SIMPLE TESTS FOR MINERALS

OR

EVERY MAN HIS OWN ANALYST

JOSEPH CAMPBELL

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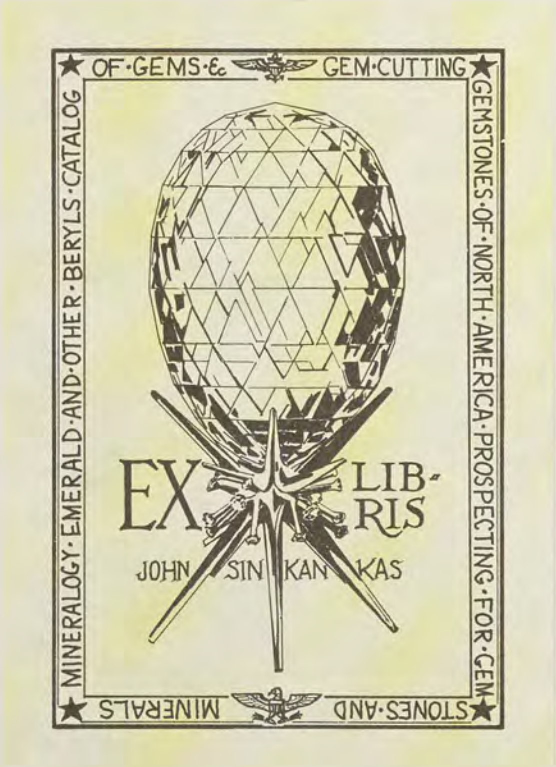

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EVERY MAN HIS OWN ANALYST

BY

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PREFACE TO THE FOURTH EDITION.

"For the cause that lacks assistance."

IT is with feelings of great satisfaction that I respond to a call for the fourth edition of my book.

This little work is designed for the use of those who have not had the advantage of systematic instruction in mineralogy, and it is therefore as free as possible from technical expressions.

Mineralogy and chemistry are so closely united, that the former cannot be properly studied without some knowledge of the latter. I have given just so much of each of these branches of science as will enable an intelligent man to test the valuable minerals and the gems and precious stones likely to be met with in Australia, New Zealand, and Tasmania.

The simple character of the book has been maintained, but the present edition contains several important additions which will greatly increase its value. For example, the question of the treatment of refractory gold ores has been briefly dealt with; the occurrence of tellurides has been enlarged upon; a simple method of determining the heating power—hence the value—of coal has been given; and many other matters, which experience has shown would be of service, have been added.

Several useful minerals are described for which space could not be found in the previous editions, and now it will be possible for miners and prospectors to *test anything which has a commercial value.*

In some cases the value of minerals is stated. It is to be distinctly understood that these are merely approximate, and are given to serve as a general guide, but not as a basis upon which to make calculations.

Feeling the importance of applying science to the development of our vast mineral resources, I have undertaken to devote for a few years the greater part of my time to assisting the development of mining, the treatment of refractory ores, and the investigation of the geological formations which are of economic importance.

Feeling that, as regards the material prosperity of these colonies, this is "the cause that lacks assistance," I am constrained to labour for it.

In doing so I shall be brought into still closer contact with those for whom this book is written. I shall be glad at all times to place my services at the disposal of all who are engaged in legitimate mining operations.

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INTRODUCTION.

The importance of some such book as the present in a country like ours can hardly be over-estimated. Our future prosperity depends to a very large extent on the development of our vast natural resources; and prominently among these stand our mineral deposits. Few countries in the world surpass Australia, New Zealand, and Tasmania in mineral wealth. There are known to mineralogists about 600 mineral species. Of these, 185 have been discovered in N.S Wales, 101 in Queensland, 100 in South Australia, about the same number in Western Australia, 172 in New Zealand, while Tasmania can show over 200 kinds, 40 of which have not as yet been discovered in Australia.

Now, in spite of this convincing evidence of the existence of enormous mineral wealth, very little has been done in the matter of its development: hence to a large extent the present want of prosperity. Truly there is work enough for idle hands, and this work will be available as soon as mining is delivered, as it must be ere long, from the degradation of a mere gamble, or at least a risky speculation, and is elevated to a sound commercial basis.

There is no lack of capital, even in our own colonies, for legitimate mining operations; and, not only so, the British public are quite ready to invest their capital in Australia and New Zealand whenever it can be shown that there is a reasonable prospect of fair returns.

Your course, then, is clear. The mineral wealth exists—you must *search* for it and make known its existence to the capitalist, taking care, of course, that your own interests are protected. In this way you will help in no small measure to lay the foundation of the future greatness of these colonies.

A WORD OF ENCOURAGEMENT.—It is the object of these pages to teach miners and others how to ascertain whether their "find" contains anything of value. The stone, rock or mineral may present a very ordinary appearance, but it probably contains something worth separating from the mass with which it is mixed,—some metal which has a greater or less commercial value; and hence it becomes necessary to apply certain tests by means of which the presence of this metal may be detected. Those who wish to become their own analysts will be surprised, and greatly encouraged, when they find how little knowledge is really necessary for all practical purposes. While I readily admit that, as in all branches of learning, so also in the science of practical mineralogy and geology, there is no royal road, yet I venture to think that I have by means of my little book made a very fair and easy path heading straight for the goal. Its chapters may be compared to finger-posts along the track, or at least to "blazes" on the trees of the wild bush in which the reef is located. As surely as by following the finger-posts or blazes, you arrive at the desired spot, so surely, by following the instructions contained in these chapters, you will ascertain what you desire to know about your specimen, viz., whether it contains anything of value or not. If not, there is an end of the matter, and no further expense need be incurred; if it does, you have my best wishes for your success, and you will, of course, adopt the best means of promoting it.

CHAPTER I

THE CONSTITUTION OF MATTER.

In order to approach our subject intelligently, let us ask what it is that makes up the specimen under examination. To answer this question we must briefly consider the constitution of matter, by which term we mean the peculiar structure of the things around us.

MINERALS, rocks, soil, plants—in short, all things with which we are acquainted, excepting the pure metals and the metalloids, as they are called, are made up, by chemical combination, of two or more simple or elementary bodies, *i.e.*, bodies which are not susceptible of analysis or separation into component parts. These simple bodies, so far as is at present known, are about 70 in number, and are called *Elements.* They are divided into two classes, viz., metallic and non-metallic. Many of them are of such comparatively rare occurrence that in a practical work like this it is not necessary to mention them. Only those which are of commercial importance are given in the following table with their symbols and atomic weights, or, as they might correctly be called, their combining weights—that is to say, the exact proportion in which they combine to make up masses of matter.

PRINCIPAL NON-METALLIC ELEMENTS OR METALLOIDS.

Name.	Symbol.	Atomic Weight.
Oxygen	O	16
Silicon	Si	28
Carbon	C	12
Sulphur	S	32
Hydrogen (sometimes called a gaseous metal)	H	1
Chlorine	Cl	35·5
Phosphorus	P	31
Fluorine	F	19
Nitrogen	N	14
Boron	B	11
Bromine	Br	80
Iodine	I	127

PRINCIPAL METALLIC ELEMENTS.

