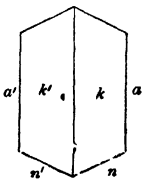


FIG. 92.



olive- or bottle-green; streak, white. Double refraction positive; indices for red, $\alpha=1{\cdot}661$, $\beta=1{\cdot}678$, $\gamma=1{\cdot}697$. Optic axes lie in 001; first median line axis a, $2V=87°\ 46'$.

Composition.—$nMg_2SiO_4 + Fe_2SiO_4$; the value of n varies from 12 to $\frac{1}{2}$. The following are some of the principal types:

	Mg : Fe	MgO	FeO	SiO_2
Chrysolite .	9 : 1	49·18	9·84	40·98
Olivine . .	6 : 1	46·0	13·73	40·27
Hyalosiderite .	2 : 1	33·06	29·7	37·20

Some varieties contain manganese, lime, and titanium. Small quantities of nickel, copper, tin, and fluorine are commonly found.

Infusible except the more ferriferous varieties, which melt to black magnetic globules. Gives iron, and sometimes manganese reaction with borax. Decomposed by hydrochloric and sulphuric acid, the ferriferous kinds most readily, with separation of gelatinous or granular silica.

Occurrence.—Essentially characteristic of volcanic rocks, being common in basalt, dolerite, and similar lavas, both ancient and modern; also in the unmelted fragments ejected from volcanoes in the Eifel, and in the stony base of meteorites, associated with enstatite and bronzite. It is very liable to alteration by hydration, which changes it into serpentine,

the so-called crystals of the latter substance being really pseudomorphs after olivine. The ferrous silicate is simultaneously altered to limonite, producing the rusty stains which are commonly seen in olivine basalts.

The transparent green crystals from Egypt and Brazil are cut into gems under the names of *Chrysolite* and *Peridot.* The latter may have a slight resemblance to emeralds, but are of a darker and less brilliant green colour.

Försterite, or *White Peridote*, is almost pure, Mg_2SiO_4 containing MgO 55·09, FeO 2·54, SiO_2 42·37. H. 7. Sp. gr. 3·24. It is found at Monte Somma in small, brilliant, colourless crystals, which are similar in form and dimensions to olivine.

Fayalite is essentially iron olivine, Fe_2SiO_4 (FeO 70·59, SiO_2 29·41 per cent.). Found at Fayal, in the Azores, and the Mourne Mountains, Ireland. An artificial crystallised product of the same composition is exceedingly common in the slags of puddling furnaces, the crystals (figs. 91, 92) forming tabular combinations of 110, 021, 010, which are dark coloured and opaque, except when very thin, when they transmit a dark green light. The opacity is as a rule increased by finely interspersed magnetic oxide of iron. Easily fusible and readily decomposed by hydrochloric acid.

Monticellite and *Batrachite* are lime magnesia olivines of the composition $Ca_2SiO_4 + Mg_2SiO_4$, with $\frac{1}{3}$ of the bases replaced by FeO, giving CaO 35·5, MgO 22, and FeO 5·63 per cent. The form approximates very closely to that of olivine. The former is from Vesuvius, and the latter from Mount Rinzoni, Tyrol. They are liable to change into Fassaite, augite, or serpentine.

TEPHROITE.—Massive, with three rectangular cleavages. Fracture, conchoidal—uneven. H. 5·5. Sp. gr. 4·12. Colour, dark grey, brownish red, or black. Some varieties are essentially Mn_2SiO_4, or MnO 70·3, SiO_2 29·7 per cent. Others contain MgO in different proportions, from 1·35 up to 21 per cent.; the latter is nearly $Mg_2SiO_4 + Mn_2SiO_4$.

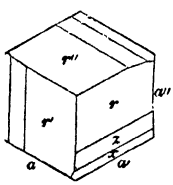
Zinc is also found up to a maximum of 12 per cent., which is, however, attributed to intermixed red zinc ore, with which it is associated at Franklin and Stirling, New Jersey.

Knebelite, $Fe_2SiO_4 + Mn_2SiO_4$, or FeO 35·47, MnO 35·97, SiO_2 29·56, found at Persberg, in Sweden, is utilised as a source of Spiegeleisen and ferro-manganese.

Dioptase Group. Hexagonal Dibasic Silicates.

Dioptase.—*Hexagonal with rhombohedral tetartohedrism.* $R = 125° 54'$, $a : c = 1 : 0{\cdot}5281$ (fig. 93), $r\kappa\{02\bar{2}1\} - 2R$, $a\{11\bar{2}0\}\infty P2$, $z\kappa\pi\{13\bar{4}1\}\ \frac{1}{4}(4P\frac{4}{3})$, $x\kappa\pi\{17\bar{8}3\}\ \frac{1}{4}(\frac{8}{3}P\frac{8}{7})$. The last two forms, usually very subordinate, sometimes only appearing as striations on alternate middle edges of *r*. Cleavage, $10\bar{1}1$ very perfect. Fracture, conchoidal. Brittle. H. 5. Sp. gr. 3·28–3·35. Transparent—translucent. Lustre, vitreous. Double refraction, positive. Indices for D line, $\omega = 1{\cdot}667$, $\epsilon = 1{\cdot}723$. Colour, between emerald- and verdigris-green.

Fig. 93.



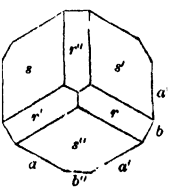
Composition.—H_2CuSiO_4, or H_2O 11·44, CuO 50·44, SiO_2 38·12 per cent. Gives off water when heated in the closed tube above 400°, turning black. In the forceps colours the flame green, and gives copper reactions with fluxes. Gelatinises with hydrochloric acid, decomposed by ammonia or carbonate of ammonia, giving a blue solution.

Occurrence.—With quartz and calcite in limestone in the Kirghiz steppe, and has recently been found at copper mines in Arizona and Colorado. The crystals from the first locality are very brilliant, and have been mistaken for emerald, from which they are distinguishable by the peculiar bluish green, lower hardness, and rhombohedral habit, emerald crystals being prominently hexagonal. Formerly it was considered to be a hydrate of the normal silicate, or $CuSiO_3 + H_2O$, but the fact that it requires a strong heat to drive off the water, which is not taken up again by exposure, and the analogy

of the form with that of Willemite and Phenakite, shows the hydrogen to be present in the basic form.

WILLEMITE. Troostite.—*Rhombohedral.* $R = 128° 30'$ $a : c = 1 : 0{\cdot}5054$ (fig. 94), $r\{10\bar{1}1\}R$, $s\{02\bar{2}1\} - 2R$, $b\{10\bar{1}0\}\infty P$, $a\{10\bar{2}0\}\infty P2$,[1] also in massive, rounded, granular, and fibrous forms. Cleavage, 0001, $10\bar{1}0$, the former most perfect. Fracture, conchoidal. Brittle. H. 5·5. Sp. gr. 3·9–4·27. Colour, white, yellowish, or apple-green, passing into brown and darker tints, when manganiferous. Lustre, vitreous or resinous. Transparent, usually translucent to opaque, showing positive double refraction.

FIG. 94.



Composition.—Zn_2SiO_4, or ZnO 72·97, SiO_2 27·03 per cent. The zinc may be partially replaced by manganese in various proportions in the American variety called Troostite; the proportion of MnO is from 3·75 to 12·5 per cent., with a corresponding diminution of ZnO.

Difficultly fusible; the edges of a thin splinter may be rounded in the oxidising flame. May be reduced on charcoal, producing an incrustation of zinc oxide by heating with an addition of soda and borax, but not with soda alone. Decomposed by hydrochloric acid with separation of gelatinous silica. The strongly coloured varieties give iron and manganese reactions.

Occurrence.—In irregular masses of a yellowish brown colour, showing small brilliant crystals in the hollows, at Vieille Montagne, and in pale green lamellar grains intimately mixed with Franklinite or red zinc ore in the New Jersey zinc deposits. It is a valuable mineral, as, although requiring a high temperature for reduction, it produces a very pure quality of zinc, being free from lead. Troostite is found in crystals several inches in length.

[1] If $R = 116°$ and $a : c = 1 : 0{\cdot}6738$, $r\{40\bar{4}3\}\frac{4}{3}R$, $s\{03\bar{3}2\} - \frac{3}{2}R$. This latter view is more generally adopted.

PHENAKITE.—*Rhombohedral.* $R = 116° 36'$, $a : c = 1 : 0{\cdot}661$ (fig. 95), $a\{11\bar{2}0\}\infty P2$, $r\{10\bar{1}1\}R$, $p\{11\bar{2}3\}\frac{2}{3}P2$. The latter form has its full number of faces, but there are several others of the same class besides scalenohedra which appear as tetartohedral rhombohedra in the more complex

FIG. 95.

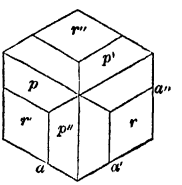
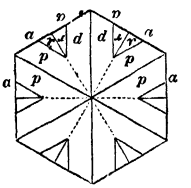


FIG. 96.



combinations. Crystals, short columnar or pyramidal. Twins on $10\bar{1}0$ with complete penetration (fig. 96). Cleavage, $r\{10\bar{1}1$ and $11\bar{2}0$; neither perfect. Fracture, conchoidal. H. 7·5–8. Sp. gr. 2·96. Colourless and transparent, yellowish white, yellow, or greenish yellow. Lustre, vitreous. Transparent to translucent.

Composition.—Be_2SiO_4, or glucina 45·78, silica 54·22 per cent. Infusible, and not acted upon by acids. Dissolves slowly when treated in salt of phosphorus, leaving a silica skeleton. With cobalt solution gives a dirty blue-grey colouration.

Occurs at Framont, in Lorraine; in the Ural, in mica schist; at Miask, in granite veins; and with topaz, amazon stone, and magnetite at Durango, in Mexico. The larger masses and crystals from the Russian localities are sometimes cut as gems, which resemble colourless topazes or rock crystal, but have a higher lustre.

HELVINE. Tetrahedral Garnet.—*Cubic, tetrahedral.* In tetrahedra and spheroidal aggregates. Cleavage, tetrahedral, imperfect. Fracture, uneven. H. 6–6·5. Sp. gr. 3·16–3·37. Lustre, vitreous or greasy. Colour, yellow, varying to brown

and yellowish green; streak, white. Translucent on thin edges.

Composition.—$2(MnFe)S + 3(BeMnFe)_2SiO_4$. An analysis by Rammelsberg of a specimen from Norway gave: S 5·71, SiO_2 33·13, BeO 11·46, MnO 49·12, FeO 4·00, total 103·42. The apparent excess is due to the metals existing partly as sulphides, whereas they are estimated as oxides. To correct it, oxygen equal to half the amount of sulphur, or 2·85, must be subtracted.

Fusible with effervescence to a yellowish brown opaque bead. Gives the reactions of manganese with fluxes. Gelatinises with hydrochloric acid, giving off sulphuretted hydrogen.

Found at Schwarzenberg and Breitenbrünn, in Saxony; Modum and Brevig, in Norway, in zircon syenite; and near Otuzco, in Peru.

Danalite is a mineral of similar constitution, but octahedral in habit, and containing a notable quantity of zinc in addition to glucinum, iron, and manganese. The crystals are in grey or flesh-coloured octahedra modified by ∞O. H. 5·5. Sp. gr. 3·57. The composition is given as follows: SiO_2 31·73, FeO 27·40, MnO 6·28, ZnO 17·51, BeO 13·83, S 5·48, total 102·23. Correction for excess of oxygen, 2·74. Readily fusible to a black enamel, otherwise behaves like helvine. Found in granite at Rockport and Gloucester, Massachusetts.

The position of these minerals in uncertain. In physical characters and habit they are closely related to garnet, while the composition is similar to that of the olivine group, with the addition of a proportion of metallic sulphides. The latter condition appears to be represented in Fayalite from the original locality in the Azores, which only gives the olivine formula after the deduction of 3·5 per cent. of ferrous sulphide.

GARNET GROUP.

GARNET. Granat, Grenat.—*Cubic.* (Figs. 97, 98.) $d\{110\}\infty O$, $n\{211\}2O2$, $s\{321\}3O\frac{3}{2}$. 110 and 210 occur as simple forms, the first very commonly, 111 is rare. No twin forms observed. Cleavage, 110 imperfect. Fracture, conchoidal, granular, or uneven. Crystals often completely developed, and included in rocks, also grouped in druses, in rounded masses and grains, lamellar and massive aggregates; the latter often without any apparent crystalline characters. H. 7–7·5. Sp. gr. 3·16–4·38. Magnesian kinds lightest, manganiferous densest. Colour, very variable, including the whole spectrum with the exception of blue. The most

FIG. 97.

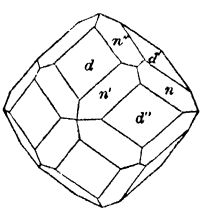
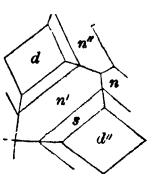


FIG. 98.



characteristic colours are crimson, brownish red (similar to that of the pomegranate flower, as the name implies), passing by lighter tints through hyacinth-red, orange- and sulphur-yellow, to nearly white, and in the other direction by chestnut- and smoke-brown to nearly black. Among the varieties are dark or brownish violet, and emerald- or bluish-emerald-green; pale green, deep bottle-green, or black being among the less translucent kinds. Most of the coloured varieties are distinguished by special names. Streak, white. Transparent—opaque. Lustre of crystal, vitreous; of surfaces of fracture, resinous. Refractive index, 1·77 for red light, in transparent red variety. Many varieties show irregular double refraction.

Composition.—The whole of the minerals included under the general name of Garnet may be referred to the dibasic silicate type, being represented by the expression $\overset{II}{R_3}\overset{VI}{R}Si_3O_{12}$ $=3R_2SiO_4RSi_3O_{12}$. According to the nature of the bases they may be classified into the following fundamental types :

I. Alumina garnets.	II. Iron (ferric) garnets.	III. Chrome garnets.
a. $Ca_3AlSi_3O_{12}$	*a.* $Ca_3FeSi_3O_{12}$	*a.* $Ca_3CrSi_3O_{12}$
b. $Mg_3AlSi_3O_{12}$	*b.* $Mg_3FeSi_3O_{12}$	*b.* $Mg_3CrSi_3O_{12}$
c. $Fe_3AlSi_3O_{12}$	*c.* $Fe_3FeSi_3O_{12}$	*c.* $Fe_3CrSi_3O_{12}$
d. $Mn_3AlSi_3O_{12}$	*d.* $Mn_3FeSi_3O_{12}$	*d.* $Mn_3CrSi_3O_{12}$

The corresponding percentage compositions are as follows :

I.				II.				III.			
	RO.	Al_2O_3	SiO_2		RO.	Fe_2O_3	SiO_2		RO.	Cr_2O_3	SiO_2
a.	CaO. 37·28	22·77	39·95	*a.*	CaO. 33·07	31·50	35·43	*a.*	CaO. 33·60	30·40	36·00
b.	MgO. 29·81	25·48	44·71	*b.*	MgO. 26·09	34·78	39·13	*b.*	MgO. 26·55	33·63	39·82
c.	FeO. 43·32	20·58	36·10	*c.*	FeO. 38·85	28·78	32·38	*c.*	FeO. 39·42	27·74	32·85
d.	MnO. 42·98	20·70	36·32	*d.*	MnO. 38·52	28·93	32·55	*d.*	MnO. 39·08	27·89	33·03

Of these compounds only three, Nos. I. *a*, I. *c*, and II. *a* appear as independent minerals, the greater number of garnets being isomorphous mixtures in variable proportions of the compounds in the series I. and II. The chrome garnets are combinations of members of the groups I. and III.

The following analyses show the range of composition actually observed :

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	Cr_2O_3	MgO	CaO	Approximate type formula.
Pale red, Mexico	39·46	21·69	1·36	—	—	—	0·67	35·75	I*a*
Bright red, Sweden	41·00	20·10	—	28·81	2·88	—	6·04	1·50	5(I*c*)+2(I*a*)
Dark red, Vosges	41·56	19·84	5·33	4·37	—	0·35	22·00	4·25	I*c*
Green, Zermatt	36·03	1·24	30·05	—	—	—	0·54	32·14	II*a*
Pale green (Grossularia)	40·55	20·10	5·00	—	0·48	—	—	34·86	7(I*a*)+(II*a*)
Black, Arendal	40·20	6·95	20·50	—	4·00	—	—	29·48	2(II*a*)+I*a*
Spessartine	36·16	19·76	—	11·10	32·18	—	0·22	0·58	3(I*d*)+I*c*
Uwarowite	36·93	5·68	—	1·76	1·54	21·84	—	31·63	5(III*a*)+2(I*a*)
Pyrope	41·35	22·35	—	9·94	2·59	4·45	15·00	5·29	1*a* +3(I*b*)+I*c* +III*b*

The following are the special names applied to the leading varieties:

Grossularia. Pale green, yellowish or asparagus-green, translucent crystals, essentially of the lime-alumina type, with about 5 per cent. of ferrous oxide. The typical locality is Wilui River in Siberia.

Essonite, Hessonite, or *Cinnamon Stone.*—Resembles the preceding, but with less iron, being the purest variety of the lime-alumina class. Includes all the pale red, yellow, and cinnamon-brown kinds. The largest and brightest examples used in jewellery are brought from Ceylon. The most interesting crystallised specimens of a delicate red tint occur with diopside and chlorite, at Ala; and a bright yellow, opaque, compact kind at the manganese mine of S. Marcel in Piedmont. A rare bright green mineral from Bobrowska, in the Urals, supposed to be a garnet of this type, is very similar in colour to emerald when polished.

Magnesia-Alumina Type.—This is never met with in a pure or approximately pure condition, the most highly magnesian varieties invariably containing sufficient manganese, chromium, or iron in either state of oxidation to impart a strong colour. The black magnesian garnet of Arendal, and the Bohemian garnet or Pyrope used in jewellery, are of this kind. The latter is of a deep red, with fiery reflections in a strong light, and contains iron, manganese, and chromium, it being doubtful whether the latter is present as CrO or Cr_2O_3. It is found embedded in serpentine and in loose grounds from the weathering of the contained rock at Zöblitz in Saxony, and Meronitz and Podsedlitz in Bohemia.

Almandine, or precious garnet, is essentially an iron (ferrous) alumina garnet (type I*c*), including all the fine bright and deep red transparent varieties other than Pyrope. Darker coloured, imperfectly translucent, and opaque kinds of this composition form a considerable proportion of the common garnets found in rocks. *Allochroite* is a compact variety.

The lime iron (ferric) garnets include varieties of pale or bright yellow, green, brown, or black, much of the common garnet being included. The bright yellow variety known as *Topazolite*, from Mussa in Piedmont, occurs in very obtuse hexakisoctahedra, whose edges appear as little more than striations upon the faces of a rhombic dodecahedron. *Colophonite* is a yellowish brown granular kind from Norway, resembling resin. *Melanite* and *Pyrenæite* are black crystallised varieties from Vesuvius and the Pyrenees. *Aplome* is of a dark brown colour.

Spessartine is a dark red manganese-alumina garnet, from Spessart in Bavaria, S. Marcel and Haddam, Connecticut.

Uwarowite, or lime-chromium garnet, occurs in dark emerald-green, rhombic dodecahedra, with chromic iron ore at Bissersk in the Ural. An opaque grass-green, chrome-green garnet is also found at Orford, Canada.

When heated, most garnets fuse more or less readily to a green, brown, or black glass. The lime-iron, except the iron be first reduced to the ferrous condition, and the lime-chrome varieties are most refractory; of the latter, Pyrope blackens when heated, and on cooling becomes yellow, and returns to its original colour; at a very high temperature it may be melted to a black glass. Uwarowite is unaltered by heat, and infusible by the mouth blowpipe. According to the bases present, the reactions of iron, chromium, and manganese are obtained with borax or salt of phosphorus. In the natural condition garnets are but slowly acted upon by acids. The more calcareous kinds gelatinise with hydrochloric acid after being strongly heated, and the others after fusion.

Occurrence.—Garnet is very widely distributed, being found in granites, gneiss, and other schistose rocks, crystalline limestone, serpentine, magnetite, and chromic iron ore. The larger crystals occur either in druses or frequently embedded in mica schist in Tyrol, Norway, Scotland, &c. The Bohemian garnet of Zöblitz is interspersed through dark green

serpentine, forming a rock, which is cut into vases and similar ornamental works.

As a constituent of rock, it forms granulite and eclogite.

The black magnetic sand obtained in gold washing and along the shores of countries where gneissic rocks prevail, almost invariably contains a notable proportion of garnet in minute red grains, which are mostly angular fragments. The massive variety sometimes occurs in bands of considerable thickness, as in the gneiss of Bengal. It is not, however, common in volcanic rocks.

As a whole, garnet may be considered as a stable mineral, the more calcareous varieties being most subject to change. These sometimes effervesce with acids, indicating partial decomposition and the formation of calcite. As pseudomorphs, it occurs altered to chlorite, steatite, and quartz, but not commonly.

Cinnamon stone, Almandine, and Pyrope are used in jewellery. The lighter coloured varieties are usually cut into thin tabular forms with bordering facets; but the bright and deep red kinds are generally polished *en cabochon*, and when very dark are sometimes hollowed behind to allow the penetration of light. The finer coloured stones of this kind are known as *carbuncles*. The name Almandine is generally given to stones of a violet tint. In addition to its ornamental applications, powdered garnet is sometimes used as an inferior substitute for emery; and the common lime-iron variety when sufficiently abundant is a useful flux in smelting iron ores.

From the optical behaviour of various kinds of garnet, Mallard considers that some are not really cubical, but complex aggregates of crystals of lower symmetry, assuming a cubical form. Thus topazolite is considered to be made up of 48 triclinic pyramids whose apices meet at the centre; the complex structure, based upon the planes of the apparent hexakisoctahedron, being evidenced by the striations of the faces and the behaviour of thin sections

under polarised light. In the same way Uwarowite may be rhombic, while Almandine from the same locality as topazolite is both optically and crystallographically cubic.

IDOCRASE. Vesuvian, Egeran.—*Tetragonal.* Z 74° 27′, $a : c = 1 : 0{\cdot}5372$ (figs. 99, 100), $c\{001\}oP$, $u\{111\}P$, $w\{221\}2P$, $r\{441\}4P$, $m\{110\}\infty P$, $f\{210\}\infty P2$, $h\{310\}\infty P3$, $a\{100\}\infty P\infty$, $e\{101\}P\infty$, $i\{321\}3P\frac{3}{2}$, $i\{211\}2P2$, $s\{311\}3P3$, $o\{421\}4P2$, $x\{411\}4P4$. No twin forms known, faces of prisms usually striated vertically.

FIG. 99.

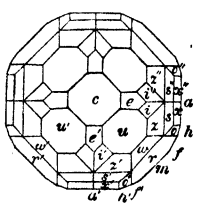
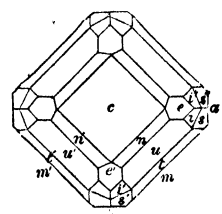


FIG. 100.



Crystals mostly short columnar or pyramidal, often of considerable size, up to 2 inches square on base, singly or grouped in druses. Sometimes in radiated aggregates and granular masses. Cleavages, 110, 100, 001, all imperfect. Fracture, uneven. H. 6·5. Sp. gr. 3·29–3·45 (2·95 after fusion). Transparent to translucent. Lustre, vitreous, greasy. Colour, yellowish-, oil-green, sulphur-yellow, bright, dark brown, turquoise-blue (cyprine). Pleochroic, transmitting grass-green parallel, and yellowish or brownish green perpendicular, to optic axis. Double refraction negative, very feeble. Indices for D line, $\omega = 1{\cdot}722$, $\epsilon = 1{\cdot}720$.

The optical structure is irregular; sections parallel to 001, which must be very thick owing to the feeble refractive energy, showing dislocated ring-systems in convergent sectors, which extinguish perpendicularly to the sides of the base, divided by a dark rectangular cross in parallel polarised light. These suggest the probability of a lower

crystallographic symmetry, the arrangement of the biaxial axes being similar to those of the quasi-tetragonal forms of the oblique system.

Composition.—Somewhat similar to that of a lime-alumina-iron-garnet, with the addition of 2 to 3 per cent. of water and alkalies. The analyses differ too much to admit of their being reduced to any simple formula. The most generalised expression, supposing the water to be basic, is $H_{14}\overset{II}{R}_{40}R_{10}Si_{35}O_{147}$, which, by reducing all the basic metals to their equivalent dyad atomicity, may be written $\overset{II}{R}_{11}Si_5O_{21} = \left\{\begin{matrix} 4R_2SiO_4 \\ R_3SiO_5 \end{matrix}\right\}$. If the water be disregarded the composition may be referred to a dibasic or unisilicate formula, R : Si = 140 : 140. The following analyses are by Rammelsberg :

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	$(Na_2,K_2)O$	H_2O	
Brown, Monzoni	37·32	16·08	3·75	2·91	35·34	2·11	0·16	2·08 =	99·75
Bright green, Ala	38·27	37·15	4·91	0·50	36·31	3·65	0·24	2·49 =	101·67

Loses from 2 to 3 per cent. of water at red heat. Fuses rather more readily than garnet, with intumescence, to a greenish or brownish glass. Not very readily attacked by hydrochloric acid except after fusion, when it gelatinises. The bright blue variety, cyprine, gives, with fluxes, the reaction of copper, and that from S. Marcel of manganese.

Occurrence.—With garnet and augite in crystalline limestones and metamorphic schists in the limestone blocks of Somma, Vesuvius; at Wilui, Siberia; Mount Monzoni, Tyrol; Mussa, and Ala and San Marcel, Piedmont. Cyprine is from Souland in Norway; and Egeran, the compact variety, from Eger and Bohemia.

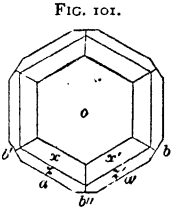
Idocrase crystals are sometimes found wholly or partially changed to steatite; another class of alteration is that into a substance resembling garnet, the crystals being changed into rough granular masses while preserving their general outline. It also happens at times that the crystals

are brown exteriorly, with a green nucleus, the change of the outer portion being due to partial peroxidation of the iron.

Mellilite and *Humboldtilite* are very similar in composition to idocrase, but contain 3·5–4·5 per cent. of alkalies. They are found in the lavas of Vesuvius and Etna in small yellow tetragonal crystals. Square prismatic crystals, with replaced edges, resembling the simpler forms of idocrase, are not uncommonly seen in the slags of blast furnaces in South Staffordshire. These are often of considerable size, and correspond approximately in composition to Humboldtilite.

NEPHELINE. Elaolite.—*Hexagonal.* $Z = 88° 10'$, $a : c = 1 : 0·839$ (fig. 101), $a\{10\bar{1}0\}\infty P$, $b\{11\bar{2}0\}\infty P2$, $x\{10\bar{1}1\}P$, $z\{20\bar{2}1\}2P$, $o\{0001\}oP$. Crystals, short columnar, prisms and basal planes best developed. Cleavage, 1001 and 10$\bar{1}$0 neither perfect. Fracture, conchoidal—uneven. Also in granular masses and thin columnar aggregates. H. 5·5–6. Sp. gr. 2·56–2·64. Transparent—translucent on edges. Lustre, vitreous, greasy in elæolite. Colourless, white, or yellow; the massive varieties dark green, bluish grey, red, or brown. Double refraction negative. Indices for D line, $\omega = 1·542$, $\epsilon = 1·537$. Sometimes slightly opalescent.

FIG. 101.



Composition.—Approximately $(NaK)_4SiO_4 + Al_2Si_3O_{12}$, but usually with 1 to 2 per cent. of SiO_2 in excess. This may be attributed to partial alteration, as most analyses show some water, 0·3 to 2·0 per cent., the combination being essentially an unstable one. The following are examples of the observed composition:

	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	H_2O
Nepheline, Vesuvius .	43·56	32·18	—	16·25	7·14	0·45	—
Elæolite, Norway .	45·43	32·06	1·41	15·97	4·76	0·40	0·78

Nepheline fuses with difficulty to a cloudy glass, and elæolite more readily with slight intumescence. Gelatinises with acids.

Occurrence.—Nepheline is principally found in crystals and granular masses in volcanic rocks, being most abundant in the lavas of Vesuvius and the Roman States; also as a constituent of rocks, especially that known as phonolite, where it may be recognised under the microscope by the hexagonal sections of the crystals. The reef called the Wolf Rock off the Land's End is the only English example of this rock. Elæolite is found in the zircon syenites of Frederiksvärn in Norway and Miask in the Ural, either massive or in large dark-coloured crystals, with a characteristic greasy lustre.

Davyne and *Cancrinite* are analogous in form and composition to Nepheline, but differ from it by containing $CaCO_3$ 12 to 14 and H_2O 2 to 4 per cent. The former occurs at Vesuvius, and the latter at the Scandinavian and Russian localities given above, and are probably products of alteration.

SODALITE.—*Cubic.* Common form {110}, both in simple crystals and as complete penetration twins upon 111. Cleavage, 110; also granular and massive. Fracture, conchoidal—uneven. H. 6. Sp. gr. 2·13–2·40. Lustre, vitreous or greasy. Translucent. Colour, white, grey, bluish or greenish grey, asparagus-green, lavender- or ultramarine blue; streak, white.

Composition.—Approximately $3Na_2Si_2O_8 + 2NaCl$, or soda 18·16, alumina 31·71, silica 37·10, chloride of sodium 12·05, the latter corresponding to 7·31 chlorine. The analyses as ordinarily computed show an excess, the whole of the sodium being returned as soda, instead of part as oxide and part as chloride. The green-coloured varieties contain less chlorine (2 to 3 per cent.), or 9 molecules of silicate to 2 of chloride. Heated in the closed tube, coloured varieties become white and opaque in the oxidising flame, fusible with more or less intumescence

to a colourless glass. Decomposed and soluble in weak acid, the solution ultimately depositing gelatinous silica. With oxide of copper and salt of phosphorus the chlorine flame colouration is obtained.

Occurrence.—Found in association with nepheline, elæolite, and idocrase, both in the lavas and limestone blocks of Vesuvius and Somma, and in old crystalline rocks at Brevig in Norway, Lichfield in Maine, Salem, Massachusetts, in the zircon syenites of Miask, and in Greenland with eudyalite.

Like nepheline, it is easily altered, becoming opaque and earthy, the change being accompanied by loss of chloride of sodium, and accession of water and lime.

HAÜYNE. Nosean.—*Cubic.* Crystals like those of sodalite, embedded in rounded grains. Cleavage, 110. Fracture, flat conchoidal. H. 5–5·6. Sp. gr. Nosean 2·28–2·33, Haüyne 2·44–2·49. Lustre, greasy, inclining to vitreous. Colour, generally sky-blue, varying to greyish and greenish blue; rarely colourless. Imperfectly transparent or translucent.

Composition.—Essentially combinations of silicates of the same constitution as nepheline, with calcium or sodium sulphates in the proportion of 2 molecules of the former to 1 of the latter. Nosean contains least and Haüyne most lime, and in the latter a portion of the alkali is usually potash. The most generalised formulæ are:

Nosean type: $\overset{I}{R}_2SO_4 + 2Na_2\overset{III}{Al}Si_2O_8$.

Haüyne type: $\left\{\begin{matrix} mCaSO_4 + 2Ca\overset{III}{Al}Si_2O_8 \\ nNa_2SO_4 + 2Na_2\overset{III}{Al}Si_2O_8 \end{matrix}\right\}$

The following analyses give the extreme types of either mineral.

	Cl	SO_3	SiO_2	AlO_3	O_3	Na_2O	K_2O	CaO	H_2O
Nosean, Laach	1·05	7·30	36·69	22·45	0·47	23·90	—	0·63	2·15
Haüyne	0·33	12·54	33·11	27·35	1·05	15·39	1·12	11·92	0·20

When heated in the oxidising flame the coloured varieties usually become white and opaque, and fuse with difficulty to a blebby glass. Nosean only fuses at the edges. The

Haüyne of Albano decrepitates and melts to a bluish green glass. Decomposed by acids, gelatinising similarly to sodalite. The bright blue varieties gives traces of sulphuretted hydrogen with hydrochloric acid.

Occurrence.—At Vesuvius, Albano, and the volcanic district of Laach; as characteristic constituents of phonolite, together with nepheline and sodalite. Haüyne in blue fragments is common in the vesicular phonolite, or millstone lava, of Niedermendig. Nosean may be recognised in most phonolites in microscopic crystals.

LAPIS LAZULI.—*Cubic*, and similar to sodalite in form and cleavage, but generally as a compact or granular mixture, with calcite, quartz, or iron pyrites, without recognisable structure. H. 5·5. Sp. gr. 2·35–2·42. Lustre, vitreous or greasy. Fracture, conchoidal—uneven. Colour, ultramarine blue, varying to greenish or greyish blue or violet. The mass is rarely uniform in tint, the colour being distributed in granular or cloudy patches through a colourless ground.

Composition.—Contains a silicate and sulphate, probably similar to that of Haüyne, with more alkaline sulphide. The analyses vary very considerably. The following is of a South American variety: SiO_2 45·70, Al_2O_3 25·34, Fe_2O_3 1·30, CaO 7·48, Na_2O 10·55, K_2O 1·35, SO_3 4·32, S 3·96. When heated loses colour and fuses partially or swells to a white porous mass. Gelatinises with hydrochloric acid, giving off sulphuretted hydrogen.

Occurrence.—Found in irregular masses and nodules in limestones, with iron pyrites, at Lake Baikal and in various localities in Tartary, Tibet, China, Persia, and other parts of Central and Northern Asia; also in the Chilian Andes. It has been used as an ornamental stone for inlaid and mosaic work from very early times, its use having probably preceded that of blue enamel coloured with cobalt or copper for the same purpose. 'Lapis lazuli of Babylon' was received in

tribute by the Pharaohs of the Middle Empire in Egypt from the subject kingdoms in Asia. Probably the finest modern example of its use is in the Basilica of St. Paul, outside the walls at Rome. When finely ground and levigated, it produces ultramarine, the most durable and valuable blue for oil- or water-colour painting, which is, however, too expensive to be used except for special purposes. The same colour is made artificially in large quantities by heating china clay with sulphate of sodium and charcoal, or mixtures of precipitated silica and alumina with carbonate of sodium and sulphur. The product, a greenish yellow mass (green ultramarine), is by subsequent heating with access of air converted into the blue colour. The artificial ultramarine is largely used for giving the blue tint to paper, having for this purpose almost entirely superseded smalts, a blue potash and cobalt glass, which was formerly used.

The minerals of the nepheline group are closely allied to leucite, both as regards composition and mode of occurrence. In the older Vesuvian lavas crystals of the latter species have been found transformed into a mixture of nepheline and sanidine. By the removal of potash and the substitution of soda and lime, and their sulphates and chlorides, a series of increasing complexity is obtained in the order Leucite, Nepheline, Sodalite, Nosean, and Haüyne.

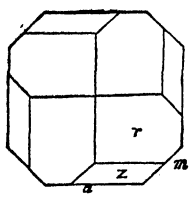
SCAPOLITE GROUP.

Under this head are included several species whose crystallographic characters are very similar, all crystallising in the tetragonal system with parallel hemihedral development. The qualitative composition is also similar, all being silicates of lime and potash or soda, but they show considerable quantitative differences.

MEIONITE.—*Tetragonal, pyramidally hemihedral.* $Z = 63° 42'$, $a : c = 1 : 0{\cdot}4398$ (fig. 102), $r\{111\}P$, $m\{110\}\infty P$, $a\{100\}\infty P\infty$, $z\pi\{311\}3P3$. The latter form sometimes occurs with both hemihedra in the same crystal. Cleavage,

010 perfect, 110 less perfect. Fracture, conchoidal. H. 5·5–6. Sp. gr. 2·71–2·74. Colourless and transparent, or white clouded. Lustre, vitreous. Double refraction, negative. Indices for D line, $\omega = 1{\cdot}597$, $\epsilon = 1{\cdot}561$. Crystals are usually full of cracks and flaws.

FIG. 102.



Composition. — Approximately, $6\left\{\begin{matrix}3Ca_2SiO_4\\ 2AlSi_3O_{12}\end{matrix}\right\} + \left\{\begin{matrix}3Na_4SiO_4\\ 2AlSi_3O_{12}\end{matrix}\right\}$ which is nearly satisfied by the following analysis of crystals from Vesuvius by Vom Rath:

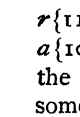
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	Total
42·55	30·89	0·41	21·41	0·53	1·25	0·93	0·19	98·46

The composition apart from the nature of the bases is analogous to that of epidote. Some varieties give off 1 per cent. of (constitutional) water at a red heat. Fusible with intumescence to a white blebby glass, soluble in hydrochloric acid, silica separating in a granular or gelatinous condition when the solution is heated.

Occurrence.—One of the most characteristic minerals of the limestone blocks of Somma, Vesuvius, in brilliant crystals in druses with idocrase, garnet, mica, &c. Also found at the Cyclopean Islands in the Greek Archipelago, and is a rarity at the Lake of Laach in the Eifel.

SCAPOLITE.

FIG. 103.



Wernerite.—*Tetragonal, pyramidally hemihedral.* Like Meionite. (Fig. 103.) $r\{111\}\ P$, $e\{101\}\ P\infty$, $m\{110\}\ \infty P$, $a\{100\}\ \infty P\infty$, $f\{310\}\ \infty P3$, $z\{311\}\ 3P3$, the last form sometimes with one half, sometimes with both halves developed.[1] Cleavage, 100, 110, tolerably perfect, but interrupted, giving a fibrous surface.

[1] It was formerly considered to be plagihedrally hemihedral, but crystals with both ends developed, both of this species and Meionite, show the hemihedral forms to be symmetrical to the base.

Crystals small columnar, also massive and granular. H. 5–6. Sp. gr. 2·62–2·85. Lustre, vitreous, pearly, or resinous on natural faces, vitreous on cleavages and fracture. Colour, white, shaded grey, blue, green, or other light tints. Transparent to nearly opaque. Brittle.

Composition.—Very variable, being rarely found in a perfectly fresh condition. The least altered varieties contain a minimum of silica and a maximum of lime; and as the former increases, the latter diminishes, the change being also accompanied by an addition of alkali (chiefly soda).

The following analyses give the extremes of composition:

	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	
Pargas	41·25	33·58	20·36	0·54	—	—	3·32	=98·05
Naples	62·72	21·85	4·63	0·31	9·37	1·15	—	=100

The first of these is of the same composition as anorthite, or $Ca_2SiO_4 + Al_2Si_3O_{12}$, while the second is similar to oligoclase. The pure mineral approximates to, without being identical with, Meionite.

According to Adams, chloride and sulphate of sodium are commonly present, and when these are deducted the residual silicate is of the normal form ($RSiO_3$). In a Scapolite from Ripon, Quebec, Cl. 2·411, and SO_3 0·796 per cent. were found. Smaller quantities of the same elements have been found in Meionite.

Most varieties fuse easily to a blebby glass; some give slight traces of fluorine in the closed tube. Decomposed by hydrochloric acid, but with difficulty, and without gelatinising.

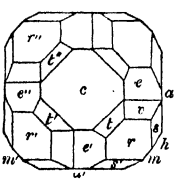
Occurrence.—In the older crystalline limestones and magnetic iron ore deposits in Norway, Sweden, and Finland, at Bolton, Massachusetts, and Franklin, New Jersey, &c., being usually associated with, and occasionally changed into, hornblende, augite, mica, and felspars. Other pseudomorphs

are into epidote, quartz, and clay. Its relation to Meionite, which is of volcanic origin, is similar to that of elæolite to nepheline.

Passauite or *Porcelain Spar* is an imperfectly crystalline compact variety occurring at several places round Passau in Austria, which by its decomposition yields the china clay worked in that neighbourhood.

SARCOLITE, another member of the Scapolite group, has similar forms but different parameters. $Z=102°\ 54'$, $a : c=1·1255$ (fig. 104), $r\{111\}P$, $t\{113\}\frac{1}{3}P$, $c\{001\}oP$, $a\{100\}\infty P\infty$, $m\{110\}\infty P$, $h\{210\}\infty P2$, $e\{101\}P\infty$, $v\pi\{313\}P3$, $s\{311\}$. It contains SiO_2 40·51, Al_2O_3 21·54, CaO 32·36, Na_2O 3·30, K_2O 1·20 per cent., and occurs in small flesh-red crystals at Monte Somma, Vesuvius.

FIG. 104.



MICA GROUP.

The minerals included under the general name of Mica, though varying considerably in composition and in some physical properties, are united by a marked common characteristic, that is, one extremely perfect cleavage, parallel to the base of an apparently hexagonal prism; their crystals, which are often of enormous size, being as a rule developed in the direction of this plane, while their other faces are rough and imperfectly developed. The best defined crystals of mica, those from Vesuvius, were formerly supposed to be hexagonal, and the larger lighter coloured plates common in granite and crystalline rocks, rhombic, but with monoclinic or monosymmetric habit in either case; the faces of forms that are rhombohedra in the sense of being equally inclined by threes upon

the basal plane, showing a tendency to develop into two similar parallel pairs, and a third dissimilar pair, which may be all present together and similarly developed, but more generally are not. The division into hexagonal and rhombic species was further supported by the optical characters, which can be easily observed, as most micas can be obtained in plates sufficiently transparent to show interference rings in convergent polarised light, these being in some cases circular, with a rectangular cross, like those of uniaxial crystals, while in others they are biaxial rings and brushes, but with great differences in the divergence of the optic axes. Upon these differences are based the division into so-called uniaxial and biaxial micas, but the study of the absorption phenomena, as in Dove's test,[1] shows that none of the species are truly uniaxial, but that all are biaxial, though in some cases the axial divergence is not measurable. It was further assumed until lately that the first median line in the biaxial micas was perpendicular to the cleavage of the crystal, or parallel to the vertical axes, as required by the symmetry of the rhombic system; but the researches of Tschermak, Bauer, and others, have shown that there is really a divergence in the direction of these lines, in different species of from 0·20′ to 6° or 7°, and that the physical symmetry is that required by the oblique system. A further characteristic of the same kind is in the difference in the position of the optic axial plane, which may be either perpendicular to the plane of symmetry, or parallel to it; the species being distinguished as micas of the first and second kinds according as they conform to one or other type of structure.

As regards crystallographic elements, Tschermak considers[2] that all micas may be referred to a single type having the parameters $a : b : c = 0{\cdot}5774 : 1 : 3{\cdot}2797$, $\beta = 90°$, or only differing from it by less than 1′. These apply equally

[1] See *Systematic Mineralogy*, p. 286.

[2] *Zeitschrift für Krystallographie*, vol. ii. p. 14.

well to hexagonal, rhombic, and oblique forms: (figs. 105, 106), $o\{112\} -\frac{1}{2}P$, $m\{\bar{1}11\} +P$, $r\{\bar{1}01\} +P\infty$, $z\{132\} \frac{3}{2}P3$, $b\{010\} \infty P\infty$, $c\{001\} oP$. Kokscharoff adopts a similar system of parameters, but halves the vertical axis, changing

FIG. 105.

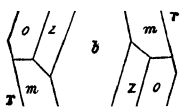
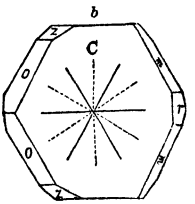


FIG. 106.



{112} of fig. 105 to {111}, {132} to {131}, &c. (fig. 107).

Both of the preceding methods involve the assumption of an upright hexagonal prism which has never been observed, a difficulty which is obviated in the position assumed by Miller and Descloizeaux, who make the form

FIG. 107.

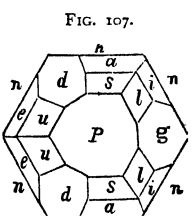
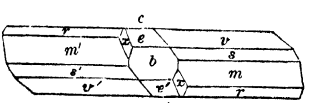


FIG. 108



{111} of Tschermak {110}, which gives the parameters $a : b : c = 1{\cdot}9287 : 1 : 1{\cdot}7305$, $\beta = 99° 57'$: (fig. 108), $v\{112\}$, $s\{111\}$, $m\{110\}$, $r\{11\bar{1}\}$, $e\{021\}$, $x\{13\bar{1}\}$, $c\{001\}$.

The crystals are sometimes developed as very acute pyramids, somewhat like those of corundum, but more generally they are short columnar, or tabular in various degrees of thinness down to mere six-sided films. Twins

on 110 of the first or 331 of second notation common with contact on the twin plane, or more commonly on 001, the components being superposed in inverse positions.

Cleavage, 001 very perfect, giving laminæ that are in most cases flexible and somewhat elastic. Besides the principal cleavage, indications of others may be obtained by punching a hole in a thin plate by a light blow with a fine needle, which develops a system of three cracks radiating from the hole, making angles of 120° with each other, as shown in the strong lines in fig. 106. These lines form the so-called compact figure (*Schlagfigur*) of Reusch; one of them is parallel to the plane of symmetry, and the other two to the edges of combination of the pyramids of the principal series with the base. When a similar plate, placed upon an elastic bearing, is subjected to pressure with a rounded point, such as the end of a penholder, a similar system of intersecting lines, but perpendicular to the preceding, is developed. These shown in the dotted lines in fig. 106 give the compression figure (*Druckfigur*) of Bauer, which, as a rule, is more apparent than the punch cracks forming the impact figure; for although the latter are better defined in direction, they rarely extend for any distance from the perforation in the plate, and require the aid of the microscope for proper definition. If both figures are developed in the same plate, the lines of one are seen to halve the angles between adjacent lines in the other.

Composition.—Micas are silicates of alumina and potash, with or without dyad bases, principally magnesia, and in some cases water and fluorine, the potash being often partly replaced by lithia or soda, and the magnesia by ferrous oxide, but they cannot be reduced to any single formula. According to Tschermak they are to be considered as isomorphous mixtures of the following molecular groups:

I. $R_6Al_6Si_6O_{24}$, $R_6=K_6$, K_4+H_2, K_3+H_3, K_2+H_4, H_4, and the equivalent sodium, lithium, and ferrous compounds. R : Si = 1 : 1.

II. $Mg_{12}Si_6O_{24}$, and the equivalent ferrous and manganous compounds, R : Si = 2 : 1.

III. $H_8Si_{10}O_{24}$, and the equivalent fluorine compound $Si_{10}O_8Fl_{24}$.

Group I. is common to all species, and in combination with II. forms the so-called magnesian micas, not containing fluorine; and with III. the muscovite and lepidolite series, or potash and lithia micas containing fluorine, while the combination of all three groups gives the magnesia fluorine (phlogopite) and iron lithia micas. Upon this basis the general systematic classification is as follows:

A. BIOTITE SERIES.

Typical forms 001, $\bar{1}11$, 010, 112, first median line nearly coincident with *c*. Sp. gr. 2·8–3·2, increasing with percentage of Fe. Includes the species—

ANOMITE. Rhombic Mica of Kenngott.—Optic axial plane perpendicular to 010. Dispersion $\rho > v$. *Composition*, $n(K_4H_2Al_6Si_6O_{24}) + (Mg_{10}Si_6O_{24})$; n varies from 1 to 2.

MEROXENE. Biotite, Uniaxial Mica, Annite.—Optic axial plane 010. *Composition*, $n(K_3H_3Al_6Si_6O_{24}) + (Mg_{12}Si_6O_{24})$, n varying from 1 to 2.

Rubellan, *Eucamptite*, *Aspidolite*, and *Hallite* are probably altered varieties of Meroxene.

LEPIDOMELANE. Optic axial plane 010. *Composition*, $(K_2H_4Al_6Si_6O_{24}) + (Mg_{12}Si_6O_{24})$, with variable proportions of ferric oxide in the first and of ferrous oxide in the second compound. In *Haughtonite* this substitution extends to one-half or two-thirds of the magnesia, and in *Siderophyllite* it is complete, giving a pure iron biotite without magnesia. *Manganophyllite* and *Alurgite* are analogous to biotite, with entire or partial substitution of manganese for magnesia.

B. PHLOGOPITE SERIES.

Maximum inclination of first median line on c, 2° 30′. Optic axial plane 010. Sp. gr. 2·75–2·97. Typical forms as in Biotite series.

PHLOGOPITE.—Apparent axial angle up to 20°. Dispersion $\rho < v$.

Composition.—$(K_6Al_6Si_6O_{24})$, $(Mg_2Si_6O_{24})$, $(H_8Si_{10}O_{24})$, often in the approximate ratio of 3 : 4 : 1, and with the last term replaced in part by the corresponding fluorine compound. The latter element is most abundant in the reddish brown varieties and least in the green ones.

The habitat in crystalline limestones is also characteristic.

Vermiculite and *Jeffreysite* are probably altered varieties.

ZINNWALDITE. Lithionite, Cryophyllite.—Apparent axial angle up to 65°.

Composition.—$(K_6Al_6Si_6O_{24})$, $(Fl_{12}Si_6O_{24})$, $(Si_{10}O_8Fl_{24})$, in the ratio of 10 : 2 : 3. One-half the potash in the first compound is replaced by lithia, and in the last of the fluorine by hydrogen.

C. MUSCOVITE SERIES.

Typical forms 001, $\bar{1}11$, 010, first median line making very small angle with c. Optic axial plane perpendicular to 010. Dispersion $\rho > v$. Sp. gr. 2·83–2·89.

LEPIDOLITE. Lithia Mica.—*Composition*, $3((KLi)_6Al_6Si_6O_{24})$ and $(Si_{10}O_8Fl_{24})$, part of the latter being replaced by the corresponding hydrogen compound.

MUSCOVITE. Potash Mica, Biaxial Mica, Phengite, Fuchsite.—*Composition* $(K_2H_4Al_6Si_6O_{24}) + (H_8Si_{10}O_{24})$. *Muscovite* proper consists mainly of the first combination: in *Phengite* both are present in the ratio of 3 : 1. *Fuchsite* contains chromium, partly replacing aluminium. *Oellacherite* contains barium. *Damourite* and *Onkosine* are compact

PARAGONITE. Pregattite.—Sodium muscovite of the composition $Na_2H_4Al_6Si_6O_{24}$. Cossaite is a compact variety.

D. MARGARITE SERIES.

MARGARITE. Pearl Mica, Corundellite, Emerylite.

Typical forms 001, 010, 112, $\bar{1}$14. Maximum inclination of first median line on *c*, 6°. Dispersion $\rho < v$. Sp. gr. 2·95–3·1. *Composition*, $H_4Ca_2Al_8Si_4O_{24}$, with a small quantity of soda.

The following are a few complete analyses of micas:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MaO	MgO	CaO	K_2O	Na_2O	Li_2O	H_2O	Fl
Biotite	40·16	15·79	2·53	4·12	W	26·15	W	7·64	0·37	—	3·58	—
Lepidomelane	37·40	11·60	27·66	12·43	—	0·60	—	9·20	—	—	0·60	—
Manganophyllite	38·50	11·00	—	3·78	21·40	15·01	3·20	5·51	—	—	1·60	—
Phlogopite	42·26	15·64	0·23	1·52	—	27·23	—	8·68	—	—	2·91	2·69
Zinnwaldite	45·87	22·50	0·66	11·61	1·75	—	—	10·46	0·42	3·28	0·91	7·94
Lepidolite	51·32	26·00	—	—	1·30	—	—	9·98	0·96	3·87	0·57	7·18
Muscovite	45·71	36·57	1·19	1·07	—	0·71	0·46	9·22	0·79	—	4·83	0·12
Paragonite	47·75	40·10	—	—	—	—	—	1·12	6·04	—	4·58	—
Margarite	28·55	50·24	1·65	—	0·69	—	11·88	—	1·87	—	4·88	—

In the closed tube most micas give off water, and in many cases the reaction of fluorine with Brazil wood paper. In the forceps, muscovite and the more purely magnesian micas fuse with difficulty, and those with much iron more easily, the latter to a black glass. Lepidolite and Zinnwaldite colour the flame crimson (lithia). Decomposed by sulphuric acid with separation of silica; also by hydrochloric acid after fusion. Paragonite is infusible, and not decomposable by acids.

As regards colour, muscovite is colourless, grey, or light brown; phlogopite, brownish red; paragonite and margarite, white and pearly; Zinnwaldite, smoky grey; lepidolite, pink; Alurgite, red; Fuchsite, pale emerald-green; Biotite and lepidomelane, various dark tints, from brown through bottle-green to black, the latter being opaque, except in very thin laminæ. These darker coloured species are strongly pleochroic. Lustre, varies from semi-metallic to vitreous and pearly.

Occurrence.—Biotite is essentially the mica of modern

volcanic rocks, being found in the lavas of Vesuvius, the Eifel, Auvergne, and also in the porphyry known as *minette*. In granites and the older crystalline rocks it is associated with muscovite, forming the black mica, the latter being light-coloured. Phlogopite is essentially characteristic of the Archean crystalline limestones of North America, and occurs in enormous crystals, up to $2\frac{1}{2}$ tons weight, with apatite. The variety from South Burgess is remarkable for its asterism, a luminous point showing a six-rayed star when viewed through a transparent plate of it. This is due to the symmetrical inclusion (in lines intersecting at 120°) of very minute crystals, which, according to G. Rose, are biotite; but Tschermak considers them not to be a mica, but some other substance as yet undetermined.