Name.	Symbol.	Atomic Weight.
Aluminium	Al	27
Calcium	Ca	40
Magnesium	Mg	24
Potassium (Kalium)	K	39
Sodium (Natrium)	Na	23
Iron (Ferrum)	Fe	56
Manganese	Mn	55
Barium	Ba	137
Antimony (Stibium)	Sb	120
Arsenic	As	75
Bismuth	Bi	208
Cadmium	Cd	112
Chromium	Cr	52
Cobalt	Co	59
Copper (Cuprum)	Cu	63
Gold (Aurum)	Au	197
Iridium	Ir	193

Name.	Symbol.	Atomic Weight.
Lead (Plumbum)	Pb	207
Mercury (Hydrargyrum) (a naturally liquid metal)	Hg	200
Molybdenum	Mo	96
Nickel	Ni	58
Palladium	Pd	106
Platinum	Pt	195
Rhodium	Rh	103
Silver (Argentum)	Ag	108
Strontium	Sr	87·5
Tellurium	Te	126
Thorium	Th	232
Tin (Stannum)	Sn	118
Titanium	Ti	48
Tungsten (Wolfram)	W	184
Uranium	U	240
Zinc	Zn	65
Zirconium	Zr	90

In the second column the letters are the symbols by which the elements are usually represented in chemistry. Each of the symbols consists of one, or at most, two letters. The first of these is, in every case, the initial letter of the name of the element; not necessarily, however, of its English name, except where that is identical with its Latin one. It will be observed that the Latin equivalents are given in the above list. In cases in which several of the elements begin with the same letter, that letter is generally taken as the symbol of one—not necessarily of the most important one—and the others are distinguished by the addition of some other letter occurring in the name. Take, for example, the elements beginning with S. It will be seen that sulphur is denoted by S, Silicon by Si, Tin by Sn, from the Latin Stannum, &c. Each symbol expresses a certain definite weight of the substance it represents. These weights, called atomic weights, are shown in the third column of the above table, and may stand for grains, grammes, ounces, or any other actual weight as circumstances may require : hence they show the proportions in which the elements unite with one another.

It will be advisable for readers to make themselves familiar with these symbols; for, when considering the composition of mineral substances, they will, for the sake of brevity, be employed.

It is to be remembered that every substance which you may desire to examine mineralogically is made up, as has already been stated, by chemical combination of two or more of these elements: for example, most of the rocks among which you work contain Silica, (SiO_2) *i.e.*, Silicon and Oxygen, which latter element forms nearly half of the crust of the earth. Many of them contain, in addition to Silica, Alumina, (Al_2O_3) *i.e.*, Aluminium and Oxygen; indeed the most common form of occurrence of Aluminium is in union with Silicon forming Silicate of Alumina, of which ordinary clay consists. Further, many rocks contain more or less iron in union with Oxygen, for Iron is the great pigment of nature, giving the colour to most rocks.

The following statement may be borne in mind:—Elements form minerals, minerals form rocks, and rocks make up the earth's crust.

The first eight of each of the metallic and the non-metallic elements, given in the foregoing table, unite together in various ways to form about 99 parts of this crust. The proportion in which they exist is as follows :—

Oxygen	50·0	per cent.
Silicon	25·0	,,
Aluminium	10·0	,,
Calcium	4·5	,,
Magnesium	3·5	,,
Sodium and potassium...	3·6	,,
Carbon, Iron, Manganese, Sulphur, Barium, Hydrogen, Chlorine, Phosphorus, and Fluorine	2·4	,,
All the others	1·0	,,
	100·0	,,

A reference to the list will show that the 8 metallic elements here mentioned do not include the precious metals and those others, with the exception of iron and manganese, which are the object of your search. These, *e.g.*, Gold, Silver, Copper, Tin, Lead, Bismuth, &c., form but a fraction, viz., about one hundredth ($\frac{1}{100}$th) part of the earth's crust. Their rarity makes them precious. It must not, however, be thought that this proportion is uniform—that every rock formation contains $\frac{1}{100}$th part of these. It is well known that many do not contain a trace, while others contain a large proportion.

Metallic substances are not generally found diffused through the whole mass of rocks, but occur in veins or lodes. In Part II. of this little work I have explained the origin of these veins, and therefore it will not be necessary to say anything further about the matter now.

To return to our list of the principal elements—and I would specially call your attention to the following remarks, for, though they may appear somewhat difficult, yet an acquaintance with them will hereafter enable you to understand many points which I cannot otherwise hope to make clear to you.

In the column of atomic weights it will be observed that hydrogen, which is the lightest substance known, being 14½ times lighter than air, is taken as unity, and all other weights have been determined according to this standard. Let us take an example. The atomic weight of copper is given as 63; which simply means that an atom of this substance weighs sixty-three times as much as an atom of hydrogen. This is an assumption based upon the atomic theory, which supposes that all bodies are composed of a *finite*, but very great, number of *invisible* and *indivisible* particles called atoms; and that, for each kind of element, these atoms are identical in shape, size, and weight, but differ in different kinds of bodies. The actual shape, size, and weight of one of these atoms are unknown, but the relative weight of the atoms of different bodies is known, and this constitutes the relative or atomic weight of bodies.

It should be explained that the word atom is used to signify the smallest quantity of an element which can enter into chemical combination. Atoms combine to form molecules and molecules to form masses. A molecule is the smallest quantity of a substance which can exist in a free state.

If we wish to express a number of atoms of any element, we usually place a numeral below, and to the right of, the symbol; thus, for example, O_2 represents two atoms of oxygen.

The mere contact or mechanical mixture of substances is expressed by the sign +; thus, for example, $C+O_2$ implies that an atom of carbon has been brought into contact with two atoms of oxygen. But when the elements are chemically combined, they are placed side by side; thus, CO_2 implies that the atom of carbon has chemically united itself with the two atoms of oxygen, resulting in a compound substance called carbonic acid (CO_2) entirely different from either of its constituents.

So again with carbonate of copper, $Cu\ CO_3$. In this case one atom of copper has united with one of carbon and three of oxygen, forming carbonate of copper.

It has already been stated that the atomic weights show the proportions in which the various elements unite with each other: now, it is important to remember, that *the same substance always consists of the same elements united in the same proportion.* Thus, for example, carbonate of copper not only consists invariably of copper, carbon, and oxygen, but the proportions are always 63 of copper, 12 of carbon, and $16 \times 3 = 48$ of oxygen. On referring to the list, it will be seen that 63, 12, and 16 are the atomic weights of copper, carbon, and oxygen. If we wish to manufacture carbonate of copper we must take the ingredients in these proportions, or in some common multiple of these proportions, as twice, six times, &c. Supposing we were to take 50 parts of oxygen, and cause them to chemically unite with 63 of copper and 12 of carbon. The result would be a waste of two parts of oxygen, for with these quantities of copper and carbon only 48 parts of oxygen can unite, in accordance with the atomic weights given in the table. The remaining two parts would be in the uncombined state, and no power that could be brought to bear upon them would make them unite with the copper and carbon.

This is a wonderful law, and by its means we can, by a simple calculation, determine the amount of precious metal that is contained in a given sample, as we shall hereafter see. It is to enable my readers to effect this that I have spoken in this chapter about the atomic weights and the combination of the elements.

It may be imagined from what has been said that any naturally formed sample of $Cu\ CO_3$ (Malachite, as it is called) with which we meet in mines, contains 63 parts of pure copper. But this is not so. Any sample manufactured artificially certainly would; but in naturally formed carbonate of copper, or crude ore, there is always more or less foreign matter mixed up with the mineral; hence many samples of $Cu\ CO_3$ may not be worth working. And the same remark applies to all other minerals.