Muscovite is the white mica of granite, gneiss, and the older crystalline rocks generally; the largest crystalline plates, which are sometimes as much as two feet across, are found in hollows in coarse granite or pegmatite veins. Zinnwaldite occurs with fluor and tinstone in the Saxon-Bohemian tin districts. Lepidolite is found chiefly at Paris, Maine, and Rozena in Moravia, and is a chief source of lithia in laboratories. Paragonite forms the mass of the white scaly mica schist inclosing staurolite and cyanite at St. Gothard. Fuchsite is the green chromium mica, containing about 4 per cent. Cr_2O_3 of Schwarzenstein in Tyrol.

The transparency, flexibility, and toughness of cleavage plates of mica render them useful as substitutes for glass in special cases. The purest and best crystals are obtained from Russia, India, the north-eastern States of America, and Canada, both muscovite and phlogopite being used. Finely ground mica has also been lately introduced as a lubricating material for machinery. In the larger masses other minerals, more especially garnet and tourmaline, are often found inclosed, the crystals being flattened in a remarkable manner. At Pennsbury, Pennsylvania, the included crystals of magnetite are so thin as to be translucent. Mica is a common

substitution product of other minerals. It occurs in pseudomorphs after corundum, orthoclase, beryl, cordierite, cyanite, andalusite, scapolite, tourmaline, idocrase, hornblende, and augite.

FELSPAR GROUP.

This most important class of minerals includes a small number of species which are closely allied in form and habit, as well as in their mode of occurrence. They are silicates of alumina, lime, and alkalies, but are practically without magnesia or iron, and crystallise in the oblique or triclinic systems, the forms of both systems having a strong geometrical and structural resemblance, especially in the prevalence of a prism approximating to 120° (118° 48′ to 121° 37′), similar methods of twinning in all the species, and two well-defined cleavages either exactly or nearly at right angles to each other. The occurrence of different species interlaminated in the same mass, and even in the same crystal, is also common. The view now most generally held of the constitution of felspars is that proposed by Tschermak, who supposes the species to form a continuous series, one extreme of which is anorthite, a dibasic silicate of the composition $Ca_2Al_2Si_4O_{16}$, and the other albite, a sesquisilicate, $Na_2AlSi_6O_{16}$, the first being pure lime, and the last pure soda felspar, the intermediate 'mixed' or lime-soda felspars. Labradorite, Andesine, and oligoclase are made up of molecules of both in different proportions, showing a progressive diminution in the content of lime, and increase in that of silica, in the order named, the differences in composition being to some extent characterised by corresponding differences in optical character. The whole of these are triclinic species; the corresponding potash felspar, $K_2AlSi_6O_{16}$, is dimorphous, being oblique in orthoclase and triclinic in microcline.

Felspars are essentially constituents of volcanic and crystalline igneous rocks, orthoclase being typical of granite, syenite, gneiss, and trachyte, usually in association with

quartz. Labradorite is the felspar of basalts and dolerites in microscopic crystals, and it also forms enormous rock masses, covering a large portion of the Labrador promontory between the St. Lawrence and Hudson's Bay. Oligoclase may be associated with orthoclase in granite, and is the felspathic constituent of diorite and diabase. Andesine is the felspar of the trachytes of the Andes. Albite is chiefly found in crystalline schists, and also in granite veins. Anorthite is best developed in the crystalline limestone blocks of Vesuvius, and also occurs in some basalts.

ORTHOCLASE. Orthose, Potash Felspar, Adularia, Sanidine.—*Oblique.* ∞P 118° 47′, $a : b : c = 0{\cdot}6585 : 1 : 0{\cdot}5554$,

FIG. 109.

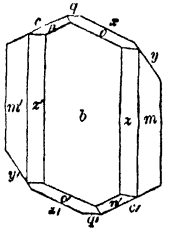


FIG. 110.

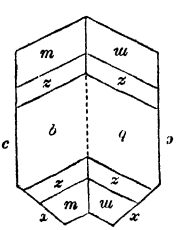
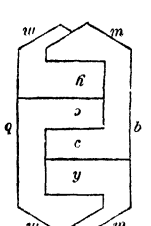


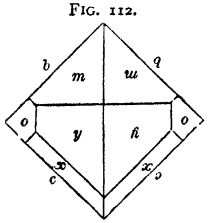
FIG. 111.



$\beta = 63° 53'$–$57'$: (fig. 109), $b\{010\} \infty \breve{P}\infty$, $c\{001\} o P$, $m\{110\} \infty P$, $z\{130\} \infty \breve{P} 3$, $o\{111\}$–P, $n\{021\} 2 \breve{P}\infty$, $q\{203\} \frac{2}{3} \breve{P}\infty$, $x\{101\} \breve{P}\infty$, $y\{201\} 2 \breve{P}\infty$. Twins: 1. On 001 (fig. 110). 2. On 021 (fig. 111), Baveno type. 3. On 100 with contact on 010 and partial penetration (fig. 112), Carlsbad type. Crystals usually somewhat elongated vertically and tabular to 010. Cleavage, 001 very perfect, 010 perfect, 110 imperfect, often better parallel to one pair of faces than to the other. Fracture, conchoidal, splintery, or uneven. H. 6. Sp. gr. 2·53–2·62. Translucent—opaque. Lustre, vitreous, pearly on cleavage. Colourless, white, flesh-red, pink, brick-red, smoky grey, pale green, bright green;

streak, white. Some varieties opalescent; others with blue iridescence or metallic play of colours. Double refraction negative. Optic axial plane usually perpendicular to 010, the first median line inclined at 111° or 112° to *c*, or 5°–6° to *a*, giving horizontal dispersion. In some cases the apparent angle of the axes is very large, as in adularia from St. Gothard, which has the indices for yellow, $\alpha = 1{\cdot}5190$, $\beta = 1{\cdot}5237$, $\gamma = 1{\cdot}5260$, $2V = 69° 43'$, $2E = 121° 6'$.

FIG. 112.



In other cases the angle may be small or even inappreciable for particular colours, while the axes of opposite ends of the spectrum are disposed in different planes. This is the case with the sanidine of Wehr in the Eifel, which has the axial plane for red perpendicular to 010 with the indices $\alpha = 1{\cdot}5170$, $\beta = 1{\cdot}5239$, $\gamma = 1{\cdot}5240$, $2V = 13° 34'$, $2E = 2° 45'$, while for blue the axes lie in 010, $\alpha = 1{\cdot}5265$, $\beta = 1{\cdot}5355$, $\gamma = 1{\cdot}5356$, $2V = 11° 51'$, $2E = 18° 44'$. By strongly heating, the angle of the axes in 010 is increased, while that for the plane perpendicular to it is diminished. If the heat exceeds 500° the original positions are not quite recovered on cooling.

Composition. — $K_2Al_2Si_6O_{16} = K_2Si_3O_7 + Al_2Si_3O_9$, corresponding to SiO_2 64·68, Al_2O_3 18·43, K_2O 16·89 per cent. In almost all cases the potash is partly replaced by soda, and in sanidine, the glassy felspar of lavas, the two alkalies are in nearly equal proportions. Baryta is sometimes present to a maximum of about $2\frac{1}{2}$ per cent. Lime and magnesia are usually small in quantity, except in some sanidines.

The following are a few characteristic analyses:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
Adularia, St. Gothard	65·75	18·28	—	—	—	14·17	1·44	99·64
Orthoclase, Baveno	65·72	18·57	—	0·34	0·10	14·02	1·25	100·00
Sanidine, Eifel	66·50	16·69	1·36	0·35	1·43	8·44	4·93	99·70
" Mont Doré	67·10	18·98	0·63	0·48	—	7·03	7·08	100·39

In some sanidines there are visible microscopic inclusions of triclinic (soda) felspar. For equal molecules of both alkalies the percentage is Na_2O 5·73, K_2O 8·69.

Fusible with some difficulty to a cloudy glass, coloured varieties becoming white before fusion. When melted in mass in a porcelain furnace the sp. gr. is reduced to 2·34–2·38 without change of composition. A fragment strongly heated in the oxidising flame, especially if moistened with hydrochloric or sulphuric acid, usually shows the violet potash colouration, but if containing much soda, the blue glass must be used. Dissolves very slowly in salt of phosphorus, leaving a siliceous skeleton. When finely powdered and strongly heated with cobalt solution on charcoal, gives the alumina frit. Not affected by acids, but partially decomposed by caustic soda lye. The fine powder moistened with water is alkaline to turmeric test paper.

The following names are applied to the principal varieties :

Adularia is the nearly transparent colourless kind occurring with specular iron at St. Gothard. Ice spar is a similar kind, but containing much soda, in small glassy crystals, from Vesuvius. Moonstone, a cloudy or slightly opalescent adularia, principally from Ceylon. Common felspar, or pegmatite, includes all the opaque white or red kinds found either in crystals or cleavable masses in granite and other crystalline rocks. Murchisonite is a flesh-coloured variety found in rolled masses near Exeter, which has a third cleavage perpendicular to 010, inclined 73° 10′ to 001, and 170° 43′ to 100, marked by a peculiar opalescence.

Orthoclase also occurs as pseudomorphs after leucite, analcime, laumonite, and prehnite, and is itself liable to change by loss of alkalies into china clay, while preserving its original form. When this change is only partial, the interior of the crystal may contain a nucleus of the unaltered mineral. In other cases the felspar substance may be completely removed, leaving a cavity which is filled up by mix-

tures of quartz, mica, and tin ore. Pseudomorphs of this character have been found in considerable quantity near St. Agnes, Cornwall.

HYALOPHANE. Baryta Felspar.—*Oblique.* ∞P 118° 41′, β=64° 16′. Cleavage, 001 perfect, 010 imperfect. In small single crystals, or groups of two or three, closely resembling orthoclase. H. 6–6·5. Sp. gr. 2·80–2·90. Colourless, white, or pale red. Lustre, vitreous. Transparent —translucent.

Composition.—$BaAl_2Si_2O_8 + K_2Al_2Si_6O_{16}$, or containing equal molecules of orthoclase and a barytic anorthite. This is the simplest expression, and is nearly represented by the following analysis. In other cases, the proportion varies from 0·5 to 2 molecules of orthoclase to one of the barytic felspar.

	SiO_2	Al_2O_3	BaO	CaO	K_2O	Na_2O	H_2O	
Binnenthal, Valais	52·67	21·12	15·05	0·46	7·82	2·14	0·58	=99·84

Other examples contain more lime and soda, as well as magnesia, the baryta being reduced to between 2½–9 per cent.

Fusible with difficulty to a blebby glass, not acted on by acids.

Occurrence.—Binnenthal in the Valais in a dolomite, and at Jacobsberg in Wermland, Sweden. Although rare, it is of great interest as establishing the dimorphism of the mixed felspars, the composition being analogous to that of Andesine, while the form is that of orthoclase. Another variety described by Descloizeaux is triclinic, the acute angle of the principal cleavages being 86° 37′. This has the composition SiO_2 55·10, AlO_3 23·20, FeO_3 0·45, BaO 7·30, CaO 1·83, MgO 0·56, NaO 7·48, K_2O 0·83, volatile matter 3·72. Baryta is, however, not unfrequently found in orthoclase proper.

MICROCLINE.—This name, originally given by Breithaupt to the blue opalescent felspar of zircon-syenite, on account

of its two principal cleavages not being perfectly at right angles, has been applied by Descloizeaux to certain felspars found in granites and crystalline schists, having a similar obliquity of cleavage (90° 16′), and also structural properties showing them to be triclinic, which the felspar of the zircon syenite is not. In form it is scarcely distinguishable from orthoclase; the crystallised varieties which are represented by the bright green crystals known as *Amazon-stone* being usually twinned on the Baveno or Carlsbad types, and though very often large, are too rough and irregular to afford good measurements. On the basal planes or cleavages of these crystals, two systems of parallel striations, nearly at right angles, may be seen by reflected light; and when a thin section parallel to 001 is observed in parallel polarised light, a very complex system of bands is observed, most of which are at their maximum extinction when inclined about 15° to the edge 001/010; while others extinguish parallel to it, the first being the triclinic constituent (microcline), and the second orthoclase. A third substance found in irregular veins extinguishing at 4° is albite. When the latter is in very small quantity or entirely absent, the composition is that of a pure potash felspar, but when the albitic bands are numerous the proportion of soda shows a notable increase. This structure is extremely easily detected in the smallest cleavage fragment when sufficiently thin, and it may often be seen on fresh cleavage of the felspar, in coarse-grained granite, with very oblique reflected light. The finest examples of the latter are from Branchville, Connecticut, where masses ten feet long are found. These, like the orthoclase of Sweden, are worked as porcelain material.

Perthite is a banded felspar made up of laminæ of albite and red orthoclase and microcline, the latter being rendered iridescent by inclusions of specular iron: from Perth, Canada. The finest green microcline (Amazon-stone) crystals are from Pike's Peak, Colorado, and the Ural. It has also been found in a boulder at Tongue in Sutherlandshire.

The colouring matter, which was formerly attributed to copper, is now supposed to be due to an organic ferrous salt, as it is entirely destroyed by calcination at a red heat.

ALBITE. Pericline.—*Triclinic.* $1\bar{1}0/110$, 120° 47′, 001/010, 86° 24′, $a : b : c = 0{\cdot}6333 : 1 : 0{\cdot}5575$, $\alpha = 85°\ 56'$, $\beta = 116°\ 28'$, $\gamma = 88°\ 08'$, (fig. 113), $p\{001\}oP$, $m\{010\}\infty\breve{P}\infty$, $n\{0\bar{2}1\}2'\breve{P},\infty$, $t\{110\}\infty\,'P$, $l'\{1\bar{1}0\}\infty\,P'$, $f\{130\}\infty P'3$, $z'\{1\bar{3}0\}\infty\,'P3$, $x\{\bar{1}01\}{}_{1}\breve{P},\infty$, $o\{\bar{1}\bar{1}1\}P_{,}$, $s\{\bar{1}11\}{}_{1}P$, $y\{\bar{2}01\}2{}_{1}\breve{P},\infty$, $g\{\bar{1}12\}\frac{1}{2}{}_{1}P$. Crystals rarely simple, being almost invariably twinned according to one or more methods.

FIG. 113.

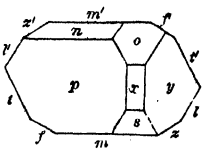
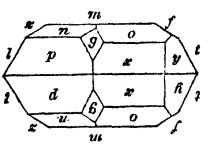


FIG. 114.



1. On {010}, as in fig. 114, or albite twinning proper, the direct and reversed faces of {001} meet in a re-entering angle of 172° 48′, and those of $\{\bar{1}01\}$ at 169° 44′. This is usually many times repeated with very thin laminæ, producing the characteristic twin striation on the basal plane. Sometimes two twins of this kind may be compounded upon the Carlsbad type as in orthoclase. 2. Twin axis *c* with contact on 010. This brings a reversed face of $\{\bar{1}01\}$ opposite to the direct one of {001}. 3. Twin axis *b* in which none of the twin edges fall into the same planes. This applies particularly to the variety Pericline, in which the crystals are excessively elongated on the axis *b*. Cleavages, 001, 010, inclined at 93° 96′, perfect; 110 and 111 imperfect. H. 6–6·5. Sp. gr. 2·59–2·65. Transparent to translucent; albite: opaque; pericline. Colourless, white, or some very pale tint of red, yellow, green, or grey. Lustre, vitreous, pearly on principal cleavage face, which is usually finely striated. Sometimes opalescent, or with a play of colours. Double refraction positive; the optic axial plane

is inclined 96° 16′ to *c* and 16° 17′ to a normal to 010 ; the first median line is inclined to the latter normal at the same angle, and 77° 19′ to the normal to 001. The direction of maximum extinction in sections parallel to 001 is inclined 3° 50′ to 4° 50′ to the edge 001/010.

Composition. — $Na_2Al_2Si_6O_{16}$, corresponding to SiO_2 68·62, Al_2O_3 19·56, Na_2O 11·82, per cent. Soda is very commonly replaced by potash, but not above 2·5 per cent. When the proportion is large there is probably orthoclase intermixed. Fusible rather more readily than orthoclase, colouring the flame yellow. Not acted on by acids. In very fine powder slightly alkaline to test paper.

Occurrence.—As a constituent of granite and other crystalline rocks, but usually in subordinate quantity to orthoclase. Crystals; or fibrous, lamellar, or globular aggregates, or veins in granites and limestones in the Swiss and Tyrol Alps, and the archæan rocks of New England, and the granites of the Mourne Mountains, often associated with tourmaline, axinite, beryl, columbite, specular iron, &c. At Tremadoc, in veins in diorite, with Brookite. The iridescent varieties known as *Avanturine*, *albite*, *moonstone*, and *peristerite*, are similar in appearance to the corresponding kinds of adularia. *Cleavlandite* is a compact opaque variety.

As pseudomorphs, albite occurs as a transformation product of Laumonite, scapolite, and spodumene; but unlike orthoclase it is comparatively stable, and is not itself subject to pseudomorphous alteration.

ANORTHITE. Christianite, Indianite.—*Triclinic.* $1\bar{1}0/110 = 120° 31'$. $001/010 = 94° 10'$. $a : b : c = 0·6347 : 1 : 0·5501$, $\alpha = 93° 13'$, $\beta = 115° 55'$, $\gamma = 91° 11'$ (fig. 115), $u\{010\}\infty\breve{P}\infty$, $t\{1$

^{P}, $x\{\bar{1}01\}_{1}\breve{P}_{1}\infty$, $y\{\bar{2}01\}2_{1}\breve{P}_{1}\infty$, $u\{\bar{2}\bar{2}1\}2'P_{1}$. Twins common of several kinds. 1. On 010, albite type (fig. 116), also repeated as in albite, but the lamellæ are not so fine or

numerous, and the alternate ones vary very irregularly in breadth. 2. Twin axis *b* like the pericline twin of albite. Also massive in granular or lamellar aggregates. Cleavage, 001 and 010 perfect. Fracture, conchoidal. Brittle. H. 6. Sp. gr. 2·66–2·78. Lustre, vitreous, pearly on cleavages. Transparent to translucent. Colourless, white, pale grey or

FIG. 115.

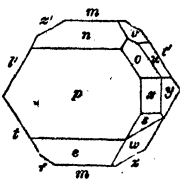
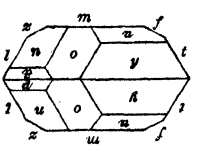


FIG. 116.



reddish. Double refraction negative. The direction of maximum extinction in basal cleavage plates is inclined between 20° and 40° to the edge 001/010, a greater obliquity than in any other felspar.

Composition. — $CaAlSi_2O_8 = Ca_2SiO_4 + Al_2Si_3O_{12}$, corresponding to SiO_2 43·08, Al_2O_3 36·82, CaO 20·10 per cent. All the more exact analyses, however, show some alkali, principally soda, and the silica is generally in excess of the theoretical quantity. This is probably due to an admixture of albite substance, the two species being closely isomorphous.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	
Anorthite, Somma	43·96	35·30	0·63	18·98	0·45	0·47	0·39	—	= 100·18
Indianite	42·09	38·89	—	15·78	—	4·08	—	—	= 100·84
Bytownite, Canada	47·40	30·45	0·80	14·24	0·87	2·82	0·38	2·00	= 98 96

Fusible about as easily as orthoclase to a white enamel. Completely decomposed by hydrochloric acid, with separation of silica after a time.

Occurrence.—The original mineral is found in glassy crystals in the limestone blocks of Somma, Vesuvius, associated with nepheline and meionite, &c. The composition approximates very closely to that of the latter species.

It occurs also in lavas in Iceland, &c., in the orbicular diorite of Corsica, and in some meteorites.

Indianite is a compact granular variety from India. *Bytownite* is a somewhat indefinite mineral from Ottawa, and generally felspars of this character are associated with Andesine and Labradorite in the Laurentian series of Eastern Canada and Labrador, in the rocks distinguished by Sterry Hunt as *anorthosites*.

LABRADORITE. Labrador.—*Triclinic.* Constants undetermined, crystals being generally imperfect. $1\bar{1}0/110 = 121° 37'$; $001/0\bar{1}0$ (cleavage), $93° 20'$. Mostly in cleavable masses, repeatedly twinned on 010, like albite, producing a series of ridges and furrows or striations corresponding to angles of $173° 20'$ on the basal surfaces. Twin forms analogous to those of the Carlsbad type in orthoclase have also been observed. Cleavage, 001 and 010 perfect, $1\bar{1}0$ in traces. Cleavage faces generally striated. H. 6. Sp. gr. 2·68–2·82. Colourless, but more generally of a bluish or brownish grey; at times nearly black. Lustre, vitreous, pearly or greasy on cleavage faces; translucent to nearly opaque. Double refraction positive. Direction of maximum extinction in basal sections, inclined 5° 12′ to edge $001/0\bar{1}0$.

The most characteristic peculiarity is the brilliant iridescence seen on the faces of 010 when viewed obliquely. The colours most generally observed are blue and green, like peacocks' feathers; golden or bronze-yellow, and brown and rose-red, are also seen, but not commonly. These colours are interference phenomena due to the existence of innumerable thin plates in the mass, which are very apparent in thin sections when viewed under the microscope with polarised light. An avanturine effect is also produced by the presence of very minute included plates of Göthite or hematite.

Composition.—$(Na_2Al_2Si_6O_{16}) + n\ (CaAl_2Si_2O_8)$, where n may vary from 6 to 2; or a combination of 1 molecule of albite, with from 2 to 6 molecules of anorthite.

The following are among the extreme types of composition observed :

		SiO_2	AlO_3	FeO_3	CaO	MgO	Na_2O	K_2O	H_2O	
Neurode, Silesia,	$n = 6$	47·05	30·44	1·56	16·53	0·09	2·10	0·78	1·87	= 100·42
Labrador	$n = 2$	55·59	25·41	2·73	11·40	—	4·83	0·32	—	= 100·28

In different analyses CaO varies from 16·5 to 5·89, Na_2O from 1·37 to 6·10, and K_2O from 0·20 to 4·58 per cent.

Fusible with ease to a white enamel, colouring the flame yellow. Decomposed by hydrochloric acid, but only slowly and when finely powdered. After fusion the specific gravity is diminished from 2·69 to 2·52.

Occurrence.—Labradorite is the common felspar of basalt and dolerite, although generally not recognisable except by the microscope, when it is seen to form thin elongated crystals in the mass of the rock.

In the massive cleavable condition it forms with hypersthene and titaniferous iron ore, the rock called Norite, which occurs in the gneissic regions of Scandinavia and North America. In the Labrador peninsula, in a nearly pure form, it covers very large areas from the St. Lawrence to Hudson's Bay, appearing in stratified masses of enormous thickness, extending from the coast for many miles into the interior. This is usually of a dull blue or smoky grey colour, with very few iridescent patches, the brilliantly coloured varieties being mainly brought from the Moravian Mission stations on the northern coast of Labrador.

By loss of lime and hydration, Labradorite may be converted into pinite, and by addition of potash into mica. Pseudomorphs of this kind have been obtained at Harthan, near Chemnitz, in Saxony. The coloured varieties are used to some extent in jewellery, being polished *en cabochon* or carved into cameos. As ornaments they are not very durable, the polish being soon lost when exposed to the air.

ANDESINE.—*Triclinic*, resembling albite, but not perfectly measured. 001/010=87°–88°. Twins similar to albite. Crystals rare, usually embedded in cleavable forms

or granular masses. Cleavages, 001 and 010. H. 5–6. Sp. gr. 2·58–2·84. Colour, white, grey, greenish yellow or pale red. Lustre, vitreous or pearly.

Composition.—$(CaAlSi_2O_8)+(Na_2AlSi_6O_{16})$, or 1 molecule of anorthite to 1 of albite substance (the proportion of the latter varying from $\frac{1}{2}$ to $1\frac{1}{2}$ molecule). The formula represents SiO_2 59·76, Al_2O_3 25·55, CaO 6·97 Na_2O 7·72, per cent. The observed amount of lime varies from 3·5 to 10·0, and of soda from 4·8 to 8·0 per cent. A portion of the alkali is invariably potash.

Fusible, but less easily than Labradorite. Only partially decomposed by acids.

Occurrence.—This species was founded upon the felspar of the trachyte of Marmato in the Andes; it is also found at Esterel in the Vosges. In Canada it forms rock masses analogous to those of the Labradorite series, but the line of demarcation between the two is somewhat indefinite. *Saccharite* is a granular variety from Frankenstein in Silesia.

OLIGOCLASE. Oligoklas.—*Triclinic.* $1\bar{1}0/110$, 120° 42′; 001/010, 86° 32′. Crystalline forms and twins generally similar to those of albite. In twins on 010: the basal planes of the component crystals meet at an angle of 173° 04′, and those of $\bar{1}01$ at 175° 50. Cleavage, 001 perfect, 010 tolerably perfect, $1\bar{1}0$ and 110 imperfect. Basal cleavage surface usually finely striated, generally in cleavable masses. H. 6–7. Sp. gr. 2·56–2·72. Colour, white, or variously tinted, yellowish grey, bluish, green, or red, mostly very pale in tint. Lustre, greasy on cleavage faces, vitreous or subvitreous on others. Usually opaque or translucent at the edges. The variety known as *Sunstone* is avanturine from interspersed scales of hematite, giving a reddish golden reflection, sometimes iridescent. Direction of maximum extinction in basal sections inclined from 2° to 3° to edge 001/010. Optic axial plane somewhat similarly placed to that of albite.

Composition.—$(CaAl_2Si_2O_8) + n(Na_2Al_2Si_6O_{16})$, or 1

molecule of anorthite to *n* (1·5–4) molecules of albite. The following analyses show the extremes of composition:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	
Neurode, Harz .	61·54	22·36	1·75	6 23	4·91	2·82	=99·61
Hamilton Sound, Labrador .	64·39	21·52	0·34	2·63	10·14	—	=99·02

Potash is almost universally present up to a maximum of 4·33 per cent. The distinction between oligoclase and albite is not very sharply defined. The varieties with 10 per cent. of soda may be classified equally well with one or other species.

Occurrence.—As a constituent of igneous rocks, either as the sole felspar, or in association with orthoclase and albite as in granite, or with Labradorite, in basalt and dolerite. Well-developed crystals are not very common, the greater number appearing embedded in the crystalline base of the rock, and usually only recognisable by the microscope, when they present the ordinary characters of triclinic structure. At Ytterby in Sweden it occurs in large masses with orthoclase, in a very coarse granite which is quarried for use in porcelain works, and forms the matrix of the yttria minerals. At Hamilton Sound, Labrador, a white variety with a pale blue iridescence shows microscopically small included patches of orthoclase.

Compact Felspars.—Apparently amorphous conditions of felspars occur in many species, two among them being minerals of some importance, namely, compact orthoclase, or Felsite, and compact Labradorite, or Saussurite or Jade. The first, which is also known as Felstone, compact felspar, or Petrosilex, is the basis of many igneous rocks; it is a red jasper or horn-like substance, harder than crystalline orthoclase, with a conchoidal fracture resembling that of flint, from which, however, it is easily distinguished by the fusibility. In composition it differs from the pure mineral by a notable excess of silica, which is seen by the microscope to be

present as quartz in an exceedingly fine state of division, the mixture being so intimate that the quartz crystals are not individualised. The *Hälleflinta* of the Dannemora Mines in Sweden, one of the most characteristic varieties of felstone, corresponds to about $\frac{2}{3}$ orthoclase and $\frac{1}{3}$ quartz.

SAUSSURITE. Jade, Nephrite. — *Amorphous*, in fine-grained or compact aggregates, with occasional traces of cleavage. Fracture, uneven or splintery. H. 6–7. Sp. gr. 2·79–3–3·34. Colour, greyish, or greenish white, to bluish green. Translucent, subtransparent. Lustre, greasy.

	SiO_2	AlO_3	FeO_3	CaO	MgO	Na_2O	K_2O	H_2O	
Saussurite, Zobten, Silesia .	51·76	26·82	1·77	12·96	0·35	4·61	0·62	0·68 =	99·57
			FeO						
Jade, China .	60·22	22·85	2·24	1·53	1·15	12·60	—	0·11 =	100·70

Another variety of Nephrite approximates in composition to Tremolite.

Fusible with difficulty on the edges to a green glass. Not acted on by acids, or only very slightly. Usually very tough.

Occurrence.—Saussurite (the variety of low specific gravity) is one of the constituents of gabbro, and at times appears to be an altered Labradorite. Jade is of specific gravity exceeding 3. It is largely used in China and other Eastern countries for ornamental purposes, especially carvings in high relief, and much undercut; the chief supply being derived from Tibet, and other high lands in Central Asia. In New Zealand and the South Pacific Islands, a dark green variety is used for weapons, and similar axes and weapons of Saussurite were used in Europe in prehistoric times.

CHLORITE GROUP.

The general name of Chlorite was formerly applied to the substances now distinguished as Pennine, Clinochlore, Ripidolite, &c., and in popular language it is still so employed. The grounds upon which the discrimination into species is made are almost entirely crystallographical, and more par-

ticularly based upon optical characters. One class being uniaxial, is referred to the hexagonal, and the other, which is biaxial, to the oblique system. The line of demarcation is not, however, very sharply defined, as sections of the same crystal may show both classes of double refraction. In habit the differences are very slight, both rhombohedral and oblique species appearing in tabular six-sided forms, the former being actually and the latter only apparently hexagonal. Both kinds are distinguished by an eminent basal cleavage, and it is from this property, as in the micas, that the structural differences can be ascertained, the crystals being rarely sufficiently well defined for measurement.

Chlorite is essentially a product of the alteration of other minerals, being found in pseudomorphs after many silicates, and also in rocks that have been partially decomposed. It also forms a principal constituent of many crystalline schists, in a manner similar to mica, and in some cases has been confounded with the latter.

CLINOCHLORE. Chlorite.—*Oblique.* β 62° 51′, ∞P, 125° 37′, $a : b : c = 0{\cdot}5774 : 1 : 0{\cdot}8532$. Crystals either tabular, acute pyramids with truncated summits, or combinations with numerous clinodomes ; the basal planes strongly developed in all. As the plane angles of the latter face are 180° and 60°, the crystals have a generally hexagonal aspect. Twins and compound crystals common on the hemipyramid $3P$; this gives rise to apparent hexagonal prisms by the intersection of the individuals. Usually in radiated or spheroidal groups, massive, in lamellar aggregates, fine scales, or microscopic particles. Cleavage, basal, very perfect. Laminæ flexible, but not elastic, i.e. do not spring back when bent. H. 1–3. Sp. gr. 2·65–2·78. Lustre, vitreous, sometimes pearly on cleavage faces. Grass-green, bluish, or blackish, occasionally green, silvery white in the masses. Transparent—translucent. Plane of optic axes, $\infty P\infty$. The median line makes an angle 75° to

78° with the base; the angle of the optic axes varies from 10° to 80° Transparent crystals often strongly dichroic, being bright green along the vertical axis, and rose-red or purple at right angles to it.

PENNINE.—*Rhombohedral.* R=65° 28′, $a : c = 1 : 3{\cdot}495$. Crystals usually rhombohedral, very much truncated by the basal plane. Cleavage, basal very perfect. Also in radiated, lamellar, massive, and scaly aggregates. H. 2–3 on edges of crystals, generally softer on basal plane. Sp. gr. 2·6–2·85. Colour, green to nearly black, sometimes yellowish white or rose-red. The green transparent kinds often dichroic, being green along the principal axes, and red or brown at right angles to it. Double refraction irregular, being sometimes negative and positive in the sections taken from the same mass.

RIPIDOLITE.—Probably hexagonal, but of undetermined dimensions, usually in fan-shaped spheroidal groups, which have the characteristic cleavage and colour of chlorite. H. 1–2. Sp. gr. 2·78–2·96.

Composition.—If the water obtained by analysis be considered as water of crystallisation, the formula may be considered to be $R_5\dot{R}Si_3O_{14}+4H_2O=\left\{\begin{matrix}R_2SiO_4\\2R_3SiO_5\end{matrix}\right\}+4H_2O$. If, however, the water is supposed to be combined, as is most probable from the very high temperature which is required to drive it off, the following formula, suggested by Rammelsberg, best expresses the composition—

$$\left\{\begin{matrix}H_2R_5Si_3O_{12}\\H_6\dot{A}lO_6\end{matrix}\right\}=\left\{\begin{matrix}H_2SiO_4\\5R_2SiO_4\\H_6\dot{A}l_2O_6\end{matrix}\right\}\quad R=MgFe;$$

which when R=Mg, or the ratio of Mg to Fe is large, very nearly corresponds to the percentage composition. When the amount of iron is too large for the formula, it is probably present as $\dot{F}eO_3$, and in many cases some Al is re-

placed by chromium. Ripidolite contains a large proportion of basic elements, and is approximately represented by $\left\{\begin{matrix}2H_3R_5Si_3O_{12}\\3H_6RO_6\end{matrix}\right\}$. The paler coloured varieties are sometimes almost free from iron. Those containing chromium are commonly of a red colour.

The reduction of the analyses is difficult, owing to the fact that the state of oxidation of the iron is not determined in many instances.

The following are a few selected analyses:

Clinochlore	SiO_2	Al_2O_3	Cr_2O_3	FeO	Fe_2O_3	MgO	H_2O	
White, Slatoust	30·80	17·27	—	1·23	—	37·08	12·30	=98·68
Green, Brosso	33·67	20·37	—	6·37	—	29·49	10·10	=100
Red, Kotschubeite	32·35	13·29	4·19	1·80	1·80	35·04	12·62	=99·29
Pennine								
Zermatt	33·57	13·37	0·20	5·33	—	34·16	12·69	=99·32
Kämmererite	33·28	10·60	4·72	1·60	—	36·35	12·95	=99·50
Leuchtenbergite	30·46	19·74	—	2·0	—	34·63	12·74	=99·57
Ripidolite	25·12	22·26	—	23·11	1·09	17·41	10·70	=99·69

All varieties, when heated, give off water, but not below a strong red heat. In the forceps whiten and exfoliate in a more or less characteristic manner, but do not melt easily unless rich in iron, when a black slag is produced. With fluxes give the reaction of iron, and in some instances of chromium. Partially decomposed by acids, and more readily after heating, sulphuric acid being most efficacious.

Occurrence.—The finest examples of clinochlore are from Achmatovsk, in the Ural, where large dark green crystals occur. A bright, nearly emerald-green variety, is from Texas, Pennsylvania. *Kotschubeite* is a red clinochlore from the Ural. Pennine includes most of the crystallised chlorite from the Alps and Piedmont, usually in hexagonal or triangular plates and flattened crystals. *Kämmererite* is a red or amethystine variety, containing chromium, from Texas, Pennsylvania, and Lake Itkul, Siberia. *Leuchtenbergite* is a nearly white or ochre-yellow coloured pennine, resembling talc, found in large crystals near Slatoust. The dark green radiated stalactitic or incrusting variety found in the

Cornish copper and tin lodes locally known as Peach, is referred to Ripidolite.

Tabergite, a dark blue-green clinochlore, occurring in large plates at Taberg, in Sweden, contains potash and fluorine, in addition to the ordinary constituents.

Delessite, a bright green, earthy, or impalpable chlorite, occurring in the hollows of agate-bearing amygdaloids, contains variable quantities (up to 4½ per cent.) of lime. The structureless green material found in the body of many crystalline rocks, and called by microscopists *viridite*, appears to belong to chlorite, but the position is not well defined.

Chlorite is found in pseudomorphs after felspar, hornblende, garnet, fluor, dolomite, and calcite. It is also commonly seen in fine scales, investing or colouring crystals of quartz and other minerals. In the magnetic iron ore of Sweden it forms thin strings or brightly polished surface incrustations known as Skölar by the miners. In Cornwall it forms a principal constituent of the vein stuff of many of the tin and copper lodes. When interlaminated with quartz it forms chlorite schist, which resembles and is sometimes confounded with mica schist. In this form it is commonly associated with serpentine.

TALC. Steatite, Speckstein. — Probably oblique or rhombic, similar to mica, being occasionally found in six-sided tabular forms, having a very perfect basal, and traces of a prismatic cleavage. Usually in foliated, spheroidal, or radiated masses (talc), also fine scaly, or compact, with a schistose structure (steatite or soap stone). H. 1. Sp. gr. 2·56–2·80. Colour, generally pale green, sometimes silvery white, the compact varieties passing to dark green or grey. Steatite is sometimes variegated with red or other colours upon a greenish grey ground. Transparent in very thin laminæ, imperfectly translucent. Lustre, pearly or greasy. From optical characters the crystalline variety seems to be rhombic, $\infty \breve{P}\infty$ being the optic axial plane, and the vertical

axis the median line. Sectile and flexible in thin laminæ, but not elastic, the compact variety rather brittle. Greasy or soapy to the touch in most cases, and sometimes making a white mark, like chalk, upon a rough surface.

Composition.— $\left\{ \begin{matrix} H_2SiO \\ 3MgSiO_3 \end{matrix} \right\}$, if the water is considered as basic, corresponding to silica 63·49, magnesia 31·75, water 4·76. This formula gives rather more silica than is generally obtained by analysis.

	SiO_2	MgO	FeO	MiO	H_2O
Foliated Talc, Tyrol .	62·12	31·15	1·58	0·24	4·73
Pseudomorph, with hornblende cleavage, Piedmont .	62·29	31·55	1·22	—	4·83

Some varieties contain alumina up to 4 or 5 per cent. Usually gives off water in the closed tube when strongly heated, but not invariably (the amount of water varying from 0 to 7 per cent.). In the forceps whitens, exfoliates, and becomes luminous, fuses on the edges of very thin laminæ to white enamel. With cobalt solution gives the pale red colouration of magnesia. Not decomposed by acids, either before or after ignition.

Occurrence.—Talc occurs in many mountain districts, notably in the Alps, in Tyrol, and Switzerland, both crystallised and forming part of crystalline schistose masses, as talcose schist, or associated with chlorite, serpentine, or dolomite. It is also commonly found as steatite in pseudomorphs after hornblende, augite, garnet, staurolite, felspar, and other silicates. In most cases it is probably a product of alteration, in which respect it stands in the same relation to the hornblende and augite group that serpentine does to olivine. Steatite also occurs in beds and masses, which are worked for ornamental purposes, carvings, and architectural models in India near Agra, in China, &c., and also into slabs for fireplaces, ovens, &c. When ground, moulded, and strongly heated, steatite forms a coherent and very refractory mass. The steatite

points of gas burners are made in this way. French chalk is a soft, slaty steatite, used by tailors for marking patterns on cloth, and also for removing grease spots from silk, &c.

PYROPHYLLITE is a foliated mineral generally similar to talc in form, lustre, and colour. Usually found in small radiated groups like wavellite. Also in compact scaly or slaty granular masses, like steatite. H. 1–2. Sp. gr. 2·75–2·92. Greasy to the touch like talc.

Composition.—

$\mathrm{AlSi_3O_9 + H_2O = SiO_2}$ 60, $\mathrm{Al_2O_3}$ 34·2, $\mathrm{H_2O}$ 6 per cent.
and
$\mathrm{AlSi_4O_{11} + H_2O =}$ „ 66·6, „ 28·3, „ 5 „

The crystallised variety from Russia corresponds nearly to the first formula, and the compact kind from Carolina to the second. Usually small amounts of magnesia and ferrous oxide are found. When heated yields water; the foliated kind swells up to a vermicular or fan-like mass, many times the original volume, but only melts on the thinnest edges. With cobalt gives the blue alumina colouration. Partially decomposed by sulphuric acid.

Occurrence.—Crystallised in the Urals and in California, compact in N. and S. Carolina, Georgia, and Arkansas. That from the Deep River, N. Carolina, is cut into pencils and used instead of chalk for lecture purposes. The Agalmatolite, or Pagoda stone of China, used for ornamental carvings, is also in part of the same composition.

Pyrophyllite is interesting as being an exact analogue of talc in all physical characters. It is, in fact, an aluminous, instead of a magnesian talc.

MEERSCHAUM. Sepiolite.—*Amorphous*, in spheroidal or reniform masses of a flat conchoidal or fine earthy fracture. Colour, white. Lustre, somewhat waxy. H. 2–5, can be impressed by the nail. Sp. gr. in dry masses below 1·0, but

when saturated with water about 2·0. Smooth to the touch and adherent to the tongue.

Composition.—$Mg_2Si_3O_8$ with 2 or 4 molecules of water, corresponding to SiO_2 60·8, MgO 27·1, H_2O 12·1, and SiO_2 54·22, MgO 24·10, H_2O 21·68, respectively. The first represents the composition of the mineral when dried at 100°, and the second when in an air-dried state. In the closed tube gives off water at a low temperature, and more abundantly when strongly heated, with some organic matter. In the forceps blackens, burns white, contracts, and becomes hard; fuses only on very thin edges. Gives the magnesia pink colour with cobalt solution. Decomposed and gelatinised by hydrochloric acid.

Occurrence.—Principally in concretionary masses resembling balls of ironstone in the alluvium of the plain of Eskahissar, near Trebisonde in Armenia, and Tchefketil in the Crimea, whence the chief commercial supply is obtained. There are a few other localities, but not of any importance. When freshly dug it is soft, and may be used instead of soap for cleaning purposes, but hardens by exposure. It is largely used for making tobacco pipes, the principal seat of the manufacture being at Vienna.

SERPENTINE. Ophite, Chrysotile.—*Amorphous*, in masses without definite structure, also lamellar and fibrous, and in pseudomorphs after olivine, augite, hornblende, mica, spinel, chondrodite, and garnet. Fracture, flat, conchoidal, smooth, uneven, granular, or splintery. H. 2·5–4. Sp. gr. 2·49–2·70. Lustre, greasy, resinous, pearly, or waxy. Translucent—opaque. Colour oil-green, yellowish green, brown, brownish red, to nearly black. The lightest colours are found in the so-called precious serpentine in pseudomorphs after olivine, and in the fibrous varieties. When in large masses it is often variegated with red veins containing ferric oxide, and white patches and seams of steatite.

$2H_2O$, upon the supposition that one-half of the water found by analysis is basic, being only given off by long-continued heating; or SiO_2 43·48, MgO 43·48, H_2O 13·04 per cent. Usually some iron is present, and occasionally alumina. Examples:

	SiO_2	MgO	FeO	H_2O
Chrysotile, Zermatt.	41·57	43·57	1·72	13·75
Kynance, Cornwall (dark red) . .	38·29	34·24	13·50	12·09

The maximum amount of alumina reported is about 3·50 per cent. Nickel, chromium, and copper are sometimes found in minute quantity, but these are probably due to intermixed minerals.

When heated it gives off water, and sometimes blackens from carbonised organic matter; afterwards burns white, and is infusible, or fusible only on very thin edges.

Most varieties give an iron reaction, and the lighter coloured ones that of magnesia with cobalt solution. Decomposed by hydrochloric and sulphuric acids with separation of silica.

Occurrence.—There are a large number of minerals described by different names that are essentially varieties of serpentine. *Precious* or *noble serpentine* includes the translucent, uniformly coloured, usually greenish masses from Snarum, Norway; Miask and other localities in the Ural; and in New York State: also the large pseudomorphs after olivine, from Snarum, which at times contain kernels of the original unaltered mineral. *Marmolite* is a green foliated variety. *Chrysotile* or *serpentine amianthus* embraces the fibrous kinds, yellowish green, or sometimes white, occasionally forming veins in the compact variety. *Common serpentine* or *serpentine rock* includes the dark-coloured and opaque kinds; these are found in great masses often nearly pure, or including diallage, hypersthene, and garnet, &c., and are used for ornamental purposes, such as columns, vases, chimney-pieces, &c. The most important localities of the ornamental kinds

are around the Lizard Point in Cornwall; Zöblitz in Saxony, where the rock is mottled with crystals of pyrope; and the neighbourhood of Amlwch, Anglesea. When mixed with calcite or dolomite, it forms a variegated green marble, known as *verd antique* marble. This is found in Connemara, Sweden, Canada (the so-called Eozoonal limestone), and other places, and is used for ornamental purposes, but does not stand exposure to the weather when polished for a long period without becoming dull. It may also be used as a source of Epsom salts, from its comparatively ready solubility in sulphuric acid.

Serpentine is in most cases probably a product of the hydration of rocks containing olivine, augite, hornblende, and other intrusive or erupted igneous masses, which often retain sufficient traces of their original structure to afford evidence of their metamorphic characters. In this way the occurrence of supposed intrusive masses and veins of serpentine may be accounted for, the transformation having been effected upon ordinary or igneous rocks. In certain limestones in Canada and Bavaria, the arrangement of laminæ of intermixed fibrous serpentine has been supposed to indicate organic structure, and to be the remains of gigantic foraminifera, under the name of Eozoa, but this view is not very generally received.

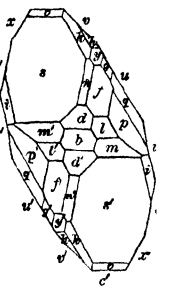
BASIC AND BORO-SILICATES.

Under this division are grouped several minerals, which, though differing considerably in character, are all of a polybasic class, with less than 40 per cent. of silica, and in many instances contain fluorine or boron, the former replacing oxygen, and the latter, as sesquioxide of boron, representing alumina. The arrangement is purely one of convenience, and the grouping is therefore to be regarded as artificial.

CHONDRODITE. Humite, Clinohumite. — The species Chondrodite has been shown by the researches of Scacchi,

Descloizeaux, Dana, and others, to include three different types of crystalline forms. One of these (*humite*) is rhombic, and the other two (*chondrodite* and *clinohumite*) are oblique. In all cases the crystals are very complex aggregates of a great number of forms (fig. 117 is one of the oblique types), and often nearly spherical. Chondrodite is commonly found in granular masses, resembling a light brown garnet, embedded in limestone. H. 6–6·5. Sp. gr. 3·12–3·24. Lustre, vitreous or resinous. Colour, various shades of yellow up to hyacinth-red or ochre-yellow; also in some massive varieties, green and brown; streak, light coloured. Transparent, translucent. Fracture, imperfectly conchoidal to uneven.

FIG. 117.



Composition.—A combination of silicate of magnesia of the form $Mg_2Si_2O_9$ in variable proportions, with the corresponding silico-fluoride $Mg_5Si_2O_{18}$, or intermediate between a dibasic and tribasic silicate.

The following analyses represent the extreme proportions of fluorine:

	F	SiO_2	MgO	FeO	Al_2O_3	
Chondrodite, Pargas .	8·69	33·10	56·61	2·35	—	100·75
Clinohumite, Vesuvius .	2·40	36·82	54·92	5·48	0·24	99·86

Infusible. Some varieties blacken and then burn white in the flame, with salt of phosphorus. In the open tube gives the reaction of fluorine on Brazil wood paper. Gelatinises with hydrochloric acid; with sulphuric gives off fluoride of silicon and hydrofluoric acid when heated.

Occurrence.—In crystalline limestones at Pargas in Finland; Sussex and Sparta, New Jersey, &c. The well-crystallised varieties are principally from Vesuvius, in the limestone blocks of Somma, and from Brewster, New York.

The crystals are remarkable for the great number of faces in the same zones. For figures of these the reader is referred to Dana and Descloizeaux.

ANDALUSITE. Chiastolite, Macle. — *Rhombic.* ∞P 90° 48′, $a : b : c = 0{\cdot}9861 : 1 : 0{\cdot}7025$. Crystals (fig. 118), $m\{110\}\infty P$, $r\{101\}\breve{P}\infty$, $s\{011\}\breve{P}\infty$, $c\{001\}0P$. Usually elongated prisms. Cleavage, 110 imperfect. Fracture, uneven—splintery. Also in imperfectly developed crystals and aggregates implanted. H. 7 to 7·5 on 001, but often

FIG. 118.

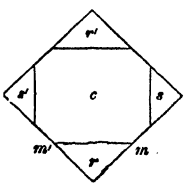
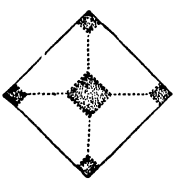


FIG. 119.



lower on other faces. Sp. gr. 3·15–3·35. Colour, white, grey, reddish brown, olive-green, or violet; streak, white. Lustre, vitreous, weak. Transparent to opaque; usually translucent at the edges. Transparent varieties usually pleochroic. Double refraction negative. Indices for red rays, $\alpha = 1{\cdot}643$, $\beta = 1{\cdot}638$, $\gamma = 1{\cdot}632$. Optic axial plane 010, c first median line.

Composition.—Al_2SiO_5, or silica 36·90, alumina 63·10 per cent. A portion of the alumina is generally replaced by ferric oxide and lime, so that the observed amount is rarely up to 60 per cent.

Infusible. Heated with cobalt solution gives the alumina blue; with soda, swells up to a porous mass, but does not fuse. Not affected by acids. Decomposed by fusion with caustic alkalies.

Occurrence.—The variety called *Chiastolite* or *Macle* is distinguished by the presence of foreign matters symmetrically disposed through the mass of the crystals, so that when

they are broken across, a white cross with dark centre or a tesselated appearance is seen as in fig. 119. Found in argillaceous schists, mica schist, gneiss, and similar rocks, being a common product of the contact metamorphism of igneous masses. When the crystals or masses are abundant, such rocks are known as *chiastolite schists.* The transparent crystals are from Minas Geraes in Brazil.

Sillimanite and *Fibrolite* are other minerals of the same composition, but referred to oblique forms. The crystals are long and slender, and distinguished by a very perfect cleavage, parallel to the orthopinakoid. In other respects they are similar to Andalusite.

CYANITE. Disthene, Rhätizite.—*Triclinic.* Dimensions undetermined. Crystals, long, thin, rhomboidal prisms, the terminal plane rarely seen, but oblique to the prism. Often twinned on the broad faces of the prism. Cleavage, parallel to macro- and brachy-pinakoids perfect, and to the basal pinakoid less so. The latter is inclined at 79·10° and 86·45° to the former. Crystals usually implanted singly or in divergent or radiating aggregates ; also in nearly compact masses of a fibrous structure. Double refraction negative. Index β for red=1·720. H. 5 on 100 and 7 on 010. Sp. gr. 3·48–3·68. Lustre, vitreous to pearly on principal cleavage surfaces. Colour, white, or various shades of light blue to azure-blue ; also grey, green, reddish, or black. Transparent to translucent at edges, the former often trichroic.

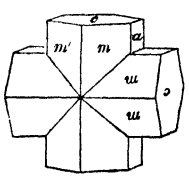
Composition and chemical properties similar to those of Andalusite.

Occurs with staurolite in paragonite schist at St. Gothard and other Alpine localities ; Roräs, Norway ; and numerous localities in the New England States. The blue long-bladed crystals are usually distinguished as *Cyanite,* and the small columnar white kinds as *Rhätizite.*

STAUROLITE.—*Rhombic.* ∞P 129° 20′, $\breve{P}\infty$ 69·32, $a : b : c$

= 0·4734 : 1 : 0·6820. (Fig. 120) $m\{110\}\infty P$, $c\{001\}$ oP, $a\{010\}\infty \breve{P}\infty$. Crystals, either short stout columnar, thin columnar, or tabular to 010. Usually twinned as penetration twins (fig. 120), the vertical axes of the two individuals intersecting nearly 90° or 60° respectively, producing in the first case a right-angled, and in the second an oblique cross. Sometimes three crystals are combined, giving either a six-armed star in one plane, or a rectangular cross in three directions. Cleavage, brachydiagonal interrupted, also prismatic in traces. Fracture, conchoidal, uneven. H. 7–7·5. Sp. gr. 3·26–3·79. The most siliceous varieties the lightest. Colour, reddish brown to brownish black. Lustre, vitreous, resinous. Translucent to opaque. Double refraction negative. Index β for red, 1·7526. 100 is the optic axial plane, and c the first median line.

FIG. 120.



Composition.—R_3SiO_5, $2R_4SiO_6$ approximately, or when R=(Mg+3Fe) containing SiO_2 30·37, AlO_3 51·92, FeO 13·66, MgO 2·53, H_2O 1·52.

Analyses usually show less alumina, it being partially replaced by ferric oxide, and in some instances up to 50 per cent. more silica. The latter is, however, due to included quartz, which is dispersed in white grains through the mass of the crystals, and may be extracted by hydrochloric acid, when the purified residue gives very close to the theoretical composition.

Infusible, and not acted upon by acids.

Occurrence.—With kyanite in paragonite schist at Monte Campione in Switzerland, and in mica schist in Brittany and the New England States.

Pseudomorphs of Andalusite and cyanite into mica, of the former into steatite, of both into talc, and of the former into the latter, are recorded.

TOURMALINE. Schorl.—*Hexagonal, rhombohedral, and*

hemimorphic. $R = 153° 08'$, $a : c = 1 : 0{\cdot}4477$ [1] (figs. 121, 122) (opposite ends of same crystal), $r\{10\bar{1}1\}$ R, $e\{02\bar{2}1\} -2R$, $t\{12\bar{3}2\} -\frac{1}{2}R^3$, $x\{32\bar{5}1\}$ R^5, $a\{11\bar{2}0\} \infty P2$, $a\{10\bar{1}0\}$ $\frac{1}{2}(\infty$ R) hemimorphic, o $\{0001\}oP$. The crystals are prominently dissimilarly ended, especially as regards 0001, which is sometimes absent at one end. Faces of prisms usually striated vertically: large crystals often in parallel columnar groups. Also fibrous in radiated and plumose forms, and included, as microscopic individuals, in crystals of other minerals, so as to resemble colouring matter. Cleav-

FIG. 121.

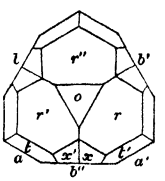
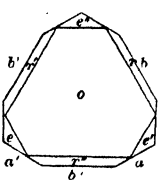


FIG. 122.



age, $10\bar{1}1$ and $11\bar{2}0$ both imperfect. Fracture, conchoidal, uneven. H. 7–7·5. Sp. gr. 2·94–3·24. Sometimes colourless, usually black; less common colours are green, brown, blue, and red, the latter the rarest. Crystals sometimes with nuclei of different colours to those of the faces, or dissimilarly coloured at opposite ends, these varieties being often distinguished by particular names. Strongly dichroic. Transparent to translucent; opaque in the black varieties. Lustre, vitreous. Double refraction negative. Indices for colourless crystals: 1·6366 ordinary, 1·6193 extraordinary ray. The coloured varieties have higher refractive indices, and have such a strong absorptive power for the ordinary ray when cut into thin plates parallel to the vertical axes, that they may be used as polariser and analyser in the so-called tourmaline pincers. Thermo-electric and polar, the analogue pole is at the end having the edges $10\bar{1}1/10\bar{1}0$ horizontal.

[1] Dana doubles this, giving 2R of the above notation as R.

Composition.—All tourmalines are tribasic silicates, containing the fundamental molecules, $\overset{I}{R}_6SiO_5$, $\overset{II}{R}_3SiO_5$, and $\overset{VI}{\mathrm{R}}SiO_5$, combined together in very variable proportions. The observed elements are $\overset{I}{R}$ = H, K, Na, and Li; $\overset{II}{R}$ = Mg, Ca, Mn, and Fe; and $\overset{VI}{\mathrm{R}}$ = B and Al. Oxygen may also be replaced by fluorine to a small extent. The diversity in the analyses is so great that no single formula will satisfy them all, but according to Rammelsberg they may be reduced to three groups, represented by the following general expressions:

$$\text{IA.}\left\{\begin{matrix}\overset{I}{R}_6R_3Si_4O_{20}\\ \overset{II}{2R}_3R_3Si_4O_{20}\end{matrix}\right\}\text{where } \overset{I}{R} : \overset{II}{R} : Al = 1 : 1 : 1$$

$$\text{IB.}\left\{\begin{matrix}5R_6R_3Si_4O_{20}\\ \overset{II}{2R}_3R_3Si_4O_{20}\end{matrix}\right\}\text{ „ „ „ „ } 5 : 2 : 3\Big\}\ R = B : Al_2$$

$$\text{II.}\left\{\begin{matrix}m\ \overset{I}{R}_6R_8Si_9O_{45}\\ n\ \overset{II}{R}_3R_8Si_9O_{45}\end{matrix}\right\}\ R = B : 3Al.$$

III. Isomorphous mixtures of Groups I. and II.

Group I. includes most of the darker coloured varieties, in which the bases are chiefly magnesia, magnesia-ferrous oxide, or ferrous oxide, the average percentage of alumina being about 33.

Group II. includes the colourless red and pale green kinds, in which the bases are principally alkalies, and the alumina averages 43 per cent.

Group III. is represented by the bright green variety from Brazil.

The following analyses are from Rammelsberg's classic investigation:

	I.	II.	III.	IV.	V.
Type	IA.	IA.	IB.	II.	III.
Sp. gr. .	3·049	3·205	2·94	3·022	3·107
Fl. .	—	0·45	0·47	0·70	0·70
SiO_2 .	38·85	37·94	37·14	38·85	38·06
B_2O_3 .	8·35	10·72	9·37	9·52	10·09
Al_2O_3 .	31·32	30·22	34·15	44·05	37·81
FeO .	1·14	13·82	10·52	—	5·83
MnO .	—	0·40	1·87	0·92	1·13
MgO .	14·89	2·62	1·68	0·20	0·92
CaO .	1·60	0·50	—	—	—
Na_2O .	1·28	1·39	2·30	2·00	2·21
K_2O .	0·26	0·65	0·75	1·30	0·42
Li_2O .	—	—	0·32	1·22	1·30
H_2O .	2·31	1·74	1·90	2·41	2·23

I. from Gouverneur, New York, brown; II. Bovey Tracey, Devon, black; III. Elba, greenish and brownish black; IV. Elba, colourless; V. Brazil, green.

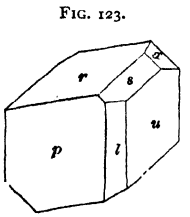
Water is not given off except by a very strong and continued red heat, when there is a simultaneous loss of silica and fluorine. The magnesian and magnesia-iron varieties are fusible to an enamel or slag, which may be either white, brown, green, or black, according to the nature of the bases, the differences being mainly due to the proportion of iron. The green, red, and pale-coloured varieties are only fusible at the edges, or infusible but becoming opaque and exfoliating by heat. All are unaffected by acids, and even by hydrofluoric acid, except when previously heated. May be decomposed by sulphuric acid after fusion. When fused with fluor spar and bisulphate of potash gives the green flame colouration of boracic acid, and with borax the reactions of iron and manganese.

Occurrence.—Tourmaline is of common occurrence in granite and other crystalline rocks, and also with quartz in the vein stuff of tin ores in Cornwall, Saxony, and Bohemia. With pink orthoclase the black variety forms a

remarkable porphyry at Luxullian in Cornwall. Large black crystals are found in the granite of Bovey Tracey, Devon, and in small plumose and radiated masses in the granite of the Land's End, near St. Just. The transparent, precious, or brightly coloured varieties are chiefly got from Elba, Brazil, and Burmah; the larger red crystals from Ava known as *Rubellite* being the most valuable. *Indicolite*, or *Brazilian sapphire*, so called from its dark blue colour, is found in Brazil, and also at Ûto interspersed in Petalite. The green and yellow kinds are known as *Brazilian emerald*, *Ceylon peridote*, &c. The colourless crystals from Elba are sometimes called *Achroite*. In Cornwall, and in mining countries in Europe, it is almost invariably known by the old German miners' name of *Schorl*. This was originally applied to many fibrous, dark-coloured minerals, but it has in course of time become specially restricted to tourmaline.

AXINITE.—*Triclinic*. Crystals usually thin, sharp-edged, and very unsymmetrical in character. (Fig. 123) $p\{010\}$ $\infty\breve{P}\infty$, $l\{\bar{1}20\}$, $\infty'\breve{P}2$, $u\{\bar{1}10\}\infty'P$, $x\{\bar{1}11\}$, P, $s\{121\}2\breve{P}2$, $r\{011\}$, $\breve{P}\infty$. In grouped and partially embedded crystals. Cleavage, very imperfect traces in several directions. Fracture, conchoidal; the sharp edges of the crystals are commonly fractured with small saw-like notches. H. 6·5–7. Sp. gr. 3·27–3·30. Colour, smoky grey, clove-brown, pearl-grey: also pleochroic, exhibiting different colours in three directions. Sometimes the crystals are pale green, from incrustation with chlorite.

FIG. 123.



Composition.—$\overset{\text{I}}{\dot{R}}_2\,\overset{\text{II}}{\dot{R}}_6\,\ddot{R}_3\,Si_8\,O_{32}$, approximately, or a dibasic silicate chiefly of calcium, aluminium, and borax. The following analysis is of the mineral from a typical locality, Bourg d'Oisans in the Dauphiné Alps:

SiO_2	BO_3	AlO_3	FeO_3	FeO	MnO	CaO	MgO	K_2O	H_2O
43·46	5·61	16·33	2·80	6·78	2·62	20·19	1·73	0·11	1·45=101·08

Fusible with intumescence to a dark-coloured glass. With bisulphate of potash and fluor spar gives the green flame of boracic acid. Not very easily acted upon by acid except after fusion, when it gelatinises with hydrochloric acid.

Occurrence.—In association with felspar and tourmaline, at Bourg d'Oisans, Dauphiné; Botallack in Cornwall; at Andreasberg and other localities in the Harz, at St. Gothard, and in the Peruvian Andes.

TOPAZ.—*Rhombic.* ∞P 124° 17′, P 101° 40′ & 140° polar, 91° 10′ basal. $a : b : c = 0{\cdot}5285 : 1 : 0{\cdot}9539$. (Figs.

FIG. 124.

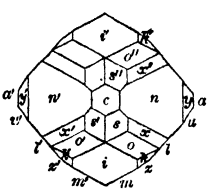
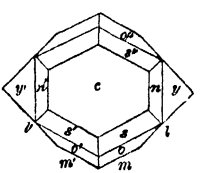


FIG. 125.



124, 125) $m\{110\}\infty P$, $z\{230\}\infty \breve{P}\frac{3}{2}$, $l\{120\}\infty \breve{P}2$, $u\{130\}\infty \breve{P}3$, $a\{010\}\infty \breve{P}\infty$, $k\{111\}P$, $o\{112\}\frac{1}{2}P$, $s\{113\}\frac{1}{3}P$, $x\{123\}\frac{2}{3}\breve{P}2$, $n\{011\}\breve{P}\infty$, $y\{021\}2\breve{P}\infty$, $i\{101\}\breve{P}\infty$, $c\{001\}oP$. The crystals are, as a rule, implanted in druses, with only one perfect termination. Where both ends are seen, they are generally dissimilar, but the hemimorphism is not completely established. Prismatic faces usually striated vertically. Also in massive columnar aggregates, and in rolled subangular fragments. Cleavage, basal perfect. Fracture, conchoidal, uneven. H. 8. Sp. gr. 3·51–3·57. Lustre, vitreous. Transparent to translucent. Colour, straw- to deep wine-yellow, pink, hyacinth-red, pale blue, greenish white, or colourless. The strongly coloured varieties are markedly dichroic, the colour being much darker when seen along the vertical axis than across it. They also as a rule become

bleached by exposure to sunlight. (For this reason the magnificent crystals from Russia in the British Museum are protected by closely fitting pasteboard covers.) Double refraction positive. Indices for D line, $\alpha = 1{\cdot}6116$, $\beta = 1{\cdot}6138$, $\gamma = 1{\cdot}6211$. $2E$ 100°. Optic axial plane, 010; first median line c. In the whole crystals, the apparent angle up to 125°. Thermo-electric.

Composition.—$\left\{ \begin{matrix} 5\mathrm{AlSiO_5} \\ \mathrm{AlSiFl_{10}} \end{matrix} \right\}$, or similar to that of Andalusite, with one-sixth of oxygen replaced by fluorine. This corresponds to Fl 17·50, Si 15·48, Al 30·18, and O 36·84 per cent., or, as the analyses are reported: Fl 17·50, SiO_2 33·16, AlO_3 56·70 = 107·36, i.e. showing an excess of $7\frac{1}{3}$ per cent. The analyses generally show a somewhat variable proportion of fluorine (16 to 19·6 per cent.), but some of the newest give almost exactly the theoretical composition.

Infusible, and not attacked by acids, except partially by sulphuric acid. With salt of phosphorus in the open tube, when very strongly heated, gives the reaction of fluorine, and with cobalt solution that of alumina. The yellow varieties may sometimes be turned pink by very careful heating. At a very high temperature, such as that of a porcelain kiln, becomes dull and opaque, with a loss of from 15 to 25 per cent. in weight. This consists mainly of fluoride of silicon, with probably some fluoride of aluminium and hydrofluoric acid.

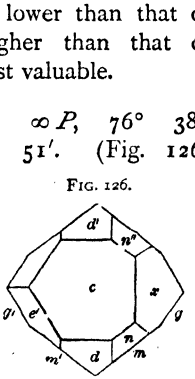
Occurrence.—In granite, gneiss, talcose and micaceous schists, and in veins in these rocks, with tourmaline, mica, beryl, tin ore, fluor spar, and apatite. The finest crystals are those from Miask and Odontaschalon in Siberia, and Villa Rica in Brazil, some of the former being about two inches across the base. Those from Brazil are generally deep yellow. In rolled masses, common in the gold washings of the Australian colonies and Tasmania, and North-Western America. Very lustrous transparent small crystals are found

with tin ore and magnetite at Durango in Mexico. In Cornwall with tin ore at St. Michael's Mount, and similarly at Schneckenstein in Saxony. In the granite of the Mourne Mountains crystals occur with felspar, quartz, and beryl. *Pycnite* is a massive columnar variety of a yellowish white colour and nearly opaque, found at Schneeberg in Saxony, and at Durango.

The transparent and coloured varieties are used as gems, being cut with facets. The lustre is lower than that of sapphire and ruby, but somewhat higher than that of emerald. The pink crystals are the most valuable.

DATHOLITE, Datolite. — *Oblique.* ∞P, 76° 38′, $a : b : c = 0{\cdot}6329 : 1 : 0{\cdot}6345$. $\beta = 89°\ 51'$. (Fig. 126) $m\{110\}\ \infty P, g\{210\}\ \infty \breve{P}2, n\{111\} -P$, $e\{211\}\ 2\breve{P}2$, $d\{011\}\ \breve{P}\infty$, $x\{201\}\ -2\breve{P}\infty$, $c\{001\}\ 0P$. Crystals mostly very complex from the great number of forms present; tabular. Also in botryoidal radiated columnar aggregates and massive compact. Cleavage, 001 imperfect. H. 5·5. Sp. gr. 2·9–3·0. Fracture, conchoidal, uneven. Lustre, vitreous. Brittle. Nearly colourless; usually of a pale greenish tint, sometimes grey, bluish, or reddish. The compact variety is dull white, like porcelain; purple, or rose-coloured; streak, white. Translucent. Opaque in compact kinds. Optic axial plane, 010, first median line inclined 4° backwards from *c*.

FIG. 126.



Composition. — $H\,Ca\,BSiO_5 = H_2\,Ca_2\,B_2\,Si_2\,O_{10} = \left\{\begin{matrix} H_6SiO_5 \\ 2Ca_3SiO_5 \\ 3\,B\,Si\,O_5 \end{matrix}\right\}$, or a tribasic silicate, giving a formula analogous to that of Euclase, corresponding to SiO_2 37·50, B_2O_3 21·88, CaO 35·00, H_2O 5·62.

Gives off water in the open tube, but only when strongly heated, a low red heat not being sufficient. In the forceps

fuses readily to a transparent glass, colouring the flame pale green. Gelatinises with hydrochloric acid both before and after fusion.

Occurrence.—In basaltic and similar igneous rocks, and occasionally in mineral veins. The finest crystallised specimens are from the trap rock of Bergen Hill, New Jersey; Isle Royal, Lake Superior; Arendal, Norway; and Andreasberg in the Harz. The compact variety occurs in the vein stuff of the Lake Superior copper mines, some being apparently coloured with suboxide of copper. *Haytorite* is a chalcedony pseudomorph, after Datholite, found at Haytor iron mine, Devon. *Botryolite*, a radiated columnar variety from Arendal, is of the same composition, with the addition of 1 molecule of water of crystallisation.

DANBURITE.—$CaB_2Si_2O_8 = SiO_2$ 48·78, B_2O_3 28·46, CaO 22·76 per cent., from Danbury in Connecticut, and Russel, New York, is remarkable for its close crystallographic likeness to topaz, the two species being almost identical both in form and habit, while in no way related in composition. The crystals, which are of considerable size, are from the second locality.

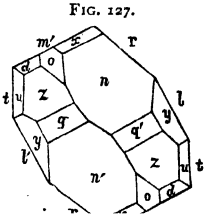
EPIDOTE GROUP.

This includes a small series of basic silicates, of which the principal members, Zoisite, Epidote, and Orthite, are closely related either in form or composition. The first two are isomorphous in the rhombic and oblique systems, and of the same general molecular constitution, the differences between them corresponding to differences in the relative proportion of sesquioxide bases ~~Fe~~ : ~~Al~~, which is 1 : 12 and upwards in Zoisite, and 1 : 6 and below in Epidote; and although crystallising in different systems, the habit of the crystals is very similar in both. The relation between these species is analogous to that subsisting between enstatite and in the group of normal silicates. Orthite is very

closely isomorphous with epidote, but the analyses are not reducible to the epidote formula without considerable manipulation. This is in part due to the difficulty of determination of the state of oxidation of the cerium metals, which form their most characteristic constituents. Lievrite and Iolite, which are here included, have no direct relation, founded on composition, to the Epidote series proper, but from similarity of association they may be conveniently considered as forming part of the group.

EPIDOTE. Pistacite, Piedmontite.—*Oblique.* ∞P 70°, $a : b : c = 1{\cdot}5807 : 1 : 1{\cdot}8057$, $\beta = 64°\ 36'$. Fig. 127 (projected on 010) m {001} o P, r {100} $\breve{P}\infty$, l {201} 2 $\breve{P}\infty$, t {100} $\infty \breve{P}\infty$, z {110} ∞P, q {$\bar{2}$21} 2P, n {$\bar{1}$11} P, x {$\bar{1}$12} $\frac{1}{2}P$, d {111} $-P$, u {210} $\infty \breve{P}2$, y {211} 2$\breve{P}2$, o {011} $\breve{P}\infty$. This position, that of Marignac, is now mostly adopted : in the older one of Mohs, $m = \{100\}$, $t = \{101\}$, l {001}, and $\beta = 89°\ 27'$. Twins on 100 common, often repeated with the intermediate individuals reduced to thin plates. Crystals usually much elongated, with faces striated parallel to axis b. Also fibrous, granular, massive, and in pseudomorphs after scapolite, garnet, felspars, hornblende, and augite. Cleavage, 001 perfect, 100 less so, giving a prism of 115° 24'. H. 6–7. Sp. gr. 3·32–3·49 (Epidote), 3·52 (Piedmontite). Lustre, vitreous, adamantine on 001. Translucent to opaque. Colours: Epidote, yellowish to oil-green, brownish grey or black; Manganese epidote, purplish or brownish red, somewhat like rutile. Double refraction negative. Indices for red, α 1·7305, β 1·7541, γ 1·7677. Optic axial plane, 010, first median line inclined 2° 56' to axis c ; $2V = 73°\ 56'$. Strongly pleochroic; the dark-coloured twinned crystals are idiocylophanic, or show the rings and brushes corresponding to one optic axis, when a light is viewed through the faces

FIG. 127.



of 101. The middle individual here represents a thin section, while the external ones, which are in parallel position, correspond to a tourmaline tongs in the same position.

Composition.—$M_2Ca_4R_3Si_6O_{26}$, which, by reducing the bases to the equivalents in dyad metals, may be represented as $\overset{II}{R}_7Si_3O_{13} = \left\{\begin{matrix} 2R_2SiO_4 \\ R_3SiO_5 \end{matrix}\right\}$, or a combination of two molecules of dibasic with one of tribasic silicate. The hexad bases are Al_2O_3, Fe_2O_3, and Mn_2O_3; and according to their relative proportions, the group is divisible into three varieties, namely, *Lime-alumina epidote*, with a minimum of iron constituting the isomorphous species *zoisite; Epidote proper*, with a large proportion of alumina replaced by ferric oxide; and *Manganese epidote*, containing about equal quantities of alumina and manganic oxide. The atomic weight of iron being higher than that of aluminium, the proportion of silica diminishes as that of iron increases, the range being from 40–42 per cent. in zoisite, and from 37–39 in epidote. The analyses give about the extremes of composition.

	SiO_2	Al_2O_3	Mn_2O_3	Fe_2O_3	CaO	MgO	H_2O	
Maigels, Grisons, grey, sp. gr. 3·361	39·07	28·90	—	7·43	24·30	0·10	0·63	= 100·43
Sulzbachthal, Bavaria, sp. gr. 3·491	37·11	21·90	—	16·00	23·19	—	2·03	= 100·23
Manganese epidote, Piedmontite, S. Marcel, sp. gr. 3·518	38·64	15·03	15·00	8·38	22·19	—	1·78	= 101·78

Gives off water in the closed tube at a strong red heat. In the forceps swells up to a brown mass, which may be rounded at the edges. Only the manganiferous and the more ferriferous varieties are fusible to a dark brown or black mass, which is sometimes magnetic. With borax gives the reactions of iron and manganese according to the bases present. But very slightly acted upon by acids, except after ignition, when it is readily decomposed with gelatinisation.

Occurrence.—In many granites and in crystalline schists, and near to the contact with intrusive rocks in sandstones. Also in dolerites and other lavas. In the magnetic iron ore mines of Scandinavia it occurs with garnet and hornblende,

and is sometimes used as a blast-furnace flux in the smelting of siliceous ores.

The principal British localities are in Cornwall and Scotland. In the Fassathal and other valleys in Tyrol enormous crystals of great brilliancy, up to six or eight inches long, and more than an inch across on the clinopinakoid, have been latterly found. In the Lake Superior copper district it forms a principal constituent of the copper-bearing rocks, at times in a granular form, making a kind of sandstone with quartz and native copper. *Manganese epidote* occurs at the manganese mine of San Marcel, above Nuz, near Aosta, associated with many other manganiferous minerals. Another variety is found at Jacobsberg, in Sweden.

ZOISITE. Thulite.—*Rhombic.* ∞P 116° 16′ to 117° 05′, $a : b : c = 0{\cdot}6168 : 1 : 0{\cdot}7089$. Crystals elongated, and usually striated parallel to *c*. Generally in imperfectly developed forms, much furrowed, and similar to epidote. Also compact. Cleavage, 010 perfect. Fracture conchoidal, uneven. H. 6–6·5. Sp. gr. 3·10–3·38. Lustre, vitreous, pearly on cleavage surfaces. Colour, usually grey, or some pale tint of brown or green : pink or rose-red in Thulite. Feebly translucent as a rule. Double refraction positive. The optic axes lie in the brachypinakoid, the brachydiagonal being the median line, but sometimes they are in the basal section.

Composition.—Similar to that of epidote, but containing only 2–4 per cent. of Fe_2O_3. In Thulite a portion of this is replaced by MnO_3.

	Sp. gr.	SiO_2	Al_2O_3	Fe_2O_3	Mn_2O_3	CaO	Mgo	H_2O	
Zoisite, Sterzing	3·35	40·00	30·34	2·06	—	24·15	0·23	2·04	= 98·82
Thulite, Arendal	3·34	40·28	31·84	1·54	1·05	21·42	0·66	1·32	= 98·53[1]

Swells up when strongly heated, giving off water and fusing partially to a blebby glass. Not affected by acids

[1] This sum includes 0·22 vanadic acid.

unless previously ignited, when it gelatinises with hydrochloric acid.

Occurrence.—It occurs similarly to epidote, and usually associated with it. The principal localities are Sterzing, Tyrol; Saualpe, Carinthia; and Arendal, Norway. Thulite from the latter place occurs interspersed in patches through a rock with cyprine or turquoise-blue idocrase.

ORTHITE. Allanite. Bucklandite. Cerine.—*Oblique*, isomorphous with and similar to epidote. ∞P 70° 48′, $a : b : c = 1{\cdot}5527 : 1 : 1{\cdot}7780$, $\beta = 65°$. Crystals, thick, tabular to 100, or columnar, or twinned and grouped like epidote, also massive and interspersed. Cleavage in traces only, orthodiagonal and basal. Fracture, conchoidal. H. 6. Sp. gr. 3·1–4·1. Lustre, submetallic or pitchy, vitreous on fracture. Colour, black, dark brown, or dark grey. Imperfectly translucent to opaque. Thin sections transparent, and show irregular composition, being partly of double and partly of single refracting substance.

Composition.—Probably an epidote in which lime is in part replaced by the oxides of the cerium metals (CeO, LaO, YtO, DiO), which view, however, supposes the presence of some of these metals as sesquioxides and of basic water. If they are all considered as protoxides and the water as non-essential, then the constitution is analogous to that of garnet. The following are some of the principal varieties:

	SiO_2	AlO_3	FeO_3	FeO	CeO	LaO	YtO	CaO	MgO	H_2O
Cerine, Riddarhyttan	31·00	9·10	8·71	12·69	17·35	16·08	—	9·08	1·36	0·33
Bucklandite, Laach	31·83	13·66	—	18·35	20·89		—	11·46	2·70	—
Allanite, Greenland .	34·47	14·36	7·66	8·23	14·79	7·66	—	10 20	1·08	1·56
Orthite, Hitteroe .	33·81	13·04	8·16	8·30	—	1·45	20·50	9·42	0·38	3·38

Some varieties from Sweden and Norway contain much more water (5 to 17 per cent.), with a proportional diminution of lime. These are considered to be partially decomposed.

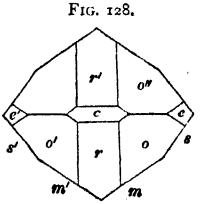
Many varieties give off water in the closed tube. Those known as *pyrorthite* ignite and glow like tinder when heated. Fusible more or less readily to a dark, blebby, magnetic glass. Generally gelatinises with hydrochloric acid; some varieties are but slightly acted on unless previously ignited. With the fluxes only an iron reaction is obtained, the characteristic constituents, the oxides of the cerium group of metals, not being recognisable unless the other bases have been removed. Their most marked chemical property is that of separating as insoluble oxalates from a hydrochloric acid solution, in which respect they differ from lime.

Orthite is a rare mineral, being confined to a small number of localities, but in these it sometimes appears in considerable masses. The chief localities are Greenland (Allanite), Snarum and Kragerö in Norway, Bastnäs (cerine), Finbo and Ytterby in Sweden; Haddam, Connecticut; Miask in the Ural (in granite, syenite, and similar crystalline rocks, associated with zirconia minerals).

Bucklandite, a nearly anhydrous variety, is found in old lavas at the Lake of Laach, and with magnetite at Arendal. The same name has been applied to a dark-coloured epidote from the Ural. At Helsingfors and Wexir in Finland, crystals are found which consist of a nucleus of orthite inclosed in epidote.

LIEVRITE. Ilvaite, Jenite.—*Rhombic.* ∞P, 112° 38′, $a : b : c = 0{\cdot}6649 : 1 : 0{\cdot}4429$. (Fig. 128) $m\{110\}\infty P$, $s\{120\}\infty \breve{P}2$, $o\{111\}P$, $r\{101\}\breve{P}\infty$, $e\{021\}2\breve{P}\infty$, $c\{001\}oP$. Faces in the prismatic zone, generally furrowed vertically: also in columnar aggregates or massive. No definite cleavage. Fracture small conchoidal, uneven. H. 5·5–6. Sp. gr. 3·8–4·2. Lustre, submetallic or pitchy. Colour, black, with a brown or green coat. Opaque.

FIG. 128.

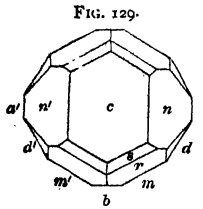


Composition.—A basic silicate, yielding by analysis both ferrous and ferric oxides, lime, and water. The constitution is not very definitely made out, owing to the difficulty of getting unaltered crystals. Rammelsberg considers the water non-essential, and the composition to be represented by the formula $\left\{\begin{matrix} 6R_2\,Si\,O_4 \\ Fe_2Si_3O_{12} \end{matrix}\right\}$. Städeler considers it to be a combination of equal molecules of dibasic and tribasic silicates, which requires the water to be basic. On this view the formula is $H_2R_6\ Fe Si_4O_{18} = H_{10}Si_2O_9 + 6R_5Si_2O_9 + Fe_5Si_6O_{27}$, $R_6 = Fe_4 + Ca_2$. Fresh and bright crystals from Elba gave by analysis, SiO_2 29·67, FeO_3 21·26, FeO 33·09, MnO 0·74, CaO 13·33, H_2O 2·32. Easily fusible to a black bead; gives with borax the reaction of iron and sometimes of manganese. Gelatinises with hydrochloric acid.

Occurrence.—Found chiefly at Rio, in the island of Elba, with hematite and other iron ores. The crystals are often of considerable size and commonly covered externally with rust, from a partial change into brown iron ore.

IOLITE. Cordierite, Dichroite.—*Rhombic, nearly hexagonal.* ∞P 119° 10′. (Fig. 129) $m\{110\}\infty P$, $d\{130\}\infty \breve{P}_3$, $n\{011\}\ \breve{P}\infty$, $a\{010\}\infty \breve{P}\infty$, $b\{100\}\infty \bar{P}\infty$, $c\{001\}oP$, $r\{111\}P$, $s\{112\}\frac{1}{2}P$. Usually short columnar, with platy or foliated structure parallel to the base: also massive, interspersed, and in boulders. Cleavage, 010 tolerably perfect, 100 and 001 indistinct. Fracture, conchoidal. H. 7–7·5. Sp. gr. 2·56–2·67. Lustre, vitreous. Colour, greyish, violet, indigo, or smoky blue (dark sapphire tone), nearly colourless, greyish, yellowish, or brown. Strongly pleochroic, the crystals appearing blue when seen along the vertical axis, and pale grey at right angles to it. Streak, white. Transparent to translucent.

FIG. 129.



Composition.—A silicate of alumina, ferric oxide, and magnesia of uncertain constitution, the condition of the iron not being exactly determined. The simplest generalised expression is $Mg_2\dot{R}_2Si_5O_{18}$. The principal variation in the analysis is in the proportion of $\dot{F}eO_3$ to $\dot{A}l_2O_3$. The following are about the extremes observed:

	SiO_2	AlO_3	FeO_3	MgO	MnO	CaO	H_2O	
Bodenmais, Bavaria	48·35	31·70	9·24	10·16	0·33	0·59	—	= 100·37
Kragerö, Norway .	50·44	32·95	1·07	12·76	—	1·12	1·02	= 93·36

When heated becomes cloudy and fuses with difficulty to a glass; very slightly acted on by acids; with cobalt solution gives a blue-grey colouration.

Occurrence.—Occurs in granite, gneiss, and crystalline schists at Bodenmais, Bavaria; Arendal and Kragerö in Norway, at various places in Finland, Cabo di Gata in Spain; Haddam, Connecticut; and other localities. The transparent rounded masses brought from Ceylon are known as sapphires, and are used as gems.

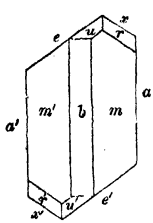
Iolite is very readily altered by exposure to the atmosphere, and is usually found in a more or less decomposed state, at least externally. These altered conditions are described as separate minerals under the names of Pinite, Fahlunite, Gigantolite, &c. Many of these have the form of iolite. The change is mainly a removal of oxides of iron and magnesium, and the addition of alkalies and water. The ultimate product is mica.

CHAPTER VIII.

HYDROUS SILICATES.

LAUMONITE.—*Oblique.* ∞P 86° 16′, $a : b : c = 1{\cdot}0818 : 1 : 0{\cdot}5896$, $\beta = 80°42'$. (Fig. 130) $m\{110\}\infty P$, $a\{100\}\infty \breve{P}\infty$, $b\{010\}\infty \breve{P}\infty$, $r\{111\} -P$, $u\{011\}\breve{P}\infty$, $x\{102\} -\frac{1}{2}\breve{P}\infty$, $e\{102\}\frac{1}{2}\breve{P}\infty$. Cleavage, 110 perfect, 100 and 010 traces; also in columnar, radiating, or fibrous aggregates. H. 3–3·5 (when weathered 1 and below). Sp. gr. 2·25–2·36. Colour, white, grey, yellowish, or flesh-red. Transparent to translucent. Lustre, vitreous or pearly. Dull and opaque when weathered. Double refraction negative, optic axial plane 010, the median line inclined about 25° to normal to 100. $2V = 52°\ 24'$ for red.

FIG. 130.



Composition.—$CaSiO_3$, $AlSi_3O_9 + 4H_2O$, or SiO_2 50·0, AlO_3 21·8, CaO 11·9, H_2O 16·3 per cent. (some analyses show alkalies, Na_2O, up to 1½ per cent.). Slowly loses water to the extent of about one-fourth by exposure to the air, becoming converted into a slightly coherent pulverulent mass. The rate at which the change progresses varies in different varieties; some may be kept perfectly bright and fresh for years, especially in a damp atmosphere. When heated swells up and fuses easily to a white enamel, which by a strong heat becomes limpid. Gelatinises with hydrochloric acid.

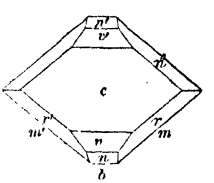
Occurrence.—Occurs with other zeolites in the cavities of

basalts and other amygdaloidal rocks. The principal localities are in the Ferrö Islands, Greenland, Dumbarton, St. Gotthard, the Fassathal, Cape Blomudin, Nova Scotia, and Lake Superior. In the latter district it is a common material, filling the veins in the copper region, with other zeolites and orthoclase. Laumonite occasionally occurs altered into orthoclase.

Leonhardite and *Caporcianite* are similar in composition, but with 3 instead of 4 molecules of water.

PREHNITE.—*Rhombic.* ∞P 99° 56′, $a : b : c = 0{\cdot}8401 : 1 : 0{\cdot}5625$. (Fig. 131) $m\{110\}\infty P$, $n\{101\}\breve{P}\infty$, $v\{102\}\frac{1}{2}\breve{P}\infty$, $r\{443\}\frac{4}{3}P$, $c\{001\}0P$. Crystals tabular or short columnar, and barrel-shaped. Usually appears in spheroidal or reniform masses, studded with crystals exteriorly. These are sometimes found about quartz crystals, also compact and granular, and in pseudomorphs, after analcime, natrolite, and Laumonite. Cleavage, basal, tolerably perfect. Fracture, uneven. H. 6–7. Sp. gr. 2·8–2·95. Lustre, vitreous, pearly on faces of pyramid. Colour, pale or leek-green, which often bleaches by exposure. Sub-transparent, translucent. Double refraction positive; optic axial plane 010, and first median line axis *a*. Thermo-electric.

FIG 131.



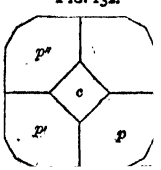
Composition.—$H_2Ca_2Al Si_3O_{12} = \left\{ \begin{matrix} H_4\,SiO_4 \\ 2Ca_2SiO_4 \\ Al_2Si_3O_{12} \end{matrix} \right\}$ corresponding to SiO_2 43 63, AlO_3 24·87, CaO 27·14, H_2O 4·36. The water is assumed as basic, as it is not given off below 300° Cent. The analyses give results very similar to the theoretical composition. Sometimes a little soda is found up to 1 per cent., and ferric oxide up to 6 or 7 per cent. Some varieties contain organic matter, and blacken when first heated, afterwards burning white. Yields water in the

fuses easily with intumescence to a blebby glass. Not very readily decomposed by hydrochloric acid unless previously ignited or fused.

Occurrence.—Occurs with zeolites at Dumbarton in Scotland, Oisans in Dauphiné, the Fassathal, Andreasberg and other localities in the Harz; Bergen Hill, New Jersey; and in the Lake Superior copper region.

APOPHYLLITE.—*Tetragonal.* $Z=121°\ 04'$ basal, $a : c = 1 : 1{\cdot}2514$ (fig. 132), $a\{100\} \infty P\infty$, $r\{120\} \infty P2$, $p\{111\} P$, $c\{001\} 0P$. Crystals long columnar, pyramidal, or short columnar, nearly cubical in appearance. Prism faces usually irregularly striated; tabular; cubic, with solid angle truncated; also lamellar, massive. Cleavage, 001 very perfect, 100 imperfect. Brittle. H. 4·5–5. Sp. gr. 2·3–2·4. Lustre, vitreous, pearly on basal planes. Transparent, translucent on edges. The cube-like crystals sometimes cloudy or opaque on basal planes. Colourless and transparent, usually some pale shade of yellowish white, green, pink, or flesh-red. Double refraction feeble, being sometimes positive, sometimes negative. Indices for red,

FIG. 132.



Very thick sections are required for examination in convergent polarised light, and these are often apparently biaxial, while in parallel light they rarely show homogeneous structure. It is therefore now held by several observers that the true crystalline symmetry is oblique, the apparent tetragonal form being due to the continued repetition of a simpler form.

Composition.—$4\left(\left\{\begin{matrix}H_2SiO_3\\CaSiO_3\end{matrix}\right\} + H_2O\right) + KFl$, corresponding to SiO_2 52·97, CaO 24·72, K_2O 5·20, H_2O 15·90, Fl 2·10=100·89, where half the water found by analysis is considered as basic.

Analyses usually show less fluorine. About 4 per cent. of water is given off at 260°, and may be reabsorbed; the remainder only expelled by a red heat.

In the closed tube exfoliates, whitens, and yields water with an acid reaction; in the open tube, with salt of phosphorus, gives the reaction of fluorine.

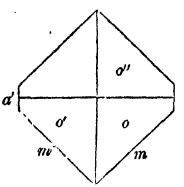
In the forceps exfoliates, giving a potash colouration to the flame, and fuses easily to a white vesicular enamel. Decomposed by hydrochloric acid, silica separating in a slimy form.

Occurrence.—With zeolites in amygdaloidal volcanic rocks and in mineral veins. The chief localities are Disco Island, Greenland; Iceland and the Ferrö Islands, Andreasberg in the Harz, the Lake Superior copper mines; Bergen Hill, New Jersey; and the Western Ghauts of India, on the lines of railway leading from Bombay to Calcutta and Madras. The crystals from these latter localities (Bore and Thill Ghauts) are often very large, up to four inches, and have a certain resemblance to fluor spar cubes with truncated corners. These are sometimes serrated all over on the basal plane by oscillatory combination of the apices of pyramids. When a ditetragonal prism enters into the combination the faces of the secondary prisms are generally striated vertically. The crystals from Bergen Hill are developed on all the faces, and are often encrusted with analcime. Those of Lake Superior sometimes include native copper, and carry orthoclase crystals on the faces of the pyramid. A pale pink, very lustrous variety, was formerly obtained in considerable quantity in the mines of Andreasberg, but is now very rare.

Apophyllite has been found by Daubrée as a deposit from thermal mineral waters in old Roman masonry at Plombières, Bourbonne les Bains, and elsewhere. Wöhler found it to be soluble without decomposition in water at a temperature of 180°–190° under a pressure of 10–12 atmospheres. On cooling it recrystallises.

NATROLITE. Mesotype, Brevicite.—*Rhombic.* ∞P 91°, $a : b : c = 0{\cdot}9287 : 1 : 0{\cdot}3521$. (Fig. 133) $m\{110\}\ \infty P$, $o\{111\}P$, $a\{010\}\ \infty \breve{P}\infty$. Slender, columnar, acicular, or fibrous, often in diverging or stellar groups; also compact. Cleavage, prismatic, perfect. H. 5–5·5. Sp. gr. 2·17–2·26. Colourless or white; sometimes yellowish, rarely reddish. Lustre, vitreous, pearly when fibrous. Transparent to translucent. Double refraction positive. Optic axial plane 010, first median line *c*.

FIG. 133.



Composition.—$Na_2\overline{Al}Si_3O_{10} + 2H_2O = \begin{Bmatrix} Na_2\overline{Al}Si_4O_{12} \\ Na_2\overline{Al}Si_2O_8 \end{Bmatrix} + 4H_2O$, or a combination of equal molecules of normal and dibasic silicates, corresponding to SiO_2 47·29, $\overline{Al}O_3$ 26·96, Na_2O 16·30, H_2O 9·45 per cent.

The analyses correspond tolerably closely to the theoretical composition, except that the amount of soda is generally less, and some ferric oxide and lime (the latter at times up to 2 per cent.) are generally found.

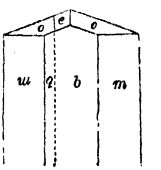
In the closed tube gives off water, becoming white and opaque. Fuses very easily and without intumescence to a clear glass. It may be fused by the flame of a candle without the blowpipe. Gelatinises with hydrochloric acid. Soluble in oxalic acid.

Occurrence.—Found in amygdaloidal cavities in basalt, phonolite, and other volcanic rocks near Aussig, in Bohemia; in Iceland; the Ferrö Islands, Antrim, and at Bishoptown, Renfrewshire. At Brevig in Norway in granitic rocks in large crystals and columnar masses. *Brevicite* is a compact variety from the same place resembling a white felspar in appearance. It contains about 7 per cent. of lime.

SCOLECITE. Lime Mesotype, Poonahlite.—*Oblique.* ∞P 91° 36′, $a : b : c = 0{\cdot}9726 : 1 : 0{\cdot}3389$, β 89° 06′. Cry-

stals long or short columnar, and generally combined on 100, *c* being the true axis. (Fig. 134) $m\{110\}\infty P$, $b\{010\}\infty\breve{P}\infty$, $o\{111\}-P$, $e\{\bar{1}11\}P$. Also in radial, columnar, or fibrous aggregates and massive. H. 5–5·5. Sp. gr. 2. Cleavage, prismatic, rather perfect. Lustre, vitreous, silky when fibrous. Transparent to imperfectly translucent. Thermo-electric in a marked degree, the free ends of the crystals being the antilogue poles. Double refraction negative. The optic axes plane with axis *b* inclined from 11° to 12° to axis *c*, the median line in 010 being similarly inclined to *c*.

FIG. 134.



Composition. — $CaAlSi_3O_{10} + 3H_2O =$

$+6H_2O$, corresponding to SiO_2 45·85, AlO_3 26·13, CaO 14·26, H_2O 13·76 per cent., similar to that of natrolite, Ca being substituted for Na_2, and the water increased one-half. Analyses usually show rather more silica and somewhat less lime than the theoretical proportion, and there is usually some soda present (up to about 1 per cent.).

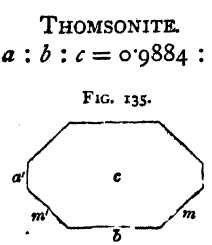
When heated, it generally curls up into a worm-like form, and fuses at a strong red heat to a blebby glass. The whole of the water is not driven off until close upon the melting point. Decomposed by hydrochloric acid, but does not always gelatinise; also by oxalic acid, the lime separating as an insoluble oxalate.

Occurrence.—In the cavities of amygdaloidal and other igneous rocks in Iceland and the Ferrö Islands, Staffa, Antrim, Auvergne, Western India, &c., usually in association with other zeolites. *Mesolite* and *Antrimolite* are fine fibrous zeolites of analogous composition, containing both lime and soda in notable quantity, and therefore intermediate in composition between natrolite and scolecite, found in the basalt of Antrim. *Poonahlite* is also a fibrous variety of scolecite. *Galactite* and *Harringtonite* are other intermediate minerals,

represented by the natrolite formula, with both lime and soda. The former is mainly from Western Scotland, Kilpatrick, Dumbarton, &c., and the latter from the trappean rocks of Bombay.

THOMSONITE. Comptonite. — *Rhombic.* ∞P 90° 40′, $a : b : c = 0{\cdot}9884 : 1 : 0{\cdot}71414$. (Fig. 135) $m\{110\} \infty P$, $a\{010\} \infty \breve{P}\infty$, $b\{100\} \infty \bar{P}\infty$, $c\{001\} oP$. Crystals, short columnar, with a very obtuse macrodome termination, resembling an angular basal plane, the ridge at the summit being very slight. Usually grouped in druses in radiated and hemispherical aggregates. Cruciform penetration-twins common. Cleavage, brachydiagonal and macrodiagonal, the latter best developed, basal in traces. H. 5–5·5. Sp. gr. 2·3–2·4. Lustre, pearly to vitreous. White or brownish. Transparent to translucent. Double refraction positive, weak. The optic axial plane, 001; positive median line, axis *b*.

FIG. 135.



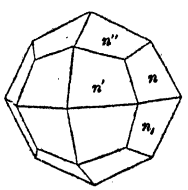
Composition. — $\left\{\begin{matrix} m(2Ca\ \overline{Al}Si_2O_8 + 5H_2O) \\ n(2Na_2\overline{Al}Si_2O_8 + 5H_2O) \end{matrix}\right\}$, or a hydrated dibasic silicate. $m : n$ varies in different samples from 3 : 1 to 2 : 1 and 1 : 1. An analysis approximating to the first ratio gives: SiO_2 38·09, $\overline{Al}O_3$ 31·62, CaO 12·60, Na_2O 4·62, H_2O 13·40 per cent.

The whole of the water is not given off until heated to redness, when it fuses to a white enamel. Gelatinises with hydrochloric acid.

Occurrence.—In cavities of lavas and other igneous rocks, and in some metamorphic rocks, with elæolite. *Thomsonite* is from Kilpatrick, Dumbarton. *Comptonite*, the well-crystallised variety, from Vesuvius and the Cyclopean Islands. *Ozarkite* is a massive variety from Magnet Cove, Arkansas. *Picrothomsonite* is a variety containing 6 per cent. of magnesia, found in the serpentine of Monte Catini, Tuscany.

ANALCIME. — In trapezohedra, which, like those of leucite, are of doubtful significance. Usually in more or less well-developed crystals grouped in druses or implanted on apophyllite or other minerals: also massive and granular. Cleavage, cubical in traces, but very imperfect. H. 5–5·5. Sp. gr. 2·21–2·29. Lustre, vitreous. Colourless, white, greyish, yellowish, or reddish white. Transparent to opaque.

FIG. 135*a*.



The optical properties are very anomalous, a section parallel to a cube face showing in polarised light a dark irregular cross bordered by four coloured sectors. Mallard considers these phenomena as evidence of a complex aggregation of 24 elementary rhombic crystals, simulating a cubical form. Vom Rath, on crystallographic grounds, considers the forms to be tetragonal.

Composition. — $Na_2\overline{Al}Si_4O_{12} + 2H_2O = \left\{\begin{matrix} Na_2Si\ O_3 \\ \overline{Al}\ Si_3O_9 \end{matrix}\right\}$, $+ 2H_2O$, or SiO_2 54·47, $\overline{Al}O_3$ 23·29, Na_2O 14·07, H_2O 8·17 per cent. The observed composition differs slightly from the theoretical, there being usually more silica, and some of the alkali is potash, as in the following analysis of the mineral from the Cyclopean Islands:

SiO_2	$\overline{Al}O_3$	CaO	Na_2O	K_2O	H_2O
55·22	23·14	0·25	12·19	1·52	7·68

In the closed tube gives off water, becoming white and opaque. In the forceps fuses to a clear glass. Decomposed by acid with separation of silica, which is sometimes gelatinous and sometimes slimy granular. Decomposes with difficulty when previously heated to redness.

Occurrence.—With other zeolites in hollows of basalts and similar igneous rocks, and less frequently in mineral veins. In the former the crystals are often of very considerable size, those from Kilpatrick, Renfrewshire, being 3 or 4

inches in diameter, and much larger than any similar crystal of leucite. The most perfectly developed crystals are from the Cyclopean Islands, but in almost all cases the faces are striated or otherwise imperfect. In the Lake Superior copper district it occurs with native copper, other zeolites, and orthoclase, and sometimes appears to be transformed into the latter mineral.

Picranalcime is an altered variety containing 10 per cent. of magnesia, found in serpentine at Monte Catini in Tuscany.

CHABASITE.—*Rhombohedral.* $R=94°\ 46'$ (variable from $94°\ 24'$ to $95°\ 02'$), $a:c=1:1{\cdot}06$. (Fig. 136) $r\ \kappa\{10\bar{1}1\}R$, $s\{02\bar{2}1\}-2R$, $e\{01\bar{1}2\}-\frac{1}{2}R$, also $10\bar{1}1$ alone resembling a cube. Twins on 0001 as complete penetration-groups, those on $10\bar{1}1$ less common (fig. 137). Faces of $10\bar{1}1$

FIG. 136.

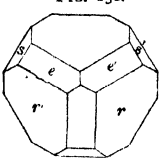
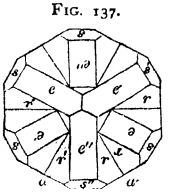


FIG. 137.



often striated parallel to the polar edges. Cleavage, $10\bar{1}1$ tolerably perfect. Fracture, uneven. Brittle. H. 4–4·5. Sp. gr. 2·08–2·18. Colourless, white, yellowish, or flesh-red. Lustre, vitreous or pearly. Transparent to translucent. Double refraction weak: optical properties anomalous, suggesting the probability of complex repeated twinning of individuals of the triclinic system.

Composition. — $(HKNa)_2\ Ca\overline{Al}Si_5O_{15} + 6\ H_2O$

$$= \left\{ \begin{matrix} (HKNa)_2Si\ O_3 \\ Ca \quad Si\ O_3 \\ \overline{Al} \quad Si_3O_9 \end{matrix} \right\} + 6H_2O, \text{ which when } H : (KNa) = 7 : 1,$$

corresponds to SiO_2 50·50, $\overline{Al}O_3$ 17·26, Ca 9·43, K_2O 1·98, H_2O 20·83 per cent.

From 17 to 19 per cent. of water is driven off at 300°, and may be reabsorbed. The remainder is considered as

basic. For the above amount of 20·83 per cent, 18·18 per cent. is water of hydration, and 2·65 per cent. basic. The analyses vary rather irregularly, usually showing more water and silica than required by the formula. Potash is the principal alkali, though some varieties contain almost exclusively soda.

Gives off water in the closed tube : fuses with intumescence to a nearly opaque glass. Decomposed by hydrochloric acid with separation of slimy silica. After fusion becomes insoluble.

Occurrence.—With other zeolites in phonolite, basalt, and similar volcanic rocks, in Bohemia, near Aussig ; Iceland, Ferrö Islands, Nova Scotia, Bergen Hill, New Jersey, &c. It forms one of the zeolites discovered in the deposits from mineral waters and Roman masonry by Daubrée.

Phacolite is a form of chabasite, occurring in lenticular crystals, which are highly modified twin forms.

GMELINITE is a rhombohedral zeolite, somewhat similar to chabasite. The primary form is a rhombohedron of 112° 16′, $a : c = 1 : 0{\cdot}7254$. The crystals are hexagonal in habit, in short truncated pyramidal combinations, or sometimes resemble quartz in form, and are never twinned. H. 4·5. Sp. gr. 2·00–2·17. Colour, reddish white to flesh-red. Subtransparent—translucent.

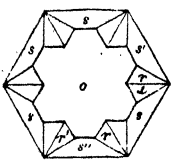
Composition. — $\left\{\begin{matrix} m(Na_2\dot{A}lSi_4O_{12}+6H_2O) \\ n(Ca\,\dot{A}lSi_4O_{12}+6H_2O) \end{matrix}\right\}$ $m : n$ being either 3 : 4, 2 : 1, or 1 : 2. The second of these ratios is nearly represented in the following analysis : SiO_2 46·48, $\dot{A}lO_3$ 20·63, CaO 3·78, Na_2O 7·19, K_2O 1·73, H_2O 20·41 = 100·22.

The whole of the water is considered to be water of hydration, a large proportion of it being lost by exposure to dry air, and the whole driven off at a temperature of 230°, the mineral crumbling when heated in the closed tube. In the forceps fuses easily to a white enamel, and gelatinises with hydrochloric acid.

Occurrence.—In old lavas at the Euganean Hills, near Vicenza; at Glenarm, Antrim; in Cyprus; Cape Blomidon, Nova Scotia; and Bergen Hill, New Jersey. *Sarcolite* and *Ledererite* are synonyms applied to varieties.

Herschellite, from Aci Castello, Sicily, and *Seebachite*, from Ballarat, Australia, are similar in composition to Gmelinite. They occur in penetration twins similar to those of Phacolite.

FIG. 138.

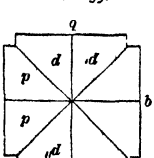


LEVYNE. — $CaAl_2Si_3O_{10}+5H_2O$ is found in penetration twins (fig. 138), similar to those of chabasite. Occurs in Antrim, the Ferrö Islands, Iceland, and Victoria, Australia.

PHILLIPSITE. Christianite.—*Rhombic.* The angles are variously given, the difference between those of the pyramid over the longer and shorter edges being only small (121° 20′ and 120° 40′), or the form is nearly tetragonal. The crystals are penetration twins of two individuals without re-entering angles, resembling the common form of apophyllite, but the apparent pyramid faces are divided by a central line, which is really an edge of combination, and, according to Descloizeaux, makes an obtuse angle of 175°.

By the further combination of two crystals twinned as above, penetration twins, forming a right-angled four-armed cross (fig. 139), resembling those of harmatome, are produced. Cleavage, brachydiagonal and macrodiagonal. H. 4·5. Sp. gr. 2·15–2·20. Lustre, vitreous. Colourless, white, grey, yellowish, or reddish. Transparent to nearly opaque.

FIG. 139.



Composition. — $\left\{ \begin{matrix} \overset{II}{R}Si\,O_3 \\ AlSi_3O_9 \end{matrix} \right\} + 4H_2O$,

or similar to Laumonite; but as $\overset{II}{R}$ is partially represented by

$\dot{R}_2$, lime is replaced to some extent by soda and potash. Analysis of a sample from the Giant's Causeway gave SiO_2 47·35, $\dot{A}lO_3$ 21·80, CaO 4·85, K_2O 5·55, Na_2O 3·70, H_2O 16·96. The proportion of the three bases varies very considerably. Sometimes magnesia is present up to 1·6 per cent.

In the closed tube gives off water in quantity; in the forceps intumesces slightly and melts to a white enamel. Gelatinises with hydrochloric acid.

Found at Marburg, Giessen, the Giant's Causeway, Capo di Bove near Rome, Vesuvius, and Aci Castello, and other localities in Sicily. At Plombières and Oran it occurs among the mineral deposits found in thermal springs.

HARMATOME. Kreuzstein. — *Rhombic.*[1] (Fig. 140.) p {111} P, a {010} $\infty \breve{P}\infty$, b {100} $\infty \check{P}\infty$, s {011} $\breve{P}\infty$, t {021} $2\breve{P}\infty$. The crystals are invariably twinned, the

FIG. 140.