Hence, though you discover in your specimen the presence of a valuable metal, you may not be justified in taking up the land from which the sample came, or joining a syndicate for the purpose of working it. You must get some idea of the percentage the ore contains. In some cases the appearance and weight are a good index; but in others you must very carefully follow out the instructions I shall give under the head of the various metals dealt with in this book, the quantity of *precipitate* (see p. 48) from a given quantity, say 100 grains of ore, being the true guide as to the quality of the ore. In some cases, however, it is better to employ the services of a qualified analyst or assayer, inasmuch as considerable skill in manipulating is frequently necessary in order to arrive at reliable results. A very little skill is, however, required for determining the *presence* of anything of value, and I can guarantee that an intelligent use of this book will supply all the information the prospector requires to possess. The grand object of this book may be summed up thus—To enable you to identify the mineral you have found, to get an approximate idea of its value, and to save you unnecessary expenditure in postage stamps or freight, assayer's fees, and the anxiety and possible risk of waiting for results; sometimes, too, secrecy may not be without its advantages to the discoverer. All these advantages may be realised by carefully reading the following pages and carrying out the experiments therein described.

CHAPTER II.

CRYSTALLOGRAPHY.

Having briefly described the constitution of matter, or at least so much of the subject as it is necessary for the miner to know, I shall make a few remarks upon crystallography, or the science which deals with the form and structure of Crystals. The subject is not by any means a popular one, for no means have been taken to render it so; and outside the Universities and higher Colleges it has received but little attention. This is a pity, and, in my opinion, the time is come for directing attention to the fact and encouraging the study of crystallography, especially the physical side of the science, an acquaintance with which is valuable to the prospector. To those desiring to study the subject I would recommend a a very useful little book published last year, entitled "Crystallography for Beginners," by C. J. Woodward, B.Sc.

It will be observed that mineral substances occur in two distinct modes of aggregation, or assemblage of particles. Some consist of minute particles simply collected together without any regularity of structure or constancy of external form, and are named *amorphous*, *i.e.*, having no determinate shape, as, for example, chalk, opal, fluor, and chert, and often carbonate of copper, &c. The other class have their atoms arranged according to definite law, and are named *crystalline*, when the mass is made up of a collection of a vast number of large or small crystals not well formed, as, for example, marble and aragonite, both of which are varieties of carbonate of lime; and *crystallised*, when the mineral occurs in a more or less regular or geometrical form, as, for example, quartz-crystal calcite, iron pyrites, galena, and the diamond, &c.

The forms of crystals that occur in nature seem almost innumerable, yet it is found on examination that they can be arranged in certain groups of which each member is intimately related to all the others. These groups or systems are as follows:—

1. Cubic or Tesseral.
2. Pyramidal or Tetragonal.
3. Rhombohedral or Hexagonal.
4. Prismatic or Orthorhombic.
5. Oblique or Monoclinic.
6. Doubly Oblique (Anorthic), or Triclinic.

By some mineralogists the first, and by others the second, of these names is preferred.

Anyone who has studied crystallography can in most cases say definitely what a mineral is simply by examining its crystal form when that is fairly well preserved. With a little trouble you can gain sufficient knowledge of the subject for practical purposes; for, out of the vast number of crystal forms known to us, only comparatively few are of importance to the miner. These forms are best studied from actual specimens in public or private collections. In the absence of these, recourse may be had to some text book on mineralogy, *e.g.*, Woodward's, which contains diagrams of the most common forms of minerals. It may not, however, be out of place here to mention a few characteristic forms of each system:—

1. To the Cubic system belong Galena, Iron Pyrites, Magnetite, Fluorspar, the Diamond, Garnet, &c.
2. ,, The Pyramidal belong Cassiterite, Copper Pyrites, Zircon, &c.
3. ,, The Rhombohedral belong Calcite, Quartz-crystal, Tourmaline, Beryl, &c.
4. ,, The Prismatic belong Stibnite, Barytes, Mispickel, Cerussite, Topaz, &c.
5. ,, The Oblique belong Malachite, Common Felspar, Mica, Epidote, Gypsum, Hornblende, &c.
6. ,, The Doubly Oblique, belong Rhodonite, Albite, Oligoclase (Lime Felspar), Kyanite, &c.

It is a remarkable fact, and one well worth remembering, that the same mineral, when it occurs crystallised, invariably presents the same form, or forms, for some minerals have two or more forms of crystallisation.

It will be observed that sometimes crystals are of large size, and sometimes so small that they require the aid of a pocket lens to determine their form. The explanation of this is simple. These crystals have been formed from the liquid or gaseous condition of matter, or from a soft porridge or pasty-like mass. In all cases, however, it is necessary that the molecules of which the crystal is made up should be in a state of freedom previous to their uniting together to form the crystals, otherwise imperfect crystals will result. When the cooling has been slow and undisturbed, with moderate pressure so that room for expansion is allowed, the crystals are large; while, on the other hand, when the cooling has proceeded rapidly and agitation has been kept up or great pressure maintained, the crystals are comparatively small and generally not well formed. The reason of this is obvious when we examine a large crystal, as, for example, one of calcite, fluorite or galena. It will be found that it is built up of a number of small crystals, as may be seen by breaking it up. Now, when cooling takes place slowly and gradually and under moderate pressure, only a few crystals are first produced, and these are gradually built around on all sides by successive layers, until large and well defined crystals are the result; but when the liquid, or gas, or pasty mass is rapidly lowered in temperature, and especially when agitation is kept up, numerous minute crystals are formed at once and do not adhere together; and, if the pressure be too great to allow of the expansion due to crystallisation, imperfect crystals must necessarily be formed.

It is interesting to notice that nearly all the metals yield crystals when deposited from their solutions by weak electric currents, and it seems probable that the beautiful crystals we sometimes meet with in nature have been formed in this way.

CHAPTER III.

THREE TESTS FOR MINERALS.

HARDNESS, STREAK, AND SPECIFIC GRAVITY OR WEIGHT.

The following apparatus and chemicals will be required for testing minerals according to this book.

- Pocket Knife
- Blowpipe
- Compressed Charcoal
- Spirit Lamp
- Grease Lamp
- Platinum Wire
- Glass Tubes
- Test Tube Holder
- Magnet
- Forceps
- Glass Filter
- Watch Glass
- Packet of Filter Papers
- Pestle and Mortar
- Borax
- Carbonate of Soda
- Potassium Cyanide
- Nitric Acid
- Hydrochloric Acid
- Sulphuric Acid
- Ammonia
- Sodium Chloride (Common Salt)
- Tartaric Acid
- Potassium Ferro Cyanide
- Quick-Lime
- Caustic Potash
- Bismuth Nitrate
- Spirits of Wine
- Nitrate of Cobalt
- Stannous Chloride
- Ferrous Sulphate
- Sapphire
- Topaz
- Quartz Crystal

All the chemicals may easily be procured; and as very small quantities of most substances will be required, the whole lot need not cost more than from 10s. to 20s.

A very neat and portable case (see Fig. 1, page 15), 13 inches long by 6 inches wide by 6 inches deep, containing everything that is required has been made in England to the order of the author for 50s.

FIG. 1 (see page 15).—This miniature laboratory contains the above 33 different chemicals and articles, which are so ingeniously packed, each fitting in its own recess, that they can be carried any distance without fear of breakage. All the bottles have ground glass stoppers, and those containing acids have their symbols (names) engraved on them.

FIG. 1. CAMPBELL'S PROSPECTOR'S BOX.

Hardness.—The first test which is usually applied for the distinction of minerals is their capability of being scratched by other bodies, or, in other words, their hardness. For the purpose of ascertaining this, the mineral is subjected to the action of certain substances, which represent a scale of hardness, as indicated in the following list—the degree of hardness being indicated by the number standing against each :—

(1) Talc
(2) Gypsum
(3) Calcite
(4) Fluorspar
(5) Apatite
(6) Orthoclase or common felspar
(7) Quartz
(8) Topaz
(9) Corundum or impure sapphire
(10) Diamond

A sharp corner of each of these scratches the one above it: thus 1 is scratched by 2, and 2 and 3 by 4; but 1 is unable to scratch 2, 2 to scratch 3, and so on If we wish to get the exact degree of hardness, we commence with the substances that occur early in the list, and try the mineral to be tested with a sharp corner of the various members of the scale, until we come to a point when it is just scratched by one and not by one above it. The hardness of the mineral under examination would be that of the number of the scale by which it is just scratched.