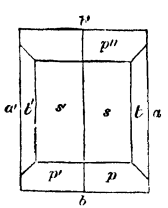


FIG. 141.

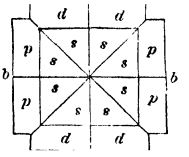
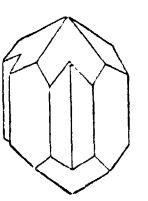


FIG. 142.



simpler forms consisting of two individuals penetrating without re-entering angles, and these by further simpler combination give rise to the crossed forms most characteristic of the species (figs. 141, 142). Faces of {111} and {100} are invariably striated, the latter in lozenge or rhombic patterns, showing the compound character of the form. (If the system is considered oblique, 100 becomes 001.) Cleavage, 100 and 010 imperfect. Fracture, uneven. Lustre, vitreous,

[1] Descloizeaux upon optical grounds considers the system to be oblique, a view which is now frequently but not universally adopted.

imperfectly transparent, translucent. Colourless, usually greyish white, yellowish, or reddish.

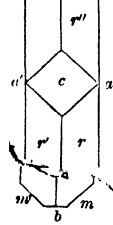
Composition.—$H_2RAlSi_5O_{15}+4H_2O$; R being principally barium. This formula requires $\frac{1}{6}$ of the water found by analysis to be considered as basic. When the relation of K_2 to Ba = 1 : 3 the theoretical composition is SiO_2 45·91, AlO_3 15·70, BaO 20·06, K_2O 3·34, H_2O (basic) 2·75, H_2O (hyd.) 12·24. Analyses differ from this by showing considerably more silica (up to 48 per cent.) and less alkali, K_2O not usually exceeding 1·1 to 1·5 per cent.

About 12 per cent. of water is driven off at 200° Cent., and may be reabsorbed. Heated in the closed tube it gives off water and crumbles to pieces. In the forceps, if carefully heated, a fragment may remain sufficiently coherent to allow a stronger heat to be applied, when it melts without intumescence to a white translucent glass; but if too suddenly heated, it decrepitates violently.

Occurrence.—In amygdaloidal igneous rocks, and also in mineral veins, being most abundant in the latter. The principal localities are Strontian in Argyleshire and Andreasberg in the Harz, the simpler forms being from the former and the cruciform compound twins from the latter place.

STILBITE. Desmine.—*Rhombic.* ∞P 94° 16′, X 119° 16′, Y 114° 0′, $a : b : c = 0{\cdot}9282 : 1 : 7{\cdot}7554$. (Fig. 143) $m\{110\}\infty P$, $a\{010\}\infty\breve{P}\infty$, $b\{100\}\infty\breve{P}\infty$, $c\{001\}\,0P$, $r\{111\}P$. Crystals usually broad columnar, 010 being best developed. Cleavage, 010 perfect, 100 imperfect. Fracture, uneven. Usually in radiated groups or aggregates, diverging to the free ends of the crystals. H. 3·5–4. Sp. gr. 2·10–2·20. Lustre on brachypinakoid, pearly; on other faces, vitreous. Colour, white, yellowish white, flesh-red, brick-red. 010 is the optic axial plane, and c the median line.

FIG. 143.



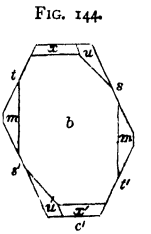
Composition. — $H_4CaAlSi_6O_{18} + 4H_2O$, which supposes $\frac{2}{3}$ of the water found by analysis to be basic. A variable quantity of the lime is replaced by soda. The following is an analysis of crystals from Seiser Alp, Tyrol: SiO_2 55·61, AlO_3 15·62, CaO 7·33, Na_2O 2·01, K_2O 0·47, H_2O 18·19. It may be regarded as an average, except that the silica is rather low: in other cases it ranges from 56 to 58 per cent.

In the closed tube gives off water; in the forceps exfoliates and swells up, and fuses to an opaque glass. Decomposed by hydrochloric acid, silica separating in powder.

Occurrence.—Mostly found in amygdaloidal rocks, and often in very large masses, Skye, the Ferrö Islands, and Iceland, being the most notable localities. In the latter it occurs incrusting the faces of the large crystals of calcite, known as Iceland spar. Also in the Kilpatrick Hills, Dumbartonshire; the Western Ghauts, India; Bergen Hill, New Jersey; and in mineral veins at Andreasberg, Harz, and Arendal, Norway.

HEULANDITE.—*Oblique.* $\beta=88°\,35'$, $\infty P\,136°\,4'$, $a:b:c=0·4035:1:0·4297$. (Fig. 144) $m\{110\}\infty P$, $b\{010\}\infty\breve{P}\infty$, $c\{001\}\,oP$, $u\{111\}-P$, $s\{201\}-2\breve{P}\infty$, $t\{\bar{2}01\}\,2\breve{P}\infty$, $x\{011\}\breve{P}\infty$. In tabular forms, the clinopinakoid being prominently developed. Cleavage, 010 very perfect. H. 3·5–4·0. Sp. gr. 2·10–2·20. Lustre, pearly or vitreous on other faces. Colour, white, grey, brown, or brick-red. Transparent, imperfectly translucent. Double refraction weak. The optic axes lie in a plane normal to the clinopinakoid. The positive median line is parallel to the orthodiagonal.

FIG. 144.



Composition.—$H_4CaAlSiO_{16} + 3H_2O$, or similar to that of Stilbite with one molecule less of water of hydration. This supposes two-fifths of the amount found by analysis to be

basic. The composition varies somewhat, as some of the lime is represented by soda, potash, or both alkalies. The following analysis by Rammelsberg is of the mineral from Iceland :

SiO_2	AlO_3	CaO	Na_2O	H_2O
58·01	16·50	8·30	1·73	16·06 = 100·60

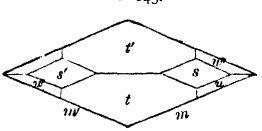
The chemical characteristics and mode of occurrence are similar to those of Stilbite, and the localities are principally the same—Iceland, Ferrö Islands, Western India, &c.

In Germany the names Heulandite and Stilbite are not used in the manner defined above.

In most German mineralogical text-books the definitions given above for Heulandite and Stilbite are inverted. The former is distinguished as Stilbite and the latter as Desmine.

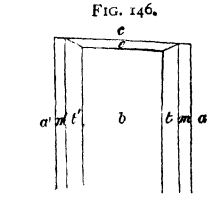
EPISTILBITE is of the same composition as Heulandite, but is rhombic in system. (Fig. 145) $m\{110\}\infty P$, $t\{101\}\breve{P}\infty$, $s\{011\}\breve{P}\infty$, $u\{121\}2\breve{P}2$. It occurs in columnar crystals; the leading form, {110}, has an angle of 135° 10′, or very nearly that of the preceding species.

FIG. 145.



BREWSTERITE.—*Oblique.* ∞P 136°, $a : b : c = 0{\cdot}4046 : 1 : 0{\cdot}4203$, $\beta = 86° 56'$. (Fig. 146) $m\{110\}\infty P$, $t\{120\}\infty \breve{P}2$, $b\{010\}\infty \breve{P}\infty$, $a\{100\}\infty \breve{P}\infty$, e a very obtuse clinodome of 172°. In short columnar crystals. Cleavage, 010 very perfect. H. 5–5. Sp. gr. 2·42–2·45. Colour, yellowish or greyish white. Lustre, vitreous.

FIG. 146.



Composition.—$H_4RAlSi_6O_{18} + 3H_2O$, or similar to that of Heulandite, R = Sr and Ba chiefly, so that it is qualita-

tively related to Harmatome, with which it is associated at the Strontian lead mines. An analysis by Mallet gives SiO_2 54·42, AlO_3 15·25, SrO 8·99, BaO 6·80, CaO 1·19, H_2O 13·22. As in Heulandite, two-fifths of the water are assumed to be basic.

Gives off water in the closed tube; in the forceps, swells up and melts to a blebby glass. Decomposed by hydrochloric acid with separation of granular silica.

Occurrence. — Occurs at Strontian, Argyleshire; the Giant's Causeway; the Col de Bonhomme in Switzerland, and near Freiburg in Baden.

ELECTRIC CALAMINE. Silicate of Zinc, Hemimorphite. —*Rhombic, hemimorphic.* ∞P 103° 50′, $a : b : c =$

FIG. 147.

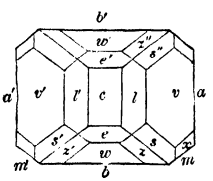
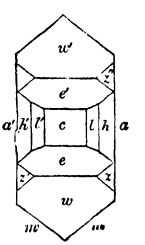


FIG. 148.



0·7835 : 1 : 0·4778. (Figs. 147–8) $a\{010\}\ \infty\breve{P}\infty$, $b\{100\}\ \infty\breve{P}\infty$, $c\{001\}\ oP$, $e\{101\}\ \breve{P}\infty$, $w\{301\}\ 3\breve{P}\infty$, $l\{011\}\ \breve{P}\infty$, $h\{021\}\ 2\breve{P}\infty$, $v\{031\}\ 3\breve{P}\infty$, $z\{211\}\ 2\breve{P}2$, $s\{121\}\ 2\breve{P}2$, $x\{141\}\ 4\breve{P}4$. Crystals, short columnar, or tabular to 010. When the upper end is formed by combinations like fig. 147, the lower is pointed by $\{12\bar{1}\}$. (See 'Syst.' fig. 258.) Cleavage, 110 perfect. Twins on the basal plane not uncommon. Usually in radiated groups, also botryoidal, stalactitic, and massive, and in pseudomorphs after fluorspar, calcite, dolomite, pyromorphite, and galena. H. 5. Sp. gr. 3·35–3·50. Lustre, vitreous. Colourless, white, or with some pale tint of

yellow, brown, green, red, or blue. Transparent, translucent, in crystallised, opaque in compact varieties. Double refraction positive. Indices for yellow, α 1·6136, β 1·6170, γ 1·6360. Optic axial plane 100, first median line axis c, $2V = 46° 9'$, $2E = 78° 39'$. Polar thermo-electric: the upper or flattened end is the analogue, and the lower or pyramidally pointed end the antilogue pole.

Composition.—$Zn_2SiO_4 + H_2O$, or SiO_2 25·0, ZnO 67·5, H_2O 7·5 per cent.: sometimes contains a little ferric oxide.

In the closed tube gives off water: almost infusible. Heated with cobalt solution gives the green colour of zinc, but only partially, becoming blue in places. On charcoal gives a crust of zinc oxide, yellow while hot and white when cold. Decomposed with gelatinisation by hydrochloric and also by acetic acid: soluble in a strong solution of caustic potash.

Occurrence.—With calamine and Willemite at Altenberg near Verviers, and with blende and lead ores in Carinthia, Baden, Upper Silesia, Derbyshire, the Cantabrian zinc mines; Phœnixville, Pennsylvania; Austin's Mine, Virginia; and many similar localities. When in quantity it is a valuable zinc ore, for the same reason as Willemite, being free from lead and iron.

PINITE GROUP.

PINITE. Gieseckite, Iberite, Gigantolite, Killinite, &c.—Amorphous or granular crystalline substances, occurring in pseudomorphs after other minerals, notably after iolite and scapolite. H. 2·5–3·5. Sp. gr. 2·62–2·89. Lustre, waxy or dull. Colour, grey, yellowish, greenish, brownish, or reddish. Feebly translucent to opaque.

Composition. — Essentially basic silicates of alumina, alkalies, and water, but very variable in composition. Pinite is chiefly iolite altered by loss of magnesia and accession of alkalies, mainly potash, and water. Average of principal constituents, SiO_2 46, AlO_3 30, K_2O 10, H_2O 6. FeO varies

considerably (from 0 up to 10 per cent.), and MgO from 0 to 7·8 per cent. If the water is supposed to be basic, $R_8\overset{I}{R}_2Si_5O_{20}$ may be an approximate formula. The ultimate product of this class of alteration is probably a mica analogous to Damourite.

Fahlunite is another alteration product of iolite with a micaceous structure, i.e. basal cleavage.

CLAY. China Clay, Kaolin, Porzellanerde, Nacrite, Pholerite, Lithomarge.—The basis of all clays is the so-called *Kaolin*, or *China clay*, which occurs more or less mixed with water, ferric hydrates, quartz, and organic matter, forming the variously coloured plastic clays.

In its purest form Kaolin appears as a white powder, usually amorphous, but showing under the microscope six-sided scales, having a structure similar to that of mica. In some rare instances these are sufficiently large to be apparent to the naked eye.

Composition.— $H_2AlSi_2O_8 + H_2O$. This supposes half the water to be basic, and corresponds to SiO_2 46·40, AlO_3 39·68, H_2O basic 6·96, hyd. 6·96 per cent. The water is only completely given off by a strong and continued heat. Infusible (except at extreme temperatures). Insoluble in acids. Soluble in boiling caustic alkaline liquors. With cobalt solution gives the blue of alumina.

Occurrence.—China clay is the result of the decomposition of orthoclase and other felspars by atmospheric water and carbonic acid, whereby the whole of the alkaline bases and lime with part of the silica are removed. It occurs in large masses in various granitic districts, especially in the neighbourhood of St. Austell, Cornwall, and on the west side of Dartmoor, in Devonshire, and is extensively worked for pottery and other manufacturing purposes. The unaltered minerals accompanying it, such as mica, quartz, and tin ore, are separated by a method of levigation, the rough clay being carried by a stream of water into settling

pits, where the larger and heavier masses deposit, and afterwards into collecting pits, where it is allowed to dry until sufficiently coherent to admit of being cut into blocks, which are finished by drying in stacks, or sometimes in heated chambers. The chief French deposits are at S. Yrieux, near Limoges, and those of Germany are at Aue near Schneeberg, and at Elgersburg in Thuringia. Although common as a product of alteration of minerals in many countries, there are comparatively few deposits sufficiently pure to be worth working on the large scale.

Pholerite and *Nacrite* are pearly substances of a micaceous character, of the same composition as Kaolin, but non-plastic. They occur in mineral veins, in the interior of ironstone nodules, and as incrustations.

Lithomarge is a compact variety, having a lustre resembling that of porcelain, usually white, but often variegated with red, blue, and other colours. H. 2–2·5. It is found in many mineral veins, as at Restormel, Cornwall, and forms the matrix of topaz at the Schneckenstein, Saxony. A ferruginous variety occurs with the aluminous iron ore of Antrim, and is worked to some extent as a flux for blast furnaces.

The origin of China clay has been referred to in the introductory remarks.

ALLOPHANE. *Amorphous*, in dull white masses, sometimes stalactitic, with a delicate surface bloom, or resembling hyalite. H. 1–3. Sp. gr. 1·85–2·10. Lustre, pearly, resinous or dull. White, pale sky-blue and green, brownish or yellow. Fracture, sub-conchoidal, flat, granular, shining or earthy.

Composition. — $\dot{A}l\ddot{S}iO_5 + 5$ or 6 H_2O. The smaller amount of water gives SiO_2 23·75, $\dot{A}l\ddot{O}_3$ 40·62, H_2O 35·63 per cent. The blue varieties contain up to 2·5 per cent. of cupric oxide or carbonate. When heated gives off water—the cupreous varieties turn black or brown—swells up, and crumbles to pieces. Infusible. Gelatinises with hydrochloric acid. The blue and green varieties give a copper reaction

with fluxes. The white earthy kind is found in the chalk at Charlton near Woolwich, and the blue and green varieties at Saalfeld in Thuringia, and at Chessy, near Lyons, where it formed the matrix of azurite crystals.

GYMNITE.—An amorphous hydro-magnesian silicate, of a pale yellow colour, and resinous lustre: imperfectly translucent, very similar to gum arabic in appearance. The composition is $Mg_4Si_3O_{10}+5H_2O$, or 2 molecules of normal to 1 of dibasic silicate. An analysis by Brush of that from Texas, Pennsylvania, gave SiO_2 42·60, Al_2O_3 3·13, MgO 34·16, H_2O 20·25 per cent. Imperfectly fusible at the edges, not readily decomposed by acids. With cobalt solution gives the pink magnesia colouration.

Occurs in serpentine at Bare Hills, Baltimore; Texas, Pennsylvania; and in Tyrol: also in crystalline limestone near Passau.

Genthite or *Nickel Gymnite*, an analogous mineral of a pale green colour (H. 3·4. Sp. gr. 2·40), is similar in composition, but contains equal molecules of magnesium and nickel, and 6 molecules of water ($Mg_2Ni_2Si_3O_{10}+6H_2O$). Analysis of that from Texas, Pennsylvania, by Genth, gave SiO_2 35·36, MgO 14·60, NiO 30·64, FeO 0·24, CaO 0·26 per cent.

In the closed tube blackens, giving off water. Infusible; gives a violet bead with borax in oxidising, and grey (from metallic nickel) in reducing flame. Decomposed by hydrochloric acid, without gelatinising. Found encrusting chromic iron ore at Texas, Pennsylvania, and at Michipicoten Island, Lake Superior.

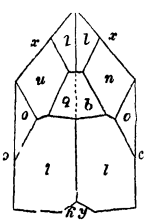
Garnierite and *Noumeite* are indefinite hydrated silicates of nickel and magnesium, that have latterly been found in considerable quantity in the Island of New Caledonia. The latter contains in some cases as much as 32·52 per cent. of nickel oxide.

CHAPTER IX.

TITANATES AND NIOBATES.

SPHENE. Titanite, Greenovite.—*Oblique.* ∞P 133° 52′, $a : b : c = 0{\cdot}4272 : 1 : 0{\cdot}6575$, $\beta = 85° 22'$. (Fig. 149) $l\{110\}\infty P$, $m\{130\}\infty \breve{P}3$, $b\{010\}\infty \breve{P}\infty$, $c\{001\}0P$, $y\{101\}P\infty$, $x\{102\}\frac{1}{2}P\infty$, $u\{163\}2\breve{P}6$, $s\{141\}4\breve{P}4$. Twins common on 001 (fig. 149), also on 101. Cleavages, 110, 011 imperfect. H. 5–5·5. Sp. gr. 3·4–3·6. Colour, green, yellow, or brown, rarely red: often dichroic. Lustre, adamantine, vitreous: imperfectly transparent to translucent.

FIG. 149.



Composition.— $\left\{\begin{matrix}CaSi_2O_5\\CaTi_2O_5\end{matrix}\right\}$ (a bisilicate, with half the silica replaced by its equivalent of titanic acid), or SiO_2 30·61, TiO_2 40·82, CaO 28·57 per cent. Usually with some FeO, up to about 5 per cent. of the former in dark coloured varieties, and MnO in Greenovite.

Yellow crystals become dark when heated. Fusible at the edges with some intumescence to a glass, varying in colour with the amount of iron present. With salt of phosphorus and tin gives the violet glass of titanium. Decomposed by hydrochloric acid, but more completely by sulphuric acid, bisulphate of potassium, or hydrofluoric acid.

Occurrence.—In granite, crystalline schists, and limestone, magnetic iron ore, and certain volcanic rocks. Among the chief localities are St. Gothard, Chamouni, Pfitschthal, Tyrol, Ala, and St. Marcel, Piedmont, the latter producing the manganiferous variety *Greenovite*; Arendal, Norway; Tremadoc, Carnarvonshire; Plauensche' Grund, Saxony, in zircon syenite; Gouverneur, New York; Franklin, New Jersey;

Achmatovsk, Ural, &c. Crystals usually embedded or developed in druses: most abundant in syenite and other hornblendic rocks.

Guarinite is a honey-yellow variety, crystallising in the rhombic system. Found in small crystals in the limestone blocks of Somma.

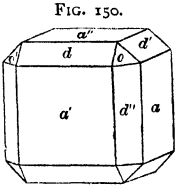
Yttrotitanite contains alumina and oxides of cerium and yttrium, in addition to the ordinary constituents of sphene. It occurs near Arendal. *Mosandrite* and *Tschewkinite* are somewhat similar in composition. *Schorlomite*, a silico-titanate of lime and ferric oxide, crystallising in the cubical system, and, according to Descloizeaux, essentially a titaniferous garnet.

Eudialyte and *Katapleite* are silico-zirconates. The former contains 6 molecules of bisilicates and zirconates of sodium, calcium, iron, and manganese, united with 1 molecule of NaCl; the latter includes tri- and tetra-silicates and zirconates of sodium and calcium, with 2 or 3 molecules of water of hydration.

Wöhlerite. Rhombic, isomorphous with bronzite. Consists of niobates, silicates, and zirconates of calcium and sodium of the form $RSiO_3$. The average percentage of the constituents is Nb_2O_5 14, ZrO_2 12–19, SiO_2 29, CaO 26, Na_2O 7·7. Found in the zircon syenite of Brevig, Norway.

PEROFSKITE.—*Cubic.* Generally in more or less modified cubes (fig. 150), with faces striated in two directions, crossing at right angles. These are sometimes considered as penetration twins. Cleavage, cubical. H. 5·5. Sp. gr. 4·01–4·04. Colour, iron-black, dark reddish brown, less commonly hyacinth-red, orange- and honey-yellow. Lustre, metallic-adamantine. Opaque or very slightly translucent when dark-coloured: the lighter varieties are transparent, and show double refraction in such a manner as to lead to

FIG. 150.



the cubic character of the crystals being questioned by many observers. Both the optical characters and crystalline form are in dispute. They may be rhombic with pseudo-cubic habit by repeated twinning.

Composition.—$CaTiO_3$ or CaO 41·17, TiO_2 58·83 per cent. CaO is usually replaced by FeO, in quantity varying from 2 to 6 per cent. Infusible ; gives the violet titanium glass with salt of phosphorus. Very slightly acted on by hydrochloric acid, but completely decomposed by fusion with bisulphate of potassium.

Occurrence.—Found in large crystals in chlorite schist at Achmatovsk, in the Ural ; at Zermatt, Switzerland ; Kaiserstuhl, Baden ; and Pfitschthal, Tyrol.

Combinations of Titanates and Zirconates with Niobates.—These form a rare and very local group of minerals, being confined almost exclusively to the zircon-syenite regions of Norway and the Ural. They have a general similarity in form and physical character, being mostly rhombic in crystallisation, and dark coloured or black. H. about 6, and sp. gr. 4·8 to 5·5. Their general constitution may be represented as $\left\{ \begin{matrix} n\overset{II}{R}TiO_3 \\ \overset{II}{R}Nb_2O_6 \end{matrix} \right\}$, Ti including Zr and Th, and $\overset{II}{R}$ the cerium group of metals. The average percentage composition of the principal members of this series is given in the following table. The analyses in many cases show considerable diversity, as the determination of the exact composition of this class of minerals is among the most difficult problems in analytical chemistry. The blowpipe and other simple chemical characteristics are of little use towards determining the nature of the elements present.

		TiO_2	NbO_2	ZrO_2	ThO_2	YO	ErO	UO_2	FeO	CaO	H_2O
Polycrase .	Rhombic	26·59	20·32	—	—	23·32	7·53 CeO	7·70	—	—	4·02
Euxinite .	,,	19·17	31·98	—	—	18·23	2·84	19·52	4·77	1·19	2·40
Aeschynite .	,,	22·64	28·81	—	15·75	1·12	18·49	—	3·17 Fe_2O_3	2·75	1·07
Polymignite .	,,	46·30	—	14·14	—	11·50	5·00	—	12·2 FeO	4·1	—
Pyrochlore .	Cubical	10·47	53·19	—	7·53	—	7·00	—	1·84	14·21	5·01 Na_2O

Pyrrhite and *Azorite*, found at St. Michael's, Azores, contain ZrO_2 and Nb_2O_5, but have not been completely analysed. They occur in minute bright orange-yellow octahedra or tetragonal pyramids, similar to those of zircon, in trachytic lavas.

TANTALATES AND COLUMBATES.

TANTALITE.—*Rhombic.* $a : b : c = 0{\cdot}8166 : 1 : 0{\cdot}6519$. COLUMBITE. Niobite. — *Rhombic.* $a : b : c = 0{\cdot}4074 : 1 : 0{\cdot}3347$. The former occurs mostly in long columnar, the latter in short columnar and tabular crystals. Cleavage: Tantalite, brachydiagonal very imperfect; Columbite, brachydiagonal rather distinct, macrodiagonal less so, basal indistinct. Fracture, conchoidal, uneven in both. H. 6·65. Sp. gr.: Tantalite, 6·10–7·39; Columbite, 5·36–6·53. Colour, brownish to iron-black; streak, brownish black. Lustre, metallic-adamantine to resinous. Opaque.

Composition.—Isomorphous mixtures of (FeMn) Ta_2O_6 and (FeMn) Nb_2O_6. The percentage composition of these compounds is: $FeTa_2O_6 = FeO$ 13·95, Ta_2O_5 86·05, and $FeNb_2O_6 = FeO$ 21·8, Nb_2O_5 78·82. The latter is nearly represented in a state of purity in the columbite of Greenland, but the nearest approach to a pure tantalate does not contain more than 76·34 per cent. of Ta_2O_5. A combination of equal molecules of the two compounds contains 49·64 Ta_2O_5 to 29·27 Nb_2O_5. This and all varieties with a large proportion of Ta_2O_5 are referred to Tantalite, while those in which Nb_2O_5 predominates are called Columbite or Niobite. MnO varies from 1 to 5, SnO_2 0·7 to 2·5, and WO_3 0·2 to 1 per cent.; ZrO_2 under 0·4 per cent. Infusible; with borax gives the reaction of iron, and when saturated turns cloudy on cooling. With salt of phosphorus gives a pale yellow bead in the reducing flame, which becomes green if treated with tin on charcoal, unless tungsten be present, when the bead is dark red and is not altered by treatment with tin. When perfectly fluxed with soda and borax, metallic tin may

be obtained on charcoal. Insoluble in acids, but when fused with bisulphate of potassium and dissolved in hydrochloric acid gives a heavy white precipitate and yellow solution, which when boiled with zinc turns to a brilliant blue. This reaction is more easily obtained, and the blue colour is more permanent, with columbite than with tantalite.

Tantalite occurs in granite at Tammela and other localities in Finland, Brodbo near Fahlun, and Chanteloupe near Limoges : Columbite at most of these places and at Bodenmais, Bavaria ; Acworth, New Hampshire ; Haddam, Connecticut; Miask ; and Arksutfiord, Greenland ; also in granite, except at the last-named place, where it is found in large well-developed crystals, embedded in cryolite.

Yttrotantalite and *Fergusonite* include several complex minerals containing the metals of the cerium group and uranium as bases. The former, also distinguished as black and yellow Yttrotantalite, is represented by the expression $\overset{II}{R}_2(TaNb)_2O_7$, R=(YErCeCaFe), and UrO_2, and when crystallised appears to be rhombic.

Fergusonite, or brown Yttrotantalite, is tetragonal and pyramidally hemihedral (isomorphous with Scheelite and Wulfenite).

Composition.—$\overset{II}{R}_3(NbTa)_2O_8$, the bases being similar to those in Yttrotantalite. Both contain tin and tungsten in variable quantity. The chief locality is at Ytterby in Sweden.

Samarskite and *Uranotantalite* are chiefly dibasic molecules mixed with normal thorates and zirconates of yttria, iron, and uranium. Found in masses embedded in felspar at Miask and in Mitchell County, North Carolina. The crystallised variety is rhombic, $a : b : c = 0{\cdot}545 : 1 : 0{\cdot}571$.

CHAPTER X.

TUNGSTATES—MOLYBDATES—CHROMATES.

WOLFRAM. — *Oblique.* ∞P 100° 37′, $a : b : c = 0{\cdot}830 : 1 : 0{\cdot}8881$, $\beta = 89° 22'$. (Fig. 151) $m\{110\}\infty P$, $b\{100\}\infty \breve{P}\infty$, $l\{210\}\infty \breve{P}2$, $r\{120\}\infty \breve{P}2$, $o\{111\}-P$, $t\{102\}-\frac{1}{2}\breve{P}\infty$, $s\{121\}-2\breve{P}2$, $u\{011\}\breve{P}\infty$, $t'\{\bar{1}02\}\frac{1}{2}\breve{P}\infty$. Crystals short columnar, with acute edge of 110 very prominent, or tabular to 100. Twins (1) on 100 (fig. 152) common ; (2) on 023

FIG. 151.

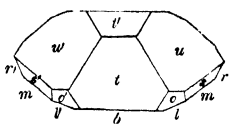
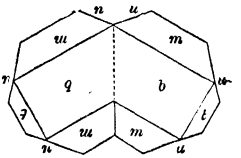


FIG. 152.



less common. Usually in massive, platy, or columnar aggregates, often of considerable size. Cleavage, 010 very perfect, 100 imperfect. Fracture, platy, uneven. H. 5–5·5. Sp. gr. 7·14–7·54. Black or brownish black ; streak, brownish red. Lustre, metallic-adamantine to resinous. Opaque, but when reduced sufficiently thin, transparent, so that the optical properties may be determined. 010 is the optic axial plane, a median line making an angle of 19° or 20° with the vertical axis.

Composition.—Isomorphous mixtures of $MnWO_4$ and $FeWO_4$ in variable proportions. The former occurs as an independent mineral called *Hübnerite*, and has the com-

position WO_3 76·9, MnO 23·1 per cent. The equivalent of iron and manganese being nearly the same, the percentage of tungstic acid is nearly constant in all the varieties. Ferrous tungstate has not been observed, the nearest approach being $\left\{\begin{matrix}MnWO_4\\4FeWO_4\end{matrix}\right\}$ in common Wolfram, which contains WO_3 76·37, FeO 18·96, MnO 4·67 per cent. In a few instances FeO slightly exceeds 20 per cent., and as a rarity about 1 per cent. of lime is recorded in some analyses.

Difficultly fusible on charcoal to a crystalline globule, which is sometimes magnetic; gives the reaction of iron with borax and with salt of phosphorus; in the reducing flame a red bead, which turns green when treated with tin. With soda on platinum foil gives the manganese green. When heated with hydrochloric or sulphuric acid out of contact of air a blue mass or syrup is produced, which after a time turns yellow from the peroxidation of the iron. If sulphuric acid is used the change is attended with the evolution of sulphurous acid. Decomposed by acids with the separation of tungstic acid as a yellow powder; also by caustic alkalies, but not completely.

Occurrence.—In association with tin ores, the chief localities being Zinnwald, Saxony, and the mines in the neighbourhood of Camborne and Callington, Cornwall. The principal production is now at East Pool Mine. The most usual associates are quartz, fluor, lepidolite, tinstone, tungstates of calcium and lead, and copper pyrites. When present in quantity it is a source of considerable trouble in dressing tin ores, as from its high specific gravity it cannot be separated by water alone. It is best removed by calcining the concentrated ores at a low heat with an alkaline salt, sulphate of soda being generally used, which decomposes it, forming tungstate of soda, a salt that, being soluble in water, may be washed out, leaving the tinstone unaltered. Formerly Wolfram was essentially a waste mineral, but of late years a certain demand for it has arisen. Tungstic acid and

soluble tungstates are used as dyers' colours, and the metal tungsten[1] when alloyed with iron communicates especial hardness to, and notably increases the magnetic coercive power of, steel used for permanent magnets.

SCHEELITE. Tungsten. Tungstate of Lime. Calco-scheelite.—*Tetragonal.* Pyramidally hemihedral. $Z=136°\ 30'$, $a:c=1:1{\cdot}5369$. (Figs. 153–4.) $e\{101\}P\infty$, $n\{111\}P$, $x\pi\{311\}$ $\frac{1}{2}(3P3)$, $z\pi\{313\}$ $\frac{1}{2}(P3)$. Twins, (1) on 101; (2) on 111. Crystals pyramidal or tabular, the former most common. Cleavage, 101 tolerably perfect, 111 less perfect, 001 imperfect. H. 4·5–5. Sp. gr. 6–6·2. Occasionally colourless, usually grey, yellowish, clove-brown, or reddish.

FIG. 153.

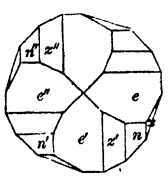
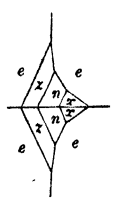


FIG. 154.



Lustre, adamantine, greasy: translucent. Double refraction positive. Indices for red light, $\omega=1{\cdot}918$, $\epsilon=1{\cdot}934$; cross and rings seen by convergent polarised light, often irregular.

Composition.—$CaWO_4$, or WO_3 80·55, CaO 19·45 per cent. A green variety from Chili contains 3·31 CuO.

Fusible with difficulty to a translucent glass. With salt of phosphorus in the reducing flame gives a bead which is yellowish or greenish while hot, and blue when cold; this

[1] Tungsten is a Swedish term, meaning 'heavy stone,' and was originally applied to the mineral scheelite. Its use as the name of an element is therefore a misappropriation, but it is a more convenient word than the German Wolfram, although the initial of the latter is preferable as a symbol, there being numerous other elementary substances using the capital T.

colour is rendered more apparent by the addition of tin. Decomposed by acids with separation of WO_3, a yellow powder soluble in caustic alkalies. The hydrochloric acid solution turns blue when heated with tin.

Occurrence.—At Zinnwald, Ehrenfriedersdorf, and other localities in Saxony and Bohemia, and in Cornwall, with tin ores, wolfram, &c.; also in Wermland, Sweden; at Traversella; and in Connecticut and Nevada. The crystals are often isolated, being implanted upon quartz, wolfram, and other minerals; occasionally they attain a considerable size; more commonly, however, are grouped in druses. It appears to be a subsequent formation to wolfram in the lodes, but pseudomorphs of the latter after Scheelite are recorded; they are of somewhat doubtful significance.

STOLZITE. Scheelitine, Scheelbleierz, Plumbo-scheelite. —*Tetragonal*, isomorphous with Scheelite, and similarly

FIG. 155.

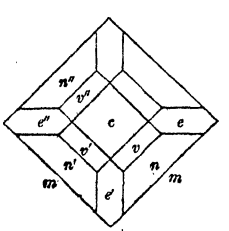
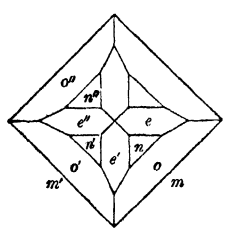


FIG. 156.



hemihedral. $Z=131°\ 25'$, $a : c=1 : 1{\cdot}567$. (Figs. 155, 156.) $m\{110\}\infty P$, $n\{111\}P$, $e\{101\}P\infty$, $v\{112\}\frac{1}{2}P$, $o\{221\}2P$, $c\{001\}oP$. Crystals mostly small, acute pyramids with truncated points. H. 3. Sp. gr. 7·9–8·1. Colour, grey, yellow, orange, or brownish red. Lustre, greasy, or horny, slightly translucent.

Composition.—$PbWO_4$, or WO_3 51, PbO 49 per cent. Tolerably easily fusible to a crystalline bead. On charcoal

gives an incrustation of PbO, and with soda, metallic lead; otherwise similar in behaviour to Scheelite.

Occurrence.—Found at Zinnwald, incrusting quartz; also in Chili, and at Southampton, Massachusetts.

WULFENITE. Gelbbleierz, Molybdate of Lead.—*Tetragonal*, pyramidally hemihedral, isomorphous with Scheelite. Z 131° 48′, $a : c = 1 : 1{\cdot}574$. Crystals either pyramidal, short columnar, or very thin tabular. (Figs. 157, 158.) $n\ \{111\}\ P$, $f\pi\ \{320\}\ \frac{1}{2}(\infty P\frac{3}{2})$, $e\ \{101\}\ P\infty$, $s\ \{113\}\ \frac{1}{3}P$, $y\ \{203\}\ \frac{2}{3}P\infty$. Cleavage, 111 fairly perfect, 001 imperfect. H. 3. Sp. gr. 6·3–6·95. Colour, usually between sulphur-

FIG. 157.

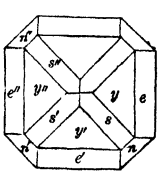
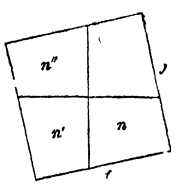


FIG. 158.



and orange-yellow, less commonly colourless or hyacinth-red. Lustre, adamantine to greasy. Transparent to translucent. Double refraction negative; indices for red light, $\omega = 2{\cdot}402$, $\epsilon = 2{\cdot}304$.

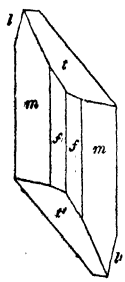
Composition.—$PbMO_4$, or molybdic acid (MO_3) 38·57, PbO 61·43 per cent. The American varieties contain some vanadic and chromic acids, the former up to 1·28 per cent. That from Chili contains 6 per cent. of lime, and corresponds to 2 molecules of lead to one of calcium molybdate. Decrepitates and darkens when heated. On charcoal fuses and is reduced to metallic lead. The glass with borax is colourless in the oxidising and black in the reducing flame, and with salt of phosphorus pale yellowish green and dark

green. Decomposed by hydrochloric acid with production of $PbCl_2$ and a green solution. Nitric acid separates molybdic acid as a yellow powder, which when treated with zinc and dilute sulphuric acid becomes bright blue.

Occurrence.—Found in considerable quantity in the lead mines of Bleiberg in Carinthia, in Jurassic limestone. Very large and brilliant tabular crystals have latterly been found at the Empire Mine, Utah. The chromic and vanadic varieties are from Phenixville, Pennsylvania. It is the chief source of molybdic acid, which is used as a test for phosphorus in analytical chemistry.

CROCOISITE. Rothbleierz, Chromate of Lead, Lehmannite.—*Oblique.* $\beta=77°\ 27'$, $\infty P\ 93°\ 42'$, $a : b : c=0{\cdot}9603 : 1 : 0{\cdot}9181$. (Fig. 159.) $m\{110\}\infty P$, $f\{120\}\infty \breve{P}2$, $t\{111\}-P$, $l\{\bar{4}01\}4\breve{P}\infty$. Crystals very variable, including a great number of forms, usually columnar to the prism or negative hemipyramid, and striated vertically. Cleavage, 110 distinct, 100 and 001 indistinct. H. 2·5–3. Sp. gr. 5·9–6·1. Colour, hyacinth-red; streak, orange-yellow. Lustre, adamantine: translucent.

FIG. 159.



Composition.—$PbCrO_4$, or PbO 69·04, CrO_3 30·96 per cent. In the closed tube decrepitates and darkens; the original colour returns when cold. On charcoal fuses to a greenish-grey slag, with spots of metallic lead. With glass-fluxes the beads are yellow in oxidising, and green in reducing flame. Decomposed by hydrochloric acid, $PbCl_2$ separating, and the solution becoming green from Cr_2Cl_3. Soluble in nitric acid, but not very readily, giving a yellow solution. In caustic potash turns reddish brown and dissolves.

Occurrence.—A rare mineral, but found in some quantity at Beresov, in Siberia, associated with the analogous minerals,

Melanochroite $\left\{\begin{matrix}2PbCrO_4\\PbO\end{matrix}\right\} = CrO_3$ 23·02, PbO 76·98 per cent.; and *Vauquelinite*, $2\left\{\begin{matrix}2PbCrO_4\\PbO\end{matrix}\right\} + \left\{\begin{matrix}2CuCrO_4\\CuO\end{matrix}\right\}$ $= CrO_3$ 27·57, PbO 61·48, CuO 10·95 per cent. Other localities are in Brazil and the island of Luzon.

Laxmannite is a phospho-chromate of lead and copper, whose constitution is not exactly defined; also from Beresov.

CHAPTER XI.

SULPHATES.

THIS class of minerals, though not large, includes substances of very varied composition. The simplest of these are the normal sulphates of monad metals, $\overset{I}{R_2}SO_4$ (R = K, Na, and (NH_4)); dyads, $\overset{II}{R}SO_4$ (R = Ba, Sr, Ca, Mg, Mn, Zn, Cu, Ni and Co); and hexads, $\overset{VI}{R_2}S_3O_{12}$ (R_2=Al_2 and Fe_2), which are found both anhydrous and hydrated, the latter usually containing a large number of molecules of water. The double sulphates are combinations of molecules of monad with dyad, or monad with hexad sulphates, and these are as a rule hydrated. In this respect there is a marked difference between the sulphates and carbonates of the same metals, natural double sulphates containing two dyad metals in definite proportions being very uncommon, although many salts of this class have been formed artificially, while double carbonates of closely allied metals are abundant in dolomite, ankerite, &c. The basic sulphates are exclusively those of dyad (lead and copper) and hexad metals (iron and aluminium): these consist of one or more molecules of the normal salt combined with the corresponding hydrated oxide, and in some instances with a further quantity of water of crystallisation, and in the latter class especially are often somewhat indefinite in composition. In regard to crystallisation, the normal dyad sulphates, when anhydrous, form a well-marked isomorphous series in the rhombic system, while those that are hydrated show more

variety, forming four principal series, of which two are oblique, one rhombic, and one triclinic, the differences corresponding to those in the number of molecules of water taken up by the RSO_4 molecule in crystallising. The types of these series are as follows:

Epsomite . .	$MgSO_4 + 7H_2O$.	Rhombic.
Copperas . .	$FeSO_4 + 7H_2O$.	Oblique.
Picromerite .	$(K_2Mg)SO_4 + 6H_2O$.	„
Blue vitriol .	$CuSO_4 + 5H_2O$.	Triclinic.

Only the first, second, and fourth of these series are of mineralogical importance. The third, though feebly represented in nature, is the type of one of the best defined isomorphous groups of artificial salts. Epsomite may be crystallised artificially in the copperas form, but the crystals are exceedingly unstable.

Another important isomorphous group among the sulphates is that of the hydrated double sulphates known as Alums, which are all octahedral or cubical in crystalline form, while subject to great diversity in chemical composition and physical characters. Only a small number of these are, however, found in nature, and to establish the complete series we have, as is also the case with the hydrated dyad sulphates, to make use of artificially prepared crystals. Only those sulphates that are difficultly soluble in water are, as a rule, found well crystallised in nature. This is especially the case with the sulphates of barium and lead, which cannot be crystallised by the chemist, and appear only as dense impalpable powders in the laboratory, but are remarkable for the extreme variety and beauty of their natural forms.

Barium and strontium sulphates are practically stable compounds. Those of calcium are nearly so, but are liable to change from the anhydrous to the hydrated form, and *vice versâ*, besides being more sensibly soluble in water than the preceding. The alkaline sulphates and alums are all exceedingly soluble, and therefore not easily preserved,

as are also those of the heavy metals, zinc, copper, manganese, and iron; the last especially is subject to rapid alteration, from the tendency to pass from the state of ferrous to ferric combination, which gives rise to the numerous and indefinite basic ferric sulphates, all of which are derivatives of normal ferrous sulphate.

Alkaline and calcic and magnesian sulphates are principally found in association with rock salt, and probably represent the original constituents of the brine from which the salt was deposited. Barium and strontium sulphates are also found in positions in mineral veins, &c., showing that they have been deposited from solution, but from their slight solubility the process must have been considerably slower. Sulphate of strontium is, however, soluble in sea water, and has been found accumulated in the deposits in marine boilers. In volcanic districts aluminous and alkaline sulphates are often produced by the direct action of sulphurous acid and steam on silicates of the same metals, and the same effect is produced by the action of vitriolescent pyrites upon shales in the ordinary process of alum-making in Yorkshire and elsewhere. Sulphate of lead is derivable from galena by simultaneous oxidation of both lead and sulphur, and a similar effect is produced by the oxidation of blende and sulphide of copper. The process of vitriolescence has already been noticed at page 347 of the volume on 'Systematic Mineralogy.'

NORMAL MONAD AND DYAD SULPHATES.

MASCAGNINE.—*Rhombic.* ∞P 121° 88′, $\check{P}\infty$ 107° 40′, $a : b : c = 0{\cdot}5643 : 1 : 0{\cdot}7310$. The dimensions are determined from artificially prepared crystals. The natural mineral is usually in crusts and stalactites. Cleavage, brachydiagonal. H. 2–2·5. Sp. gr. 1·7–1·8. Colourless, white, or yellowish. Soluble, with a sharp bitter taste.

Composition.—$NH_4SO_4 + H_2O$, or ammonia (NH_4O) 25·8, sulphuric acid 60·6, water 13·6 per cent.

Heated in the closed tube decrepitates, fuses, gives off

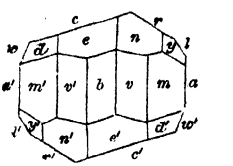
water, is decomposed, and volatilises completely. When heated with soda-lime gives off ammonia.

Occurrence.—As a sublimate in the hollows of lavas in Ætna and Vesuvius, and in the volcanic steam jets (*soffioni*) of Tuscany.

GLASERITE.—K_2SO_4, isomorphous with mascagnine, is found under similar conditions in Sicily.

GLAUBER SALT. Mirabilite.—*Oblique.* ∞P 86° 31′, $a : b : c = 1{\cdot}1161 : 1 : 1{\cdot}2382$, $\beta = 72°\ 15'$. (Fig. 160.) $a\{100\}\infty\breve{P}\infty$, $m\{110\}\infty P$, $v\{120\}\infty\breve{P}2$, $b\{010\}\infty\breve{P}\infty$, $d\{\bar{1}11\}P$, $e\{011\}\breve{P}\infty$, $n\{111\}-P$, $y\{211\}-2P$, $r\{101\}-\breve{P}\infty$, $l\{201\}2\breve{P}\infty$. Crystals usually prismatic, elongated parallel to *b*. Generally efflorescent or incrusting. Cleavage, 100 perfect. H. 1·5–2. Sp. gr. 1·4–1·5. Colourless and transparent, or white. Opaque. Soluble, with a cooling saline bitter taste.

FIG. 160.



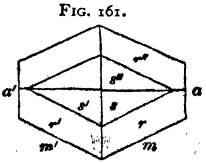
Composition.—$Na_2SO_4 + 10H_2O$, or Na_2O 19·3, SO_3 24·8, H_2O 55·9 per cent. By exposure to the air it effloresces, changing to $Na_2SO_4 + 2H_2O$.

In the closed tube gives off water; in the platinum loop fuses, colouring the flame yellow; on charcoal with soda gives a reddish-coloured hepatic mass, which blackens silver.

Occurrence.—With rock salt in the salt marls of Hallein and other localities in the Austrian Alps, and as a constituent of mineral springs and sea-water.

THENARDITE.—*Rhombic.* ∞P 129° 21′, $a : b : c = 0{\cdot}4734 : 1 : 0{\cdot}8005$. (Fig. 161.) $m\{110\}\infty P$, $a\{010\}\infty\breve{P}\infty$, $r\{111\}P$, $s\{113\}\frac{1}{3}P$, usually in acute pyramidal forms, in druses and crusts, the faces generally rough and covered with a white incrustation. Also in granular masses. Cleavage, 001 tolerably perfect. Translucent. Lustre, vitreous. Fracture, uneven or granular. H. 2–5.

FIG. 161.



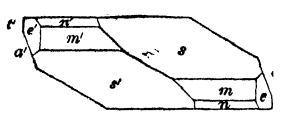
Sp. gr. 2·6–2·7. Colourless or white. Taste slightly saline.

Composition.—Na_2SO_4, or soda 43·66, sulphuric acid 56·34. In the air attracts moisture, and becomes dull. Fusible on charcoal, giving sulphide of sodium in reducing flame. Readily soluble in water.

Occurs with rock salt.

GLAUBERITE.—*Oblique.* $\infty P\,83°\,20'$, $a : b : c = 1·2083 : 1 : 1·0215$, $\beta = 68°\,16'$. (Fig. 162.) $s\{111\}$–P, $m\{110\}\,\infty P$, $n\{11\bar{1}\}P$, $e\{31\bar{1}\}\,3\breve{P}_3$, $a\{100\}\,\infty\breve{P}\infty$, $t\{20\bar{1}\}\,2\breve{P}\infty$. Also massive in platy aggregates. Cleavage, 001 perfect, 110 in traces. H. 2·5–3. Sp. gr. 2·7–2·8. Colourless, bluish grey, yellowish grey, wine-yellow to brick-red. Lustre, vitreous or greasy. Transparent to translucent. In damp air weathers and becomes opaque. Optic axial plane parallel to b, and nearly perpendicular to 001. The axial angle, small at ordinary temperatures, first diminishes to 0 by heating, and then separates in the plane of symmetry, as in gypsum.

FIG. 162.



Composition.—$Na_2CaS_2O_8 = Na_2SO_4 + CaSO_4$, or Na_2O 22·30, CaO 20·08, SO_3 57·55 per cent. Some varieties contain a little chlorine. When heated decrepitates and fuses readily to a white enamel, colouring the flame yellow. Fused on charcoal in reducing flame is partially absorbed, giving an hepatic residue. Decomposed by water, sulphate of sodium being dissolved, the residue consisting chiefly of sulphate of calcium. In a very large quantity of water it is entirely soluble, with a saline bitter taste.

Occurrence.—With rock salt at Aussee in Austria: at Vic in France; in the district of Tarapaca, Peru, with borax minerals; and at Ciempozuelos, near Madrid. At the latter place it is found in quantity in clear bluish crystals, and is used as a source of alkali for glass-making.

SYNGENITE is an analogous compound of potassium and calcium sulphates, but hydrated; the composition being $K_2SO_4.CaSO_4 + H_2O$. It crystallises in the oblique system, and is found in the salt bed of Kalusz in Gallicia. It has also been described by J. A. Phillips as an artificial product, in the manufacture of tartaric acid, under the name of *Potassogypsite.*

KIESERITE.—Crypto-crystalline aggregates of probably rhombic forms making up translucent greyish-white masses, often of considerable size. Sp. gr. 2·517.

Composition.—$MgSO_4 + H_2O$, or magnesia (MgO) 28·98, sulphuric acid 57·98, water 13·04 per cent. Does not give off water at 100° Cent., and loses some sulphuric acid by heating. Slowly soluble in water, but very hygroscopic, passing into Epsom salts by absorption of water. When mixed with a small quantity of water it sets like plaster of Paris.

Occurrence.—Found in large quantities at Stassfurt with rock salt, inclosing crystals of sylvine and anhydrite.

POLYHALITE.—*Rhombic.* ∞P 115°, usually in parallel columnar or fibrous aggregates. Cleavage, 110 imperfect. H. 3·5. Sp. gr. 2·72-2·77. Usually flesh-coloured or brick-red. Feeble greasy lustre. Translucent at the edges.

Composition.—$K_2MgCa_2S_4O_{16} + 2H_2O = \left\{\begin{matrix} 2CaSO_4 \\ MgSO_4 \\ K_2SO_4 \end{matrix}\right\} + 2H_2O$, or $\left\{\begin{matrix} 45{\cdot}17 \\ 19{\cdot}92 \\ 28{\cdot}93 \end{matrix}\right\} + 5{\cdot}98$ per cent. of the respective constituents in the order given.

Easily fusible to a red bead, white when cooled. Decomposed by water, leaving sulphate of lime. Insoluble. When dehydrated and mixed with water, it hardens at first like burnt gypsum; then increases in volume, and decomposes very readily.

Occurrence.—In the Austrian and Bavarian salt mines; at Stassfurt; and Vic in Lorraine.

Cerbolite $\left\{\begin{matrix}(NH_4)_2SO_4\\MgSO_4\end{matrix}\right\}$ is found in crystals deposited by the mother liquors of the boracic acid works in Tuscany.

Picromerite, $\left\{\begin{matrix}K_2SO_4\\MgSO_4\end{matrix}\right\}+6H_2O$, is a salt crystallised from the watery solution of an incrustation deposited by fumaroles upon lava at Vesuvius during the eruption of 1855.

Astrakanite and *Blödite* contain $\left\{\begin{matrix}Na_2SO_4\\MgSO_4\end{matrix}\right\}+4H_2O$. The first is found in white opaque prismatic crystals in the salt deposited by the bitter lakes east of the mouth of the Volga. The latter is a red, finely fibrous variety from Ischl in Austria, and is also found at Mendoza in the Andes.

Simonyite, another substance of the same composition, is oblique in form.

Löweite is of similar composition to the preceding, but with five molecules of water. It occurs in masses, apparently with tetragonal cleavage, of a yellowish-white or flesh-red colour, and sometimes rather opalescent, embedded in anhydrite, at Ischl.

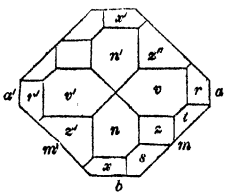
Fauserite, a double sulphate of manganese and magnesia, occurs in stalactitic masses and large rounded crystals of a rhombic character in the mines of Herrengrund, Hungary. It corresponds in composition to the formula:

$$\left\{\begin{matrix}MgSO_4\\2MnSO_4\end{matrix}\right\}+6H_2O.$$

EPSOM SALTS. Bittersalz, Epsomite.—*Rhombic;* sphenoidally hemihedral. ∞P 90° 38′, $a:b:c=0{\cdot}990:1:0{\cdot}571$. (Fig. 163.) $m\{110\}\ \infty P$, $a\{010\}\ \infty \breve{P}\infty$, $b\{100\}\ \infty \bar{P}\infty$, $z\ \kappa\{111\}\ \frac{1}{2}(P)$, $z\ \kappa'\{1\bar{1}1\}-\frac{1}{2}(P)$, $s\ \kappa\{211\}\ \frac{1}{2}(2\bar{P}2)$, $t\kappa\{121\}\ \frac{1}{2}(2\breve{P}2)$, $x\{201\}\ 2\bar{P}\infty$, $n\{101\}\breve{P}\infty$. $r\{021\}\ 2\breve{P}\infty$, $v\{011\}\breve{P}\infty$. Usually in fibrous or earthy

efflorescences. Cleavage, brachydiagonal, perfect. H. 2–2·5. Sp. gr. 1·7–1·8. Transparent—translucent. Colourless or white. Lustre, vitreous, earthy. Double refraction negative. Plane of optic axes oP, median line axis *b*. Mean refractive index for D line, 1·4454. Taste, bitter and saline.