Where the scale of hardness is wanting, or for a first rough determination, the following scale will serve :—

If the mineral can be scratched by the finger-nail, its hardness is 2 or less.
If by Copper, 3 or less.
If by Cast Iron, 4½ or less.
If by Window-glass, 5 to 5½ or less.
If by point of good Steel knife, 6 to 6½ or less.
If by Quartz, 7.
If by Topaz, 8.
Only a few minerals, including the precious stones or gems, are harder than Topaz.

Let us take an example to illustrate the use of this scale I will suppose that you wish to ascertain whether a clear worn crystal is a topaz or a piece of quartz. Take a quartz crystal and scratch the specimen with it. If it just scratches it with very great pressure, it is only quartz; but if it does not scratch the specimen, and, on trying, the latter is found to scratch the quartz crystal, the specimen is a topaz. Or you have a specimen of pyrites, and you do not know whether it is copper or iron pyrites, both these being somewhat similar in appearance: take your knife, and with the point try to scratch the specimen. If the knife only just scratches it, the specimen is iron pyrites, which has a hardness of 6 to 6½; but if the knife scratches it very easily, the specimen is copper pyrites, which has a hardness of 3½ to 4.

In the following pages the hardness of the various minerals will be given, so that this test may always be applied when endeavouring to ascertain what any particular specimen may be.

The following table shows the hardness of some of the metals :—

Titanium	Harder than Steel.	Chromium	...Scratches Glass.
Manganese		Nickel	Scratched by Glass.
Platinum	Scratched by a Crystal of Calcite or a Copper nail.	Cobalt	
Palladium		Iron	
Copper		Antimony	
Gold		Zinc	
Silver		Lead	Scratched by the Finger-nail.
Tellurium		Potassium	Soft as Wax at 60° F.
Bismuth		Sodium	
Cadmium		Mercury	...Liquid.
Tin			

Streak.—The colour of a mineral frequently helps us in identifying it,—colour, as seen upon the natural surface, and especially colour as seen when that surface is scratched, so that the mineral at the part so scratched is reduced to fine powder. This powdered line is called the streak. As it is sometimes a great help in determining a mineral, it will be mentioned among the characteristics of each as it is described, but we may here give the following as familiar and practical examples: specular iron or hæmatite, streak red; limonite, streak orange-brown; galena, streak gray; pyrargyrite, purple-red; cuprite, brownish-red. In the case of soft minerals the streak can easily be determined by rubbing the mineral on white paper, porcelain, or white stone, in which case the friction reduces the mineral to powder, or makes the streak.

It should be noted that the streak is not always of the same colour as the mineral mass, as for example :—The colour of cassiterite (Tin oxide) is generally *black*, but its streak, as seen when the ore is crushed, is *white* or *pale gray*. The colour of hæmatite, or specular iron, is frequently *black*, but its streak is always *red*.

Sometimes, too, the streak of a mineral is shining, as in Galena, or in Argentite.

Sometimes the streak can best be ascertained by reducing a fragment of the mineral to very fine powder, by means of a hammer or a pestle and mortar, *e.g.*, Stream Tin, black-jack, or small fragments of other minerals.

Specific Gravity.—Another guide to the determination of a mineral is its specific gravity, by which is meant its relative weight compared with an equal volume of pure water at temperature 60° F., which is taken as the standard. For example, the specific gravity, which for sake of brevity will always be represented by sp. gr., of pure gold is 19 or 20, which simply means that the weight of gold is 19 or 20 times as heavy as the same bulk of pure water. The way to ascertain the specific gravity is as follows:—Take a fragment of the mineral, or, if it be a gem take it, and weigh it first in air. Note the number of grains. Now attach it by means of a fine silk thread to the scale pan and weigh it in water. Note the difference in weight, that is, the loss of weight of the specimen in water, and divide the weight in air by this difference. The result will be the specific gravity of the mineral.

Thus if W = weight in air, and W^1 = weight in water, and G = specific gravity, then $G = \frac{W}{W - W^1}$.

By doing this we have ascertained the weight of a body of water exactly the size of the specimen we are dealing with; for one of the principles of Hydrostatics is that "a solid immersed in a liquid loses a weight equal to the weight of an equal volume of the liquid;" therefore the difference between the weight of the mineral in air, and its weight in water, gives the weight of a body of water exactly the size of the specimen.

The specific gravity of the various minerals will be given as each is considered. Under "gold" will be found a formula for ascertaining the weight of this metal in a given specimen of quartz, which illustrates the value of some knowledge of sp. gr.

It may be useful here to describe a method of determining the specific gravity of certain substances, *e.g.*, precious stones or very small specimens of minerals by means of a dense liquid. If you have a liquid of known density, and one specimen floats readily upon the surface, while another just floats and remains sluggishly wherever it is placed, and a third sinks very slowly, while a fourth sinks rapidly, some idea of the relative specific gravities may be obtained. The mineral that just floats and remains sluggishly wherever it is placed will be of the same specific gravity as the liquid; the sp. grs. of the others are judged according to the ease with which they float or sink. Several different liquids have been used for this purpose. One of these—known as "Sonstadt's Solution"—I will describe, as it is easily made and is often of great service. It must, however, be used with caution, as it is a deadly poison. It is made as follows:—Dissolve a small quantity of the salt known as Potassium Iodide in as little distilled water as possible, *i.e.*, make a saturated solution. Then add Mercuric Iodide till this substance ceases to be dissolved. It will now be found that the mixture has the power of dissolving a little more Potassium Iodide. Add this Salt until no more will dissolve; now add a little more Mercuric Iodide until no more will dissolve. Continue doing this, constantly stirring and gently heating, until neither Salt is further affected. The result is a honey-yellow liquid, having a specific gravity of 3·17. It is well to keep a drop of Metallic Mercury in the bottle containing the solution.

The specific gravities of the principal metals are as follow:

Platinum	21·50	Cobalt	8·54
Uranium	18·40	Manganese	8·00
Gold	19·50	Iron	7·79
Tungsten	17·60	Tin	7·29
Mercury	13·59	Zinc	7·00
Palladium	11·50	Antimony	6·80
Lead	11·45	Tellurium	6·11
Silver	10·50	Arsenic	5·88
Bismuth	9·90	Aluminium	2·56
Copper	8·96	Magnesium	1·74
Nickel	8·50	Sodium	0·97
Cadmium	8·70	Potassium	0·86
Molybdenum	8·63	Lithium	0·59

CHAPTER IV.

FLAME COLORATION AND GLASS TUBE TESTS.

Hardness, weight or specific gravity and streak or colour are physical properties, and we have seen that, by noticing these, some idea of the mineral can be got, but there are two methods usually employed in testing minerals, other than by their physical properties. The one is by heat, chiefly applied through the blowpipe, and in tubes closed at one end; the other by acids and various reagents in solution.

The two tests to be described in this chapter, viz, the flame coloration and the glass tube tests, are worth knowing, inasmuch as they sometimes give a clue to the identification of the substance under examination.

Flame Coloration Test.

This test is suggested by the fact that certain substances impart to flame characteristic colorations which give evidence of the presence of those substances.