FIG. 163.



Composition.—$MgSO_4 + 7H_2O$, or magnesia 16·26, sulphuric acid 32·52, water 51·22 per cent. The natural salt often contains traces of iron, manganese, cobalt, or copper. When heated liquefies in water of crystallisation; gives off water in the closed tube; and ultimately, when strongly heated, sulphuric acid. The dehydrated salt behaves like Kieserite, fusing, but ultimately yielding an infusible mass. With cobalt solution, gives the reaction of magnesia.

Occurrence.—In solution in many mineral waters, notably in those of Epsom, Püllna, and Saidschütz. In steppe and desert regions it is found in silky efflorescences, and in some cave earth in limestone caverns in earthy nodules.

Uses.—This salt is largely used in medicine, but no portion of the supply is obtained from the natural mineral (except in the case of mineral waters), it being produced by heating serpentine, dolomite, or chloride of magnesium in sulphuric acid, and crystallising the solution. It is now also procured on the large scale from Kieserite and other magnesian minerals in the Stassfurt alkali works.[1]

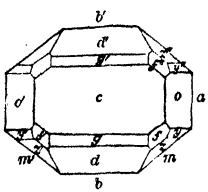
BARYTES GROUP.

The minerals in this group are closely isomorphous in crystallographic elements, being nearly identical; they are further remarkable for simplicity and homogeneity, twin crystals being practically unknown.

[1] This species is misplaced: it should adjoin *Goslarite*, p. 295.

BARYTES. Heavy Spar, Cawk, Schwerspath, Barytspath, Barytine.—*Rhombic.* ∞P 101° 40′, $a : b : c = 0{\cdot}8446 : 1 : 1{\cdot}312$. (Fig. 164.) $m\{110\}\infty P$, $b\{100\}\infty \breve{P}\infty$, $a\{010\}\infty \breve{P}\infty$, $z\{111\}P$, $f\{113\}\frac{1}{3}P$, $y\{122\}\breve{P}2$, $o\{011\}\breve{P}\infty$, $d\{102\}\frac{1}{2}\breve{P}\infty$, $g\{103\}\frac{1}{3}\breve{P}\infty$. Forms very numerous and diversified in combinations. Crystals are usually thin, tabular to 001; prismatic or short columnar by elongation in the direction of one or other of the horizontal axes; or nearly square tabular by equal development on both. The forms are prominently prisms or domes, the fundamental pyramid or its series being usually very subordinate if present. Cleavage, 001 perfect, 110 less so, 010 imperfect (or on the other view, brachydiagonal perfect, macrodomatic less so, macrodiagonal imperfect). Individual crystals are often of large size, up to eighteen inches in length, but generally in parallel or divergent groups: also in spheroidal aggregates; lamellar, cleavable, massive; and in stalactite forms with a fibrous structure. As pseudomorphs after Witherite and barytocalcite. H. 3–3·5. Sp. gr. 4·3–4·72. Colourless and transparent in many instances; also variously translucent, white, grey, yellowish, or brown, rarely blue. The stalactitic varieties are banded in various shades of black, dark brown, or yellow. Streak, white. Double refraction positive. Optic axial plane 010. a = median line; indices for D line, $\alpha = 1{\cdot}6363$, $\beta = 1{\cdot}6375$, $\gamma = 1{\cdot}6480$. The angle between the optic axes for red light is 63° 05′ at 12°; increases to 74° 42′ at 196° Cent. Lustre of transparent crystals, vitreous; of translucent ones, nacreous.

FIG. 164.



Composition.—$BaSO_4$, or BaO 65·68, SO_3 34·32 per cent.; often containing some strontium sulphate, which, in extreme cases, may amount to as much as 15 per cent., but generally very much less. Calcium sulphate also pre-

sent sometimes; and silica, clay, bituminous or carbonaceous substances, as impurities.

When heated in the forceps, decrepitates and melts on the edges, colouring the flame yellowish green; with soda on charcoal melts to a clear bead, which becomes opaque on cooling, and when kept melted is absorbed by the charcoal. In the reducing flame gives sulphide of barium, which blackens on silver when moistened. Insoluble in acids.

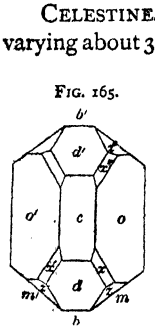
Occurrence.—Barytes is a very common vein mineral, especially accompanying lead ores. The largest crystals are obtained from the lead mines of Northumberland and Westmoreland, especially from the Dufton and Silverband mines near Crossfell, where large rectangular tabular groups are found in great abundance in a lode carrying lead and manganiferous brown iron ores. The rhombic tabular variety, known as *chisel-edged barytes*, is common in the same district. Yellowish and brownish or greenish crystals occur in the Gwennap and Liskeard districts in Cornwall, and transparent forms of great beauty at Kremnitz and Přzíbram. At Freiberg it occurs in rosette and spheroidal groups with fluor spar. Blue crystals are found at Gersdorf and in the Cumberland hematite mines. Bright yellow crystals, irregularly aggregated with quartz, occur in the fuller's earth pits at Nutfield, Surrey. At Bologna a radiated columnar variety known as ***Bologna stone*** occurs in nodules in marls. The fibrous variegated stalactitic kind is from Middleton, near Matlock, Derbyshire.

Uses.—When of a good colour it is ground for mixing with white lead in the manufacture of paint, and for this purpose when slightly tinged by brown iron ore it may sometimes be rendered sufficiently white by treating it with hydrochloric acid. The dark brown stalactitic variety from Derbyshire is used as an ornamental stone, being carved into vases and similar objects. It may also be used for the production of the chloride, nitrate, and other barium salts, being first reduced to sulphide of barium by heating with carbon, after

which it is soluble in acids. Generally these salts are made from Witherite, which is soluble without any special preparation. Nitrate of baryta is used by pyrotechnists in making green fire, and also to some extent as a nitre in certain blasting powders and similar explosive substances.

CELESTINE.—*Rhombic.* ∞P 104′ 02′ (mean value, but varying about 30′ above or below); $a : b : c = 0{\cdot}781 : 1 : 1{\cdot}283$. (Fig. 165.) $m\{110\}\infty P$, $b\{100\}\infty \breve{P}\infty$, $z\{111\}P, x\{135\}\frac{3}{5}\breve{P}_3, c\{001\}\,0P, o\{011\}\breve{P}\infty$, $d\{102\}\frac{1}{2}\breve{P}\infty$. Crystals similar to those of barytes, but not so rich in forms and combinations. The crystals most commonly found are short columnar combinations of ∞P, $\breve{P}\infty$, $\frac{1}{2}\breve{P}\infty$, $0P$, $\infty \breve{P}\infty$, but varying in character according to the predominating planes, being sometimes thin tabular. The position adopted is similar to the first given under Barytes. Naumann, on the other hand, adopts the second position, in which case $\infty P = \breve{P}\infty$ &c. Also fibrous and in columnar radiated or spheroidal forms, granular and earthy. H. 3–3·5. Sp. gr. 3·92–3·985. Cleavage, 001 perfect, 110 less so, 010 imperfect; or similar to barytes. Lustre, vitreous or pearly in crystals, silky in fibrous variety. Fracture, conchoidal to uneven. Transparent to imperfectly translucent. Colourless, white, or pale blue, sometimes reddish. Double refraction positive. Index for D line, $\beta = 1{\cdot}625$. Optic axial plane 010; first median line a; $2E = 89°\ 36$, increasing when heated.

FIG. 165.



Composition.—$SrSO_4$, or strontia (SrO) 56·52, sulphuric acid 43·48 per cent. Usually containing some proportion of lime or baryta (from 0·2 to 1·2 per cent. of each). Heated in the forceps, melts to an opaque bead, colouring the flame crimson. The colour is best brought out by heating in the reducing flame, moistening with hydrochloric acid, and exposure in the least luminous outer portion of the natural

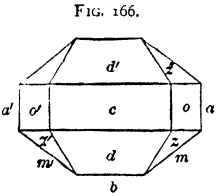
flame without blowing. Reduced to sulphide of barium on charcoal with soda. Almost insoluble in acids.

Occurrence.—Found principally in marls and limestones, the most abundant locality being in the sulphur district of Girgenti, in Sicily, with native sulphur, in large brilliant white crystals. Also in pale blue crystals in geodes in the New Red marls of Pyle Hill, Bristol; as a blue fibrous variety in the red marls of Dornburg near Jena; and in large complicated crystals in Silurian limestones at Strontian Island, Lake Erie. In the nummulitic limestones of Mokattam, near Cairo, large crystals and groups are found inclosing nummulites and other remains of marine animals, which become exposed owing to the gradual erosion of the crystals by water. Sometimes a secondary growth of perfectly formed crystals, free from included substances, is formed upon the eroded ones. This locality and Strontian Island have yielded the largest known crystals, but they are very much inferior in size to the largest crystals of baryta.

Uses.—Celestine is the principal source of strontia salts; of these, the nitrate is the most important, being used in fireworks as the basis of red fire. Celestine is sensibly soluble in water, and very decidedly so in brine. A crystal with bright faces was eroded in the same manner as those of Egypt by immersion in a saturated solution of sodium chloride for eighteen months.

ANGLESITE. Bleivitriol.—*Rhombic.* ∞P, 103° 43′, $a : b : c$ = 0·7756 : 1 : 1·2178. (Fig. 166) $m\{110\}\infty P$, $z\{111\}P$, $o\{011\}\breve{P}\infty$, $d\{102\}\frac{1}{2}\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$, $b\{100\}\infty\breve{P}\infty$, $c\{001\}oP$. Combinations similar to those of Barytes, but much more diversified. 31 forms and 178 combinations have been described by Viktor von Lang. The habit of the crystals varies according to the character of the dominant faces, as follows:

FIG. 166.



Group A. Pyramidal to 122, vertically short columnar to 110, horizontal columnar to 011.
„ B. Horizontally columnar to 102.
„ C. Rectangular tabular to 100, vertical columnar to 110.
„ D. Horizontal columnar to 104, rhombic tabular to 001.

The second of these groups may be taken as typical of crystals from the original locality. The faces of 110 and 100 are often striated vertically, and those of 102 horizontally. Cleavage, 110 and 001, both interrupted. Also massive and granular, and pseudomorphous after galena. Fracture, conchoidal. Very brittle. H. 3. Sp. gr. 6·12–6·35. Lustre, adamantine to vitreous and resinous. Colourless, white, yellowish, or brown. Transparent to opaque. Double refraction positive. Indices for red, $\alpha = 1{\cdot}8740$, $\beta = 1{\cdot}5795$, $\gamma = 1{\cdot}5924$. Optic axial plane 010, first median line a, $2V = 66° 50'$.

Composition.—$PbSO_4$, or PbO 73·6, SO_3 26·4 per cent., or lead 68·32, sulphur 10·56, oxygen 21·12 per cent.

Decrepitates when heated, and fuses in the oxidising flame to a clear bead; opaque when cooled. In the reducing flame gives a bead of metallic lead. Completely soluble in caustic potash lye, and slightly in nitric acid. When heated in hydrochloric acid is converted into chloride of lead.

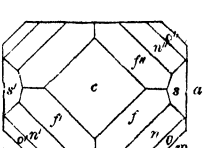
Occurrence.—A common product of the oxidation of galena in many lead mines. The original locality is Parys Mine, Anglesea, where it is found in crystals upon, and often partially encrusted by, brown iron ore. Very large and limpid crystals are found in Sardinia, especially at the Monte Poni mines; also at Phenix Mine, Pennsylvania; in the Siegen district, and at Leadhills. A compact variety formed by the alteration of masses of galena, and containing 120 oz. of silver to the ton, occurs in quantity at Chilote in

Peru, the silver being present as chloride. By exposure to water containing alkaline or calcic carbonates, it may be altered to carbonate. Pseudomorphs in which the change has taken place are not uncommon.

The crystalline forms of Anglesite are of especial interest as showing the amount of variation of character possible in substances of rhombic symmetry. The study of this species is therefore especially recommended to the student, the observed forms being figured and described in the fullest detail in Victor von Lang's memoir in the 'Transactions of the Vienna Academy' for 1859. A good selection is also given in Schrauf's 'General Atlas of Crystalline Forms.'

ANHYDRITE. Karstenite. — *Rhombic.* ∞P, 90° 04′, $a : b : c = 0{\cdot}9988 : 1 : 0{\cdot}9244$ (near a cube). (Fig. 167) $a\{010\}\ \infty \breve{P}\infty$, $s\{110\}\ \infty P$, $c\{100\}\ \infty \bar{P}\infty$, $b\{001\}\ 0P$, $o\{111\}\ P$, $m\{011\}\ \breve{P}\infty$, $n\{211\}\ 2\breve{P}2$, $f\{311\}\ 3\breve{P}3$. Crystals uncommon, usually massive, and distinguished by three rectangular cleavages, of which 010 and 100 are the most perfect. Also in fibrous, lamellar, and granular aggregates, the former being often curved. H. 3–3·5. Sp. gr. 2·89–3. Lustre, vitreous on basal cleavage, pearly on the others. Colour, usually white or blue, sometimes red; streak, white. Transparent to translucent. Fracture, uneven or splintery. Double refraction positive. Indices for yellow $\alpha = 1{\cdot}571$, $\beta = 1{\cdot}576$, $\gamma = 1{\cdot}615$. Optic axial plane, 100; first median line c, $2E = 43° 32'$.

FIG. 167.



Composition.—$CaSO_4$; or lime (CaO) 41·18, sulphuric acid 58·82 per cent. Difficultly fusible to a white enamel. When heated with soda on charcoal is not absorbed in the same manner as barytes or celestine. Difficultly soluble in water and acids, but decomposed when heated with alkaline carbonates.

Occurrence.—Essentially an associate of rock salt, being found interspersed through the salt beds, or forming the floor upon which they are deposited, in the principal salt works of the Austrian and Bavarian Alps and those of North Germany. Generally in association with gypsum. Some of the compact and siliceous varieties are used as building stones. That of Vulpino and Bergamo (*Vulpinite*) is cut and polished as a marble or alabaster. When exposed for a long period to the air it becomes partially hydrated, or changes into gypsum ; and conversely, gypsum crystals when exposed in very dry air are liable to become opaque from loss of water, or partial change to anhydrite. It may be used for making plaster, but must be calcined before grinding, as, although anhydrous, it will not set by absorbing water when in the natural condition, except with extreme slowness. In rock-salt mines its presence is unwelcome ; being tough and hard, it blunts the boring tools, and increases the cost and labour of driving.

GYPSUM. Gypse, Gesso, Alabaster, Selenite, Fraueneis, Marienglas.—*Oblique.* ∞P 111° 30′, $a : b : c = 0{\cdot}6891 : 1 :$

FIG. 168.

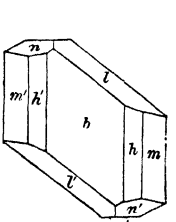


FIG. 169.

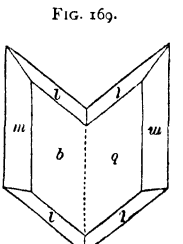
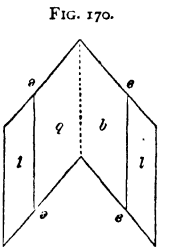


FIG. 170.



0·4156, $\beta = 81°\ 05'$. (Fig. 168) $m\{110\}\infty P$, $h\{120\}\infty \breve{P}2$, $b\{010\}\infty \breve{P}\infty$, $l\{111\} -P$, $n\{\bar{1}11\} P$, $e\{\bar{1}03\}\frac{1}{3}\breve{P}\infty$. Crystals mostly stout columnar, or tabular to 010. Faces of 103 often curved. Twins of two kinds common. In the first c is the twin axis, and 100 the plane of composition (fig. 169): also occurring as complete penetration twins. In the second

the twin axis is normal to 101 (fig. 170), producing, when the faces of 111 or 102 are curved, the so-called lance-head crystals. More complicated groups are stellate or spheroidal, with parallel or curved planes. Aggregates also common; and massive, granular, or earthy. Crystals sometimes bent. Cleavage, 010 highly perfect, 111 or $\bar{1}11$ less so, 100 imperfect. Flexible in thin laminæ. H. 1·5–2. Sp. gr. 2–2·4. Colourless and transparent, snowy white, grey, reddish, or brown. The darker-coloured varieties usually contain clay or sand, or other mechanical impurities, which may often be present in considerable quantity without affecting the crystalline form. Lustre vitreous, nacreous on the best developed cleavage planes, and silky on those of the pyramid. Transparent or translucent. Double refraction negative. The optic axes lie in the plane of symmetry at the ordinary temperature, one making an angle of 83° and the other of 22° with the vertical axis, which inclinations are diminished by heat. At 80° Cent. both optic axes coincide with a line inclined $52\frac{1}{2}°$ to the vertical axis.

Composition.—$CaSO_4 + 2H_2O$, or lime 32·54, sulphuric acid 46·51, water 20·95 per cent.

Gives off water when heated, becoming opaque and exfoliating, and fuses to a white enamel, which has an alkaline reaction. On charcoal, in the reducing flame, gives sulphide of calcium. Soluble in about 400 times its weight of water, or considerably more so than barytes or celestine. Completely decomposed by boiling with solution of carbonate of potassium.

Occurrence.—Very abundant in certain sedimentary formations and as a deposit from water. The finest crystals are those of a cavern at Reinhardsbrunn, near Gotha, which are of great size, exceeding a foot in length, and often sharply curved for a portion of their length without fracture. In the Alpine salt mines, where the salt is removed as brine, fine groups of crystals are often found deposited on the sides of the exhausted workings: and in mineral veins crystals are formed in similar places. The latter are, however, products of the

action of vitriolescent sulphides upon calcite, while in the former case the deposit takes place from solution in water. Around London, and at Headington and other places in Oxfordshire, single and twin crystals, and groups of more complex kinds, are found inclosed in hard blue clays; and fibrous and granular masses, often forming beds of considerable size, are common in the New Red Marl over a great part of England, especially near Bristol, Retford, and Derby. The arrow-head forms of twin crystals are abundant at Montmartre, Paris. From its ready solubility it is a common constituent of natural waters, especially in those districts where gypseous formations abound, and is the principal source of so-called permanent hardness in such waters as are not softened by boiling. In steam boilers supplied with these waters deposits of fibrous and crystallised gypsum have been occasionally found exactly similar to those observed in nature.

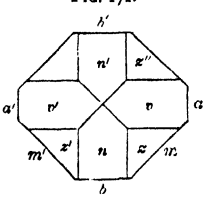
Uses.—The applications of gypsum are very numerous. The clear transparent crystals, also called *Selenite*, are used for optical purposes in thin plates for producing definite colours in polarised light. The fibrous silky variety called *Satin Spar* is carved into beads and other ornaments, giving chatoyant or 'cat's-eye' reflections. This is principally got in Nottinghamshire and Derbyshire. The compact finely granular kind, or *Alabaster*, is used for small ornamental sculptures, the principal supply being from Volterra, near Pisa, where it is found in irregular nodules in clays. The best kinds are very similar to fine statuary marble in colour and texture; other kinds, variegated with blue or black veins, are cut into vases. A white alabaster strongly veined with brown or red, found at Fauld in Staffordshire and Chellaston in Derbyshire, was a favourite material for effigies on tombs in the fifteenth and sixteenth centuries, and its use has been revived during the last twenty years to a considerable extent. The chief use is, however, in the production of plaster of Paris, which is made by driving off the water in the kiln from the rough gypsum or plaster stone,

and afterwards grinding it to a fine powder. As a manure, gypsum is also used.

VITRIOL GROUP.

GOSLARITE. Zinc Vitriol, White Vitriol.—*Rhombic; inclined hemihedral, isomorphous with Epsomite.* ∞P 90° 42′ $a : b : c = 0{\cdot}980 : 1 : 0{\cdot}563$. (Fig. 171) $m\{110\}\ \infty P$, $a\{010\}\ \infty \breve{P}\infty$, $b\{100\}\ \infty \breve{P}\infty$, $n\{101\}\ \breve{P}\infty$, $v\{011\}\ \breve{P}\infty$, $z\kappa\{111\}\ \frac{1}{2}(P)$, $z'\kappa\{1\bar{1}1\}\ -\frac{1}{2}(P)$. Crystals of an elongated columnar type. Generally found as an incrustation or in stalactites. Cleavage, 010 perfect. H. 2–2·5. Sp. gr. 2–2·1. Colourless or greyish white. Soluble, with an acrid, astringent taste. Lustre, vitreous. Optical characteristics similar to those of Epsomite, but the refractive index smaller; the mean for D line = 1·4801.

FIG. 171.



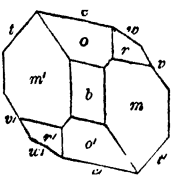
Composition.—$ZnSO_4 + 7H_2O$, or oxide of zinc 28·22, sulphuric acid 27·88, water 43·90 per cent. Some varieties contain only six molecules of water, or 40·15 per cent. Heated in closed tube gives off water; on charcoal with soda gives an incrustation of oxide of zinc, which takes a green colour with cobalt solution, and sulphide of sodium, which blackens a silver plate when moistened with water.

Occurrence.—As a product of the alteration of zinc blende in old mine workings at Goslar, Falun, Schemnitz, &c., in small quantity. The salt used in medicine is entirely of artificial production.

COPPERAS. Eisen Vitriol, Green Vitriol, Melanterite, Ferrous Sulphate. — *Oblique.* ∞P 82° 21′, $a : b : c = 1{\cdot}1838 : 1 : 1{\cdot}4975$, $\beta = 75°\ 45'$. (Fig. 172) $m\{110\}\infty P$, $b\{010\}\ \infty \breve{P}\infty$, $r\{111\}-P$, $o\{001\}\ \breve{P}\infty$, $c\{001\}\ o\,P$, $w\{103\}\ -\frac{1}{3}\breve{P}\infty$, $v\{101\}\ -\breve{P}\infty$, $t\{\bar{1}01\}\breve{P}\infty$. The combination 110, 001, often occurs alone, and resembles a rhombo-

hedron. Crystals short columnar, or thick tabular. Usually in stalactitic, fibrous, incrusting, and other aggregates, definite crystals being rare. Cleavage, basal perfect; prismatic imperfect. H. 2. Sp. gr. 1·8–1·9. Transparent to translucent when fresh. Lustre vitreous. Colour, very pale green in crystals; almost white in fibrous forms; but tarnishing and altering very rapidly to a yellowish brown or rust colour. Double refraction positive. Indices for D line, $\alpha = 1{\cdot}4713$, $\beta = 1{\cdot}4782$, $\gamma = 1{\cdot}4856$. Optic axial plane 010. First median line inclined 62°28′ to c in the acute angle a/c, $2V$ 85° 27′. Soluble. Taste, chalybeate (like ink).

FIG. 172.



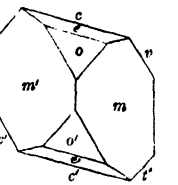
Composition.—$FeSO_4$, or ferrous oxide (FeO) 25·90, sulphuric acid 28·78, water 45·32 per cent. Heated in the closed tube melts in water of crystallisation, which at a higher temperature is driven off, leaving the white anhydrous salts; this, when very strongly heated, gives up its acid, and ferric oxide remains.

Occurrence.—Abundant as a secondary product from the oxidation of iron pyrites, being usually found in delicate fibrous efflorescences and accompanied by free sulphuric acid. It may be generally recognised by its very characteristic taste. In Bohemia it is prepared from shales in large quantities for use in the production of fuming sulphuric acid by the old process of distillation in earthen pots. Well formed crystals may be found in almost all samples of commercial copperas, but they are never pure, being always more or less rusted.

Pisanite is a variety containing both iron and copper, having the composition $(Fe, Cu)SO_4 + 7H_2O$, and isomorphous with the normal ferrous sulphate, found at Arghaneh Maden, in Turkey. This is a representative of the so-called mixed vitriols which are formed from the oxidation of pyritic copper ores.

COBALT VITRIOL, Bieberite.—*Oblique.* Forms almost identical with those of Melanterite. (Fig. 173), $m\{110\}\infty P$, $o\{011\}\breve{P}\infty$, $e\{012\}\frac{1}{2}\breve{P}\infty$, $v\{101\}-\breve{P}\infty$, $t\{\bar{1}01\}\breve{P}\infty$, $c\{001\}0P$.

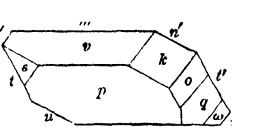
FIG. 173.



Composition.—$CoSO_4+7H_2O$. Has been found as a stalactitic or fibrous efflorescence at Bieber, near Hanau. It is of the pale red colour characteristic of cobalt sulphate, but contains about four per cent. of magnesia. Artificially prepared crystals are analogous in form to those of ferrous sulphate.

COPPER VITRIOL. Blue Vitriol, Cyanose, Sulphate of Copper, Chalcanthite.—*Triclinic.* $a:b:c=0{\cdot}566:1:0{\cdot}550$, $\alpha=97°39'$, $\beta=106°49'$, $\gamma=77°37'$. Crystals very unsymmetrical in character (fig. 174). Usually in stalactitic, reniform, or encrusting masses. H. 2·5. Sp. gr. 2·22. Lustre, vitreous. Colour, Berlin or azure-blue, sometimes decidedly greenish; streak, white. Translucent. Soluble. Taste, metallic and nauseous in a high degree.

FIG. 174.



Composition.—$CuSO_4+5H_2O$, or oxide of copper 31·85, sulphuric acid 32·07, water 36·08 per cent. The native mineral usually contains some ferrous sulphate.

Heated in the closed tube gives off water, leaving a white powder, which is the anhydrous sulphate. This when moistened reabsorbs the water of crystallisation and recovers the blue colour, the change being accompanied by the evolution of heat and a hissing sound. On charcoal with soda in the reducing flame yields metallic copper. The solution in water, when heated with ammonia, first gives a green flocculent precipitate, which dissolves in excess of the reagent,

forming a deep purple blue solution. A piece of polished iron placed in the solution is soon covered with a film of metallic copper.

Occurrence.—Found occasionally in crystals in old mine workings, but usually in stalactitic forms, or even more commonly in solution in the drainage water of copper mines or heaps of decomposing or burnt cupreous pyrites. These waters are of a pale bluish-green colour, and when sufficiently rich to be worth treatment are collected in tanks containing scrap iron, which separates the copper as precipitate or cement metal, an equivalent quantity of ferrous sulphate being formed. This process is carried on at several mines in Cornwall, at Parys Mine, Anglesea, and on a very large scale at Rio Tinto, in Spain.

Sulphates of manganese, $MnSO_4 + 5H_2O$ and $MnSO_4 + 7H_2O$, are isomorphous with sulphate of copper and ferrous sulphate respectively. They do not occur in nature. The mineral described as *Fauserite* or *Manganese Vitriol*, from Herrengrund, in Hungary, crystallising in the rhombic system, contains magnesia, and is isomorphous with Epsom salt and sulphate of zinc.

NORMAL HEXAD SULPHATES.

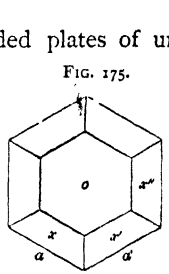
ALUNOGEN. Hair Salt. Keramohalite.—In fibrous and acicular crystals of undetermined symmetry, but probably oblique; and in fibrous or scaly aggregates. H. 1·5–2·5. Sp. gr. 1·7. Colour, white, yellowish, or greenish. Lustre, silky. Very soluble in water.

Composition.—$Al_2S_3O_{12} + 18H_2O$, or alumina 15·4, sulphuric acid 36, water 48·6 per cent., but usually containing iron, manganese, and other sulphates in small proportions. Heated in closed tube, swells, gives off water, and leaves an infusible mass, which strikes a blue colour with cobalt solution, if tolerably free from iron. When

strongly heated is partly decomposed, giving off acid vapours. Occurs in burnt or vitriolescent shales, 'alum schists,' especially those of the lignite formations of the Rhine, Bohemia, and the coal measures of Saxony and Scotland, and in certain volcanic districts, as the island of Milo, and Pasto in New Granada.

COQUIMBITE.—*Hexagonal.* In six-sided plates of undetermined dimensions (fig. 175), also in granular aggregates. Cleavage, basal perfect. H. 1·5. Sp. gr. 2·14. Translucent. Lustre, nacreous. Colour, yellow. Soluble in water.

FIG. 175.



Composition.—$Fe_2S_3O_{12} + 9H_2O$, or ferric oxide 28·47, sulphuric acid 42·70, water 28·83 per cent., usually with some magnesia, lime, and silica. When heated gives off water, and at a higher temperature sulphurous acid, leaving a residue of ferric oxide. Occurs near Coquimbo, in Chili, and at the Rammelsberg Mine in the Harz, where it is known as *Misy*, under which name other basic ferric sulphates are included.

ALUM GROUP.

The alums are cubic when definitely crystallised, being usually found in octahedra piled in the direction of one of the axes. They show certain anomalous phenomena of double refraction when examined by polarised light, which leads to the inference that the crystals are built up of parallel laminæ, those in the interior being subjected to strain from the outer ones. Mallard, however, considers that these phenomena are evidence of complex structure, and that the crystals may be merely compounds of simple crystals of a lower degree of symmetry. In nature they are not generally crystallised in definite forms, being found in silky or hair-like fibres and aggregates. As a rule they occur

under the same conditions as the sulphates of alumina, namely in decomposing pyritic shales, and in volcanic craters, being formed by direct action of sulphuric acid upon aluminous rocks. They are all distinguished by their peculiar taste—sweetish and styptic; and when heated, give off water, swell up, and leave a cauliflower-like mass of 'burnt alum,' which, in those not containing iron or manganese, is white, and gives the alumina blue with cobalt solution.

Composition.—Represented by the variation being principally in the protoxide base, $R_2SO_4 + Al_2S_3O_{12} + 24H_2O$.

		RO	Alumina	Sulphuric acid	Water
Potash alum . .	Potash	9·95	10·82	33·75	45·48
Soda alum . .	Soda	7·0	11·0	—	47·0
Ammonia alum .	Ammonia	5·74	11·30	35·50	48·39
Magnesia alum .	MgOMnO	6·0	10·40	38·85	46·0
Manganese alum .	MnO	7·68	11·08	34·57	46·67
Iron alum . .	FeO	7·75	11·07	34·56	46·62

Potash and ammonia alums are found at Ætna, Vesuvius, and the Solfatara; on burnt shales above underground fires at Saarbrücken, and at a few similar localities. Soda and magnesia alums are from the salt deserts of Peru, and manganese alum is found at Bosjesman River and Delagoa Bay in South Africa, and in Tasmania and New South Wales. Hair salt or feather alum is from Iceland, the Solfatara, and Urumia in Persia, and from the North of England and Scottish alum shale districts.

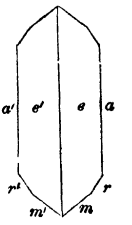
Very little alum is now made from this class of minerals, the bulk of the commercial supply being obtained by acting directly upon clay by sulphuric acid, adding crude sulphate of ammonia from gas liquor, and crystallising.

BASIC DYAD SULPHATES.

BROCHANTITE. Krisuvigite, Waringtonite, Königite.—*Rhombic.* ∞P 104° 10′, $a : b : c = 0{\cdot}7789 : 1 : 0\,2506$.

(Fig. 176) $m\{110\}\infty P$, $r\{120\}\infty \breve{P}2$, $a\{010\}\infty \breve{P}\infty$, $e\{011\}\breve{P}\infty$. The measurements vary in different varieties. In short columnar crystals, with vertically striated faces, and in fibrous reniform aggregates. There are several varieties, which, according to Schrauf, vary in their crystalline symmetry, some being rhombic and others oblique; but the angle of the clino-diagonal on the vertical axis differs only by a few minutes from a right angle. Cleavage, brachydiagonal perfect. Usually in acicular crystals or incrustations. H. 3·5–4. Sp. gr. 3·78–3·87. Colour, emerald- to blackish green; streak, paler green. Lustre, vitreous. Transparent to translucent.

FIG. 176.



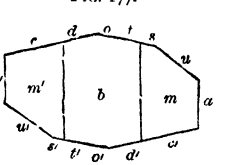
Composition.—$Cu_4SO_7 + 3H_2O = \left\{\begin{matrix} CuSO_4 \\ 3H_2CuO_2 \end{matrix}\right\}$, or cupric oxide 70·34, sulphuric acid 17·71, water 11·95 per cent. Gives off water when heated, but not below 300° Cent., and leaves a residue of cupric oxide and sulphate. In other respects it behaves like normal sulphate of copper, except that it is not soluble in water.

Occurs as a product of oxidation of copper ores in Cornwall, the Ural, Krisuvig in Iceland, Nassau, and Chili.

Langite is similar in composition to Brochantite, with the addition of two molecules of water; and *Waringtonite* is another variety, with one molecule of water. These occur as incrustations upon clay slate in Cornwall.

LINARITE. Bleilasur.—*Oblique.* $\infty P 61° 41'$, $a : b : c = 1·7186 : 1 : 0·8272$, β 77° 22'. (Fig. 177) $m\{110\}\infty P$, $a\{010\}\infty \breve{P}\infty$, $b\{100\}\infty \breve{P}\infty$, $c\{001\}oP$, $u\{201\} - 2\breve{P}\infty$, $t\{506\} - \frac{5}{6}\breve{P}\infty$, $o\{203\} - \frac{2}{3}\breve{P}\infty$, $d\{108\}\frac{1}{8}\breve{P}\infty$. Crystals broad columnar, elongated on *b*. Twins common on 100. Cleavage, 100 very perfect, 001 less so. H. 2·5. Sp. gr.

FIG. 177.

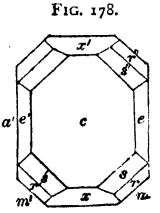


5·3–5·45. Colour, deep or azure-blue; streak, paler blue. Translucent. Lustre, adamantine to vitreous. Fracture, conchoidal. Brittle.

Composition. — $PbCuSO_5 + H_2O = \left\{\begin{matrix} PbSO_4 \\ H_2CuO_2 \end{matrix}\right\}$ or $\left\{\begin{matrix} PbSO_4 \\ H_2PbO_2 \end{matrix}\right\} + \left\{\begin{matrix} CuSO_4 \\ H_2CuO_2 \end{matrix}\right\}$, or oxide of lead 55·69, oxide of copper 19·83, sulphuric acid 19·98, water 4·50 per cent. Some varieties show an additional molecule of water, bringing it up to 6·6 per cent. Heated in the closed tube, gives off water and loses colour. On charcoal, fuses to a globule, which gives an incrustation of oxide of lead, and by treatment with boracic acid a bead of malleable copper. Decomposed by nitric acid, giving a blue solution of nitrate of copper and an insoluble white residue of sulphate of lead. Found in the lead mines of Roughton Gill, Cumberland, and Leadhills, Scotland; in Hungary and Siberia; but rare at all of them. It is similar in appearance to azurite, but rather deeper in colour and more brilliant.

CALEDONITE is another mineral of the same class from Leadhills, where it occurs in small groups of acicular crystals, which are *rhombic*. ∞P 105°, $a : b : c =$ 0·9163 : 1 : 1·4032. (Fig. 178) $m\{110\}$ ∞P, $r\{111\}P$, $s\{223\}\frac{2}{3}P$, $x\{201\}2\breve{P}\infty$, $e\{011\}$ $\breve{P}\infty$, $a\{010\}\infty P\infty$, $c\{001\}oP$. H. 3. Sp. gr. 6·4. Colour, green, generally resembling malachite; streak, greenish white. Transparent. Lustre, greasy.

FIG. 178.



Composition.—This was formerly supposed to be a compound of sulphate of lead, with carbonates of lead and copper; but, according to Flight, the carbonates are only present as intermixed white lead ore, the true composition being $\left\{\begin{matrix} 5PbSO_4 \\ 2H_2PbO_2 \\ 3H_2CuO_2 \end{matrix}\right\}$, or a particular variety of the

Linarite formula corresponding to SO_3 19·14, PbO 65·17, CuO 11·39, water 4·30. The amount of sulphuric acid being insufficient to form sulphate with the whole of the oxide of lead, the nitric acid solution will contain both copper and lead as nitrates. In all other respects the chemical characteristics will be similar to those of Linarite.

LANARKITE.—*Oblique.* In columnar crystals elongated in the direction of the orthodiagonal, with perfect basal cleavage. Flexible in thin laminæ. H. 2. Sp. gr. 6·3–6·8. Colour, yellowish or greenish white. Lustre, adamantine on cleavage faces, greasy on others.

Composition.—This was formerly regarded as containing equal molecules of sulphate and carbonate of lead, but late researches by Flight and Pisani have explained away the carbonate and make it to consist of $\left\{\begin{matrix}PbSO_4\\PbO\end{matrix}\right\}$, or $PbSO_4$ 57·6, PbO 42·4. One of the rare minerals from Leadhills.

LEADHILLITE.—*Rhombic.* ∞P 120° 20′, $a : b : c =$ 0·5735 : 1 : 1·7193. (Fig. 179) $m\{110\}\infty P$, $x\{111\}P$, $v\{112\}\frac{1}{2}P$, $s\{114\}\breve{P}_4$, $e\{021\}2\breve{P}\infty$, $f\{011\}\breve{P}\infty$, $a\{010\}$ $\infty\breve{P}\infty$, $c\{001\}o.P$. Twins on 130, producing by repetition

FIG. 179.

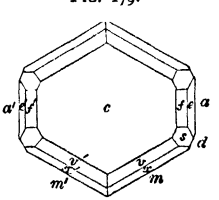
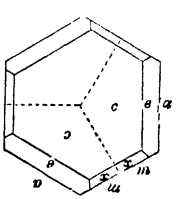


FIG. 180.



quasi-rhombohedral forms (fig. 180). Cleavage, basal perfect. H. 2·5. Sp. gr. 6–6·5. Colour, yellowish white, grey, green, or brown ; streak, white. Lustre, adamantine on oP, other faces greasy.

Composition.—Formerly held to be $\left\{\begin{matrix}3PbCO_3\\PbSO_4\end{matrix}\right\}$, but later analyses show that some water has been overlooked, having been previously estimated with the carbonic acid. The simplest expression for the corrected determination is $\left\{\begin{matrix}4PbCO_3\\2PbSO_4\\H_2PbO_2\end{matrix}\right\}+H_2O$, corresponding to $PbCO_3$ 55·25, $PbSO_4$ 31·35, PbO 11·53, H_2O 1·87. Like Anglesite, it is reduced to metallic lead on charcoal, but is infusible. Also effervesces and probably dissolves in nitric acid. *Susanite* is of similar composition, but rhombohedral. Both are found at Leadhills, Lanarkshire; Red Gill, Cumberland; Nertschinsk, Siberia; and Iglesias, Sardinia.

ALUMSTONE. Alunite. Alaunstein. — *Rhombohedral.* R 89° 10′, $a:c=1:1{\cdot}043$. Crystals small rhombohedra, often with curved faces, grouped in druses: usually compact, fine-grained, or earthy, intimately mixed with quartz, hornstone, and other products of alteration of siliceous rocks. Cleavage, basal tolerably perfect. H. 3·5–4. Sp. gr. 2·6–2·8. Colourless, or white, with greenish red or grey tints. Lustre, vitreous, pearly on oR. Translucent.

Composition. — $K_2\overline{Al}_3S_4O_{22}+6H_2O=\left\{\begin{matrix}K_2SO_4\\\overline{Al}S_3O_{12}\\2H_3\overline{Al}O_6\end{matrix}\right\}$, or potash 11·3, alumina 37·1, sulphuric acid 38·5, water 13·1. The above composition is calculated as free from silica, which is present to the extent of 20–30 per cent. in the mineral as found. Gives off water, but only at temperatures approaching redness; some sulphuric acid is lost at the same time. Imperfectly soluble in sulphuric and hydrochloric acids. After heating to low redness, water dissolves out alum, the residue consisting chiefly of hydrated alumina not soluble in acids, and giving the blue colour with cobalt solution.

Occurrence.—At Tolfa in the Roman States, the island of Milo, and a few localities in Hungary; being essentially a product of the decomposition of trachytic rocks by the action of steam and sulphuric acid. At Tolfa it is used in the manufacture of Roman alum, which has a high reputation for purity, being free from iron.

Jarosite, from the Sierra di Almagrera in Spain, is of similar constitution, supposing FeS_3O_{12} to be substituted for the corresponding aluminium salt in the above formula.

WEBSTERITE. Aluminite.—*Amorphous*, in reniform and irregular masses, of an earthy texture. H. 1–2. Sp. gr. 1–7. Snow-white, or tinged with yellow or brown. Opaque, with earthy fracture. Adheres to the tongue.

Composition.—$AlSO_6 + 9H_2O = \left\{ \begin{matrix} AlS_3O_{12} \\ 2H_6AlO_6 \end{matrix} \right\} + 21H_2O$,

or sulphuric acid 23·32, alumina 29·77, water 47·01 per cent. Infusible, and gives the blue colour with cobalt solution. In the closed tube evolves a large quantity of water, which at a high temperature becomes acid from the decomposition of sulphuric acid. Easily soluble in hydrochloric acid.

Occurrence.—In irregular masses, sometimes of considerable size, in the chalk at Newhaven, Sussex; near Halle, in Prussian Saxony; and Auteuil, France. Numerous other compounds of a similar character have been described under the names of *Werthemanite*, *Löwigite*, and *Felsobanyite*, varying chiefly in the amount of hydrate of alumina and water which they contain.

KAINITE.—*Oblique.* $C = 80° 05'$. In small tabular crystals in druses in the massive mineral, which is usually granular and of yellowish or grey colour. H. 2. Sp. gr. 2·13. Cleavage, 100 perfect, 110 less perfect, 010 imperfect. Plane of optic axes, 010, median line in the acute angle of the axes makes an angle of 8° to the vertical axis.

Composition.—$MgSO_4 + KCl + 3H_2O$, or magnesia 16·1, potash 15·7, chlorine 14·3, sulphuric acid 32·2, water 21·7. Part of the alkali is usually soda, which may be due to an admixture of common salt.

Not deliquescent in the atmosphere, but soluble in water, the solution depositing crystals of a salt similar to Picromerite, or $\left\{\begin{matrix}K_2SO_4\\MgSO_4\end{matrix}\right\} + 3H_2O$, while chlorides of magnesium and potassium remain in solution.

Occurrence.—In thick beds above rock salt at Leopoldshall in Anhalt, and at Kalusz in Galicia; at the latter locality the bed is in places from 60 to 70 feet thick. It is used with sylvine and other associated minerals for the production of potash salts, and also in the raw state as a potassic manure in the reclamation of peat lands.

COPIAPITE.—*Hexagonal?* In six-sided tabular crystals and granular aggregates. Cleavage, basal perfect. H. 1·5. Sp. gr. 2·14. Lustre, pearly. Colour, sulphur- to lemon-yellow. Translucent.

Composition. — $Fe_2S_5O_{21} + 13H_2O = \left\{\begin{matrix}5FeS_3O_{12}\\H_6FeO_6\end{matrix}\right\} + 36H_2O$, or sulphuric acid 41·93, ferric oxide 33·54, water 24·53 per cent. Heated in the closed tube yields water, and at a red heat sulphuric acid. On charcoal is rendered magnetic, and with soda gives the reaction of sulphur. Insoluble in water, readily soluble in acids.

Occurrence.—With Coquimbite at Copiapo, and as a product of the rusting of pyrites in the Harz and elsewhere. The yellow salt called Misy at the Rammelsberg mine is very similar in composition, but not so basic, containing three atoms of sulphate to one of ferric hydrate.

STYPTICITE or *Fibroferrite* is another variety found in radiated yellowish green silky crystals, forming spheroids resembling Wavellite in appearance.

Composition.—$FeS_2O_9 + 10H_2O = \left\{ \begin{matrix} 2FeS_3O_{12} \\ H_6FeO_6 \end{matrix} \right\} + 27H_2O$

or sulphuric acid 32, ferric oxide 32, water 36 per cent. Decomposed by water with the separation of a ferric sulphate of a more basic character, $Fe_2SO_9 + 3H_2O$. Seven-tenths of the contained water is given off at 100° Cent.

Raimondite, another yellow basic ferric sulphate, has the composition $Fe_2S_3O_{15} + 7H_2O$. It is found with tin ore in Bolivia. *Carphosiderite* from Greenland is of similar constitution.

There are several other varieties of the basic ferric sulphates, but those mentioned above are the most important. Probably none are very definite or constant in composition.

CHAPTER XII.

PHOSPHATES—ARSENIATES—VANADIATES.

THESE minerals are for the most part closely related, in small but well-defined isomorphous groups. The constitution of phosphoric, arsenic, and vanadic acids is represented by $H\overset{V}{R}O_3$, their anhydrides by R_2O_5, and the corresponding normal salts by $\overset{I}{R}\ \overset{V}{R}O_3$ and $\overset{II}{R}\ \overset{V}{R}_2O_6$, which latter by the addition of one or two molecules of basic oxide give rise to the dibasic or tribasic series of salts respectively. Of these, only the last or tribasic series is of importance mineralogically, the greater part of the natural phosphates being of this or even more basic kinds. The most important and characteristic species, Apatite, is the type of a group in which three molecules of tribasic salt are combined with one molecule of a fluoride or chloride of the same metal. This type is represented in the corresponding arsenic and vanadic acid salts, all of which are hexagonal, with pyramidal hemihedrism, and afford a somewhat remarkable contrast to the remaining phosphates (principally basic copper salts), which have as a rule very strong individuality, differing considerably from each other in form and physical character for very slight differences of chemical composition.

The metals found in natural phosphates are chiefly calcium, magnesium, lead, copper, aluminium, and iron ; and less abundantly uranium and the metals of the cerium group, the alkaline metals being exceedingly rare. In arseniates they are nickel, cobalt, copper, lead, magnesium, and calcium. The vanadiates are principally those of lead and copper.

The greater portion of the phosphates in the world may be regarded as on permanent loan from the mineral to the animal and vegetable kingdoms, a portion being returned from time to time by the destruction of organic bodies, and the formation of hydrated and amorphous phosphates more or less indefinite in composition, as in soils and sedimentary deposits, the original stock being represented by the calcium chloro- and fluo-phosphates contained in the older crystalline rocks. The existence of phosphorus in granites, lavas, and other crystalline rocks was demonstrated chemically by Fownes and others about forty years since, but it is only since the introduction of systematic microscopic research that the tolerably constant presence of crystallised apatite in these rocks has been demonstrated. The existence of phosphates in iron ores of sedimentary origin is also a well-known and unwelcome fact; they are probably present as amorphous calcium or aluminium phosphates.

The natural arseniates are chiefly found in cobalt and nickel ore veins, and are obviously products of the oxidation of the arsenides of those metals and of the action of soluble arseniates upon calcite or dolomite. Those of copper and iron are similarly found in lodes carrying arsenical pyrites in close admixture with pyritic copper ores. Vanadium minerals are not common, although the metal appears to be present in small quantity in sedimentary brown iron ores in the secondary formations at various points in England, France, and Germany, and may be recognised in the analyses of the pig iron smelted from such ores. It probably exists in much the same way as phosphorus does in similar ores. Latterly vanadium has been obtained by Roscoe in quantity by the systematic treatment of products from the stratified copper ore deposits of Cheshire.

APATITE.—*Hexagonal, pyramidally hemihedral.* $Z=80°\ 26'$, $a : c = 1 : 0{\cdot}7346$. (Figs. 181–183) $a\{10\bar{1}0\}\infty P$, $b\{11\bar{2}0\}\infty P2$, $o\{000\bar{1}\}oP$, $i\{10\bar{1}2\}\frac{1}{2}P$, $x\{10\bar{1}1\}P$, $z\{20\bar{2}1\}2P$,

$r\{11\bar{2}1\}\,2P_2$, $u\,\pi\{12\bar{3}1\}\,\frac{1}{2}(3P\frac{3}{2})$, $h\,\pi\{12\bar{3}0\}\,\frac{1}{2}(\infty P\frac{3}{2})$. Crystals when of large size are usually columnar, and moderately broad, like those of beryl; but when microscopic are often acicular. Also occurs in massive forms without recognisable structure, and in botryoidal and reniform aggregates, with a radiated fibrous composition. No well-defined cleavage. Fracture, conchoidal. H. 4·5–5. Sp. gr. 3·05–3·25. Double

FIG. 181.

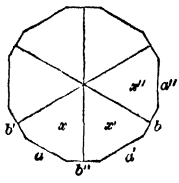


FIG. 182.

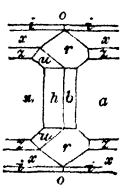
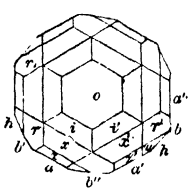


FIG. 183.



refraction negative. Indices for D line, $\omega = 1{\cdot}6461$, $\epsilon = 1{\cdot}6417$. The ring system, seen in convergent polarised light, is usually broken and irregular, often due to imperfections of structure. Colour, variable; bluish green and greenish yellow most common; sometimes colourless and transparent; also pink, violet, blue, or grey. Transparent, translucent, or opaque. Lustre, vitreous on crystal faces, resinous on fractures. Sometimes strongly dichroic. Often phosphorescent, emitting a yellow light when heated.

Composition.—$3Ca_3P_2O_8 + CaCl_2$ and $3Ca_3P_2O_8 + CaFl_2$. The first is known as chlor-apatite and the second as fluor-apatite. Corresponding to—

A. Chlor-apatite:

CaO 48·43 P_2O_5 40·92 Ca 3·84 Cl 6·81 = 100

B. Fluor-apatite:

CaO 50·00 P_2O_5 42·26 Ca 3·97 Cl 3·77 = 100

Neither of the above types is found in a state of absolute

purity, all crystallised apatite containing both fluorine and chlorine. A direct determination of the former is, however, very difficult. The maximum amount of chlorine observed is in the apatite of Snarum, Norway, which contains 4·10 per cent., and corresponds to a mixture of $\frac{2}{3}$ A to $\frac{1}{3}$ B. On the other hand, some of the transparent crystals from the Tyrol are almost entirely free from chlorine, and therefore practically pure fluor-apatite. Most varieties contain ferric oxide, alumina, alkalies, organic matter, and silica in variable quantity, the whole not exceeding 2 to 3 per cent. The Snarum mineral also contains at times cerium and yttria, but apparently from an intermixed phosphate of these metals (*cryptolite*). Water and carbonic acid, when found, are evidences of alteration.

Fusible with difficulty, and only in thin splinters, to a colourless glass. Borax dissolves it slowly, and salt of phosphorus more readily. The bead of the latter, when nearly saturated, becomes dull, and shows crystalline facets on cooling. With complete saturation an opaque white enamel is produced. Fused with salt of phosphorus in the open tube, or heated with sulphuric acid, gives in most cases the reaction of fluorine. Moistened with sulphuric acid, and heated, colours the flame bluish green. Soluble in hydrochloric and nitric acids. Sulphuric acid decomposes it, combining with two atoms of calcium to form gypsum and normal phosphate CaP_2O_6, which is readily decomposable by vegetation, and forms the so-called superphosphate of the chemical manure manufacturer.

Occurrence.—Found principally in veins, or interspersed in irregular crystals, often of very considerable size, in crystalline limestones. The most perfect crystals are from the Saxon and Bohemian tin mines, at Schlakenwald, and Ehrenfriedersdorf; Miask in the Ural; Snarum and Arendal, Norway; Cabo di Gata, Spain; Bovey and Tavistock, Devon; various localities in Cornwall. In America very large examples are found in New York, and Ottawa, Canada. The greenish yellow variety,

known as *asparagus* stone, occurs in highly modified or rounded crystals, isolated in calcite. *Phosphorite* includes all the massive varieties, the most typical kind being that found at Logrossan in Estremadura, in opaque snow-white masses, having a fibrous radiated structure, and intimately mixed with quartz, in veins in granites.

Osteolite is a compact earthy phosphorite. *Staffelite* is a concretionary crystalline kind, containing about 9 per cent. of carbonate of calcium, found in masses resembling calamine or prehnite, scattered through the alluvium of the Lahn Valley in Nassau.

In the greensand formations both of Europe and America impure varieties of phosphorite, known as *coprolites* or phosphatic nodules, are often found extending over considerable areas. These are either the remains of reptilian or other bones, and animal excreta, or pseudomorphs by substitution of ammonites, brachiopods, and other calcareous shells. These deposits are of very considerable importance economically, and are eagerly sought for and worked as a source of artificial manures. The phosphorite rock of Sombrero, in the West Indies, is similarly a coral limestone transformed apparently by the action of phosphate or guano to a compact phosphorite.

Guano is the partially mineralised excreta of sea birds, seals, and other marine animals, and consists essentially of a phosphate analogous to osteolite mixed with hydrated calcium phosphates and Struvite, an ammonia-magnesian phosphate. In some instances a considerable quantity of ammonia is also contained. Found along the seashore and on islands and rocks in rainless regions, such as the coasts of Peru and Bolivia, Saldanha Bay, S. Africa, &c. It forms a white discolouration on the rocks when seen from a distance, but when in mass is often of a brownish colour from intermixed ferric hydrate, &c. It is of a granular or oolitic texture, and occasionally contains the remains of mummified birds and other animals.

PYROMORPHITE. Green Lead Ore, Brown Lead Ore, Phosphate of Lead, Linnets.—*Hexagonal.* $Z=80°\ 44'$, $a : c = 1 : 0{\cdot}7362$. (Figs. 184, 185) $a\{10\bar{1}0\}\infty P$, $b\{11\bar{2}0\}\infty P2$, $x\{10\bar{1}1\}P$, $o\{0001\}oP$. Crystals, short hexagonal prisms, with flat ends; usually somewhat tub-shaped. The prism faces generally striated vertically. Pyramidal hemihedrism has not been observed, owing to the absence of dihexagonal pyramids in the combinations, but is inferred from the figures developed by the action of etching liquids on the

FIG. 184.

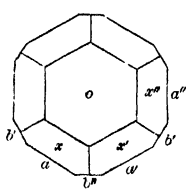
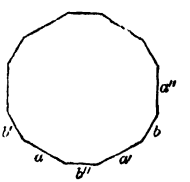


FIG. 185.



faces. Crystals usually grouped irregularly in druses ; also in botryoidal, reniform, and massive aggregates. Cleavage, pyramidal and prismatic, but scarcely apparent. Fracture, conchoidal to uneven. H. 3·5. Sp. gr. 5·53–7·2; the low density characteristic of varieties containing arsenic acid. Colour: sometimes colourless, white, or grey; usually green (bright grass-green to yellowish green); hair- or clove-brown, straw- or honey-yellow, the latter least common. Lustre, resinous, vitreous to subadamantine when transparent, imperfectly translucent as a rule. Double refraction negative. Indices for red, $\omega=1{\cdot}474$, $\epsilon=1{\cdot}465$.

Composition.—Analogous to that of apatite. The purest is $\left\{\begin{matrix}3Pb_3P_2O_8\\ Pb\quad Cl_2\end{matrix}\right\}$, corresponding to PbO 74·1, P_2O_5 15·7, Pb 7·6, Cl 2·6 per cent. If the whole of the lead is reported as oxide PbO=82·27 with 0·59 percentage excess. Another variety containing As_2O_5, partially replacing P_2O_5,

and a third containing fluorine and calcium, are isomorphous mixtures of pyromorphite and fluor-apatite.

Heated in the closed tube, gives a white sublimate ($PbCl_2$). On charcoal fuses easily, but is not reduced; the bead shows crystalline facets when cooled, and glows at the moment of solidification. When fluxed with soda or borax and metallic iron is reduced to metallic lead; in the latter case a brittle regulus of iron phosphide is produced. A bead of salt of phosphorus saturated with CuO gives the blue flame of chlorine. Arsenical varieties give the garlic odour on charcoal in the reducing flame.

Soluble in nitric acid, and also in caustic potash when free from lime.

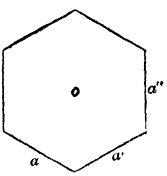
Occurrence.—In lead-bearing veins with galena, and most abundantly in granitic, gneissic, and schistose rocks. Among the principal localities are East Cornwall; Leadhills, Cumberland; Přzibram, and Mies, Bohemia; Freiberg and Zschopau, Saxony; Braubach and Ems, Rhenish Prussia; Beresof, Siberia; Wheatley Mine, Pennsylvania. It is sometimes found in pseudomorphs after white lead ore and galena. The so-called *blue lead ore* is galena pseudomorphous after pyromorphite.

Uses.—When in quantity it is a valuable lead ore, but very brittle, and of comparatively low density; it cannot, when mixed with quartz or other vein stuff, be concentrated to a high yield without considerable loss. It is therefore generally smelted without mechanical concentration. Mixed ores of phosphate and carbonate of lead with earthy matter are known in Derbyshire as Linnets. The phosphates of some of the Spanish lead mines are highly argentiferous.

MIMETISITE. Kampylite, Hedyphane.—*Hexagonal*, like pyromorphite.—$Z=81° 48'$, $a : c = 1 : 0{\cdot}7276$. (Fig. 186) $a\{10\bar{1}0\}\infty P$, $o\{0001\}oP$. Crystals, short columnar, with flat ends, and commonly tub-shaped. Cleavage, pyramidal very imperfect. H. 3·5. Sp. gr. 5·5, 7–7·25. The lighter varieties contain calcium, the denser do not. Lustre, re-

sinous. Colour, white or pale yellow, sulphur-, orange-yellow, grey, or brown. Transparent to translucent. Double refraction negative. Indices for red, $\omega = 1{\cdot}474$, $\epsilon = 1{\cdot}465$, Mimetisite; $\omega = 1{\cdot}467$, $\epsilon = 1{\cdot}463$, Hedyphane.

FIG. 186.



Composition.—$3Pb_3As_2O_8 + PbCl_2$, or PbO 67·45, As_2O_5 23·21, Pb 6·96, Cl 2·38 per cent., which is closely approached by some varieties. As a rule, however, phosphoric acid is tolerably commonly present either with or without calcium; the former up to 3·3 per cent., and the latter up to 14 per cent. These are essentially mixtures of the isomorphous substances mimetisite and pyromorphite, and of the former or both with chlorapatite. The variety with a maximum of phosphoric acid is called kampylite, and that with phosphate of calcium hedyphane.

Chemical characteristics similar to those of pyromorphite, except that it gives an arsenical odour in the reducing flame on charcoal, and is not quite so easily fusible. Soluble in nitric acid.

Occurrence.—In the lead mines of Cornwall; Caldbeck Fell, Cumberland; Johan Georgenstadt; Nertschinsk; Phenixville, Pennsylvania; and Zacatecas, Mexico. Like pyromorphite, but less common. The calcareous variety, hedyphane, from Långbanshytta, in Sweden. The hemihedrism is only apparent on etched surfaces, like pyromorphite.

VANADINITE.—*Hexagonal.* $P = 78° 52'$, $a : c = 1 : 0{\cdot}7122$. In hexagonal prisms, some with planes of pyramids. Usually in reniform masses of a fibrous structure, or incrusting. No definite cleavage. H. 3. Sp. gr. 6·8–7·2. Lustre, resinous. Colour, straw-yellow, brownish yellow, or reddish brown. Imperfectly translucent to opaque.

Composition.—$3Pb_3V_2O_8 + PbCl_2$, or PbO 70·67, V_2O_5 19·60, Pb 7·29, Cl 2·44 per cent. Usually some P_2O_5 present up to about 2 per cent. and in some cases As_2O_5

Decrepitates when heated, and fuses on charcoal to a bead which scintillates, and is reduced to metallic lead, sometimes giving arsenical fumes. With salt of phosphorus in the oxidising flame the bead is reddish yellow when hot, and yellowish green when cold, and in the reducing flame emerald-green.

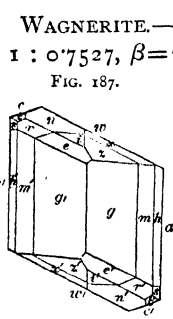
Decomposed by nitric acid, first turning red from separation of vanadic acid, which afterwards dissolves, giving a yellow solution. Hydrochloric acid gives a green solution with a separation of $PbCl_2$.

Occurrence.—Found at Zimapan, Mexico; Wanlockhead, Scotland; Wendischkappel, Carinthia; and Beresof, Siberia. At the latter place the crystals sometimes contain kernels of pyromorphite.

Xenotime or *Ytterspath*, and *Cryptolite*, are rare phosphates of the cerium metals. The former is $Y_3P_2O_8$ (yttria 62·13, P_2O_5 37·87 per cent.). It occurs in small yellow or brown tetragonal pyramids at Ytterby, and a few other places. Cryptolite or Phosphocerite, $Ce_3P_2O_8$, is found in grains embedded in apatite at Arendal.

WAGNERITE.—*Oblique.* ∞P 95° 25′, $a : b : c = 0{\cdot}9569 : 1 : 0{\cdot}7527$, $\beta = 71°\ 53'$. (Fig. 187) $m'\{110\}\infty P$, $g'\{120\}\infty \breve{P}2$, $h'\{320\}\infty \breve{P}\frac{3}{2}$, $a'\{100\}\infty \breve{P}\infty$, $z\{\bar{1}11\}P$, $s\{111\}-P$, $x\{\bar{2}12\}\breve{P}2$, $i\{\bar{1}22\}\breve{P}2$, $e\{021\}2\breve{P}\infty$, $r\{011\}\breve{P}\infty$, $t\{012\}\frac{1}{2}\breve{P}\infty$, $c\{001\}\circ P$. Crystals, prismatic, faces deeply striated. Cleavage, 110 and 100 imperfect. H. 5–5·5. Sp. gr. 2·98–3·15. Lustre, vitreous. Colour, yellow or grey. Translucent.

FIG. 187.



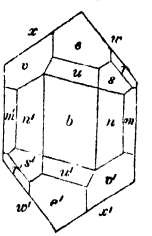
Composition.—Approximately $\left\{\begin{matrix} Mg_3P_2O_8 \\ MgFl_2 \end{matrix}\right\}$, or MgO 37·1, P_2O_5 43·8, Mg 7·4, Fl 11·7 per cent. Analyses show CaO and FeO together, from 7 to 10 per cent.; and the P_2O_5 and Fl are generally less than the theoretical amount.

Fusible with difficulty in thin splinters, the ferriferous variety more easily. Gives the iron reaction with fluxes. Moistened with sulphuric acid colours the flame bluish green. With salt of phosphorus in open tube gives fluorine reaction. Soluble in nitric and hydrochloric acids, and in sulphuric acid, giving off hydrofluoric acid.

Found near Werfen in the Salzburg Alps.

MONAZITE.—*Oblique.* $\infty P\, 93°\ 10'$, $a : b : c = 0{\cdot}9742 : 1 : 0{\cdot}9288$, $\beta\ 76°\ 14'$. (Fig. 188) $m'\{110\}\infty P$, $n'\{120\}\infty \breve{P}2$, $a\{100\}\infty \breve{P}\infty$, $b\{010\}\infty \breve{P}\infty$, $r'\{\bar{1}11\}-P$, $v\{111\}-P$, $w\{101\}-\breve{P}\infty$, $x\{10\bar{1}\}\breve{P}\infty$, $s\{121\}-2P2$, $u\{021\}2\breve{P}\infty$, $e\{011\}\breve{P}\infty$. Crystals, thick tabular or short columnar, the former elongated on the ortho-diagonal, and embedded singly. Cleavage, 001 very perfect. H. 5–5·5. Sp. gr. 5–5·25. Colour, reddish or yellowish brown, flesh-red, hyacinth-red. Lustre, resinous. Translucent at edges.

FIG. 188.



Composition.—A compound tribasic phosphate of dyad metals of the cerium group, and of the corresponding or a more acid phosphate of thoric and stannic oxides. No general formula is given, as the few analyses vary too much to be represented by a single expression. The mineral from Slatoust has the special composition $\left\{\begin{matrix} 5\overset{II}{R}_3P_2O_8 \\ Th_2P_2O_9 \end{matrix}\right\}$, the analysis by Kersten giving $\underbrace{CeO\ 24{\cdot}78, LaO\ 23{\cdot}40, CaO\ 1{\cdot}68, MnO\ 1{\cdot}86,}_{\overset{II}{R}O\ \text{bases}}$ $\underbrace{ThO_2\ 17{\cdot}95, SnO_2\ 2{\cdot}10,}_{\overset{IV}{R}O_2\ \text{bases}}$ $P_2O_5\ 28{\cdot}50$ per cent.

Infusible, or difficultly fusible; moistened with sulphuric acid and heated gives blue-green phosphoric acid flames. With borax gives a bead yellowish red hot, and nearly

colourless cold. Soluble in hydrochloric acid, but not readily, leaving a white residue.

Occurs at Slatoust in the Ural; near Antioquia, New Granada; at Norwich, Conn.; and a few other American localities.

Triplite and *Zwieselite* are similar in composition to Wagnerite, or contain equal molecules of tribasic phosphate and fluoride of iron and manganese. Average percentage composition, P_2O_5 30–33, MnO 20–32, FeO 23–41, Fl 3–8. Probably rhombic or oblique in form. H. 4–5·5. Sp. gr. 3·6–4·0. Dark brown or black. Lustre, resinous. Fusible to a black magnetic bead. Soluble in acids.

Found near Limoges; Bodenmais, Bavaria; and Schlaggenwald, Bohemia.

TRIPHYLLINE.—*Rhombic.* ∞P 98°, $a : b : c = 0{\cdot}8692 : 1 : 1{\cdot}0518$. Crystals, columnar, prismatic, with terminal pinakoid: usually massive or in imperfectly developed crystals. Cleavage, 001 perfect. H. 4–5. Sp. gr. 3·56. Colour, greenish grey, olive-green, brown, or black. Lustre, greasy. Slightly translucent at edges. Opaque.

Composition.—Approximately $\left\{\begin{matrix} \overset{\text{I}}{\text{R}}_3\text{PO}_4 \\ \overset{\text{II}}{\text{R}}_3\text{P}_2\text{O}_8 \end{matrix}\right\}$ $\overset{\text{I}}{\text{R}} = \text{Li}$ and Na, $\overset{\text{II}}{\text{R}} = \text{Fe}$, Mn, Ca. An average of four analyses by Rammelsberg gave Li_2O 7·28, Na_2O 1·45, K_2O 0·58, MnO 9·80, FeO 39·97, P_2O_5 40·72. Other analyses show considerable variations, which are partly due to the alteration of the substance.

Decrepitates when first heated, afterwards fuses readily to a dark grey metallic bead. The flame shows flashes of lithia-red at intervals, and at the outside a pale blue-green (phosphoric acid). These may be better seen by heating the pulverised mineral in the loop of a platinum wire after moistening with sulphuric acid. With borax and soda gives iron and manganese reactions. Soluble in hydrochloric acid.

Occurrence.—Found at Bodenmais in Bavaria, and Norwich, Connecticut.

Lithiophilite, a nearly pure manganese triphyllite (MnO 41, Li_2O 8–9 per cent.), has been found, with several analogous phosphates, at Branchville, Connecticut, by Brush and Dana.

AMBLYGONITE. Montebrasite. —*Triclinic.* Usually in masses cleavable in three directions. The most perfect is basal, the second parallel to the macropinakoid, the third to a hemiprism. H. 6. Sp. gr. 3·07–3·11. White or some pale shade of green or brown. Lustre, pearly on basal cleavage, greasy on fracture. Opaque in mass, transparent in thin sections.

Composition.—$2\overline{Al}P_2O_8 + 3RFl$. R=Li.Na. Analysis from Montebras: Fl 9·00, P_2O_5 45·91, $\overline{Al}O_3$ 35·50, Li_2O 6·70, Na_2O 5·30, CaO 0·50=102·91. The variety from Hebron, Maine, contains 4·5 per cent. of water, and 4·5–10 per cent. of lithia.

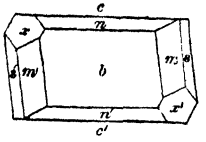
In the closed tube some varieties yield water, which shows the corrosive action of fluorine, others only show fluorine when fused with salt of phosphorus. Fuses readily in the flame with intumescence, giving an opaque white bead. Colours the flame strong lithia-red either with or without sulphuric acid, and bluish green from phosphoric acid. Most readily decomposed by sulphuric acid, evolving hydrofluoric acid. Not so easily by hydrochloric acid.

Found near Penig, Saxony; Montebras, France; and Hebron, Maine. Montebrasite and Hebronite are from the two latter localities, and the names have been applied on account of differences in composition and optical character from the original mineral of Penig.

When massive the appearance is very similar to that of albite or oligoclase, but the absence of triclinic striation marks the difference, as well as the fusibility and other chemical characters.

PHARMACOLITE.—*Oblique.* Rarely in defined crystals. ∞P 117° 17′, $a : b : c = 0{\cdot}6137 : 1 : 0{\cdot}3622$, $\beta = 83°\ 13'$.

FIG. 189.



(Fig. 189) $m\{110\}\infty P$, $s\{310\}\infty P3$, $l\{\bar{1}11\}P$, $n\{011\}\breve{P}\infty$, $b\{010\}\infty\breve{P}\infty$, $c\{001\}oP$. Usually in silky fibres or powdery incrustations, also massive. Cleavage, 010 perfect. H. 2–2·5. Sp. gr. 2·73. Lustre, vitreous, pearly on cleavage faces, silky when fibrous. White opaque, sometimes pink or red when containing cobalt.

Composition. — $2HCaAsO_4 + 5H_2O$, or As_2O_5 51·11, CaO 24·89, H_2O 24·00 per cent.

In the closed tube gives off water. In the oxidising flame fuses with intumescence to a white enamel, colouring the flame light blue from arsenic. On charcoal gives off arsenical fumes; some varieties give a cobalt reaction with fluxes. Soluble in hydrochloric acid.

Occurrence.—Found with arsenical cobalt and silver ores at Wittichen, Baden; Riechelsdorf and Bieber, Hesse; Andreasberg, Johanngeorgenstadt, and Joachimsthal.

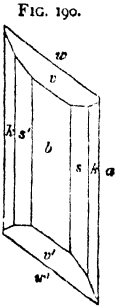
Haidingerite and *Wapplerite* are of a similar composition, but the former has only two-fifths of the quantity of water of hydration, the formula being $HCaAsO_4 + H_2O$. The latter contains both calcium and magnesium, and crystallises with seven molecules of water.

Picropharmacolite is a tribasic arseniate of the same metals, with six molecules of water of crystallisation.

COBALT BLOOM. Erythrine.—*Oblique.* ∞P 111° 16′, $a : b : c = 0{\cdot}7237 : 1 : 0{\cdot}5603$, $\beta = 70°\ 54'$. (Fig. 170) $v\{111\} - P$, $w\{101\} - \breve{P}\infty$, $a\{100\}\infty\breve{P}\infty$, $k\{320\}\infty P\frac{3}{2}$, $\{340\}\infty P\frac{4}{3}$, $b\{010\}\infty\breve{P}\infty$. Crystals usually small, acicular or capillary, and grouped in radiated or starlike masses; also earthy and incrusting. Cleavage, 010 very perfect. Sectile, and somewhat flexible in thin laminæ. H. 1·5–2·5.

Sp. gr. 2·91–2·95. Colour, crimson or peach-blossom-red; with a bluish tint, perpendicular to cleavage faces; pale pink when earthy. Streak, light red. Lustre, adamantine to vitreous, pearly on cleavage faces. Transparent to opaque.

FIG. 190.



Composition.—$Co_3As_2O_8+8H_2O$, or CaO 37·56, As_2O_5 38·40, H_2O 24·04 per cent. A portion of the cobalt may be replaced by Ca, Fe, or Ni, the last being very commonly present.

Heated in the closed tube gives off water, turning blue; or, when containing iron, green or brown. Fusible on charcoal, giving off arsenical vapours, and leaving a grey arsenide which with borax gives the deep blue cobalt glass, and if containing nickel ultimately a reddish brown bead. Soluble in hydrochloric acid, giving a solution which is blue or green while concentrated, and rose-red when diluted.

Occurrence.—With the arsenides of cobalt at Schneeberg, and generally with cobalt ores at Wolfach, Baden; Modum, Norway; Riechelsdorf, &c. The earthy variety forms slowly upon speiss cobalt by exposure to damp air, and is sometimes a mixture of cobalt bloom and arsenious acid.

NICKEL BLOOM. Nickel Ochre, Annabergite.—In microscopic crystals, isomorphous with cobalt bloom; usually in earthy incrustations of an apple-green colour. Dull and earthy; streak, somewhat brighter.

Composition.—$Ni_3As_2O_8+8H_2O$, or NiO 37·25, As_2O_5 38·59, H_2O 24·16 per cent. Usually some nickel is replaced by iron or cobalt.

In the closed tube gives off water and behaves similarly to cobalt bloom, except that the regulus obtained on charcoal gives the brown glass of nickel with borax when any iron or cobalt has first been removed by oxidation. If either of these metals is present the colour is considerably

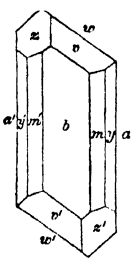
modified. Soluble in hydrochloric acid, giving a deep green solution.

Occurs in arsenical nickel ores as a product of oxidation similarly to cobalt bloom, at Schneeberg, Annaberg, Riechelsdorf, &c.

Köttigite, *Hörnesite*, and *Roselite* are all of similar constitution to cobalt and nickel bloom, i.e. $\overset{II}{R}_3As_2O_8+8H_2O$. In the first the metals are Zn and Co, in the second Mg, and in the last Ca, Mg, and Co, with only two molecules of water.

VIVIANITE.—*Oblique.* ∞P 108° 02′, $a : b : c = 0{\cdot}7498 : 1 : 0{\cdot}7017$, $\beta = 75°34'$. (Fig. 191) $m\{110\}\infty P$, $y\{310\}\infty P3$, $v\{111\}-P$, $z\{\bar{1}12\}\frac{1}{2}P$, $a\{100\}\infty P\infty$, $b\{010\}\infty\breve{P}\infty$, $w\{101\}-\breve{P}\infty$. Crystals invariably columnar, being elongated on the vertical axis. Faces, 010 smooth, others striated. Cleavage, 010 perfect. In single crystals grouped in druses and in reniform or globular masses; also in pulverulent crusts. H. 2. Sp. gr. 2·58–2·72. Colour, indigo-blue, passing to blackish green and brown; in the variety from Delaware sometimes nearly colourless; streak, bluish white, becoming bluer by exposure. The earthy variety is sometimes white when freshly obtained, but turns blue on exposure. Transparent to translucent.

FIG. 191.



Composition.—$Fe_3P_2O_8+8H_2O$ (isomorphous with cobalt bloom), or FeO 43·03, P_2O_5 28·29, H_2O 27·95 per cent. This, however, only represents the colourless crystals. The ordinary blue varieties contain more or less of ferric oxide, and are represented as compounds of the general constitution $(Fe_3P_2O_8+16H_2O)$ with $Fe_4P_2O_{19}+16H_2O$.

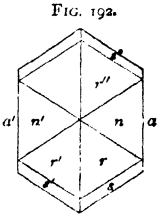
	P_2O_5	FeO	Fe_2O_3	H_2O
Colourless crystals, Delaware .	27·17	44·10	—	27·95
Allentown, New York, blue .	28·81	38·26	4·26	28·67
Bodenmais, dark blue . .	29·01	35·65	11·60	23·74
Kertch, dark brown . . .	28·73	9·75	38·20	24·12

In the closed tube gives off water, swells, becomes grey, and in places red. Fusible in the forceps, colouring the flame bluish green. On charcoal burns red and fuses to a dark grey magnetic globule. Easily soluble in acids.

Occurrence.—The finest crystals have been obtained from mines near Tavistock, usually associated with iron pyrites; Bodenmais, Bavaria; and Commentry and Cransac, in France, in burning coal shales. In the greensand of New Jersey and in the Crimea it occurs, filling fossils, and has been similarly found in the earthy form, filling casts of shells, in the Oxford clay. It also deposits in fossil teeth and bones in peat bogs, and even in beech trees growing upon soils containing soluble iron salts. In Silesia, Vivianite crystals were found in the bones of a miner who had been drowned by an irruption of water several years previously. In some instances Vivianite seems to pass entirely into a ferric phosphate; the mineral known as *Beraunite*, found near Zbirow, in Bohemia, being an alteration product of this kind.

CHILDRENITE. Eosphorite.—*Rhombic.* $X=130°\ 10'$, $Y=101°\ 43'$, $Z=98°\ 44'$, $a:b:c=0{\cdot}6758:1:0{\cdot}6428$. (Fig. 192) $s\ \{111\}\ P$, $r\ \{223\}\ \frac{2}{3}P$, $n\ \{021\}\ 2\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$. Cleavage, 010 imperfect. H. 4·5–5. Sp. gr. 3·18–3·28. Colour, yellowish, wine- to ochre-yellow, and brownish. Lustre, vitreous. Translucent to opaque.

FIG. 192.



Composition. — $R_2Al_2P_2O_8+4H_2O=Al_2P_2O_8+2(RH_2O_2)+2H_2O$. R=(FeMn), Fe : Mn = 3 : 1 in Childrenite, 1 : 3 in Eosophorite. An analysis by Church gives P_2O_5 30·65, AlO_3 18·85, FeO_3 3·51, FeO 23·48, MnO 7·74, MgO 1·03, H_2O 17·10.

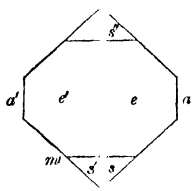
In the closed tube gives off water in the forceps, the flame bluish green, swells, and remains infusible; the

fluxes, gives the reaction of iron and manganese. Soluble in hydrochloric acid after long exposure.

Occurrence.—Childrenite from mines near Tavistock and Par, Cornwall, and Hebron, Maine. Eosphorite from Branchville, Connecticut.

LIBETHENITE.—*Rhombic.* $\infty P 92° 20'$, $a : b : c = 0.9602 : 1 : 0.7020$. (Fig. 193), $a\{010\}\infty\breve{P}\infty$, $m\{110\}\infty P$, $s\{111\}P$, $e\{011\}\breve{P}\infty$. In small detached crystals. Cleavage, 010 and 100 both imperfect. H. 4. Sp. gr. 3·6–3·8. Colour, dark olive- or verdigris-green, nearly black; streak, olive-green. Lustre, resinous. Translucent on thin edges.

FIG. 193.



Composition.—$Cu_4P_2O_9 + H_2O = \left\{\begin{matrix} Cu_3P_2O_8 \\ H_2Cu\ O_2 \end{matrix}\right\}$, or CuO 66·50, P_2O_5 29·73, H_2O 3·77 per cent. Some varieties contain traces of As_2O_5. In the closed tube gives off water and blackens. Fuses easily to a black crystalline mass, colouring the flame green, or, when moistened with hydrochloric acid, blue. On charcoal, is reduced to metallic copper, sometimes giving an arsenical odour. The phosphoric acid may be detected by fusion with metallic lead on charcoal, when metallic copper and a characteristically crystalline bead of phosphate of lead is obtained. Soluble in acids and also in ammonia, giving a green or blue solution.

Occurrence.—At Libethen in Hungary in small crystals implanted in quartz; Nischne Tagilsk, Ural; in Chili and Bolivia; and S. Paul de Loanda, Africa.

PHOSPHOCHALCITE.—*Oblique or triclinic.* Usually in mammillated aggregates of a fibrous structure. H. 5. Sp. gr. 4·4. Emerald-, verdigris-, or blackish green. Lustre, vitreous, nearly opaque.

Composition.—$Cu_6P_2O_{11} + 3H_2O = \left\{\begin{matrix} Cu_3P_2O_8 \\ 3H_2CuO_2 \end{matrix}\right\}$, or CuO 71·10, H_2O 8·02 per cent.

Allen, Bodenmais, Kertch, dark

Chemical characteristics similar to those of Libethenite.

Occurrence.—At Rheinbreitbach; Hirschberg, Saxony; Nischne Tagilsk; and Libethen. Also called *Pseudomalachite* from its occurrence in botryoidal masses with a polished surface resembling malachite.

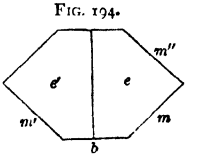
DIHYDRITE and EHLITE, or PRASINE, are intermediate in composition between Libethenite and Phosphochalcite. The former is $\left\{\begin{matrix}Cu_3P_2O_8\\2H_2CuO_2\end{matrix}\right\}$ and the latter $\left\{\begin{matrix}Cu_3P_2O_8\\2H_2CuO_2\end{matrix}\right\} + H_2O$, the corresponding percentages of water found by analysis being 6·25 and 9 respectively. Ehlite, from the original locality Ehl near Linz, contains in some instances a considerable proportion of vanadic acid.

MOTTRAMITE, from Mottram St. Andrew's, Cheshire, is a vanadiate of lead and copper of the composition $\left\{\begin{matrix}(PbCu)_3V_2O_8\\2H_2(PbCu)O_2\end{matrix}\right\}$ or isomorphous with dihydrite, with CuO 20·39, PbO 57·18, V_2O_5 18·74, H_2O 3·69 per cent.

Occurrence.—It occurs in brownish or purplish black incrustations in the copper-bearing sandstones of Alderley Edge, Cheshire, and has been utilised for vanadium preparations by Roscoe. Probably a similar mineral may be present in the lead-bearing sandstones of the Eifel, which also contain traces of vanadium.

OLIVENITE.—*Rhombic.* Isomorphous with Libethenite. ∞P 92° 30′, $a : b : c = 0{\cdot}9573 : 1 : 0{\cdot}68944$. (Fig. 194) $m\{110\}\infty P$, $b\{100\}\infty \breve{P}\infty$, $e\{011\}\breve{P}\infty$. Crystals columnar or acicular: usually in reniform or spheroidal aggregates of a fibrous texture. H. 3. Sp. gr. 3·92–4·40. Lustre, vitreous to resinous (pearly or even lower in some fibrous kinds). Colour, olive-green, leek-, yellowish, or blackish green, liver-brown, yellowish brown, straw-yellow, or greyish white, these latter

FIG. 194.



often variegated in the fibrous masses, which resemble wood; streak, olive-green, brown. Imperfectly translucent to opaque.

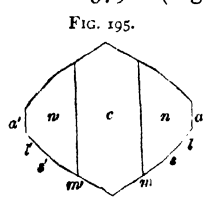
Composition.—$Cu_4As_2O_9 + H_2O = \left\{\begin{matrix} Cu_3As_2O_8 \\ H_2CuO_2 \end{matrix}\right\}$, or CuO 56·15, As_2O_5 40·66, H_2O 3·19 per cent. Usually some P_2O_5 (3 to 5 per cent.) partially replaces As_2O_5.

In the closed tube gives off water. In an oxidising flame fuses easily to a crystalline bead, colouring the flame bluish green. On charcoal is reduced with deflagration and arsenical fumes to a grey arsenide of copper, which when scorified with B_2O_3 gives metallic copper. Soluble in acids and ammonia, giving a blue solution. Decomposed by heating with solution of caustic potash, CuO separating.

Occurrence.—Found principally in Cornwall, most abundantly in the mines about Redruth and St. Day; also near Tavistock; in the Banat, Hungary; Siberia, Chili, &c. The fibrous variety is known as *wood copper ore.*

EUCHROITE.—*Rhombic.* ∞P 117° 20′, $a : b : c$=0·6088 : 1 : 1·0379. (Fig. 196) $m\{110\}\infty P$, $s\{230\}\infty \breve{P}\frac{3}{2}$, $l\{120\}\infty \breve{P}2$, $n\{011\}\breve{P}\infty$, $c\{001\}oP$, in short columnar crystals. Cleavage 110, 010, both imperfect. Very brittle. H. 3·5–4. Sp. gr. 3·3–3·4. Lustre, vitreous. Colour, emerald- or leek-green; streak, verdigris-green. Transparent to translucent.

FIG. 195.

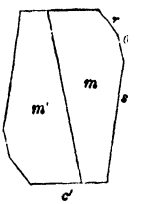


Composition. —$Cu_3As_2O_9 + 7H_2O = \left\{\begin{matrix} Cu_3As_2O_8 \\ H_2CuO_2 \end{matrix}\right\} + 6H_2O$, or CuO 47·15, As_2O_5 34·15, H_2O 18·70 per cent. The same as olivenite, with six molecules of water of crystallisation. In the closed tube gives off water, turning yellowish green, otherwise the chemical behaviour is like that of olivenite.

Occurrence.—In single crystals implanted in mica schist at Libethen, and is, with the possible exception of dioptase, the most emerald-like of all copper ores.

CLINOCLASE. Aphanèse, Abichite.—*Oblique.* ∞P 56°, $a : b : c = 1{\cdot}9069 : 1 : 3{\cdot}8507$ $\beta = 80° 30'$. (Fig. 196) $m\{110\}$ ∞P, $c\{001\}0P$, $r\{101\} -P\infty$, $a\{100\}\infty P\infty$, $s\{302\}\frac{3}{2}P\infty$. In short columnar crystals and radiated aggregates with convex surfaces. Cleavage, 001 highly perfect. The cleavage faces curved in the compound groups. H. 2·5–3. Sp. gr. 4·20–4·36. Colour, dark bluish green, nearly black externally, verdigris-green internally; streak, bluish green. Lustre, vitreous, pearly on cleavage faces.

FIG. 196.



Composition.—An analogous arseniate to phosphochalcite. $Cu_6As_2O_{11} + 3H_2O = \left\{ \begin{matrix} Cu_3As_2O_8 \\ 3H_2CuO_2 \end{matrix} \right\}$, or CuO 62·65, As_2O_5 30·25, H_2O 7·10 per cent. Chemical characteristics similar to those of olivenite.

Occurrence.—In Cornwall and Devonshire with other arseniates of copper.

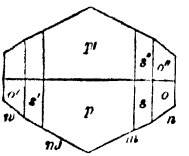
CHALCOPHYLLITE. Copper Mica.—*Rhombohedral.* In tabular crystals resembling mica, with a perfect basal cleavage; also in platy cleavable masses. H. 2. Sp. gr. 2·44–2·66. Colour, emerald- or verdigris-green; streak, bright green. Lustre, pearly on cleavage faces. Transparent to translucent.

Composition.—A basic arseniate of copper, with some hydrate—or hydrated phosphate—of aluminium, and a large amount of water of crystallisation. The few analyses vary very considerably, and are not reducible to a single formula. One by Damour gives P_2O_5 1·56, As_2O_5 21·27, CuO 52·30, ~~Al~~O 2·13, H_2O 22·58. In the closed tube decrepitates violently, giving off water and turning black; otherwise behaves like olivenite.

Occurrence.—Found formerly at Huel Gorland, Unity, Ting Tang, and other mines in Gwennap, Cornwall; but has become scarce for many years.

WAVELLITE.—*Rhombic.* ∞P 126° 25′, $a : b : c = 0{\cdot}5048 : 1 : 0{\cdot}3750$. (Fig. 197) $m\{110\}\infty P$, $n\{340\}\infty \breve{P}\frac{4}{3}$, $a\{010\}\infty \breve{P}\infty$, $o\{121\}2\breve{P}2$, $s\{111\}P$, $p\{101\}\breve{P}\infty$. Crystals usually long columnar or acicular, and aggregated in hemispherical masses, which when broken show a star- or wheel-like arrangement. Also reniform and stalactitic, with the same structure. Cleavage, 110 and 010 fairly perfect. H. 3·5–4. Sp. gr. 2·3–2·5. Colourless, greyish, yellowish, sometimes bright blue or green. Lustre, vitreous. Transparent to translucent.

FIG. 197.



Composition.—$\dot{A}l_3P_4O_{19} + 12H_2O = \left\{ \begin{matrix} 2\dot{A}lP_2O_8 \\ H_6\dot{A}lO_6 \end{matrix} \right\} + 9_2HO$, or $\dot{A}lO_3$ 38·10, P_2O_5 35·16, H_2O 26·47 per cent. Some varieties contain $\dot{F}eO_3$ (up to 3 per cent.), and fluorine up to 2·25 per cent. About three-fourths of the water are driven off at and below 200°, and the remainder only by a red heat. In the closed tube gives off water, and sometimes traces of hydrofluoric acid. In the forceps swells up, colouring the flame bluish green, especially if moistened with sulphuric acid. On charcoal turns white, but does not fuse, and gives the alumina blue with cobalt solution. Soluble in acids and caustic potash.

Occurrence.—On the joint surfaces of clay slate at Barnstaple, Devon; Langenstriegis, Saxony; Amberg, Bavaria; &c. The stalactitic variety is from Chester County, Pennsylvania.

EVANSITE.—A hydrated phosphate of alumina from Hungary. In botryoidal aggregates of a pearly colour and lustre. H. 3·5–4. Sp. gr. 1·94.

Composition.—$\left\{ \begin{matrix} \dot{A}lP_2O_8 \\ 2H_6\dot{A}lO_6 \end{matrix} \right\} + 12H_2O$, or $\dot{A}lO_3$ 19·32, P_2O_5 40·54, H_2O 40·52 per cent.

LUDLAMITE.—*Oblique.* ∞P 131° 52′, $a : b : c = 2{\cdot}2785 : 1 : 2{\cdot}0351$, $\beta = 79°\ 27'$. Crystals mainly short columnar

prismatic forms. Cleavage, 001 very perfect, 100 less perfect. H. 3·5. Sp. gr. 3·12. Colour, pale copperas-green. Lustre, vitreous. Transparent.

Composition.—$Fe_7P_4O_{17}+9H_2O=\left\{\begin{matrix}2Fe_3P_2O_8\\H_2FeO_2\end{matrix}\right\}+8H_2O$, or P_2O_5 29·88, FeO 53·06, H_2O 17·06 per cent. Darkens in the air like Vivianite. From Cornwall on iron pyrites.

TURQUOISE. Kalaite. — *Amorphous*, in small nodules, veins, and stalactitic forms. Fracture, conchoidal. H. 6. Sp. gr. 2·62–2·75. Colour, sky-blue to bluish green, sometimes passing into apple-green, pale or white. Lustre, waxy, earthy varieties dull. Opaque, sometimes very slightly translucent in thin fragments.

Composition.—A hydrated phosphate of aluminium, iron, and copper, of undefined constitution. An analysis by Church of a Persian specimen gave P_2O_5 32·86, Al_2O_3 40·19, FeO 2·21, CuO 5·27, MnO 0·36, H_2O 19·34 per cent. This is approximately $\left\{\begin{matrix}Al_3P_2O_8\\6AlP_2O_{11}\end{matrix}\right\}+32H_2O$.

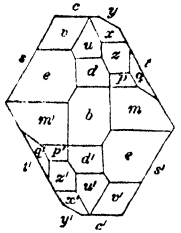
In the closed tube decrepitates, gives off water and turns black. In the forceps colours the flame green, becomes brown and glassy, but does not fuse. With borax gives the reactions of copper and iron. Soluble in acids.

Occurrence.—Occurs chiefly in Persia and Arabia. The Arabian mines are situated in Wady Maghara in the Sinaitic desert. The mineral occurs in nodules inclosed in red marl, scattered through sandstones, and sometimes filling small veins in joint-cracks. The nodules produce the finest stones. These mines are of enormous antiquity, extending back to the time of the building of the Great Pyramid. The turquoises produced are not of the same value as those from Persia, as they are said to lose colour when exposed to the air for a time. The Silesian variety called Kalaite is of an inferior colour. The Oriental varieties are extensively used as gems, the principal supply being from Persia, whence they

are imported ready polished. The Sinaitic mines were reopened a few years since, but have been again abandoned.

LAZULITE.—*Oblique.* ∞P 91° 30′, $a : b : c = 0{\cdot}9747 : 1 : 0{\cdot}8470$, $\beta = 88°\ 15'$. (Fig. 198) $m\{110\}\infty P$, $p\{111\}-P$, r, $z\{112\}-\frac{1}{2}P$, $x\{113\}-\frac{1}{3}P$, P, $q\{212\}\breve{P}2$, $b\{010\}\infty\breve{P}\infty$, $d\{011\}P\infty$, $u\{012\}\frac{1}{2}P\infty$, $t\{101\}-P\infty$, $s\{\bar{1}01\}\breve{P}\infty$, $y\{103\}-\frac{1}{3}P\infty$, $c\{001\}0P$. H. 5–6. Sp. gr. 2·78–3·12. Sometimes colourless, but usually cobalt or ultramarine blue of greater or less intensity; streak, colourless. Lustre, vitreous, imperfectly translucent to opaque.

FIG. 198.



Composition. — $R\text{Al}P_2O_9 + H_2O = \left\{ \begin{matrix} R_3P_2O_8 \\ 2\text{Al}P_2O_8 \\ H_6\text{Al}O_6 \end{matrix} \right\}$, R= (Fe, Mg, Ca). A dark blue variety from Styria contained P_2O_5 42·58, Al_2O_3 32·89, FeO 8·11, MgO 9·27, CuO 1·11, H_2O 6·04 per cent. The colour varies with the proportion of FeO, which is least in the lighter varieties; these contain up to 12·5 MgO.

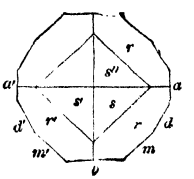
In the closed tube gives off water, turning white. In the forceps cracks and intumesces, and crumbles without fusion, colouring the flame bluish green, the latter more apparent when previously moistened with sulphuric acid. With cobalt solution gives the alumina blue. Not affected by acids, except after calcination, when it is tolerably easily soluble.

Occurrence.—It is found in the Salzburg and Styrian Alps, and in Sweden. The crystallised varieties are abundant at Grave's Mount, Georgia, and Crowder's Mount, N.C.

SCORODITE.—*Rhombic.* X 114° 40′, Y 102° 52′, Z 116° 06′, $a : b : c = 0{\cdot}8673 : 1 : 0{\cdot}9558$. (Fig. 199) $m\{110\}\infty P$, $d\{120\}2\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$, $b\{100\}\infty\bar{P}\infty$, $r\{111\}P$, $s\{112\}\frac{1}{2}P$. Crystals short columnar or pyramidal, usually

small and grouped in druses; also in fibrous, compact, and earthy aggregates. Cleavage, 100 traces, 120 imperfect. H. 3·5–4. Sp. gr. 3·10–3·20. Colour, leek- or copperas-green, sometimes blackish green, blue, or brown. Lustre, vitreous. Transparent to translucent. Double refraction positive. 100 is optic axial plane, and axis *c* median line.

FIG. 199.



Composition.— $Fe_2As_2O_8+4H_2O$, or As_2O_5 49·78, FeO_3 34·63, H_2O 15·59 per cent. Some varieties contain a little P_2O_5. Chemical characteristics similar to those of cube ore.

Occurrence.—Found in Cornwall associated with arseniates of copper, and in the gold mines of Minas Geraes, Brazil; and Victoria, Australia.

LIROCONITE. Linsenerz.—*Oblique*, closely approximating to rhombic forms. Crystals resemble very thin rhombic or lenticular pyramids, whence the name. Cleavage, 110 very imperfect; also massive in small veins, with irregular fracture. H. 2. Sp. gr. 2·85–2·99. Lustre, vitreous. Colour, sky-blue (or nearly that of blue vitriol when in particles of the same size), bluish green. Transparent to translucent.

Composition. — Approximately . . . . $\left\{\begin{array}{l} 3\left(\left\{\begin{array}{l}Cu_3As_2O_8\\3H_2CuO_2\end{array}\right\}+9H_2O\right)\\ 2\left(\left\{\begin{array}{l}Al\,P_2O_8\\H_6AlO_6\end{array}\right\}+9H_2O\right)\end{array}\right\}$

or P_2O_5 3·57, As_2O_5 23·11, CuO 35·90, AlO_3 10·30, H_2O 27 12 per cent. Apart from water of crystallisation the arseniate in the above formula is analogous in constitution to phosphochalcite, and the phosphate approximates to Wavellite.

In the closed tube splits without decrepitating, gives off water, turns green; at a higher temperature glows and turns brown. Fusible with some difficulty on charcoal to a brown

slaggy mass with disseminated shots of copper, giving off arsenical fumes. Soluble in nitric acid and ammonia.

Occurs with olivenite &c. in Cornwall, and Herrengrund, Hungary.

CUBE ORE. Pharmacosiderite.—*Cubic, tetrahedral, inclined hemihedral.* Usually in cubes with tetrahedral modifications. Crystals small, and clustered in druses. Cleavage, 100 imperfect. H. 2·5. Sp. gr. 2·9–3. Lustre, adamantine to greasy. Leek- or copperas-green, sometimes yellowish, or brown. Translucent to transparent.

Composition.—$Fe_4As_6O_{27} + 15H_2O = \left\{\begin{matrix} 3FeAs_2O_8 \\ H_6FeO_6 \end{matrix}\right\}$, or As_2O_5 43·14, FeO_3 40·00, H_2O 16·57 per cent. Some of the arsenic acid may be replaced by an equivalent proportion of phosphoric acid ; also contains some CuO as a rule. The state of oxidation of the iron is uncertain, as there is a want of good analyses.

In the closed tube gives off water, turns red and swells up. On charcoal melts to a steel-grey magnetic slag, giving off arsenical fumes. Soluble in acids. Caustic potash decomposes it, depositing red-brown ferric hydrate.

Found principally in Cornwall with other arseniates of iron and copper.

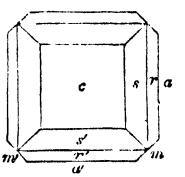
URANITE GROUP.

This series includes a small number of minerals that are either phosphates or arseniates of uranium oxide (UO_2 or the radical uranyl, which enters into combination like a dyad metal), and calcium or copper. They are generally very similar in appearance, and although not now held to be isomorphous, those in rhombic crystalline forms are scarcely distinguishable from those belonging to the tetragonal system. The phosphorus uranites have been known for a long time, and were once tolerably abundant, but the analogous arsenic compounds are of recent discovery, and found principally in the nickel mines of Schneeberg, Saxony:

they are probably products of the alteration of arsenical ores and pitchblende.

COPPER URANITE. Chalcolite, Uranium Mica, Torbernite. — *Tetragonal.* $Z = 142° 08'$, $a : c = 1 : 1{\cdot}0307$. (Fig. 200) $m\{110\}\infty P$, $a\{101\}\infty P\infty$, $r\{201\}2P\infty$, $s\{203\}\frac{2}{3}P_{\infty}$, $c\{001\}oP$. In tabular crystals, usually thin with the terminal pinakoid dominant. Cleavage, 001 very perfect. H. 2–2·5. Sp. gr. 3·4–3·6. Colour, grass- or emerald-green, less commonly bluish green; streak, somewhat paler green than the mass. Lustre, vitreous. Cleavage faces pearly. Transparent to translucent. Double refraction negative. Uniaxial.

FIG. 200.



Composition.—$CuU_2P_2O_{12} + 8H_2O = \left\{ \begin{matrix} Cu_3P_2O_8 \\ 2(UO_2)_3P_2O_8 \end{matrix} \right\} + 24H_2O$, or P_2O_5 15·08, UO_3 61·19, CuO 8·43, H_2O 15·30 per cent. Some analyses show a partial replacement of P_2O_5 by As_2O_5 up to 3·24 per cent. In the closed tube gives off water; in the forceps fuses to a black mass, colouring the flame green; on charcoal with soda gives a bead of copper, which is sometimes white and brittle from arsenic. With salt of phosphorus a green bead, which becomes opaque red with tin. Soluble in nitric acid, giving a yellowish green solution. Completely decomposed by boiling with a solution of carbonate of ammonia.

Occurrence.—The principal localities are Gunnis Lake near Callington, Wheal Buller, and Tincroft, Cornwall, where it occurred in large drusy aggregates, the crystals often of considerable size, or in scattered mica-like scales. It has become rare of late years. Also at Schneeberg, Joachimsthal, Eibenstock, and Zinnwald in Saxony and Bohemia.

LIME URANITE. Autunite.—*Rhombic*, approximating to *tetragonal.* ∞P 90° 43′, Z 127° 32′, $a : b : c = 0{\cdot}9876$

: 1 : 1·4265. In nearly square tabular crystals with eminent basal cleavage. H. 2. Sp. gr. 3·05–3·20. Lustre, pearly on 001, otherwise vitreous, approaching adamantine. Colour, siskin-green to sulphur-yellow; streak, yellowish. Transparent to translucent. Double refraction negative. $\beta = 1{\cdot}572$, red. Optic axial plane 010. $2E = 60°$.

Composition.—$CaU_2P_2O_{12} + 10H_2O = \left\{ \begin{matrix} Ca_3P_2O_8 \\ 2(UO_2)_3P_2O_8 \end{matrix} \right\} + 30H_2O$, or P_2O_5 14·89, UO_3 60·37, CaO 5·87, H_2O 18·87 per cent. This represents the perfectly fresh mineral. By exposure to the atmosphere one-fifth of the total water is given off, in a desiccator over sulphuric acid one-half, and in vacuo at ordinary temperatures, or by heating to 100° four-fifths, the remaining fifth requiring a red heat for its expulsion. In the closed tube gives off water; in the forceps melts to a black crystalline bead; with borax or salt of phosphorus gives beads that are yellow in oxidising and green in reducing flame. With soda on charcoal forms a yellow infusible slag. Dissolves in nitric acid, giving a yellow solution. Decomposed by carbonate of ammonia.

Occurrence.—Found at Autun in France, and in most of the localities producing copper uranite. Sometimes both species occur together in parallel laminations. If the secondary pyramid 101 of copper uranite be assumed as the primary form, the ratio of the vertical axis becomes 1·4691, or very nearly that of the same axis in lime uranite.

Fritzscheite is a rare variety of uranite, in which CuO is replaced by MnO. It is reddish brown, and occurs bordered with lime uranite at Neudeck and Johanngeorgenstadt, Bohemia.

Zeunerite is an arseniate of uranium and copper, exactly similar in form and general characters to the corresponding phosphate. *Walpurgine*, an arseniate of uranium and bismuth. *Uranospinite*, an arsenical lime uranite. *Trögerite*, a hydrated tribasic arseniate of uranium. All these are yellow, and occur in thin tabular crystals in the Schneeberg nickel mines.

CHAPTER XIII.

BORATES.

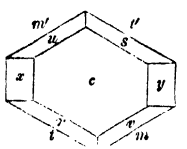
BORON may be assumed to exist in minerals either as boric or boracic acid HBO_2, or its anhydride B_2O_3. The latter is isomorphous with alumina, and, as has been already seen, may replace it in combination in silicates; while the former may exist alone or form double salts with sodium, calcium, magnesium, or manganese. In one instance the sesquioxide is found in combination with protoxide, forming a compound analogous to magnetite or spinel, but there is no crystallographic resemblance between the two series.

The principal localities of boracic acid minerals are in dormant volcanic regions, where steam and heated vapours are given off in quantity, and in the lagoons of Tuscany, in the Lipari Islands, and Southern California. In these places boracic acid is obtained by concentrating the water of the pools in which the volcanic steam condenses, and in California and Tibet borax (sodium borate) is obtained from such water by slow evaporation. The less soluble borates, those of calcium and magnesium, are found as efflorescences in dry salt deserts in Peru, and in gypsum and rock-salt deposits at Lüneburg and Stassfurt. As they are very valuable minerals they are actively worked in almost all the known localities, but the supply from all is but small as compared with the demand. The uses of borax and boracic acid depend upon their power of dissolving almost all metallic oxides when fired at a red heat, and so producing a clean metallic surface, which property is utilised in

soldering gold and other metals, as well as in the blowpipe examination of minerals.

SASSOLINE. Boracic Acid.—*Triclinic.* $1\bar{1}0/110$, 118° 30′. (Fig. 201) $m\{110\}\infty P'$, $t\{\bar{1}\bar{1}0\}\infty'P$, $v\{111\}P'$, $r\{1\bar{1}1\}'P$, $s\{\bar{1}11\}_1P$, $u\{\bar{1}\bar{1}1\}P$, $y\{011\}'\breve{P}\infty$, $x\{0\bar{1}1\}_1\breve{P}\infty$, $c\{001\}oP$. Usually in small pearly six-sided scales (produced artificially) having a basal cleavage. Kengott considers them to be oblique in system. Also in scaly stalactitic forms. H. 1. Sp. gr. 1·48. White, or yellowish when stained with sulphur. Feel unctuous. Soluble, with an acid and bitter taste.

FIG. 201.



Composition.—$H_6B_2O_6$, or $H_4B_2O_4 + 2H_2O = 2(HBO_2 + H_2O)$; corresponding to B_2O_3 56·46, H_2O 43·54 per cent. Some varieties contain sulphates of calcium, manganese, &c. as impurities.

The first of the above formulæ is analogous to those of Hydrargillite and Limonite. The others represent the crystallised mineral. If the molecule of water of crystallisation be removed by heating to about 100°, the formula becomes HBO_2, which is that of normal dry boracic acid, and this when fused is decomposed into water and B_2O_3, the so-called vitrified boracic acid, which is a very hygroscopic substance, and becomes readily rehydrated when exposed to the atmosphere. In the closed tube gives off water in quantity; on platinum wire boils up, and ultimately fuses to a colourless glass, tingeing the flame yellowish green.

Occurrence.—Found in Vulcano, in the Lipari Islands, and in the basins about the suffioni or fumaroles of the Tuscan lagoons, and in various thermal mineral waters in Europe and in California. The chief commercial supply is obtained from Tuscany by boiling down the waters of the lagoons in which the hot vapours discharge by means of the heat gathered from a number of steam jets until the solution is

sufficiently concentrated to crystallise. The proportion existing in the water as condensed does not exceed 2 per cent.

BORACITE. Stassfurtite.—*Cubic, tetrahedral.* In isolated well-developed crystals, mostly cubic and rhombic dodecahedral combinations, with replacements of one or both tetrahedra, which in the latter case are unequally developed, one series being bright and the other dull. (Figs. 202–204)

FIG. 202.

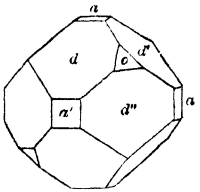


FIG. 203.