It may be applied in the following manner:—Powder and make into a stiff paste with water a small portion of the mineral to be tested, and, having heated to red heat a loop made at the end of a piece of Platinum wire, dip it into the powdered mineral and return it to the blowpipe flame (to be described by-and-by), or that of a spirit lamp

If the flame is coloured—	It indicates the presence of—
Yellow	Sodium Salts
Red to Yellow Red	Calcium (Lime)
Emerald Green	Copper Oxide
Faint Green	Antimony

If the flame is coloured—	It indicates the presence of—
Yellowish-green	Barium
Bluish	Arsenic
Pale-blue	Lead
Azure-blue, then Green	Copper Chloride
Violet	Potassium
Crimson, approaching Purple	Lithium
Crimson of yellower tinge	Strontium
Bright-green (must be moistened with Sulphuric Acid)	Boron
Dull-green ,,	Phosphorus. In the dark even 3 per cent. of phosphoric acid may be detected.

If the flame of a spirit lamp be used when examining the colour imparted to flame, a black background (*e.g.*, the cover of a book) should be used, lest the faint green and blue coloration should be overlooked.

Inasmuch as the chlorides of the above substances give the best colorations, it will be well if, after heating the substance, you dip it into a little hydrochloric acid, and again return it to the flame.

You must be careful that the platinum wire which you use as a holder is perfectly clean. To make quite sure of this, dip it in Hydrochloric acid and heat it ; repeat this until it imparts no color to the flame.

N.B.—Do not dip the wire into the bottle of Hyrochloric, but put a little out for use.

The experiment is a pretty one, and, as it sometimes proves helpful in the determination of minerals, I would recommend you to procure some of the above substances, which may be obtained from any chemist, and note the colour which they impart to flame. Common salt is chloride of sodium, lime is carbonate of calcium, and borax is borate of soda, *i.e.*, boron and sodium ; so that if you cannot procure any of the others, the experiment may at least be tried with these.

The colorations thus imparted to flame are worth remembering; for even though you do not specially apply the test, yet if, when using the reduction test (to be described), you notice that any of the colours enumerated in the foregoing table are imparted to the flame of the blowpipe, it will give you an idea of what the substance under examination contains.

The characteristic flame colorations of various minerals will be given as each is considered, though it may here be mentioned that only a few of the many mineral substances known to us give evidence of their presence in this way.

The absence of any one of these colours is not to be regarded as a conclusive proof that the substance of which it is indicative is not contained in the specimen which is being tested: for, if several flame colouring substances occur together, a mixed colour of an intermediate character may result: or it may happen that the colour produced by one substance quite overpowers the other. For example, mix equal quantities of common salt and chlorate of potassium, and hold a little in the flame. It will be found that the yellow of the common salt is so powerful that it prevents the violet of the potassium from being visible.

Nevertheless, as I have pointed out, the flame coloration test may sometimes prove helpful in determining minerals.

THE GLASS TUBE TEST.

This test is applied as follows:—Reduce the mineral to be tested to a fine powder, and place a little in a small tube, which is then gradually heated in a spirit lamp, or, if a spirit lamp be wanting, in the flame of a candle, until the powder reaches a dull red heat. Certain inferences may be drawn from what now takes place.

Thus—1. A strong smell of sulphur indicates, of course, the presence of that substance, which has united with the metal present to form a sulphate or sulphite—the difference between the two being that the former contains more oxygen than the latter. A sulphate contains 4 atoms, a sulphite 3.

2. Sulphuretted hydrogen, known by its odour, which resembles that of rotten eggs, arises from sulphides containing water.

N.B.—Sulphides, or, as they are sometimes called, sulphurets, are formed by the chemical union of sulphur with metals, but without oxygen, the absence of which constitutes the difference between sulphides and sulphates and sulphites, both of which contain oxygen.

3. The substance, either wholly or in part, fuses, and a portion of the vapour becomes solid on the sides of the tube; in other words, a sublimate is formed.

a If the sublimate is white, it may be owing to the presence of antimony, or arsenic combined with oxygen, in which cases the sublimates are in the form of minute crystals; or it may be owing to the presence of mercury combined with chlorine (calomel).

b If the colour of the sublimate is from deep-yellow to brownish-red when hot, and sulphur yellow on cooling, it indicates the presence of much sulphur.

c If the sublimate is dark reddish-brown when hot, and reddish-brown when cold, it probably indicates the presence of arsenic combined with sulphur.

d If the sublimate is black, and gives a red powder on rubbing, it indicates the presence of mercury combined with sulphur (cinnabar).

e If the sublimate is black when hot, and reddish yellow when cold, it indicates the presence of antimony combined with sulphur.

f If metallic globules appear it proves the presence of mercury.

g If a metallic mirror is formed on the inside of the tube just above the powdered mineral, it indicates the presence of arsenic. This is sometimes formed in addition to the reddish-brown sublimate of *c*.

With reference to the glass tube test, it must be remembered that should none of the foregoing reactions appear, the absence of the substances causing the various reactions cannot always be inferred; for sulphur, arsenic, and antimony occur in many compounds, which give no certain evidence of their presence on being heated in a closed tube. When, however, we have an unknown substance to deal with we are glad of any hint as to its probable composition, and therefore we make use of these tests before proceeding to the borax bead test and the reduction test, which will be hereafter described.

CHAPTER V.

THE BLOWPIPE FLAME.

In order to understand rightly the use of the blowpipe, it is necessary to know something of the structure of flame, which may be defined to be gaseous matter, heated to the temperature at which it becomes visible, or emits light.

On examining an ordinary flame—that of a candle, for example—it is found to consist of three distinct parts, which are shown in the accompanying engraving.

Fig 2.

1. A dark core in the centre, consisting of the unburnt gases produced by the wax being heated, and which are unable to burn for want of oxygen.

2. A luminous cone surrounding the core, consisting of particles of carbon, derived from the gases, raised to a state of luminosity by meeting with a considerable quantity of oxygen derived from the air (which is made up chiefly of oxygen and nitrogen), insufficient, however, for complete combustion. This luminous cone is called the reducing flame, because all oxidisable bodies placed in it yield up their oxygen, which is withdrawn from them by the carbon, which is eagerly looking for a companion in the shape of oxygen.

3. The portion marked 3 is a feebly luminous mantle encircling the whole flame, in which the separated carbon is finally consumed, and which may be called the zone of perfect combustion. Here the supply of O is unlimited, and hence combustion is speedily effected. This mantle is the hottest portion of the candle flame, and its hottest

part lies at the extreme point. It is called the oxidising flame, since the conditions of oxidation are here united, viz., high temperature and an unlimited supply of oxygen.

Besides these three distinct parts, a beautiful clear blue border is seen at the base of the flame. Although there is plenty of oxygen here the temperature is low, and hence complete combustion cannot take place. The blue colour is due to the burning of a gas known as carbonic oxide (CO) which burns with a blue flame.

FIG. 3.

Let us now examine the instrument by which we act on the flame when using it for analytical purposes—I mean the blowpipe, the simplest form of which is represented in fig 3. It consists of a cone of tin, *a b*, open for the application of the mouth at *a*, and having a brass beak projecting from the side near the broad end *b*. In the end of this beak is a minute circular aperture not larger than a fine needle. The space below the beak is intended as a chamber for condensing the moisture of the breath. This costs about 1s. and answers the purpose quite as well as a more elaborate blowpipe.

The effect of blowing a fine stream of air against a flame is fourfold, viz., to drive it sideways, to reduce its luminosity, to lengthen and narrow it and to extend the sphere of perfect combustion, *i.e.*, 3, fig. 1, from the outer to the inner part. The latter circumstance results from the oxygen thrown into the flame by the blowpipe; for the particles of which the gas consists, and which are in want of oxygen for their combustion, get a supply, and thus up to a certain point perfect combustion takes place within the flame. There is not, however, perfect combustion of all the particles, because the supply of air, and consequently of oxygen, is limited.