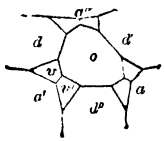
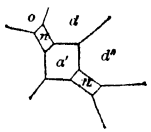


FIG. 204.



$\kappa\{111\}\frac{1}{2}(O)$, $d\{110\}\infty O$, $a\{100\}\infty O\infty$, $n\kappa\{211\}\ \frac{1}{2}(202)$, $v\kappa\{531\}\ \frac{1}{2}(5O\frac{5}{3})$. Cube faces sometimes striated, also massive. Cleavage, octahedral, very imperfect. Fracture, conchoidal. H. 7 (4·5 massive variety). Sp. gr. 2·93–2·98 (2·91 massive). Colourless, white, grey, bluish or greenish white. Lustre, sub-adamantine, vitreous. Pyro-electric and polar along the trigonal interaxes. The optical structure very complicated. Mallard considers it as indicating polysynthetic structure in the apparently simple crystals, which are made up of twelve rhombic pyramids whose apices are in a common central point, while their bases are the faces of the rhombic dodecahedron.

Composition. — $Mg_7B_{16}Cl_2O_{30} = \left\{\begin{matrix}2Mg_3B_8O_{15}\\MgCl_2\end{matrix}\right\} = \left\{\begin{matrix}6MgB_2O_4\\MgB_4O_6\\Cl_2\end{matrix}\right\}$, or Cl 7·93, Mg 2·68, MgO 26·82, B_2O_3 62·57 per cent. The actual composition found by analysis usually shows more Cl 8–8·8 per cent., and 0·4–1·66 per cent. FeO. The compact variety (Stassfurtite) contains up to

1·9 per cent. H_2O, and gives off water when heated in the closed tube; the crystals do not. Both fuse with intumescence to a white crystalline bead, colouring the flame yellowish green. The colour is more readily brought out by fusion with bisulphate of potassium and fluor spar. With oxide of copper on charcoal gives the blue flame colour of chlorine ($CuCl_2$). Completely, but very slowly, soluble in hydrochloric acid. The crystals often get moistened and dull by exposure, owing to the magnesian chloride becoming hydrated.

Occurrence.—The principal localities for crystals are in Lüneburg and Holstein, where they are found embedded in gypsum or anhydrite. The massive variety Stassfurtite is from the rock-salt bed of Stassfurt.

SUSSEXITE.—Form unknown. In fibrous masses resembling asbestus, of a pink or yellowish tint. H. 3. Sp. gr. 3·42. Lustre, silky, pearly, or like wood. Translucent in splinters, opaque in mass.

Composition.—$(MgMn)_2B_2O_5 + H_2O$, with Mn : Mg = 4 : 3, corresponding to B_2O_3 34·33, MnO 39·93, MgO 16·84, H_2O 8·90 per cent.

In the closed tube darkens and gives off water. Fuses readily to a black crystalline bead in the oxidising flame, giving the yellowish green colouration of boracic acid.

Gives the manganese reaction with nitre and soda on platinum. Soluble in hydrochloric acid, evolving a trace of chlorine.

Occurrence.—Found at Franklin, New Jersey, with the characteristic zinc and manganese minerals of that locality.

BORAX. Tincal.—*Oblique.* ∞P 87·00°, $a : b : c = 1·0997 : 1 : 0·5394$. β 73° 25′. (Fig. 205) $m'\{110\}\ \infty P$, $a\{100\}\ \infty \breve{P}\infty$, $b\{010\}\ \infty \breve{P}\infty$, $z\{\bar{1}11\}\ P$, $o\{\bar{1}12\}\ \frac{1}{2}P$, $c\{001\}\ oP$, $s\{021\}\ 2\breve{P}\infty$. In broad and short columnar crystals, similar to certain forms of augite. Cleavage, clinodiagonal perfect, prismatic less so. Fracture, conchoidal. H. 2–2·5. Sp. gr. 1·72. Colourless and transparent when pure or recrystallised: usu-

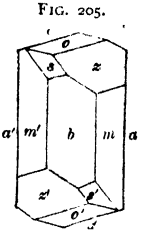
ally dull grey or dirty white and opaque. Lustre, vitreous, resinous, or earthy, also according to purity. Double refraction negative. Indices for D line, $\alpha = 1{\cdot}4668$, $\beta = 1{\cdot}4686$, $\gamma = 1{\cdot}4715$. Optic axial plane perpendicular to 010, first median line *b*, the second is in the acute angle *a*/*c* and inclined to *c*, 55° 33′ for red, and 54° 45′ for blue light, giving crossed dispersion. $2V = 39°\ 36'$, $2E = 59°\ 23'$.

Composition.—$Na_2B_4O_7 + 10H_2O = 2\begin{Bmatrix} NaBO_2 \\ HBO_2 \end{Bmatrix} + 9H_2O$, or Na_2O 16·23, B_2O_3 36·65, H_2O 47·12 per cent.

This represents the purified salt; the native kind usually contains clay and organic matter intermixed.

When heated gives off water, increasing very considerably in volume to a white spongy mass (dried borax), which by continued heating contracts and melts to a colourless glass (borax glass). The flame shows a strong yellow colouration, soluble in water, usually depositing clay or organic impurities.

FIG. 205.



Occurrence.—Occurs on the shore deposits of lakes in Tibet, whence the greater part of the commercial supply is derived; and also as very large crystals on the shores of Borax Lake, California.

Uses.—Borax is largely used by metal-workers, assayers, enamellers, and in glass and pottery manufacture, and to some extent in pharmacy. Besides the native mineral a good deal is prepared by saturating boracic acid with carbonate of sodium and crystallising.

ULEXITE. Hayesine, Natroborocalcite, Boronatrocalcite. —In nodular masses made up of fine fibres, whose crystallographic characters are undetermined. H. 1. Sp. gr. 1·65–1·85. Lustre of nodule when broken, silky. Colour, snow-white. Insoluble in cold water, and tasteless.

Composition.—$NaCaB_2O_9 + 5H_2O$, or $8H_2O$. The former

corresponds to B_2O_3 49·7, CaO 15·9, Na_2O 8·8, H_2O 25·6, and the latter to B_2O_3 43·0, CaO 13·8, Na_2O 7·6, H_2O 35·6 per cent. Most varieties contain some sulphate and chloride of sodium in intimate admixture.

When heated, gives off water, and fuses readily with intumescence to a clear glass, colouring the flame yellow, but the green colouration of boracic acid may be brought out by moistening it with sulphuric acid. It is partially soluble with decomposition in hot water, with a liberation of boracic acid, so that the constitution cannot be exactly determined.

Occurrence.—In the nitrate of soda district of Iquique, Peru, on the West Coast of Africa, in Nova Scotia, and in Nevada, in all cases in nodules associated with salt, alum, gypsum, glauberite, and other alkaline salts. The most productive localities are the South American, a considerable quantity being exported from Peru as borate of lime; the native name is Tiza.

LUDWIGITE.—In dark green or black fibrous masses. H. 5. Sp. gr. 3·95–4·01.

Composition.—$\overset{II}{R}_4Fe_2B_2O_{10} = \left\{\begin{matrix} B_2O_3 \\ Fe_2O_3 \\ 4RO \end{matrix}\right\}$ where R = Fe : Mg

Mg, varying from 1 : 3 to 1 : 5. The former corresponds to B_2O_3 16·59, FeO_3 37·91, FeO 17·06, MgO 28·44. When heated, turns red, fusing with difficulty to a black magnetic mass, soluble in acids, giving a yellow (ferric) solution.

Found in crystalline limestone at Morawitza, in the Banat, associated with magnetite.

PANDERMITE. Priceite.—Massive in granular crystalline aggregates like statuary marble. H. 3. Sp. gr. 2·48.

Composition. — $Ca_2B_6O_{11} + 3H_2O$, corresponding to B_2O_3 55·85, CaO 29·79, H_2O 14·36 per cent. Occurs in nodules in gypsum, about twenty miles from Panderma (the ancient Panorma, near Cyzicus), on the Sea of Marmora, whence it is exported for borax manufacture.

CHAPTER XIV.

CARBONATES AND NITRATES.

THE natural carbonates may be divided either into anhydrous and hydrated, or into normal, acid, and basic classes. The normal carbonates of dyad metals $\overset{II}{R}CO_3$ are exclusively anhydrous, and form a well-marked dimorphous series. Only one monad element is known as a neutral carbonate, namely sodium, which exists in the alkaline efflorescences of desert countries as an indefinite hydrate of the form $Na_2CO_3 + nH_2O$, and as a double salt with $CaCO_3$, also hydrated in Gay Lussite. Sesquicarbonate of sodium $\left\{\begin{matrix} 2Na_2CO_3 \\ H_2CO_3 \end{matrix}\right\} + nH_2O$, is the only natural acid carbonate, and with these exceptions the whole of the hydrated carbonates are basic. The existence of a carbonate containing a hexad metal aluminium (Dawsonite) has lately been established.

As regards crystalline form the anhydrous carbonates are, with one or two exceptions, either rhombohedral in the calcite series, rhombic approximating to hexagonal in dimensions in the aragonite series, or dimorphous in both series. The hydrated carbonates belong almost entirely to the oblique system.

From their method of occurrence the carbonates must be held to be of secondary origin, i.e. products of the alteration of pre-existing combinations. The most abundant of all, carbonate of calcium, is invariably produced by the action of atmospheric carbonic acid upon silicates containing calcium, and when formed is practically unchangeable, but being

easily soluble in water containing carbonic acid, it is readily moved from place to place by solution, and re-deposition without alteration; except where brought into contact with sulphuric acid, from vitriolescent pyrites, when it may be converted into gypsum. The corresponding carbonates of iron and manganese are essentially unstable minerals, and by absorption of oxygen and water pass readily into limonite and pyrolusite respectively.

The carbonates of lead and copper are in like manner produced by atmospheric action from the sulphides of those metals, and as such are commonly found in the gozzans or superficial portions of mineral veins.

I. CALCITE SERIES.

In this group are included all the normal carbonates crystallising in the rhombohedral system, which are closely isomorphous both as regards form and habit, and therefore subject to considerable variation in composition while conforming to the type $\overset{II}{R}CO_3$. The simplest and best defined members of the series—those containing only a single metallic element—are five in number, as follows:

1. Calcite, $CaCO_3$.
2. Magnesite, $MgCO_3$.
3. Dialogite, $MnCO_3$.
4. Spathic Iron Ore, $FeCO_3$.
5. Calamine, $ZnCO_3$.

Of these, however, only the first is found to approximate to the theoretical composition, the analyses of the others showing more or less of replacement of the typical metal by one or more of the same series.

The more complex members of the series which may be regarded as combinations of molecules of two or more of the simple types, are:

6. Dolomite, $\left\{\begin{matrix}CaCO_3\\MgCO_3\end{matrix}\right\}$, $\left\{\begin{matrix}m\,CaCO_3\\MgCO_3\end{matrix}\right\}$ and $\left\{\begin{matrix}CaCO_3\\n\,MgCO_3\end{matrix}\right\}$
7. Mesetin Spar, $\left\{\begin{matrix}MgCO_3\\FeCO_3\end{matrix}\right\}$, Breunnerite, $\left\{\begin{matrix}n\,MgCO_3\\FeCO_3\end{matrix}\right\}$

8. Pearl Spar, $\left\{\begin{matrix}CaCO_3\\RCO_3\end{matrix}\right\}$. R=Mg and Fe in very variable proportions.
Ankerite

9. Iron-Zinc Spar, $\left\{\begin{matrix}ZnCO_3\\RCO_3\end{matrix}\right\}$. R=Mn, Fe, Mg.

From the nature of these latter formulæ it may be imagined that any one of them may represent not a single mineral but a series, varying in physical characters according to the relative preponderance of one or other base; and this is actually the case, the varieties when sufficiently well defined receiving special names, which, however, are not of sufficient general interest to be set out at length. The most complex series of this kind are those represented by No. 9, which occur with calamine at Vieille Montagne, in Belgium.

In the last member of the series, Plumbo-calcite, calcium carbonate is combined with that of lead, which indirectly establishes the dimorphism of the latter salt, although when pure it is only found in rhombic forms.

CALCITE.—*Rhombohedral.* $R=105°\ 08'$ (varying in the minutes from 3′ to 13′), $a:c=1:0{\cdot}8543$. (Figs. 206–211) $b\{10\bar{1}0\}\infty R$, $r\{10\bar{1}1\}R$, $e\{01\bar{1}2\}-\frac{1}{2}R$, $s\{05\bar{5}1\}-5R$, $v\{21\bar{3}1\}R^3$, $t\{21\bar{3}4\}\frac{1}{4}R^3$, $w\{31\bar{4}5\}\frac{2}{5}R^2$, $\lambda\{31\bar{4}2\}R^2$. The

FIG. 206.

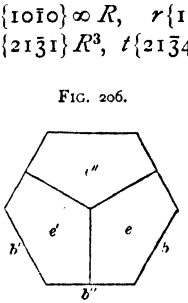


FIG. 207.

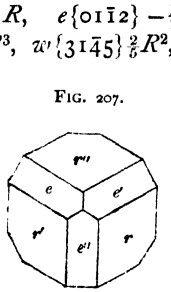
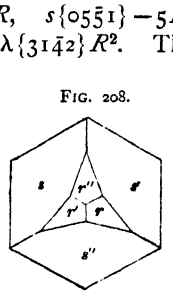


FIG. 208.



crystalline series is extraordinarily rich both in forms and combinations. Nearly 1,000 of the latter have been figured and described. They include more or less complex associations of scalenohedra and rhombohedra, with $c\{0001\}oR$,

$\{10\bar{1}0\}\infty R$, and a few secondary pyramids $\{hh2\bar{h}2i\}$ $mP2$. Of the rhombohedra, $\{01\bar{1}2\}-\frac{1}{2}R=135°$, $\{05\bar{5}4\}-\frac{5}{4}R=95°\ 30'$; $\{02\bar{2}1\}-2R=77°$, and $\{40\bar{4}1\}$ $4R=66°$, and the scalenohedra, $\{21\bar{3}1\}$ R^3, $\{31\bar{4}2\}$, R^3, and $\{21\bar{3}4\}$ $\frac{1}{4}R^3$, are the most abundant, the first, third, and fifth of these forms being as common as simple crystals. The unit form $\{10\bar{1}1\}$ R, does not usually occur alone. The habit of the crystals

FIG. 209.

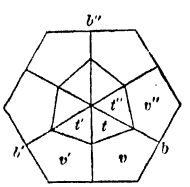


FIG. 210.

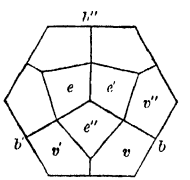
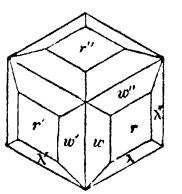


FIG. 211.



may be either columnar, tabular, in various degrees down to the thinnest hexagonal scales, rhombohedral or scalenohedral, the last two kinds being most common. Crystals having $\{01\bar{1}2\}$ and $\{21\bar{3}1\}$ as dominant forms are known in the Derbyshire lead mines as nail-head and dog-tooth spar respectively.

The faces of $\{01\bar{1}2\}$ are usually striated parallel to their inclined diagonals, while in scalenohedra and $\{11\bar{2}0\}$ the striations are parallel to the middle edges of $\{10\bar{1}1\}$.

Twins common (1) on 0001, (2) on $00\bar{1}1$, (3) on $01\bar{1}2$. In the first case the simple combinations produce by juxtaposition very symmetrical forms, as in fig. 279, *Syst. Min.*; in the second, the principal axes of the component individuals meet nearly at right angles (89° 04′), fig. 275, *Syst.*; and in the third at 127° 30′, fig. 274, *Syst.* Repeated twinning of the last kind produces two systems of striations on the faces of $10\bar{1}1$ (*Syst.* p. 172).

Cleavage, $10\bar{1}1$ highly perfect. Fracture, when not disturbed by cleavage planes—which is not a common occurrence—conchoidal. Secondary cleavage or slip faces repro-

ducing the lamellar twins on $o\bar{1}\bar{1}2$ are easily obtained in crystals by compressing them parallel to the polar edges of $10\bar{1}1$. Crystals are sometimes developed at both ends, but generally implanted and forming parts of groups in druses. Crystalline aggregates of various kinds abundant, especially in stalactitic and radiated forms, and in finely granular masses and pulverulent crusts. In all cases the crystalline structure is recognisable, even the fine powder known as rock milk, being resolved into crystalline grains by the microscope. H. 3. Sp. gr. 2·6–2·8. Colourless and perfectly transparent in the purest variety, but generally more or less translucent, with a slight tinge of colour, usually grey, bluish, or greenish; also opaque, white, or strongly coloured by foreign matters. Lustre, vitreous, pearly on opaque varieties, especially on oR. Double refraction, strong: negative. Indices for D line, $\omega = 1{\cdot}659$, $\epsilon = 1{\cdot}486$.

Composition.—$CaCO_3$, carbonate of calcium (carbonate of lime), or calcium oxide (lime) 56, carbonic acid 44 per cent. In most instances the lime is in part replaced by the isomorphous oxides of magnesium, manganese, iron, or zinc. The coloured varieties often contain mechanical impurities, such as native copper or silver in Lake Superior crystals, orpiment in those from Hungary, clay, cinnabar, chlorite, &c. The so-called crystallised sandstone of Fontainebleau consists of calcite rhombohedra, containing a considerable proportion of quartzose sand.

When heated decrepitates, and loses carbonic acid at a red heat, caustic lime being produced, which emits a bright light when strongly heated, and is alkaline in reaction to test-paper when moistened. Soluble with effervescence in hydrochloric and other mineral acids; also in acetic acid; the solution when containing iron usually being of a yellow tinge. Varieties containing manganese, zinc, or lead show the reactions of these metals.

Occurrence.—Abundant in all limestone regions, being especially common as a deposit from water in caverns and

in veins. The largest and finest transparent crystals are brought from Iceland, whence they are known as Iceland spar, where they occur in volcanic rocks. The crystals, often of enormous size, are usually covered externally with stilbite, and are doubtless derived from the action of water upon calcareous silicates. The mines of Lake Superior, Derbyshire, and Northumberland, Andreasberg and Freiberg, are among the other more important localities.

MAGNESITE. Bitter Spath.—*Rhombohedral. R* 107° 10′ to 30′; for the latter, $a : c = 1 : 0{\cdot}809$. The crystals of a rhombohedral or prismatic habit are rare; usually granular, crystalline, or massive. Cleavage, rhombohedral, perfect. H. 4–4·5. Sp. gr. 2·9–3·1. Colourless and translucent, with strong vitreous lustre in some crystallised kinds, but usually opaque white or variously tinted with yellow, brown, or grey.

Composition.—$MgCO_3$, or magnesia 48·73, carbonic acid 51·27 per cent. The crystallised varieties vary from the type composition by the partial substitution of iron or manganese for magnesium, and are sometimes distinguished as magnesite spar, the compact kind being known as magnesite proper. This sometimes approximates to perfect purity, but often contains silica in the soluble state, which under certain conditions passes into a mixture of opal or amorphous silica and magnesite, forming the substance called giobertite. Infusible, but when strongly heated is converted into caustic magnesia, giving a rose-coloured frit with cobalt solution. Soluble in hydrochloric acid, but less readily than calcite. The mineral must be finely powdered and heat applied. Not acted upon by acetic acid.

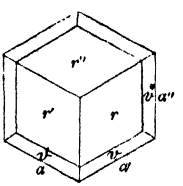
Occurrence.— In crystals in talcose schist, and occasionally in beds at St. Gothard and various localities in Tyrol and Styria, Snarum in Norway, and Vermont. Also in hexagonal prisms and parallel fibrous aggregates.

Uses.—Magnesite is occasionally used as a refractory ma-

terial for furnace building in metallurgical works, and for the production of Epsom salts by dissolving the pure mineral in sulphuric acid, and crystallising. It is essentially a product of metamorphic action, being chiefly found in association with talcose schist, and serpentine or other rocks containing magnesian silicates.

SPATHIC IRON ORE. Siderite, Chalybite, Spatheisenstein, Stahlstein.—*Rhombohedral.* R 107°, $a : c = 1 : 0{\cdot}818$. (Fig. 212) $r\{10\bar{1}1\}$ R, v $\{21\bar{3}1\}$ R^3, $a\{11\bar{2}0\}\infty P2$. Crystals usually rhombohedra, often with strongly curved faces. Cleavage, rhombohedral, perfect. H. 3·5–4·5. Sp. gr. 3·7–3·9. Colour, pale yellowish grey, or bluish when fresh, but becoming darker or brown by exposure. Prismatic crystals sometimes banded concentrically in different colours. Lustre, pearly; slightly translucent. Usually found in crystalline aggregates, which are coarsely foliated, radiated, or finely granular in structure, or in apparently amorphous nodules, known as clay ironstone or *spherosiderite.* The latter term is, however, more properly applied to the spherical varieties with radiated structure.

FIG. 212.



Composition.—$FeCO_3$. Ferrous carbonate with ferrous oxide, 62; carbonic acid, 38 per cent.; the corresponding amount of metallic iron being 48·2 per cent. This composition is not realised on the large scale, as the mineral invariably contains calcium, magnesium, or manganese, in partial replacement of iron, besides being mechanically mixed with quartz, copper and iron pyrites, and galena, among other minerals. The nearest approach to the theoretical composition is observed in crystals deposited in hollows in basalt, which sometimes contain up to 60 per cent. FeO. Infusible, decrepitates when heated, and is converted into magnetic oxide. The particles retain their form as cleavage rhombohedra, but turn black and affect

the magnetic needle. With borax and salt of phosphorus give the reaction of iron; and with soda, as a rule, that of manganese. Slowly soluble in hydrochloric acid, with effervescence. When containing manganese, rendered magnetic by calcination, and evolves chlorine on solution in the same acid.

The purer varieties of spathic iron ore and those rich in manganese are especially valued for the production of the highest classes of malleable iron and steel, and the manganesiferous alloys known as spiegeleisen and ferro-manganese. The latter kind, which is usually largely crystalline in structure, and associated with a small proportion of metallic sulphides, especially copper pyrites, is found in the Siegen district in Prussia, and in the Brendon Hills in Somersetshire, in veins traversing strata of Devonian age, and in the neighbourhood of Irun, in Spain, in granite ; the proportion of manganese varying from 5 to 9 per cent. The variety without or poor in manganese is generally finely crystalline or granular, and of a lower lustre than the former. The spathic ores of the Perran district in Cornwall, and more especially those of Eisenerz in Styria, and other localities in Carinthia, and the Eastern Alps, are of this kind. The Erzberg of Eisenerz, a large bed about 500 feet thick, forming an arched capping to a hill of slate and limestone strata of probably Silurian age, is the largest known deposit of this ore.

The following are the average contents of the two important metals in the ores of different districts :

		Per cent.		Per cent.
Weardale, Durham . . .	Iron	38·56	Manganese	1·86
Eisenerz, Styria	„	41·51	„	2·37
Müsen, Siegen	„	37·31	„	7·31
Brendon Hills, Somerset .	„	34·65	„	9·73

Clay iron ores are found in spheroidal or flattened

nodules, occasionally united into irregular beds in the shales of the coal measures, and also in those of Wealden and other argillaceous strata, but less abundantly. When recently mined they are generally of a dull bluish grey; but by exposure to the weather change to a rusty brown, like spathic ores. When broken the nodules sometimes contain a fossil plant or animal as a central nucleus, and are often traversed by radiating fissures, which are, as a rule, filled with calcite, wholly or in part. In the latter case the hollows are lined with crystals of calcite, pyrites, blende, and other minerals. It is in hollows of ironstone nodules of this kind, which are called Septaria, that the acicular crystals of Millerite are found with Hatchettine (native paraffin or mineral tallow) in parts of the South Wales coal-field. In composition they may be regarded as carbonates of iron, containing very little manganese, but more foreign matter than the crystallised varieties, though there is considerable variation in this respect; the best kinds, such as those of South Staffordshire and the West Riding of Yorkshire, being of high quality and containing but little sulphur or phosphorus, while others, such as the stratified ores of the oolitic districts of Cleveland, are notably inferior to the preceding.

Black band ironstone is a variety of compact ferrous carbonate, mixed with sufficient carbonaceous matter to burn readily when ignited, so that it can be calcined without additional fuel. It is found principally in the western and central coal-fields of Scotland, in beds which appear in some cases to be local modifications of cannel coal seams, and in North Staffordshire.

Although nodular ironstones are often of good quality, they are expensive ores to use on account of the difficulty of mining, a large amount of shale having to be removed for every ton of ore raised, and the percentage of iron is low, not exceeding 30 to 35 per cent. on the average, so that their use is becoming restricted, except where they can be

worked together with a coal seam in one excavation. The stratified ores of Cleveland and Northamptonshire, on the other hand, being very readily mined or quarried, are extending in use, forming the principal supply to furnaces, often at a considerable distance, in the coal-producing districts.

	Iron.	Lime.	Sulphur.	Phosphorus.	Insoluble: clay and silica.
South Staffordshire, best . .	36·6	1·00	0·15	0·03	16·00
North Staffordshire, blackband .	36·4	2·41	0 20	0·40	2·27
Cleveland, stratified . . .	34·5	0·58	0·05	1·90	—

DIALOGITE. Rhodochroite, Manganese Spar.—*Rhombohedral.* R 106° 51′ to 107°; for the former $a : c = 1 : 0{\cdot}821$. Usually in rhombohedral and prismatic forms, which are small and often aggregated; and with curved faces in the rhombohedral form, like those of other members of the group. Cleavage, rhombohedral. Also in reniform, fibrous, platy, and granular aggregates; sometimes stalactitic. H. 3·5–4·5. Sp. gr. 3·5–3·6. Lustre, vitreous to pearly, translucent. Colour varying from pale pink to deep rose-red, which becomes duller by exposure, ultimately passing into brown by the higher oxidation of the manganese.

Composition.—$MnCO_3$, or manganous oxide (MnO) 61·74, carbonic acid 38·26 per cent. The nearest approach to this is found in the dark-coloured variety from Vieille in the Pyrenees, containing 97·1 per cent. $MnCO_3$, but generally a larger proportion of the manganese is replaced by Fe, Ca, and Mg, MnO ranging from 46 to 57 per cent.

Decrepitates when heated, and turns green, grey, or black, according to the amount of iron present, the residue giving a green colouration with cobalt solution; with borax gives the violet manganese colour. Slowly soluble in hydrochloric acid in the cold, and more readily when warmed.

Occurrence.—It is a somewhat rare mineral, usually accompanying silver ores in veins, and found principally at Freiberg, Kapnik, Nagyag, and in the Mexican silver mines. Large transparent rhombohedra have been found with fahlerz

at Buckskin Gulch, Colorado. The colour being fugitive in direct sunlight, specimens should be kept in the dark.

CALAMINE. Zinc Spar, Smithsonite, Galmei.—*Rhombohedral.* R 107° 40′, $a : c = 1 : 0{\cdot}806$. (Figs. 213, 214) $-\frac{1}{2}R$, $f\{02\bar{2}1\} - 2R$, $x\{07\bar{7}2\} - \frac{7}{2}R$.

FIG. 213.

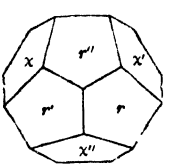
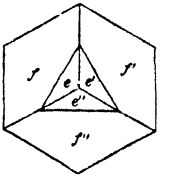


FIG. 214.



Crystals usually rhombohedra, of different values, analogous to those of dolomite but rarely of large size, usually in groups, forming reniform or botryoidal masses, which are the most characteristic methods of occurrence; also spongy or cellular, and at times in impalpable masses, without definite crystalline structure, like chalk or limestone in texture; also pseudomorphous after fluor spar, calcite, and fossil corals. Cleavage, rhombohedral. H. 5. Sp. gr. 4–4·5. Rarely colourless, and transparent, or black; usually light grey, yellow, buff-coloured, or brown, translucent to opaque. Lustre, vitreous, resinous, or pearly.

Composition.—$ZnCO_3$, or zinc oxide 64·8 (metallic zinc 52), carbonic acid 35·2 per cent., but, like the allied species, varies considerably by partial substitution of calcium, magnesium, iron, or manganese, and in a few cases of cadmium. The massive varieties often contain clay, silica, and ferric acid as mechanical impurities.

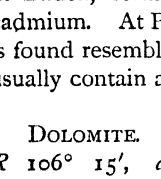
When heated, carbonic oxide is driven off and the residue behaves like oxide of zinc, the cadmiferous varieties giving the red iridescent fringing of cadmium oxide to the incrustation formed on charcoal. Soluble in hydrochloric acid with effervescence, and also in potash lye.

Occurrence.—Found with silicate of zinc, blende, and

lead ores in many districts, especially in deposits in limestone and dolomitic strata, which being essentially products of atmospheric alteration rarely extend to any great depth, the zinc ore if persistent changing into blende. As a rule they are exceedingly irregular, and appear to be in many instances actual pseudomorphs of limestone or dolomite beds. The famous Kelmisberg, or Vieille Montagne, between Verviers and Aachen, is of this character, being a basin or trough of dolomite irregularly penetrated by calamine, and similar carbonates containing zinc, iron, manganese, and calcium, in spongy or drusy masses. The mountain limestone mines of the Mendip Hills, Derbyshire, and Northumberland formerly produced some quantity, but are now mainly exhausted; as are the similar deposits in Silesia. There are irregular deposits in the north of Spain near Santander, in the south near Carthagena, in the island of Sardinia, and at Laurium in Greece. Calamine is one of the best zinc ores, giving a higher quality of metal than blende, and requiring less fuel for reduction. Much of the present supply is, however, very low in produce, 10 to 20 per cent., so that a mixture with blende is often necessary. The canary-yellow variety from Wiesloch, in Baden, contains as much as 3 per cent. of oxide of cadmium. At Poppelsdorf, in Belgium, a dull black variety is found resembling a limestone. The blue and green kinds usually contain a little copper.

DOLOMITE. Bitter Spar.—*Rhombohedral, tetartohedral.* R 106° 15′, $a : c = 1 : 0{\cdot}832$. (Fig. 215) $r\{10\bar{1}1\}R$, $o\{0001\}oR$. Crystals rhombohedral, with curved faces, often of considerable size; also in druses and irregular aggregates, and in crystalline concretions of stalactitic, spheroidal, and other forms. Compact in rock and masses, sometimes slaty or finely granular.

FIG. 215.



Cleavage, $10\bar{1}1$; cleavage planes usually curved. H. 3·5–4·5. Sp. gr. 2·85–2·95. Usually white,

or some pale shade of yellow or brown; blue, green, or red less common. Lustre, nacreous, translucent.

Composition.—$\left\{\begin{matrix}CaCO_3\\MgCO_3\end{matrix}\right\}$ or lime 30·43, magnesia 21·74, carbonic acid 47·83 per cent.; but usually containing some iron and manganese.

When heated becomes caustic, and gives the magnesia reaction with cobalt solution, if not containing much iron. Not so easily soluble in hydrochloric acid as calcite, and insoluble in acetic acid.

Besides the above composition, which is that of normal dolomite, many other varieties are described in which the molecules of the constituent carbonates are to each other in different proportions. When lime predominates, the substance passes into a dolomitic calcite, and in such cases it may be resolved into a mixture of normal dolomite and calcite by acetic acid, in which the latter is soluble, but not the former.

Occurrence.—Abundant in mineral veins, especially with copper and lead ores; and also forming rock masses, often of considerable extent. Among the largest developments are the dolomitic mountains of the Eastern Alps, and in England the Permian magnesian limestone, which extends from Nottinghamshire to Durham, on the eastern flank of the northern coalfields. Much of it is a good building stone, but it is not well suited for lime-burning for agricultural purposes. At Marsden, near Sunderland, a finely laminated variety occurs which is slightly flexible when freshly raised. It is also used on a large scale for making Epsom salts.

The tetartohedrism of dolomite is evidenced, not only by the occasional appearance of rhombohedra of the second and third orders $\kappa\pi\{hh2hi\}$ and $\kappa\pi\{hkli\}$ in very subordinate combination, but more generally by the asymmetric position of the figures produced by corroding the faces of $\{10\bar{1}1\}$ with weak acid. The contrasted direction of these figures upon the same face also shows that the apparently simple crystals are often complete penetration twins of right and

left handed individuals. Similar figures are obtained in all the other rhombohedral carbonates with the exception of calcite, although no tetartohedral forms are known in these as yet. Calcite, on the other hand, gives monosymmetric corrosion figures, and is prominently hemihedral in all its forms. Tschermak, to whom the above observations are due, considers calcite and dolomite not to be properly isomorphous, the correspondence in form being accompanied by essential divergence in structure. The relation between these species is, in fact, similar to that subsisting between hematite and ilmenite.

Pearl spar, or brown spar, is a dolomite containing more or less iron, which is usually light-grey or white, with a pearly lustre when fresh, but by exposure to the air turns brown. It is a common mineral in lead-bearing veins at Alston Moor, Nenthead, &c. *Ankerite* or *Rohwand* of the miners is a similar mineral, which occurs with spathic iron ore in Styria, and is occasionally used as a flux in iron smelting.

Mesitin spar and *Breunnerite* are isomorphous combinations of ferrous and magnesium carbonates, crystallising in rhombohedra, and generally resembling dolomite in appearance. The former occurs at Traversella, in Piedmont, in large pearly rhombohedra and lenticular or rosette-like combinations, of a grey or yellowish-grey colour, and has the composition $\left\{\begin{matrix}MgCO_3\\FeCO_3\end{matrix}\right\}$, or magnesia 20, ferrous oxide 36, and carbonic acid 44 per cent. Breunnerite contains more magnesia and less iron, or generally $\left\{\begin{matrix}nMgCO_3\\FeCO_3\end{matrix}\right\}$. It is found in detached rhombohedra, usually of a brown colour, in clay slate at various places in Tyrol, Switzerland, and the Eastern Alps.

Plumbo calcite is a variety of calcite containing some carbonate of lead, the proportion of the latter varying from 2·34 to 2·75 per cent. The sp. gr. is higher than that of calcite—2·77–2·92. When heated it turns red, from the

production of oxide of lead, and on charcoal with soda gives a bead of lead and a yellow incrustation. It has been found at Leadhills and Wanlockhead in Scotland, and at Bleiberg in Carinthia.

II. ARAGONITE SERIES.

This includes the following species, isomorphous in the rhombic system.

1. Aragonite, $CaCO_3$.
2. Witherite, $BaCO_3$.
3. Strontianite, $SrCO_3$.
4. White Lead Ore, $PbCO_3$.
5. Alstonite, $\left\{\begin{matrix}BaCO_3\\CaCO_3\end{matrix}\right\}$, and $\left\{\begin{matrix}n BaCO_3\\n CaCO_3\\SrCO_3\end{matrix}\right\}$.
6. Tarnowitzite, $\left\{\begin{matrix}n CaCO_3\\PbCO_3\end{matrix}\right\}$.
7. Iglesiasite, $\left\{\begin{matrix}6 PbCO_3\\ZnCO_3\end{matrix}\right\}$.

ARAGONITE.—*Rhombic.* ∞P 116° 10′, $\breve{P}\infty$ 108° 26′, $a : b : c = 0{\cdot}623 : 1 : 0{\cdot}721$. (Fig. 216) $m\{110\}\infty P$, $p\{111\}P$,

FIG. 216.

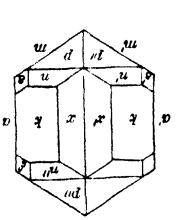


FIG. 217.

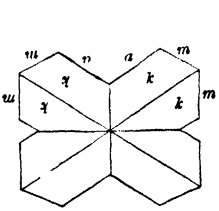
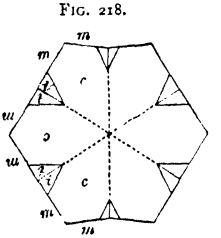


FIG. 218.



$n\{122\}\breve{P}2$, $s\{121\}\breve{P}2$, $x\{012\}\frac{1}{2}\breve{P}\infty$, $k\{011\}\breve{P}\infty$, $i\{021\}2\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$, $c\{001\}oP$. Twins common on 110, both as hemitropic and complete penetration groups (figs. 217, 218). In the latter, when the re-entering angles at *i* are suppressed, the form resembles a simple hexagonal prism; but the compound structure is rendered apparent by the striations on {001}, which are parallel to *a* in each individual. Usually the twinning is irregularly repeated with parallel individuals of different thicknesses. Crystals

usually short, prismatic, such as fig. 216, pointed, from the prevalence of acute pyramids and brachydomes, somewhat resembling the acute scalenohedra of calcite. Also in fibrous, radiated, granular, stalactitic, spheroidal, and curved coral or plant-like forms (*flos ferri*). Cleavage, 010 imperfect. Fracture, conchoidal, uneven. H. 3·5–4. Sp. gr. 2·9–3. Double refraction negative, very strong. First median line c, $2V = 17° 50'$, $E = 30° 14'$. Optic axial plane, 100. Indices for D line, α 1·5301, β 1·6816, γ 1·6859.

Composition.—$CaCO_3$, or the same as calcite. Generally with variable quantities (from a mere trace up to 2·4 per cent.) of carbonate of strontium. Also small amounts under 0·8 per cent. of water and ferric hydrates.

Heated in the closed tube it swells and breaks into a coarse powder, the specific gravity being reduced to 2·7, or that of calcite. The powder, if containing strontia, gives a crimson flame colouration. In other respects it behaves like calcite.

Occurrence.—Principally in hollows and druses in marls, limestone, basalts, or other rocks, and in mineral veins, especially those of iron ore. The original localities are near Valencia in Aragon. Fine groups in pyramidal form are found in the hematite mines of Cleator, in Cumberland; and the coral-like variety (*flos ferri*) at Eisenerz, in Styria. The basalts of the Upper Elbe valley, in Bohemia, are also rich in crystallised forms. The pisolitic variety *Sprudelstein*, an aggregate of small polished spheroids with fibrous radiated structure, is deposited by the hot springs of Carlsbad, in Bohemia.

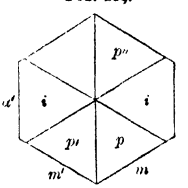
The convertibility of aragonite into calcite by heat was first demonstrated by Gustav Rose, who also showed that when carbonate of calcium is precipitated from solution by alkaline carbonates in the cold it has a lower specific gravity than when the reaction takes place at the boiling point of the solution, the precipitate consisting in the first

instance of microscopic rhombohedra of calcite, and in the latter of prisms of aragonite.

Tarnowitzite is a variety of aragonite containing 3·86 per cent. of carbonate of lead.

WITHERITE.—*Rhombic.* Z 110° 49′, ∞P 118° 30′, $a : b : c = 0{\cdot}595 : 1 : 0{\cdot}7413$. (Fig. 219) $m\{110\}\infty P$, $p\{111\}P$, $i\{021\}2\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$. Crystals nearly hexagonal in form, but doubtful if simple, being optically compound penetrating forms of three or six individuals, according to Senarmont. Cleavage, 110 imperfect. Usually in spheroidal or compact aggregates of a radiated or columnar texture. Fracture, uneven. H. 3–3·5. Sp. gr. 4·2–4·3. Colourless, but generally light grey or white ; streak, white. Transparent, with vitreous lustre, but generally translucent, with a greasy lustre on fracture. Crystals often with a dull outer crust. Double refraction negative. Index α 1·740 ; optic axial plane, 010 ; first median line c ; $2E = 26°\ 30'$.

FIG. 219.



Composition.—$BaCO_3$, or baryta (BaO) 77·67, carbonic acid 22·33 per cent., generally with some carbonate of strontium or sulphate of barium, the former in isomorphous, the latter in mechanical mixture.

When heated in the forceps, colours the flame pale yellowish green and melts to a clear glass, which becomes opaque on cooling ; on charcoal effervesces and becomes caustic baryta, which, by an addition of soda, melts and is absorbed. Soluble in hydrochloric acid if not too concentrated, but effervesces less violently than calcite.

Occurrence.—The principal localities are in the lead mines of the north of England, especially at Fallowfield, near Hexham, where it is mined in considerable quantity, being employed as a source of barium salts, such as the chloride and nitrate.

STRONTIANITE.—*Rhombic.* ∞P 117° 19′, $a : b : c =$ 0·610 : 1 : 0·724. (Figs. 220, 221) $m\{110\}\infty P$, $p\{111\}P$, $o\{112\}\frac{1}{2}P$, $k\{011\}\breve{P}\infty$, $i\{021\}2\breve{P}\infty$, $z\{041\}4\breve{P}\infty$, $q\{061\}6\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$, $c\{001\}oP$. Crystals very similar to those of aragonite, especially in the twinning on

FIG. 220.

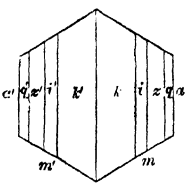
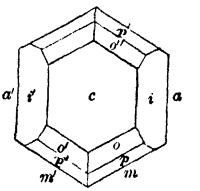


FIG. 221.



110, with innumerable parallel repetitions, producing an exceedingly complex structure; also in fibrous and granular aggregates. Cleavage, 110 somewhat perfect. Fracture, uneven. H. 3–3·5. Sp. gr. 3·6–3·8. Colourless or tinged with pale green, yellow, or brown; streak, white. Transparent to translucent. Lustre, vitreous on crystal faces; resinous or greasy on fractures.

Composition.—$SrCO_3$, or strontia (SrO) 70·27, carbonic acid 29·73 per cent.; some of the base usually replaced by lime (up to 3 or 4 per cent.).

In the forceps fusible at the edges, afterwards swells up to a cauliflower-like mass, colouring the flame crimson, and becomes caustic, emitting a brilliant light. The mass is afterwards alkaline to test-paper. Soluble in hydrochloric acid, with effervescence; the solution evaporated to dryness gives a residue of $SrCl_2$, which when dissolved in alcohol burns with a crimson flame. Double refraction negative, but from the very fine twinned structure it is almost impossible to obtain plates that show the interference figures singly. Transparent plates when held before a bright light show a great range of diffraction spectra.

Occurrence.—A rare mineral, principally from the lead

mines of Strontian in Argyleshire, in granite; also at a few places in Saxony, the Hartz; and near Hamm, in Westphalia, in veins in cretaceous strata, which are now mined on the large scale as a source of caustic strontia, which is used for recovering sugar from molasses in refining. In the United States it has been observed in geodes in limestones.

WHITE LEAD ORE. Ceruse, Cerussite, Bleispath. — *Rhombic.* ∞P 117° 14′, $a : b : c = 0{\cdot}610 : 1 : 0{\cdot}723$. (Fig 222) $m\{110\}\infty P$, $p\{111\}P$, $k\{011\}\breve{P}\infty$, $i\{021\}$, $2\breve{P}\infty$, $a\{010\}\infty\breve{P}\infty$, $b\{100\}\infty\breve{P}\infty$. Forms like those of aragonite. Twins very common on ∞P, usually in intersecting cruci-

FIG. 222.

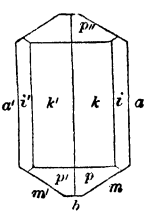
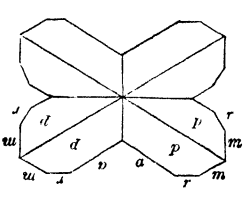


FIG. 223.



form, or stellar forms. Cleavage, 110 and 021 neither very distinct. Fracture, conchoidal; very brittle. Also in stalactitic and various crystalline aggregates; massive, and earthy, occasionally as a cementing material of sandstone. H. 3–3·5. Sp. gr. 6·4–6·6. Lustre, adamantine, inclining to metallic when slightly tarnished. Colourless and transparent opaque, and dull in compact kinds. Double refraction negative. Indices for D line, $\alpha = 1{\cdot}804$, $\beta = 2{\cdot}076$, $\gamma = 2{\cdot}078$. Optic axial plane, 010. Median line axis c, $2V = 8°\ 14'$, $2E = 17°\ 08'$.

Composition.—$PbCO_3$, or protoxide of lead (PbO) 83·53 (metallic lead 77·54), carbonic acid 16·48 per cent. When massive usually contains some silver. Heated decrepitates, turns yellow and red, yielding ultimately a globule of lead on charcoal. Soluble in nitric acid with effervescence.

Occurrence.—In most lead mines as a product of the alteration of galena, the change being sometimes effected without loss of the original form. Generally the crystals are developed upon the faces of galena crystals or in druses with malachite and similar secondary minerals. The finest crystals are from near Liskeard, Cornwall; Mies, in Bohemia; Phœnix mines in Pennsylvania; Lamotte, in Missouri; and the Lead Hills mines. At Leadville, Colorado, it forms the chief ore in large contact deposits between porphyry and limestone, in places up to 80 feet thick.

Carbonate of lead may be reconverted to sulphide of lead by the action of sulphuretted hydrogen, crystals often being tarnished with a film of sulphide, in which case they are remarkable for their high lustre. It is supposed to originate from galena by the action of water, containing $CaCO_3$ in solution upon $PbSO_4$, the first product of the oxidation of PbS. The earthy variety is formed by the action of the air upon metallic lead or oxidisable lead products, such as old mine waste or slags, and in this way large quantities have been formed from the remains of Roman and other ancient mine workings in Derbyshire; the Mendip Hills, Carthagena in Spain, and elsewhere. Such ores are usually smelted at a low produce, as, in spite of their comparatively high density, they are so brittle as to be in great part floated away and lost if subjected to crushing and dressing processes like galena. When sufficiently pure—i.e. free from copper and iron compounds—natural mixtures of white lead ore and silica are sometimes used as pottery glazes. An ore of this kind is found at Mechernich, in the Eifel.

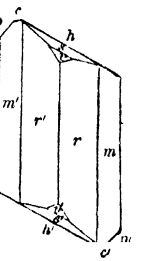
ALSTONITE.—*Rhombic*, and nearly similar in dimensions to Witherite. Crystals resembling hexagonal pyramids. Cleavage, 110 and 010 not very distinct. H. 4·45. Sp. gr. 3·65–3·76. Colourless or greyish white. Lustre, vitreous, translucent. Fracture, granular, uneven.

Composition.—$BaCO_3 + CaCO_3$, or $BaCO_3$ 66·33, $CaCO_3$ 33·67 per cent. $SrCO_3$ may be present to the maximum of 6·66 per cent., in which case the formula becomes $7BaCO_3 + 7CaCO_3 + SrCO_3$. Not so readily fusible as Witherite, but in other respects behaves similarly.

Occurs with Witherite at Fallowfield and at Bromley Hill, Alston.

BARYTO CALCITE.—*Oblique.* ∞P 84° 52′, $a : b : c = 0{\cdot}974 : 1 : 0{\cdot}8468$. $\beta = 69°\ 30'$. (Fig. 224) $m\{110\}\infty P$, $r\{130\}\infty P3$, $s\{111\} - P$, $v\{121\} - 2P2$, $h\{101\} - P\infty$, $p\{\bar{1}01\}P\infty$, $c\{001\}oP$. Cleavage, 111, $\bar{1}01$, the first most perfect. In other physical characters and composition similar to Alstonite. Found at Alston, in Cumberland.

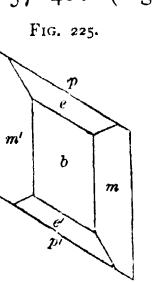
FIG. 224.



HYDRATED CARBONATES.

SODA. Natron, Carbonate of Soda.—*Oblique.* ∞P 79° 41′, $a : b : c = 1{\cdot}4186 : 1 : 1{\cdot}4828$. $\beta = 57°\ 40'$. (Fig. 225) $e\{110\}\infty P$, $m\{111\} - P$, $a\{101\} - P\infty$, $p\{100\}\infty P\infty$, $b\{010\}\infty P\infty$. Cleavage, 100, 010, neither perfect. H. 1–1·5. Sp. gr. 1·4–1·5. The natural mineral occurs as a pulverulent incrustation or efflorescence, which is white, grey, or yellowish, and has a strongly alkaline taste.

FIG. 225.



Composition.—$Na_2C_2O_3 + 10H_2O$, or soda (Na_2O) 21·68, carbonic acid 15·38, water 62·94 per cent.

Usually mixed with sulphate and chloride of sodium, the purest natural specimens rarely containing more than 75 per cent. of carbonate of sodium in water of crystallisation, and subsequently, when dehydrated, fuses readily, colouring the flame yellow; the charcoal, when saturated, giving the

reaction of sulphur, with a silver plate in most instances. Soluble in water with alkaline reaction, and with effervescence in acids.

Occurrence.—Occurs very commonly in desert regions or in countries without summer rains as a surface efflorescence, or mixed with the soil to some depth.

The western valleys of North America and the basin of the great Salt Lake are more or less characterised by this substance in the so-called alkali flats ; it also occurs in the Natron Lakes of Upper Egypt and in Western India.

By exposure to the air soda crystals become opaque, losing water, and change into *Thermonatrite*, $Na_2CO_3 + H_2O$, which is rhombic. (Fig. 226) $a\{010\}\infty\breve{P}\infty$, $o\{011\}\ \breve{P}\infty$, $r\{012\}\ \frac{1}{2}\breve{P}\infty$, $c\{001\}oP$, $p\{111\}P$, $d\{120\}\infty\breve{P}2$.

FIG. 226.

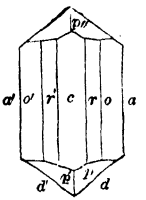
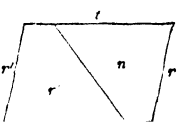


FIG. 227.



TRONA. Urao.—*Oblique.* $a : b : c = 2{\cdot}81 : 1 : 2{\cdot}99$. $\beta = 76° 45'$. (Fig. 227) $t\{001\}oP$, $r\{100\}\infty\breve{P}\infty$, $n\{111\}-P$. Crystals elongated parallel to *b*. Usually in columnar aggregates. Cleavage, 100. H. 2·5. Sp. gr. 2·1–2·2. Colourless, white or yellowish. Lustre, vitreous, translucent. Taste, alkaline.

Composition.—$Na_4C_3O_8 = \left\{\begin{matrix}2Na_2C_2O_3\\H_2CO_3\end{matrix}\right\}$ with two, three, or four equivalents of water. The first of these corresponds to soda 40, carbonic acid 42·58, water 17·42. Gives off water in the closed tube, does not melt in water of crystallisation, otherwise behaves like soda.

Occurrence.—Found in the Natron Lakes of Egypt, in Fezzan, New Granada, Lagunilla, and India. In Fezzan

the compact kind is used as a building stone, the country being nearly rainless.

GAYLUSSITE. Natrocalcite. — *Oblique.* ∞P 68° 51′, $a : b : c = 1{\cdot}4895 : 1 : 1{\cdot}444$. $\beta = 78° 27'$. Crystals columnar, elongated parallel to *a*, occurring isolated in clays and marls. Cleavage, 110 imperfect. Fracture, conchoidal. H. 2·5. Sp. gr. 1·95. Translucent; lustre, vitreous, colourless or white.

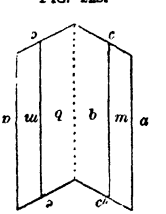
Composition.—$Na_2CaC_2O_6 + 5H_2O = \left\{\begin{matrix} Na_2CO_3 \\ CaCO_3 \end{matrix}\right\}, 5H_2O$, or Na_2O 20·95, CaO 18·92, CO_2 29·71, H_2O 30·42 per cent.

Decrepitates in the closed tube, giving off water at 100° Cent. Fusible in charcoal to an opaque bead, which by stronger heating loses its fusibility. Decomposed by cold water, especially when previously dehydrated, soda going into solution and $CaCO_3$ remaining undissolved.

Occurrence.—Found at Lagunilla in New Granada, and in salt lakes in Nevada. Small pseudomorphs in calcite after this mineral are found at Sangershausen in Thuringia, and in the alluvial soils of Schleswig and East Friesland, and are known as 'fossil barleycorns.' It is not, however, certain whether the original mineral was Gay Lussite or celestine.

MALACHITE. — *Oblique.* ∞P 104° 20′. $\beta = 61° 50'$. (Fig. 228) $m\{110\} \infty P$, $a\{100\} \infty \breve{P}\infty$, $b\{010\} \infty \breve{P}\infty$, $c\{001\}$. Twin-plane 100. Individual crystals microscopically small, usually in fibrous aggregates more or less spheroidal in arrangement, producing botryoidal and reniform masses often of considerable size. Also as pseudomorphs after copper, copper pyrites, ruby copper ore, copper-glance, and other copper ores, as well as after calcite, calamine, and white lead ore. Cleavage, 001, 010, very perfect. Fracture, granular or splintery. H. 3·5–4. Sp. gr. 3·7–4·1. Colour, emerald-green, grass-

FIG. 228.



green, verdigris-green, to nearly black; streak, pale green. Lustre of crystals, vitreous, of aggregates silky. Optic axial plane, 010. First median line makes an angle of 85° 20′ with 001.

Composition.—$Cu_2CO_4 + H_2O = \left\{\begin{matrix} CuCO_3 \\ H_2CuO_2 \end{matrix}\right\}$, or CuO 71·95, carbonic acid 19·90, water 8·15 per cent.; metallic copper, 57·45 per cent.