The reduction of luminosity is also the result of the main body of the particles of carbon (which, as has been explained above, cause the luminosity), receiving enough oxygen to make combustion complete. This circumstance greatly increases the heat of the flame and further, through its being lengthened and narrowed, a concentration of heat at any given point is caused, and thus the reasons of the exceedingly energetic action of the blowpipe flame become apparent.

Experiment.

The Reducing and Oxidising Flames.

Take a blowpipe, and blow a stream of air against the flame of a candle having its wick slightly bent away from the beak of the blowpipe.

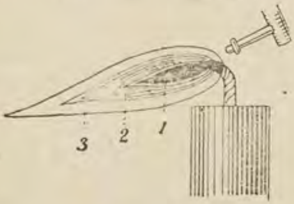

FIG. 4.

What do you observe? Three distinct parts (fig. 4) similar to those of the ordinary candle flame—1, a blue cone having its base at the beak of the blowpipe, consisting of the cool mixture of air and combustible gas; 2, surrounding this, but more especially at the apex, a shining yellow or reddish-yellow envelope consisting of the particles of carbon in partial union with oxygen, but of which there is insufficient to convert them into carbonic acid gas, CO_2.; therefore, any mineral containing oxygen, on being placed in this part of the flame, will rapidly lose its oxygen and become reduced to the metallic state, hence the name *reducing* flame; and 3 is a very feebly luminous envelope which requires to have some dark surface placed behind it to render it visible. In this the carbon has as much oxygen as it requires, taking part from the air around the flame and part from the air supplied by means of the blowpipe, and hence the combustion is complete and the heat intense. Any metallic substance, on being placed in this, will get oxygen mixed with it, or, in other words, will become oxidised; hence the name *oxidising* flame. Now it is very important to learn to distinguish accurately these two portions of the flame.

Fig. 4 shows the reducing flame which is produced as is indicated in the woodcut, by bringing the blowpipe beak to the edge of the flame, and at a little distance from the wick.

Fig. 5 shows the oxidising flame which is produced by passing the blowpipe beak into the flame about $\frac{1}{3}$ of the breadth of the flame and blowing pretty strongly. The flame now consists of two parts, viz., the blue cone and the very feebly luminous envelope surrounding it.

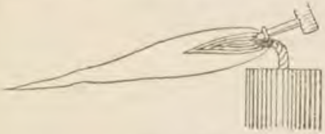

FIG. 5.

Owing to the blowpipe beak being placed in the flame, enough oxygen is furnished to produce complete combustion; consequently the reducing flame vanishes, and the oxidising flame is greatly extended. On looking at fig. 4 it will be seen that the oxidising flame exists together with the reducing flame; but only on a small scale. When we wish to use the oxidising flame we must produce it in the manner above described. "While the oxidising flame can be easily produced, some practice is required in order to obtain a good reducing flame. It is necessary that the reducing flame should be maintained unchanged for sometime, and that the piece of mineral under examination should be completely enveloped in it, in order to get good results. Care must also be taken that the test piece be not held too far in the flame, as soot may be deposited upon it, which will interfere with the reduction. The current of air necessary for the production of the blowpipe flame must be produced by the muscles of the cheeks without co-operation of the lungs." The way this is effected is as follows:—"The mouth is filled with air, which is pressed by the cheeks through the blowpipe, while the passage to the throat is stopped by the palate and breathing is maintained through the nostrils. When the mouth requires refilling, air is passed in from the full lungs, but without any effort on the part of the muscles of the breast. These operations are repeated continuously without interrupting the continuity of the blast. Only in this way can a constant current of air be maintained without prejudicially affecting the health. The requisite skill is soon obtained by practising breathing with distended cheeks, then taking up the blowpipe, and, whilst blowing, continuing to breathe neither quicker nor slower than the ordinary rate. The blowpipe is held in the right hand so that the thumb and third and fourth fingers support the tube, whilst the first and second fingers rest upon it. The forearm leans for support against the edge of the table."—J. LANDAUER, on Blowpipe Analysis.

The behaviour of a mineral before the blowpipe not unfrequently furnishes almost conclusive evidence as to its identity, and hence it will be well if my readers will perfect themselves in ready production of the blowpipe flames. One of the best ways of doing this, and of illustrating the difference between the two flames, is to perform the following experiment with a piece of metallic tin:—Scoop out a small cavity in a piece of charcoal to serve as a holder, and in it place a piece of tin about the size of a pepper-corn. First allow the reducing flame to play upon it for a minute; it remains unchanged. Now allow the oxidising flame to play upon it. What is the result? It becomes covered with a coating, owing to the formation of oxide of tin, the oxygen from the air becoming mixed with the tin by reason of the oxygen being plentiful and the temperature very high.

CHAPTER VI.

BLOWPIPE ANALYSIS.

In order to use the blowpipe for the detection of minerals, the following substances will be required :—

A spirit-lamp, or candle with a tolerably thick wick, which should be bent in the direction in which the flame is to be blown.

A piece of firm well-burnt charcoal, that of soft wood being the best.

Two ounces of dried carbonate of soda and one ounce of dried powdered borax in wide-mouthed stoppered bottles; a little nitrate of cobalt solution; a magnet; and a few pieces of platinum wire of about the thickness of a horse hair and three inches long, having at the ends small loops somewhat less than one-eighth of an inch in diameter. These loops are easily made by winding the end of the wire round the point of a pencil case or a splinter of wood of the required size.

N.B.—The carbonate of soda and borax must be moderately heated for a few minutes in a spoon or some convenient vessel to expel the water which these substances always contain. The stopper should never be left out of the bottle, or moisture will again be absorbed.

BORAX BEAD TEST.

I will now suppose that you have a mineral substance, the composition of which you wish to determine by means of the blowpipe. There are two methods which are commonly employed, viz.—(1) by a borax bead, and (2) on charcoal. The first of these we will now consider. But before making a trial by means of this test, read very carefully what I am about to write. Borax has the power of dissolving under the influence of a very high temperature, such as that produced by the blowpipe, many metallic oxides; and when this is the case, a characteristic colour is imparted to the borax, by which we are able to detect the presence or absence of a certain mineral.

Mark what I say: metallic oxides, not metals simply. Unoxidised metals, and those which are combined with sulphur, arsenic, or antimony, differ in this respect very materially from the pure oxides. Hence it is necessary to convert the mineral you wish to examine into an oxide before applying this test.

Take your mineral and reduce a little bit of it to a very fine powder, either by means of a pestle and mortar, hammer and anvil, or any other convenient means that may suggest itself. Now take as much of the powder as will lie on the point of the small blade of your pocket knife, and put it into a glass tube sealed at one end. Place the end of the tube in a candle flame, or, better, in that of a spirit lamp, and allow the powdered mineral to reach a cherry-red heat. Do not heat it beyond this point, or the mineral may fuse, in which case oxidation can only proceed with difficulty. Should this happen, it is advisable to throw the powder away and start with a fresh lot. Keep the mineral at cherry-red heat for several minutes: the sulphur, arsenic, and other impurities are driven off, and the oxygen of the air, playing upon the powder all the while it is heated, causes it to become oxidised, or, in other words, forms an oxide of whatever mineral happens to be present.

Should the mineral that you are desirous of testing be an oxide, the fact of your subjecting it to the process just described will not affect it; hence the safest plan, if you are not sure, is always to treat your specimens in this manner before applying the borax bead test.