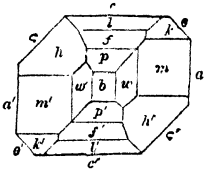
In the closed tube gives off water and carbonic acid, leaving a black residue of CuO. On charcoal melts, and is reduced to a malleable bead of copper, soluble in hydrochloric acid with effervescence, and in ammonia.

Occurrence.—Malachite is the most stable product of the oxidation of copper ores, and is commonly found near the surface in veins carrying these minerals. The largest masses have been obtained at Nischne Tagilsk in the Ural, and in the Australian and Chilian copper mines; but in smaller examples it is found in almost every copper mining district in the world. At Alderley Edge, in Cheshire, it is found as the cementing material of a sandstone, and is extracted by solution with acid. As a copper ore it is of great value, being especially useful in certain of the processes of smelting sulphuretted ores as an oxidising agent, apart from its high produce for copper. Large quantities were formerly sent from South America and Australia, but of late years the supply has almost ceased. The poorer kinds are not very easy of treatment on account of the difficulty of concentrating them to a fair percentage by mechanical means. The large and finely variegated specimens command high prices for ornamental purposes, being cut into vases and slabs of various kinds, the latter being used either solid or as veneers with the pattern matched over extended surfaces.

AZURITE. Blue Carbonate of Copper, Kupferlasur, Chessylite.—*Oblique.* ∞P 99° 32′, $a : b : c = 0{\cdot}880 : 1 :$

0·847. $\beta = 87° 39'$. (Fig. 229) $m\{110\}\infty P$, $k\{111\}-P$, $h\{\bar{1}11\}P$, $w\{120\}\infty \breve{P}2$, $l\{023\}\frac{2}{3}\breve{P}\infty$, $f\{011\}\breve{P}\infty$, $p\{021\}2\breve{P}\infty$, $\varepsilon\{\bar{1}01\}-\breve{P}\infty$, $\theta\{101\}-P$, $a\{100\}\infty \breve{P}\infty$, $b\{010\}\infty \breve{P}\infty$, $c\{001\}$ $0P$. Crystals usually elongated in the direction of b, tabular to 001, and sharp-edged by the prevalence of hemiorthodomes. 001 usually striated parallel to the clinodiagonal. Forms very numerous and often very complex. Commonly aggregated in spheroidal masses, with one end freely developed. Also compact and earthy. Pseudomorphous after ruby copper ore, tetrahedrite, and dolomite. Cleavage, 021 perfect, 100 less perfect. Fracture, conchoidal, uneven, or fibrous splintery. H. 3·5. Sp. gr. 3·76–3·83. Colour, deep azure or sapphire-blue in crystals, cobalt-blue in earthy variety; streak, cobalt-blue. Translucent to opaque. Lustre, vitreous. Optic axial plane parallel to b. The first median line in 010 is inclined 12° 36′ to c and 75° to a.

FIG. 229.



Composition. — $Cu_3C_2O_7 + H_2O = \begin{Bmatrix} 2CuCO_3 \\ H_2CuO_2 \end{Bmatrix}$, or CuO 69·21, carbonic acid 25·57, water 5·22 per cent., metallic copper 55·26 per cent. Chemical characteristics similar to those of malachite.

Occurrence.—Very similar to that of malachite, with which it is usually associated in Cornwall, the Ural, and other copper-mining districts. The finest crystallised examples are from Chessy, near Lyons, where it was found in nodular masses, in lithomarge, in a copper-ore vein in the new red sandstone. Latterly, very fine crystals have been brought from the South Australian mines. As a copper ore its properties and value are similar to those of malachite.

BURATITE. AURICHALCITE.—Microcrystalline; system undefined; in acicular and fibrous aggregates. Sp. gr. 3·32.

Colour, sky-blue, or various shades of pale green. Lustre, nacreous.

Composition indefinite, hydrated carbonates containing copper, zinc, and lime, the proportion of the different constituents varying as follows: CuO 19–29, ZnO 32–56, CO_2 14–21, CaO 2–9, H_2O 8–11 per cent. The name Buratite is applied specially to the calcareous varieties.

When heated, behaves similarly to malachite, except that a strong incrustation of oxide of zinc is produced on charcoal. Buratite is soluble in ammonia, leaving a residue of carbonate of calcium. Found with calamine at Chessy, and in the Altai copper mines.

ZINC BLOOM, or HYDROZINCITE, is a hydrated carbonate of zinc containing from 12 to 15 per cent. of water, which occurs with calamine and other zinc ores as a white earthy mass or efflorescence at Bleiberg in Carinthia, and in the district of Santander in Spain. The chemical behaviour is similar to that of calamine, except that it gives off water in the closed tube.

EMERALD NICKEL.—A hydrated carbonate of nickel, corresponding approximately to $\left\{\begin{matrix}NiCO_3\\2H_2NiO_2\end{matrix}\right\} + 4H_2O$, or oxide of nickel (NiO) 59·36, carbonic acid 11·77, water 28·87 per cent., a portion of the nickel being sometimes replaced by magnesia. It occurs in thin varnish-like crusts of an emerald-green colour on chromic iron ore at Texas, in Pennsylvania. When heated it gives off water and blackens the residue, giving the reaction of nickel oxide with borax. Soluble in hydrochloric acid with effervescence, giving a green solution.

Double hydrated carbonates of calcium and uranium (*Voglite*), with or without copper (*Liebigite*), are found as products of the alteration of pitchblende at Joachimsthal, near Adrianople. They are essentially variable in com-

position ; but the proportion of oxide of uranium is tolerably constant, being from 36 to 38 per cent.

Carbonate of Bismuth occurs as a white amorphous earthy substance in the Saxon and Bohemian cobalt mines, and in the gold districts of Carolina and Queensland ; in the latter as an incrustation of native bismuth. It contains in the purest forms : bismuth oxide 90, carbonic acid 6·6, water 3·4 per cent. When heated it decrepitates and turns brown, on charcoal fuses easily, and is reduced to metallic bismuth.

DAWSONITE.—*Oblique*, forms undefined. In thin-bladed or fibrous crystals resembling tremolite. H. 3. Sp. gr. 2·40. White, transparent.

Composition.—$Na_2Al_2C_2O_8 + 2H_2O = 3(Na_2CO_3) + Al_2C_3O_9 + 2H_2O$. Infusible. Gives off water and CO_2 at a red heat ; the residue dissolves easily in HCl.

Occurrence.—On the joint surfaces of a trachytic dyke at Montreal, and in marl and sandstone with cinnabar in Tuscany. Remarkable as being the only natural carbonate containing aluminum.

NITRATES.

These minerals occur mainly as efflorescences or in fibrous crusts and granular masses, in hot and dry regions of the earth or upon the floors of limestone caves, stables, or other places where animal matters accumulate and decompose ; the formation of these salts being presumably due to the oxidisation of ammonia in the presence of lime, soda, or potash minerals. The natural minerals are usually more or less mixed with sand, chlorides, or sulphates, forming saltpetre earth or *caliche*, which when subjected to crystallisation from solution yields crude—and, by a further operation of the same kind, refined—nitre or saltpetre, and it is from these refined products that the crystalline and physical characters are deduced.

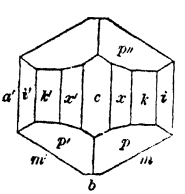
NITRATE OF SODA. Soda Saltpetre, Cubic Nitre, Chili Saltpetre, Nitratine.—*Rhombohedral.* $R=106°\ 30'$, $a:c=1:0{\cdot}8276$. Isomorphous with calcite. Crystals artificially produced, simple rhombohedra. Cleavage, rhombohedral perfect. H. 1·5–2. Sp. gr. 2·1–2·2. Colourless, or white when pure; transparent, translucent. Very strong negative double refraction. Indices for D line, $\omega=1{\cdot}587$, $\epsilon=1{\cdot}336$. Soluble, with a saline cooling taste.

Composition.—$NaNO_3$, or Na_2O 36·47, N_2O_5 63·53 per cent. Fuses easily, colouring the flame yellow. Deflagrates on ignited charcoal. Easily soluble in water.

Occurrence.—In deposits, often several feet in thickness, over a great part of the rainless area of South America, Southern Peru, Bolivia, and Northern Chili. The beds are associated with salt in superficial strata of clay and sand, in the level ground or on the flanks of hills. The rough nitrate, or *caliche*, in places contains small quantities of iodates, which are recovered on the large scale in the refineries, and it is now the principal commercial source of iodine.

NITRE. Nitrate of Potash, Potash Nitre, Saltpetre. —*Rhombic.* ∞P 118° 49′, $a:b:c=0{\cdot}5843:1:0{\cdot}7028$, close to aragonite. Crystals, prismatic, columnar, elongated on *c*. (Fig. 230) $m\{110\}\infty P$, $b\{100\}\infty P\infty$, $p\{111\}P$, $a\{010\}\infty\breve{P}\infty$, $i\{021\}2\breve{P}\infty$, $k\{011\}\breve{P}\infty$, $x\{012\}\frac{1}{2}\breve{P}\infty$. Twins common on 110. Cleavage, brachydiagonal and prismatic imperfect. The native mineral usually fibrous or earthy granular. H. 2. Sp. gr. 1·9–2·1. Colourless, white, grey, or darker, according to degree of purity. Strong negative double refraction. Indices for D line, $\alpha=1{\cdot}3365$, $\beta=1{\cdot}5056$, $\gamma=1{\cdot}5064$. Optic axial plane, 100. First median line *c*, $2V=7°\ 12'$.

FIG. 230.



Composition.—KNO_3, or K_2O 46·53, N_2O_5 53·47 per cent. Easily fusible, colouring the flame violet. Deflagrates on ignited charcoal more strongly than soda nitre.

Occurrence.—Occurs in limestone caverns and as a surface efflorescence in many parts of the world. Ceylon and India furnish the largest supply; also in Aragon, Calabria, the plain of Hungary, adjoining farms and villages, &c.

Uses.—It is now chiefly used in gunpowder manufacture, for which it is better suited than soda nitre, as being less hygroscopic. The latter is, however, principally used for making nitric acid, as giving a larger percentage, besides being cheaper.

Nitrate of Lime, $CaN_2O_6 + H_2O$, forms the principal constituent of the nitrous efflorescences formed on old walls in damp places; and in the Mammoth Cave of Kentucky it occurs in grey fibrous aggregates, together with the corresponding magnesia salt $MgN_2O_6 + H_2O$.

The nitrates of barium, strontium, and lead, which do not occur as natural minerals, form a remarkable isomorphous group, crystallising in the cubic system. Nitrate of barium is octahedral, and is remarkable as being the only substance in which an actual tetartohedron $\kappa\pi\{531\}$ has yet been noticed. It also possesses circular polarisation, but the specific rotatory power is very small. The tetartohedrism of the strontium or lead salts has not as yet been fully made out.

CHAPTER XV.

HALOID SALTS.

THE number of compounds of chlorine, bromine, iodine, and fluorine found in nature is but small, although some individual minerals among them have a very wide range. Prominent among these are the salts of sea-water, especially the chlorides of the alkaline metals—sodium, potassium, and magnesium. Of the chlorides of the heavy metals only that of silver is in any way abundant, those of lead and copper being most frequently found as oxychlorides. Bromine and iodine are only recognisable in definite minerals in their silver compounds, although they occur in sufficient quantity to be commercially valuable as accessory constituents of other minerals in the alkaline salts of Stassfurt and the nitrate of soda deposits of Peru. In these instances they are probably present as bromide of magnesium and iodide of sodium, which being exceedingly deliquescent salts are unable to exist independently in the solid state under the ordinary conditions of atmospheric exposure. Chloride of magnesium does not occur independently, but is found in combination with other chlorides or sulphates as double salts, all of which are hydrated.

Fluorine forms simple fluorides with calcium and magnesium in fluor spar and Sellaite, and double salts with sodium and magnesium in kryolite. The first of these is abundant and widely distributed, and the last abundant in a single locality in Greenland. Fluorine also forms a constituent of the more complex minerals—topaz, chondrodite, apophyllite, mica, and apatite; and chlorine enters similarly

into the composition of some varieties of apatite and the analogous lead phosphates.

As a whole the minerals of this group are isomorphous in the cubic system, with distinct octahedral or cubical cleavage. Cryolite is remarkable as being triclinic in symmetry, while its parameters and cleavages differ but very slightly from the cubical type, it being one of the best examples of the theory of limiting forms.

The chlorides are almost entirely of secondary origin, being found as deposits from sea-water or to a small extent as products of volcanic sublimation. The fluorides are confined to mineral veins, where they are associated with other minerals, obviously produced by deposition from solution in water.

ROCK SALT. Steinsalz, Sel gemme.—*Cubic.* Usually in cubes, but may be obtained in octahedra by crystallising from a solution containing urea. Cleavage, 100 perfect. Secondary cleavages or slip faces may be produced by filing down two opposite edges of the cube and pressing or striking the crystal perpendicularly to the new faces, when planes will be started internally parallel to the faces of {110} These may also be produced by striking the cube in the centre of one of its faces with a conical punch, which develops a rectangular cross, whose arms are diagonal to the edges. Crystals often developed with hollow faces, being built up of small cubes piled symmetrically in all directions around a central cube. Generally in cleavable masses. In dry countries occurs as an efflorescence in fibrous masses, which are often curved and in thin beds of a fibrous structure like gypsum. H. 2–2·5. Sp. gr. 2·25. Transparent, translucent. Fracture, conchoidal, brittle, but cuts somewhat toughly. Lustre, vitreous. Transparent to radiant heat in a high degree. Colourless when pure, or with a slight blue or green tinge; in a few instances deep sapphire-blue, being the most perfect example of this colour

among minerals. Often reddish brown and opaque from intermixed ferric oxide and clay.

Composition.—NaCl, or sodium 39, chlorine 61 per cent. The purest kinds contain only a trace of chloride of magnesium; other impurities are chloride and sulphate of calcium, the whole not exceeding 1·5 to 2 per cent. as a rule. Cavities containing liquids (usually saturated solutions of salt) and gases are very frequently seen in the crystals. The salt deposited during the eruptions of Vesuvius contains a considerable quantity of chloride of potassium, as much as 53 per cent. having been observed in one instance.

When heated decrepitates (some kinds more than others), melts to a clear bead, colouring the flame yellow, and volatile at a strong heat. In salt of phosphorus with oxide of copper gives a blue colouration of chloride of copper to the flame. Soluble in water. The solution gives a white curdy precipitate with nitrate of silver.

Occurrence.—With other salts of the same class, gypsum and anhydrite, in beds and masses of considerable extent in many geological formations, the larger number being in the Trias or New Red Sandstone series, as at Northwich, in Cheshire; Carrickfergus, in Ireland; Lüneburg, Stassfurt, Schonebeck, and other places in the North German plains. In Michigan there are large deposits in Silurian strata, and the famous salt mines of Wielickza, in Poland, are of tertiary age. In the Austrian Alps saliferous clays, known as *Haselgebirge* are worked in the Trias at Hallein, Hallstatt, &c. by solution. At Cordova in Spain, an enormous mass of rock salt forms a cliff more than 100 feet high.

The usual associates of salt are gypsum, anhydrite, boracite, and other haloid minerals, such as polyhalite, kieserite, kainite, sylvine, &c. At the mines of Leopoldshall and Stassfurt in Prussian Saxony, salts of potash and magnesia form a deposit of great thickness above a bed of rock salt 600 feet thick, and represent the more soluble con-

stituents of the sea-water from which the main salt-bed was derived. The preservation of these substances is, however, exceptional, although occurring on the great scale in the particular localities mentioned.

SYLVINE.—*Cubic.* Usually in cubes and octahedra; rarely in complex combinations. Cleavage, 100. H. 2. Sp. gr. 1·92. Lustre, vitreous or resinous. Transparent or translucent and diathermanous. Colourless or white.

Composition.—KCl, or potassium 52·3, chlorine 47·7 per cent. Usually containing some NaCl (about 5 per cent.). Soluble in water. Fusible and colouring the flame purple when seen through a dark blue glass, which cuts off the sodium light.

Occurs as a sublimate on Vesuvian lavas, and in large cubes and octahedra at Stassfurt in Prussia. At Kalusz, in Galicia, more complex combinations have been found.

SAL AMMONIAC.[1]—*Cubic.* Usual forms 111, 121, and other icositetrahedra, with or without 100 and 110. Crystals not readily recognisable, being much distorted and having a pseudo-rhombohedral character, due to the elongation of an icositetrahedron in the direction of a trigonal inter-axis. In radiated arborescent and columnar groups, and in pulverulent incrustations. Cleavage, 111. Fracture, conchoidal, soft, and tough. H. 1·5. Sp. gr. 1·6. Colourless or white, with a yellow or brown tinge. Soluble: salt, bitter, and astringent in taste. Lustre, vitreous, adamantine.

Composition.—NH_4Cl, or nitrogen 26·17, hydrogen 7·48, chlorine 66·35 per cent. The yellow colour is due to a trace of Fe_2Cl_6. Volatilises without fusion or residue when pure. Heated in closed tube with soda gives off vapour of ammonia. With salt of phosphorus and oxide of copper tinges the flame blue.

[1] See note, p. 383.

Occurs as a sublimate in the cracks and hollows of the lavas of Etna, Vesuvius, Stromboli, &c., and in burning waste-heaps, or in the steam given off by underground fires in collieries.

CHLORIDE OF SILVER. Kerargyrite, Horn Silver.—*Cubic.* Crystals, small cubes, single, grouped or in twins on 111; usually massive. Cleavage, none. Fracture, conchoidal; malleable, sectile, and cannot be powdered. H. 1. Sp. gr. 5·58–5·60. Lustre, waxy, resinous to nearly adamantine. Translucent. Colour, pearl-grey, greenish green; by exposure to light, changing to violet, brown, or nearly black. When quite pure sometimes colourless. Refractive index for D line, 2·071.

Composition.—AgCl, or silver 75·3, chlorine 24·7 per cent. Fusible in the closed tube without alteration; with soda on charcoal is reduced to metallic silver. Soluble in ammonia, but not so readily as the freshly precipitated artificial salt. A fragment placed on a strip of zinc and moistened with water is rapidly reduced to spongy metallic silver.

Occurrence.—Chiefly in the silver mines of Peru, Chili, and Mexico; being a product of the alteration of sulphuretted silver ores, it is usually, in the earlier workings of the veins, more abundant among the gossan or *pacos* ores, rather than in depth. Pseudomorphous it occurs in the form of silver glance and pyrargyrite. In Northern Peru it is found with anglesite as a product of alteration of argentiferous galena. In the Leadville district, Colorado, it occurs in large irregular masses, with white lead ore. *Buttermilk ore* is an earthy variety consisting of about one-third AgCl and two-thirds clay. It is a very valuable silver ore, being easily reduced by the process of amalgamation, but owing to its volatility is not so readily treated by fusion with lead ores.

HUANTAJITE, from the Tarapaca district, Peru, is a double chloride of silver and sodium, $2aNaCl + AgCl$, or

NaCl 89, AgCl 11 per cent. In transparent cubes and fibrous aggregates, like salt. Soluble in water, which is rendered milky by the separation of AgCl. From this circumstance the miners call it *Lechedor.*

BROMIDE OF SILVER. Bromargyrite, Bromyrite, Plata Verde.—*Cubic.* In minute cubes and octahedra and crystalline grains. H. 1·2. Sp. gr. 5·8–6. Colour, olive-green or yellow, weathering to grey; streak, yellowish green—shining.

Composition.—AgBr, or silver 57·45, bromine 42·55 per cent. Fusible at a low temperature and otherwise generally similar in behaviour to chloride of silver.

Found in Peru and Chili.

EMBOLITE includes all isomorphous mixtures of chloride and bromide of silver. These are either yellow or green in colour, crystallise in cubes, and vary in composition from $\left\{\begin{matrix}3AgCl\\AgBr\end{matrix}\right\}$ to $\left\{\begin{matrix}AgCl\\3AgBr\end{matrix}\right\}$, or per cent. 61 to 70 silver, 5 to 17·5 chlorine, and 12·40 to 33·80 bromine. They are found principally in the mines of the neighbourhood of Copiapo, Chili, and in the Leadville district, Colorado.

IODIDE OF SILVER, or Iodargyrite, another rare mineral of this group, crystallises in the hexagonal system, usually in thin flexible scales and masses, foliated in texture with basal cleavage. H. 1·15. Sp. gr. 5·37–5·67. Soft, but easily powdered. Colour, grey, lemon, or greenish yellow. Strong resinous lustre. Translucent. Double refraction positive.

Composition.—AgI, or silver 46, iodine 54 per cent.

Fusible on charcoal, colouring the flame reddish blue, with iodine vapour, and leaving metallic silver. Insoluble in acids and ammonia. When placed upon wetted zinc, silver is reduced and iodide of zinc passes into the water.

Found at Mazapil, in Mexico, in hornstone; Chañarcillo and Arqueros, in Chili, in limestone.

FLUOR SPAR. Fluorine. Fluss Spath. Fluor. *Cubic.* —(Figs. 231–233) $o\{111\}$ *O*, $a\{100\}\infty O\infty$, $q\{133\}3O$, $t\{321\}4O2$, $e\{120\}\infty O2$. Crystals either cubical or octahedral in habit, the former being most abundant. Secondary

FIG. 231.

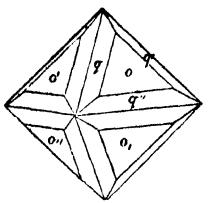


FIG. 232.

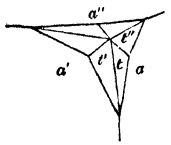
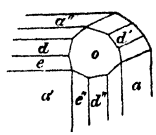


FIG. 233.



forms as a rule present as very subordinate modifications of the edges and angles of the cubes, and being very rarely fully developed. Twins on *O* interpenetrating. Octahedral crystals, sometimes with rough faces, built up of a regular succession of small cubes, also in fibrous radiated or agate-like masses and compact or earthy. Cleavage, 111 very perfect, except in the compact varieties, which are perfectly uncleavable. Fracture, subconchoidal or splintery in massive varieties, but rarely observable in crystals owing to the cleavage. H. 4. Sp. gr. 3·16–3·19. Lustre, vitreous. Colour, very variable, rarely colourless, and transparent; generally purple or pale green, dark green, yellow, deep blue less common, pink or rose colour the rarest. Crystals often show two colours, being lighter in the centre than along the edges. The concentric radiated variety banded in different colours. Transparent to subtranslucent, the compact variety opaque. Streak, white. Refractive index for D line, 1·435.

Composition.—$CaFl_2$, or calcium 51·28 = (lime 71·79), fluorine, 48·72 per cent. = (hydrofluoric acid 51·28).

When heated in closed tube decrepitates and phosphoresces. In the forceps fuses to an opaque enamel, colouring the flame orange-red. When strongly heated on charcoal, becomes caustic. Gives similar opaque beads with

borax and salt of phosphorus; when melted in a tube with the latter salt gives off vapour of hydrofluoric acid, which corrodes the glass. The same effect is more readily obtained by heating the powdered mineral with sulphuric acid in a platinum vessel, which, when covered with a watch-glass, partially protected by wax or resin, is etched in the exposed portions.

Occurrence.—Fluor is essentially a vein mineral, being found with tin and copper ores in Cornwall and Saxony, and much more abundantly with lead and silver ores. In veins in granitic and crystalline rocks the crystals are usually small, but in those traversing sedimentary strata, as in the clay slates of Cornwall and more especially in the carboniferous limestone districts of Northumberland and Durham, they are often of great size. At Nenthead, in Northumberland, cubes fifteen inches on the side have been found. At Altenberg, in Saxony, very deep blue and reddish crystals, often with complex modifications, are found with mica and hematite. White and wine-yellow cubes are characteristic of the Freiberg mines. The lead mines near Liskeard produce pale green cubes of considerable size, having the solid angles modified by planes of hexakisoctahedra. At Nenthead, Alston Moor, and Weardale large purple cubes abound in lodes, with galena, blende, calcite, and quartz. A brilliant coloured variety, the crystals being dark green in the centre and bright blue along the edges, is characteristic of the last-mentioned district. The pale green octahedral variety is found near Tavistock, and is especially liable to change, becoming opaque white, and changing into chalcedonic pseudomorphs by total replacement. The pink or red octahedral kinds are found in granitic rocks in certain difficultly accessible points of the chain of Mont Blanc. *Chlorophane*, a cleavable variety which phosphoresces with an emerald-green light, is found in the Ural, and near Camborne, Cornwall. The uncleavable varieties are pale bluish grey, resembling chalcedony, from Stollberg in the Harz; or white and opaque, with a splintery fracture like some kinds of quartzite,

found at East Pool, Camborne. The radiated crystalline variety banded in different colours, known as 'Blue John,' is obtained at Castleton, in Derbyshire.

The colour of fluor is probably due to some hydrocarbon compound, as most of the dark-coloured varieties are bleached, or turn to a pale yellow, when heated up to the phosphorescing point. Bubbles of a hydrocarbon gas have been found inclosed in hollows in the crystals. The chief uses of fluor spar are for the production of hydrofluoric acid and as a flux in metallurgical operations, it being specially adapted for dissolving quartz, sulphate of baryta, and other refractory minerals forming slags which melt at a comparatively low temperature. Blue John is cut into slabs for brooches and other ornamental purposes, and when in sufficiently large masses is turned into vases.

SELLAITE.—*Tetragonal*, in forms analogous to those of scapolite. Colourless. H. 5. Sp. gr. 2·97.

Composition.—$MgFl_2$, or magnesium 38·7, fluorine 61·3 per cent. Easily fusible with intumescence to a white enamel, which subsequently by loss of fluorine becomes infusible and emits a strong light.

Found inclosed in anhydrite on the glacier of Gerbulaz, in Savoy.

YTTROCERITE.—Massive, in granular aggregates, apparently with tetragonal prismatic cleavage. H. 4–5. Sp. gr. 3·4. Colour, violet-blue or grey, with feeble lustre. This rare mineral is of somewhat undefined composition, containing, besides fluorine and lime, calcium, cerium, yttrium, lanthanum, didymium, and erbium. It occurs at Finbo, near Falun, and a few places in New York and Massachusetts.

CRYOLITE.—*Triclinic*, approximating very closely to *cubic* in dimensions. $a : b : c = 0{\cdot}967 : 1 : 1{\cdot}388$, $\alpha = 89° 44'$, $\beta = 90° 18'$, $\gamma = 90° 03'$. Crystals small and resembling cubes with octahedral replacements, which only appear on four of the six solid angles. Usually massive

with cleavage parallel to the three axial planes, or nearly cubical. Fracture, irregularly platy, or coarsely fibrous. H. 3. Sp. gr. 2·96. Crystals transparent, and when colourless, massive, usually greyish, while slightly translucent, with vitreous or pearly lustre. Double refraction positive. Optic axial plane nearly parallel to the macrodiagonal, the median line making an angle of 5° with a plane containing the axes *a* and *c*.

Composition.—$Na_6Al_2Fl_{12} = \left\{\begin{matrix}6NaFl\\Al_2Fl_6\end{matrix}\right\}$, or sodium 32·81, aluminum 12·98, fluorine 54·21 per cent.

Easily fusible in the forceps, colouring the flame yellow. In the open tube gives the reaction of fluorine, and when strongly heated leaves an infusible crust, giving the alumina reaction with cobalt solution. Easily decomposed by sulphuric acid, and also by boiling with caustic lime and water; when insoluble, fluoride of calcium and a solution containing hydrates of soda and alumina are formed.

Occurrence.—At Evigtok, in South Greenland, in large beds, in gneiss, associated with tin, lead, and copper ores, and fine crystals of columbite; also at Miask, in the Ural. It is largely used for the production of alum and caustic soda, according to the reaction given above, and has also been employed for the production of aluminium.

Pachnolite is a hydrated fluoride of sodium, calcium, and aluminium; *Chiolite*, a mineral from Miask, analogous to cryolite, but containing less alkali and more aluminia, crystallising in tetragonal forms; and *Prosopite* probably a double fluoride of calcium and aluminium, found at Altenberg, in Saxony. The last, which is usually more or less altered into china clay or fluor spar, and is of an exceedingly doubtful constitution, is found in crystals resembling those of datholite or barytes.

CARNALLITE.—*Rhombic*, as determined from crystals of recent formation; usually in coarse-grained aggregates, showing parallel platy structure by the action of water, but

without definite cleavages. Fracture, conchoidal. H. 2. Sp. gr. 1·6. Lustre, strongly vitreous, becoming dull and deliquescent in the air. Colourless when pure, but usually red from interspersed microscopic crystals of hematite or Göthite (which are so small as to be translucent). Bi-axial, 010 is the plane of optic axes and the axis *a* the median line. Strongly double refracting.

Composition.—$KMgCl_3 = \left\{\begin{matrix} KCl \\ MgCl_2 \end{matrix}\right\} + 6H_2O$, or potassium 14·05, magnesium 8·65, chlorine 38·38, water 38·92 per cent., or KCl=26·9, and MgCl 34·2 per cent., generally with some chloride of sodium. Soluble in water, and readily fusible. The flame, when seen through blue glass to cut off the sodium light, shows potash colouration, and with the spectroscope cæsium and rubidium may sometimes be detected.

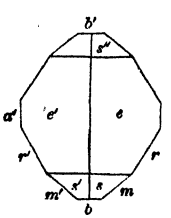
Forms one of the principal associated minerals in the Stassfurt potash-salt bed, and is also found at Kalusz, in Gallicia.

Tachydrite is a hydrated double chloride of calcium and magnesium $\left\{\begin{matrix} CaCl_2 \\ 2MgCl_2 \end{matrix}\right\} + 12H_2O$ occurring in deliquescent masses of a yellow or orange colour in anhydrite at Stassfurt, which are by cleavage and optical properties rhombohedral.

OXYCHLORIDES.

ATACAMITE.—*Rhombic.* ∞P 112° 20′, $a : b : c$ = 0·6704 : 1 : 0·746. (Fig. 234) $m\{110\}\infty P$, $s\{120\}\infty \breve{P}2$, $x\{140\}\infty \breve{P}4$, $a\{010\}\infty \breve{P}\infty$, $c\{011\}\breve{P}\infty$, $r\{111\}P$. Crystals usually combinations of {110} and {011}, which, when short in the prism, have a general resemblance to a regular octahedron; also in columnar and fibrous forms, often radially aggregated, or in earthy incrustation. Cleavage, brachydiagonal, perfect. H. 3–3·5. Sp. gr. 3·7–4·3. Colour, green of various degrees of intensity, according to the size of the

FIG. 234.



crystals, which when small are often translucent and emerald-green, while those of larger size are nearly black, bluish green, or verdigris-green; the duller, fibrous, and earthy varieties, grass-green. Streak, pale green. Lustre, adamantine to vitreous: translucent in various degrees.

Composition not very definite, containing cupric chloride and hydrated cupric oxide in various proportions. The following types have been distinguished:

	Copper	Corresponding to Chlorine	Oxygen	Water
$\left\{\begin{matrix}CuCl_2\\3H_2CuO_2\end{matrix}\right\}$	59·45	16·64	11·25	12·66
$2\left\{\begin{matrix}CuCl_2\\3H_2CuO_2\end{matrix}\right\}+3H_2O$	55·91	15·65	10·59	17·85
$\left\{\begin{matrix}CuCl_2\\3H_2CuO_2\end{matrix}\right\}+3H_2O$	52·77	14·77	9·99	22·47

or $\left\{\begin{matrix}CuCl_2\\3CuO\end{matrix}\right\}$, with 3, $4\frac{1}{2}$, and 6 molecules of water respectively.

The measured crystals all belong to the first type.

In the closed tube is decomposed, giving off water at 200°, and a grey sublimate of $CuCl_2$. In the forceps, colours the flame blue-green, and on charcoal is reduced to metallic copper. Easily soluble both in acids and ammonia, giving a green solution with the former and blue with the latter.

Occurrence.—As an incrustation on lavas at Vesuvius and other volcanoes, in the copper-mining districts of Chili and Peru, and especially in South Australia, the finest crystals being from the Burra-Burra and Moonta mines. It is readily formed when sulphuretted copper ores are exposed to the joint action of air, water, and common salt, and is therefore characteristic of hot dry saline deserts, like that of Atacama in Peru (after which the species is named), and dry climates like South Australia, or when copper pyrites is exposed to sea-water. It is also found in the slags of the ancient Egyptian copper works in the Arabian desert. In Chili it is ground and used as blotting sand for letters.

MENDIPITE.—*Rhombic*, in masses cleavable to a prism of 102° 36′; also in thin columnar aggregates. Fracture, conchoidal, uneven. H. 2·5–3. Sp. gr. 7·1. Colour, yellowish white to pale red. Lustre, adamantine to nacreous on cleavage surfaces: translucent.

Composition. — $\left\{\begin{matrix}PbCl_2\\2PbO\end{matrix}\right\}$, or lead 85·8, chlorine 9·81, oxygen 4·42, or $PbCl_2$ 38·4, PbO_2 61·6 per cent. The latter constituent is often more or less changed into plumbic carbonate, so that the species passes into phosgenite. Decrepitates when heated, fuses, and burns yellow; on charcoal is reduced to metallic lead, giving off vapour of hydrochloric acid. With salt of phosphorus and cupric oxide gives the blue flame chlorine reaction. Easily soluble in nitric acid.

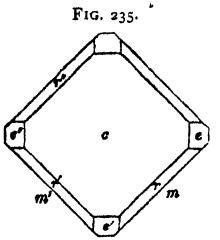
A rare gossan mineral from the lead mines of the Mendip Hills.

Cotunnite, $PbCl_2$, occurs in small brilliant crystals, as a product of sublimation, in the lavas of Vesuvius.

Calomel, or dichloride of mercury, HgCl, is found as a product of the alteration of cinnabar, at Idria, Almaden, Moschellandsberg, and other mercury mines. It crystallises in tetragonal forms, and is generally similar to the pharmaceutical preparation, except that it is of somewhat lower specific gravity: 6·5 as against 7·0.

MATLOCKITE.—*Tetragonal.* Z 136° 19′, $a : c = 1$. (Fig. 235) $m\{110\}\infty P, r\{111\}P, e\{101\}P\infty$, $c\{001\}0P$. Crystals small, tabular combinations: 001 often striated. Cleavage, 001, 110, imperfect. Fracture, uneven. H. 2·5. Sp. gr. 7·21. Transparent or translucent, with adamantine lustre and negative double refraction. The crystals have a yellow or greenish tinge.

FIG. 235.



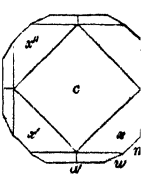
Composition. — $\left\{\begin{matrix}PbCl_2\\PbO\end{matrix}\right\}$, or lead 82·6, chlorine 14·2,

oxygen 3·2 ; or $PbCl_2$ 55·5, PbO 44·5 per cent. Chemical properties similar to those of Mendipite.

Found originally in the Cromford Level lead mine at Matlock, and subsequently.

PHOSGENITE.—*Tetragonal.* Z 113° 48′, $a : c = 1 : 1{\cdot}0871$. (Fig. 236) $m\{110\}\infty P$, $u\{210\}\infty P2$, $a\{100\}\infty P\infty$, $x\{111\}P$, $s\{211\}2P2$, $c\{001\}oP$. Crystals short columnar or acute pyramidal. Cleavage, 110 tolerably perfect. Fracture, conchoidal. H. 2·5–3. Sp. gr. 6·0–6·2. Colourless, yellow, grey-green, or brown. Transparent, translucent. Lustre, adamantine, waxy. Double refraction positive. Indices for D line, $\omega = 2{\cdot}114$, $\epsilon = 2{\cdot}140$.

FIG. 236.



Composition.—$PbCO_3 + PbCl_2$, or carbonate of lead 49, chloride 51 per cent. Fuses readily to a yellow opaque bead, with a crystalline surface ; on charcoal is reduced to metallic lead, with production of acid vapour. Soluble in nitric acid with effervescence, the solution giving the reaction of chlorine. A rare and beautiful gossan mineral from Cromford in Derbyshire, and Monte Poni, Sardinia. At Tarnowitz in Silesia the crystals are mostly converted into white lead ore.

Note to Sal Ammoniac, p. 373.—Tschermak has lately noticed on sal ammoniac crystals the occurrence of faces truncating the trihedral edges of 211 unsymmetrically, which he refers to an asymmetric hemihedral form $\alpha\{875\}$. This is remarkable as being the first observed example of this hemihedrism, which has hitherto been only a geometric possibility.

CHAPTER XVI.

MINERALS OF ORGANIC ORIGIN.

THIS division includes all the carbon and hydrogen compounds derived from the alteration of organic, and more particularly vegetable substances, such as coal, lignite, asphalt, petroleum, and the fossil resins, amber and retinite, &c. Many of these are but slightly altered, so that their vegetable origin is easily recognised ; as, for example, in the more woody kinds of lignite and amber ; but in the harder varieties of coal the original plant-structure is generally effaced ; and their origin is only demonstrable by comparison with less altered kinds, in which more or less of plant remains may be detected. The extreme term of carbonaceous metamorphism is probably represented by graphite, which might therefore be included, were it not more common to consider it among native elements.

COALS.

ANTHRACITE. Stone Coal. Culm.—*Amorphous.* Massive. Fracture, conchoidal. H. 2·5–3·5. Sp. gr. 1·4–1·75. Colour, black, often with a bronzy or rainbow-coloured iridescence ; streak, black. Lustre, metallic, vitreous. Opaque.

Composition.—Nearly pure carbon, the average of many analyses showing carbon 90–94, hydrogen 1·5–4·2, oxygen and nitrogen 2·1–3·6, incombustible ash 1–7 per cent.

In the anthracite of the older formations the ash is often much higher, but the relative proportion of the other constituents remains about the same. Ignites with difficulty and burns with a small amount of flame. That from South

Wales usually decrepitates when first heated, but the Pennsylvanian does not. In the closed tube usually gives off a little water, but no dark-coloured tarry oils. Not affected by acids or caustic alkalies.

Occurrence.—In the coal-measures it forms extensive beds covering large areas, the principal localities being in the Appalachian coal-fields of America, and the South Wales coal basin, west of Swansea.

In the culm series of Devon, near Bideford, it is worked for conversion into paint for covering ironwork. In the older strata of the Alps and North America it occurs occasionally in irregular masses or in veins.

Uses.—Used for drying malt and hops, where a smokeless fuel is required ; also for iron smelting, and melting metals in air-furnaces.

COAL.—*Amorphous.* Massive, with platy, or rarely somewhat fibrous structure. Often containing pseudomorphs of plants, and woody fibre. Fracture, flat, conchoidal, granular, uneven, or platy. H. 2–3. Sp. gr. 1·20–1·35. Pitchy black to brownish black ; streak, brownish. Lustre, vitreous to resinous ; in cannel dull and woody.

Composition.—The following are a few selected types :

	C	H	N	O	S	Ash
Steam coal, South Wales .	90·27	4·12	0·63	2·53	1·20	1·21
Caking coal, Durham . .	83·47	6·68	1·42	8·16	0·06	0·20
Cannel coal, Wigan . .	80·07	5·53	2·10	8·10	1·50	2·70

The ash may vary very considerably, and in inferior qualities is as much as 20–30 per cent. In most English coals it is below 10 per cent. According to its colour, coals are distinguished as white- or red-ash. In the former the composition of the ash is nearly that of fire-clay, while in the latter iron pyrites or ferrous carbonate is present, and remains as ferric oxide after combustion.

In the closed tube steam coals behave similarly to anthracite, giving off little else than water, but those contain-

ing a larger proportion of hydrogen, such as cannel and so-called bituminous coal, often evolve tarry vapours and inflammable gases at a red heat, with an apparent fusion or softening. The residue is a more or less spongy mass of coke, which may be burned before oxidising flame. If the coal when powdered and heated out of contact with air softens and forms a coherent mass of coke, it is said to be caking; but if the coke is of the form of the original fragments of coal, it is non-caking. Bituminous coals are those that soften, swell up, or appear to melt when heated. The term, though well-established and with a definite meaning, is an incorrect one, as no real fusion takes place until decomposition has commenced, and there is no pre-existing bitumen extractable by benzole or bisulphide of carbon.

Cannel is a hard, tough, and slaty-looking coal, dull but taking a fine polish: it contains a considerable quantity of disposable hydrogen, i.e. above the amount necessary to form water with the oxygen present, and when subjected to heat gives off hydrocarbon gases of high illuminating power. It is therefore of great value for gas-making, but gives a very inferior coke, usually containing a large amount of ash.

It forms the bulk of the fossil fuel in the older formations, and to a less extent in those of secondary and tertiary age. The best dry or anthracitic steam coals are raised in the central and eastern part of the South Wales basin; caking house coals in North Durham; those best suited for hard coke-making about Durham and Bishop Auckland; cannel and best gas coals in Flintshire, Wigan, and Scotland; and non-caking white-ash house coal in the Derbyshire, Yorkshire, and South Staffordshire districts. The foreign localities are very numerous, and will be found described in the larger text-books on geology.

LIGNITE. Brown Coal. Pitch Coal. Paper Coal.—*Amorphous*; often with woody structure, sometimes fibrous or earthy. H. 2 in the most compact; the softest loose and

incoherent, marking paper with a brown streak. Sp. gr. 1·2–1·4. Colour, black, brown, yellowish brown, the lighter colours the softest; streak, brown. Lustre, pitchy black to dull, wood-like, or earthy.

Composition.—Analogous to that of coal, containing more oxygen and hydrogen in proportion to the carbon; also a large amount of hygroscopic water. Apart from the latter and sulphur and ash, which may vary considerably, the constituents range as follows: Carbon 55–75, oxygen 26–19, hydrogen 6–3.

When heated most kinds give off a large amount of water, often of acid reaction, and in the air burn with a considerable quantity of light-coloured smoke and a strong smell, but do not produce a coherent coke. All are more or less acted upon by caustic potash, which gives a deep brown extract, of a shining or pitchy lustre; these are known as pitch coal. The more compact kinds are very similar to bituminous coals. *Jet* is dark-coloured, with a granular conchoidal fracture, taking a fine polish. Lignite proper is dark brown, with masses of fossil or so-called bituminous wood included. These, when splitting into thin laminæ, are distinguished as paper-coal. The pulverulent earthy variety from the neighbourhood of Cologne is used as a brown pigment under the name of Cologne earth.

Occurrence.—Similar to that of coal, but generally in much thicker beds, in the newer geological formations in Europe and America. Those nearest approaching to coal in character are found in Styria, and the western territories and Pacific States of America, while those of a more peaty and woody structure are common in the newer tertiary formation covering the plains of Northern Europe. Jet, which is largely worked for small ornamental purposes, occurs in the estuarine strata of the Yorkshire oolites, and also in Spain, the manufacture being principally carried out at Whitby. Some varieties yield liquid and solid hydrocarbons by

destructive distillation, and are utilised for paraffin manufacture. In the old mines of the Harz, pine timber that has been underground for a period not exceeding four centuries, has been converted by slow alteration into lignite, and a similar change is observed in the lower parts of thick masses of peat, the latter being the first stage in the transformation of actual woody fibre into coal. For the further consideration of this subject, which is not strictly within the province of this work, the student is referred to the works of Bischoff, Percy, Zincken, &c.

AMBER. Bernstein. Succinite.—*Amorphous*, in irregular masses, with flat conchoidal fracture. H. 2–2·5. Sp. gr. 1·07–1·08. Lustre, vitreous or greasy. Colour, sulphur-yellow ranging to white, and through deeper shades of yellow to orange-red, brown, and very rarely black. Transparent to translucent: often variegated and clouded in different colours. Becomes electric when rubbed. Fusible at 287° Cent.

Composition.—$C_{10}H_{16}O$, or carbon 78·94, hydrogen 10·53, oxygen 10·53 per cent. The proximate constituents are an insoluble resin, two other resins soluble in alcohol and ether, an ethereal oil and succinic acid.

Burns with a bright flame, emitting a pleasant odour and leaving a shining spongy coke. The oil and succinic acid are driven off at the temperature of fusion.

Occurrence.—Found in the newer lignite and alluvial formations of N. Germany, the principal localities being on the coast of Samland, near Danzig, where it is thrown up by the sea from the waste of submerged strata after storms, or sought by shallow diggings inland. Latterly it has been obtained in large quantity by steam dredging off the shore, and shafts have been sunk to the amber-bearing stratum, with a view to regular mining. The largest and finest pieces are used for making mouthpieces for Turkish pipes, those of smaller size for other pipes, beads, and various orna-

ments, and the waste and dust for varnish. The principal market is in Turkey, the Levant, and China, and latterly, owing to the very large supply obtained by dredging, the value has considerably diminished for all but the very finest pieces. It is a fossilised resin, and often contains insects and vegetable remains, which have evidently been included when in a plastic condition. Copal is a somewhat similar substance, found in a sub-fossil condition, and is sometimes mistaken for it, but may be distinguished by its more ready solubility and lower melting-point—200° to 220°. The fossil resin of Highgate, found in the London clay, is very similar in character to copal.

Retinite is a fossil resin of an indefinite composition, but approximating to amber, found in lignite at Bovey, Devon, and various other places in Europe and America.

PETROLEUM. Rock Oil.—Liquid in every degree of consistency from thin and watery to viscid and tarry. Transparent and nearly colourless, to dark brown or black; the lighter colours usually showing a strong blue fluorescence. Sp. gr. 0·7–0·9. More or less volatile, with a peculiar aromatic bituminous odour.

Composition.—Variable mixtures of hydrocarbons of the general formula, C_nH_{2n+2}, which may be separated by fractional distillation, the density and boiling-point increasing with the value of n; the lightest constituents are gaseous at ordinary temperatures, approximating in composition to marsh gas, and all give off inflammable vapours, but at temperatures increasing with the density. The heavier oils often contain paraffin dissolved, which may be separated by freezing.

Occurrence.—Found in large quantities in N.W. Pennsylvania and the adjacent States, where it is obtained from borings often exceeding 1,000 feet in depth, in association with gas, water, and occasionally brine. Also in Western Canada, near Sarnia and London; at the latter place it is found

filling the hollows of fossil corals in Devonian limestones. Other principal localities are in Austrian Galicia, Baku on the Caspian, and British Burmah. In America the oils from the deepest borings are as a rule the lightest and most liquid ; those that rise to the surface or from shallow depths are commonly darker-coloured and thick, being best suited for lubricating purposes. These by long exposure become changed, with partial oxidation, into a pitchy substance like asphalt. The natural oils are, as a rule, unsafe for burning in lamps, and require first to have the more volatile constituents removed by fractional distillation, which separates benzole or gazoline, the denser product known as kerosine, astral oil, &c., which should not give off inflammable vapours at a lower temperature than about 60° Cent.

HATCHETTINE. Ozokerite, Earth Wax, Mineral Tallow, Paraffin.—In masses resembling wax or spermaceti. The latter (*Hatchettine*) colourless and translucent with a pearly lustre. Sp. gr. 0·6. *Ozokerite* is generally yellowish or brownish, and when sufficiently translucent greenish, by reflected and brownish red by transmitted light. Sp. gr. 0·85–0·90. Soft and sticky to the touch, may be kneaded between the fingers, and fusible from 46° to 63° Cent., with a not unpleasant aromatic odour.

Composition.—Essentially $CnH2n$, or isomeric with marsh gas ; corresponding to carbon 85·7, hydrogen 14·3 per cent. This is similar to the artificial paraffins which are either derived directly from petroleum or by the destructive distillation of cannel, bituminous shale, peat, or lignite. Some of the German paraffins from the latter material contain up to 3·43 per cent. of oxygen.

When fused produces a clear mobile liquid which burns from a wick without residue, like wax or tallow. Easily soluble in turpentine or benzole, and but slightly in alcohol and ether.

Hatchettine was originally found in the hollows of clay

ironstone nodules, associated with acicular crystals of *Millerite* and minute transparent crystals of quartz, at Dowlais, near Merthyr, in Glamorganshire.

Ozokerite occurs in the sandstones of the coal-measures near Edinburgh, and in very large quantities in the Carpathian sandstones of Austrian Galicia, where it is raised from a great number of shafts in association with liquid petroleum. It is largely used as a source of paraffin.

Elaterite or *Elastic Bitumen* is of the same composition as the preceding; it occurs in masses of a dark brown or black colour, which are soft or slightly elastic and somewhat resemble india-rubber; at the Odin lead mine, near Castleton, Derbyshire.

Pyropissite is a wax-like substance soluble in ether, occurring in small proportion in the lignite of Weissenfels, in Thuringia, which yields by distillation a large quantity of tar containing paraffin, and is worked to a considerable extent in the neighbourhood of Halle. The ultimate composition is C 68·9, H 10·3, O 20·8 per cent.

ASPHALT. Bitumen. Mineral Pitch.—*Amorphous*, filling cavities and veins in rocks encrusting other minerals, also in drops and stalactitic. Fracture, conchoidal, sometimes vesicular. Black and lustrous, like pitch. Sometimes brown and earthy. H. 2. Sp. gr. 1·0–1·8. Becomes negatively electric by friction. Fusible at 90 to 100 Cent., mostly with a strong bituminous odour.

Composition.—Contains carbon, hydrogen, and oxygen, but not in any very well-defined proportions. By means of alcohol and ether various hydrocarbons may be extracted, and the residue, soluble in benzole or bisulphide of carbon, called *asphaltine*, has the composition: carbon 75·5, hydrogen 9·9, oxygen 14·8 per cent. Burns with a smoky flame and leaves a spongy coke, and in most cases yields liquid hydrocarbons by distillation.

Asphalt is essentially a product of the partial oxidation

of petroleum after the loss of the more volatile constituents, and as such occurs where oil-springs rise to the surface. Among the more striking localities are the pitch lake of Trinidad, the 'gum beds' of the Canadian oil regions, and the Dead Sea.

Rock asphalt is a granular limestone or dolomite, containing from 7 to 15 per cent. of bituminous substances soluble in bisulphide of carbon ; found at various places in the Rhone Valley and the Jura, notably at Seyssel, near Lyons, and Val de Travers, in Neufchatel. It is of a light or snuff-brown colour, and when heated to about 140° Cent. decrepitates and falls to powder. This when perfectly free from water and pressed together by heated cast-iron stampers, reconsolidates, producing a material scarcely differing in cohesion from the original rock, which is known as compressed asphalt, and is used for street paving. Limestones of this character are tolerably abundant in parts of Germany, Sicily, Savoy, Egypt, and Syria, but the quality best adapted for paving purposes is mostly obtained from Val de Travers.

Albertite is a brilliant black substance like asphaltum, but differs from it in being only partially soluble in turpentine and imperfectly fusible ; it occurs in a vein in the carboniferous strata at Hillsborough, Nova Scotia, and is very valuable for gas-making. The composition is : carbon 86, hydrogen 8·96, nitrogen 2·93, oxygen 1·97 per cent. It is probably a product of the oxidation of petroleum, and may be regarded as intermediate in position between asphalt and cannel coal.

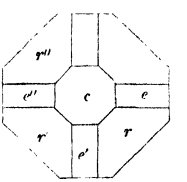
BOGHEAD COAL. *Torbanite.*—A dull slaty cannel, containing carbon 60 to 65, hydrogen 9, oxygen 41·5, ash 18 to 24 per cent. Burns with a brilliant smoky flame, and yields large quantities of oil and paraffin by distillation, besides a very highly illuminating gas. Turpentine extracts a resinous substance, in which character it differs from coals proper. Occurs in a restricted area in the central coalfield of Scotland, and, although worthless as a coal from its large amount of

ash, it is so much sought after as a means of enriching coal gas and for paraffin-making that the known extent has been nearly worked out.

Idrialine.—A hydrocarbon of the formula C_3H_2, soluble in oil of turpentine. Occurring in the black schist, forming the matrix of cinnabar at Idria, in Carniola. The native mineral is intimately mixed with cinnabar, quartz, clay, iron-pyrites and calcite, forming a slaty substance known as *Quecksilberbranderz*, which ignites readily in the flame of a candle and burns with a smoky flame and sulphurous acid fumes to a reddish brown ash.

SALTS OF ORGANIC ACIDS.—A very small number of these have been found native. These are *Whewellite*, an oxalate of calcium, $CaC_2O_4 + H_2O$, observed in small oblique crystals on calcite from Hungary; *Humboldtine*, a hydrous oxalate of iron, $2FeC_2O_4 + 3H_2O$, found in fibrous crystals and botryoidal or platy aggregates in lignite in Bohemia and Hesse; and *Mellite* or *honeystone*. The latter is a melitate of aluminium, of the composition $\dot{A}lC_{12}O_{12} + 18H_2O$ or $\dot{A}lO_3$ 14·36, $C_{12}O_9$ (mellitic acid) 40·30, H_2O 45·35 per cent. It crystallises in tetragonal forms. $Z = 93° 05'$, $a : c = 1 : 0·7454$. (Fig. 237) $r\{111\}P$, $e\{101\}P\infty$, $a\{010\}\infty P\infty$, $c\{001\}oP$. The crystals are simple or very slightly modified pyramids. H. 2. Sp. gr. 1·57–1·64. Colour, honey- to amber-yellow, sometimes white. When heated, gives off water and carbonises; in the air burns, leaving a white residue of alumina. Found in considerable quantities at Artern, in Thuringia, and other localities in Bohemia and Moravia, in lignite. It is remarkable as being the only source of mellitic acid, a compound which has not yet been produced artificially.

FIG. 237.



Note to page 91.—The etymology given for Fahlerz is incorrect: it is literally 'pale ore.'

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