If you have not a glass tube at hand, place the powdered mineral in a cavity made in a piece of charcoal, and allow the oxidising flame of the blowpipe to play upon it for a few minutes, keeping it at a cherry-red heat.

Now place the roasted mineral on a piece of a plate or glass bottle or any convenient holder, and with your candle, blowpipe, platinum wire and borax at hand, seat yourself at the table and calmly proceed to work thus:—

Holding the blowpipe in the right hand, produce the blowpipe flame, and taking the platinum wire in the left hand, insert the loop in the flame. It becomes red hot. Now dip it in the borax. Return it again to the flame, taking care not to hold it close to the candle-wick or soot will become mixed with it, and in a few seconds a clear transparent bead is formed on the loop. If this bead is not large enough, dip it again, while hot, in the borax and return it to the flame. When the bead is quite clear, dip it, while hot, into the powdered mineral and take up a little—not too much. It is always better to try with a very small quantity at first, and add more afterwards.

Place the bead first in the oxidising flame, and then in the reducing flame, and note in each case whether it is clear, opaque (enamel-like), or coloured.

The following table will show of what metals the various colours thus obtained are indicative:—

Explanation of contractions—c. bl = continued blowing while the bead is in the flame; fl = by flaming, *i e*, when the bead is repeatedly taken out and returned to the flame, which operation in one or two instances produces peculiar effects; s. b. = saturated bead, *i e.*, when the bead has taken up as much of the mineral as it possibly can take up.

BEHAVIOUR WITH BORAX.

COLOUR.				Indicative of
In Oxidising Flame while—		In Reducing Flame while—		
Hot.	Cold.	Hot.	Cold.	Oxide of
Colourless .	Colourless .	Colourless...	Colourless...	Tin
Colourless; s. b. yellow	Colourless; s. b., enamel white	Yellow ...	Yellowish-brown	Wolfram (Tungsten)
Colourless; s. b. yellow	Colourless .	Yellow to brown ...	Yellow to brown ; s. b., fl., blue	Titanium
Colourless...	Opalescent, or milk-white	Gray ; c. bl. Colourless...	Gray , c. bl. Colourless...	Silver
Yellowish ...	Colourless; s b., enamel-white	Gray ; c. bl. Colourless ..	Gray ; c. bl. Colourless ..	Zinc
Yellowish ...	Colourless...	do.	do.	Antimony
Yellow ...	Colourless...	do.	do.	Lead
Yellow ...	Colourless; s b , yellow to opalescent	do.	do.	Bismuth
Yellow to red	Colourless to opalescent	Brown ...	Opaque-brown	Molybdenum
Violet ...	Reddish-brown	Gray; c. bl., colourless	Gray ;c. bl., colourless	Nickel
Yellow to red	Colourless to yellow	Green ...	Bottle-green	Iron
Yellow to red	Colourless to yellow	do.	do. s. b. fl , black	Uranium
Violet-red ; s. b., black	Reddish violet ; s. b , black	Colourless...	Colourless, or feeble rose colour	Manganese
Blue ...	Blue ; s. b., very dark blue	Blue ...	Blue ; s. b., very dark blue	Cobalt
Green; s. b. dark green to opaque	Blue ; s. b., bluish green	Colourless...	Brown ; c. bl red and becomes opaque	Copper
Yellow to red	Grass-green	Green ..	Emerald-green	Chromium and also Chromic Iron

From the above table it will be perceived that, owing to the similarity existing between the colours imparted to beads by various metals, it cannot always be definitely said what the mineral you are testing is. It may be one of two or one of three which give somewhat similar results on being tested in this way. It is, however, something to have approached thus nearly to an identification; and it is an easy matter to apply a confirmatory test, as will be shown later on.

To prevent disappointment and perplexity I may here state that it sometimes happens that the impurities or other oxides which are present in the mineral under examination mask the colour you ought to find, and cause quite a different one to be imparted to the bead. It fortunately happens that we are not bound down to one method of testing, so that I hope to be able to show a way out of the difficulty.

Meanwhile I would recommend that a series of trials be made with known substances to produce the results set forth in the above table. The last six are perhaps the most important inasmuch as their presence may always be proved in this way. It will be noticed that the same colours are imparted both by iron and uranium; but under Uranium will be found a confirmatory test which will enable you to decide with ease whether your specimen is iron or uranium. The latter is, however, comparatively of rare occurrence.

The borax bead can be removed from the platinum wire loop by simply steeping it in water for some twenty minutes, or it may be melted and instantly jarred off or pulled off, when cool, by means of finger and thumb. The best plan is to have several pieces of wire, and as each is used place it in a wineglass of water, in which it may be left until again required.

There are one or two reactions obtained by means of Nitrate of Cobalt which it is useful to know.

Powder the mineral, mix it with a drop of Nitrate of Cobalt solution and take up some on a loop of platinum wire. Treat it in the oxidising flame.

1. A pale pink or brown pink ... indicates Magnesia
2. Pale blue ... ... ,, Alumina
3. Green ... ... ,, Zinc Oxide
4. Yellowish-green (not so fine as with zinc) ,, Titanic Oxide

THE REDUCTION TEST.

This test is the determination of minerals by means of the blowpipe and carbon (charcoal). It is applied in the following manner :—

Reduce the mineral to be tested to fine powder and mix with it from three to four parts of moist carbonate of soda, to act as a flux. I say *moist* because if placed before the blowpipe flame dry, it will probably be scattered. Having prepared a small cavity in a piece of firm, well-burnt charcoal, place in it a ball of the mixture (the mineral and soda), not exceeding the size of a pepper-corn, and allow the REDUCING flame of the blowpipe to play upon it. It may require a considerable amount of blowing, and properly applied blowing (see p. 30), before you get a satisfactory result; still, you will always be amply rewarded for your trouble.

In order to make my description thoroughly practical I will describe exactly the manner in which to deal with each result obtained in this way. I may perhaps mention a few chemicals you have not heard of, but I would recommend you to purchase these because they will be useful, if not indispensable, when testing for minerals by what is termed the "wet process," and which I shall by-and-by explain. All the chemicals required will be found enumerated on page 14 of this little work.

After dealing with the mineral in the manner above described, your efforts are rewarded by seeing either—

A—An incrustation, *i.e.*, a crust on the charcoal surrounding the little ball of mineral you placed in the cavity, and which is called the "test piece."

Or B—An incrustation with a metallic bead.

Or C—A metallic bead without incrustation.

Or D—Simply a gray or blackish residue.

If after a careful trial you do not get either of these results, you may test the specimen by the wet process, which it is always best to do if you have any doubt about your blowpipe results.

(A.) Well, we will suppose you have an incrustation.

1. The incrustration is white and very volatile, disappearing with a bluish flame, and odour of garlic. This indicates **arsenic.**

Confirmation.—Heat a little of the substance you are testing in a glass tube closed at one end, with potassium cyanide and sodium carbonate, when, if arsenic be present, a metallic mirror will be formed. See also glass-tube test, pages 24-25.

2. The substance fuses readily, and thick, white fumes are given off, which, partly condensing on the charcoal, cause an incrustation, which is, while hot, yellow; when cold, white, and is not volatile. The test piece also burns, perhaps, with an intensely luminous greenish-white flame. This indicates **zinc.**

Confirmation.—Scrape off the incrustation into a glass tube or gather it into a little heap on the charcoal, add a little solution of nitrate of cobalt and heat it.

If the substance is zinc, the mass becomes green.

N.B.—You must be careful not to mistake the white ash of the charcoal for an incrustation.

3. The test piece fuses very easily and coats the charcoal near the test piece with a white incrustation, which has a

reddish or dark yellow border, and disappears under the reducing flame, imparting a green colour to the flame. This indicates **Tellurium.**

4. No incrustation is formed, but a strong smell of burning sulphur is given off. This indicates the presence of **sulphur.**

Confirmation.—Place the fused mass, caused by the action of the blowpipe flame, on a shilling and moisten it. A black stain proves the presence of sulphur.

(B.) You have an incrustation with a metallic bead.

1. The test piece fuses easily and covers the charcoal with an incrustation, which is bluish-white in colour, and may be driven from one place to another by the oxidising flame, but disappears under the reducing flame, which is thereby coloured faint-green. A metallic bead is also formed, which is white, brittle, and oxidisable. This indicates **antimony.**

N B—I ought to mention that in the case of antimony the bead is not always formed; for it sometimes happens that the metal is oxidised as soon as it is reduced, thus causing the incrustation, which is oxide of antimony.

Confirmation.—If a bead has been formed put it into a small tube, add a little dilute nitric acid, and heat it. A white powder forms owing to the nitric acid oxidising the antimony. Add a little tartaric acid solution and again heat it; the white powder dissolves, thus proving that the bead was antimony.

2. The test piece fuses easily in both the O and R flames, and gives an incrustation which is, while hot, orange, and, when cold, lemon-yellow, disappearing under both flames without flame coloration. A metallic bead is also formed which is reddish-white, brittle, and oxidisable. This indicates **bismuth.**

Confirmation—Dissolve the bead in a little dilute nitric acid and pour the solution into a large amount of water, say a tumbler full A dazzling white precipitate will generally be formed if enough water is present. If the water fails to produce the precipitate, add a little common salt solution to the mixture and shake the containing vessel. If bismuth be present the white precipitate will either immediately or in a few minutes appear.

3. The test piece is easily fusible and forms an incrustation, which is, while hot, lemon-yellow, and, when cold, sulphur-yellow. This disappears in the O and R flame, colouring the latter a beautiful blue. A metallic bead is also formed, which is white, malleable, that is capable of being hammered out, and oxidisable. This indicates **lead.**

Confirmation.—Dissolve the bead in a little dilute nitric acid in a watch glass. Heat to drive off some of the acid, and add a few drops of sulphuric acid. Evaporate until white acid vapours appear. A white powder remains. This is sulphate of lead.

4. The test piece fuses easily, and forms an incrustation which is, while hot, yellowish, and, when cold, white, small in quantity, and forms close to the essay. It is not volatile. A bead also forms, which is white, malleable, and very oxidisible. This indicates **tin.**

Confirmation.—Dissolve the bead in strong nitric acid by the aid of heat. A white precipitate forms. This is oxide of tin, and is insoluble in tartaric acid solution, which serves to distinguish tin from antimony; although to those who are accustomed to blowpipe analysis, the fact of the antimony bead being brittle is sufficient to distinguish it from tin, which is malleable.

Another way of proving that the bead is tin is as follows: —Dissolve it in strong hydrochloric acid with the aid of heat, and add to the solution a mixture of bismuth nitrate and excess of caustic potash. A black precipitate proves the presence of tin.

(C.) We will now suppose you have a metallic bead without incrustation.

1. The bead is white, malleable, and very brilliant; and if the assay piece is kept in a strong oxidising flame for some time a reddish-brown incrustation is formed. This indicates **silver.**

Confirmation.—Dissolve the bead in nitric acid and add solution of common salt or a little hydrochloric acid. A white curdy precipitate forms, which turns first purple and then black on exposure to the sunlight. If there be much lead present in the ore, *e.g.*, as in Galena, thelead must be got rid of either by the means described on page 40 or as follows:—Bore a hole in the charcoal, and fill it with damped bone-ash made by burning bones in an open fire, when the oxygen of the air burns away the organic matter and leaves the earthly constituents as a white friable mass, which is easily crushed to powder, and which is called bone-ash. This bone-ash has the power of absorbing oxide of lead. Place therefore your bead, made up of lead, and, as you suppose, silver, in a cavity in the bone-ash, and apply the O flame. The lead will be oxidised and will sink into the bone-ash, leaving the silver, if any be present, as a bright globule. This process is known as Cupellation, and the whole operation, from the crushing of the ore to the cupellation of the bead, is, in effect, a miniature assay.

2. The bead is yellow, very brilliant, malleable, and non-oxidisable. This indicates **gold.**

Confirmation.—If there is any doubt about it, mix three parts of strong hydrochloric acid and one part of strong nitric acid (this mixture is called *aqua regia*), and with the aid of heat dissolve the yellow bead in it. A light yellow solution results. Take up a little of this on white blotting paper, and moisten with stannous chloride. A purple-red colour, which sometimes inclines rather to violet or to brownish-red, is produced. This has been named "Purple of Cassius," and is a delicate test for gold.

3. Little specks of red metal appear which can be cut with a knife and which are oxidisable. This indicates **copper.**

Confirmation.—Place the metal in a watch glass and add a few drops of nitric acid. Heat gently, and the metal dissolves. Take up a little of the solution on white blotting paper and add a little ferrocyanide of potassium solution. A reddish-brown coloration proves the presence of copper.

(D.) We will now suppose that you have simply a gray or black residue.

1. The fused mass is black. This is probably **iron.**

Confirmation.—Scrape it out of the charcoal into a small mortar or other convenient holder and grind it. Add a little water; the charcoal floats to the top, and may be poured off, leaving the iron behind. Or the particles of iron may be separated from the charcoal by means of a magnet. Place them in a watch glass and add a few drops of aqua regia (3 of hydrochloric and 1 of nitric mixed when required). Heat gently; a yellow liquid results. Take up a little on white blotting paper and add a drop of solution of ferrocyanide of potassium; a beautiful blue colour shows presence of iron.

1. You have white glistening metallic spangles which may be cut with a knife. This indicates **nickel** or **cobalt.**

Confirmation.—They adhere to a magnet. Separate them by water from the charcoal, place them in a watch glass and dissolve by heat in nitric acid. If the solution is green, it indicates the presence of nickel; if the solution is pink, it indicates cobalt. In the latter case, take up a little of the solution on white blotting paper, add a drop of hydrochloric acid. If when dry a green stain is produced which disappears again on moistening, it proves cobalt.

I have now given you all the simple blowpipe reactions with which it is desirable to be familiar. There are of course many highly interesting reactions that might be described, but it would be much beyond the scope of this work were I to describe them.

In practice we frequently meet with complex compounds; and to examine these by means of a blowpipe requires great practice and extended knowledge, because the indications above described are frequently obscured by the presence of other substances, and hence a special examination is necessary. Though experts can with certainty detect the presence of most of the substances contained in a given sample with the aid of the blowpipe, yet they are sometimes obliged to confirm their results by the wet process; and it shall be my aim in the following chapters to describe as much of that process as may be necessary to enable you to prove the presence or absence of the valuable or useful metals, when the blowpipe has failed to enable you to arrive at a satisfactory conclusion.

Note.—The following table of the melting points of various metals and of certain temperatures may be found useful for reference: –

Name.	Symbol.	Melting Point.
Antimony	Sb	... ... 840° F.
Bismuth	Bi	... . 507° F.
Cobalt	Co	... ... 2000° to 2200° F.
Copper	Cu	... ... 1996° F.
Gold	Au	... ... 1913° F.
Iron	Fe	Between 1700° F. and 2400° F.
Lead	Pb	... . 633° F.
Nickel	Ni	... ... 2500 to 2900° F.
Platinum	Pt	Oxyhydrogen blowpipe (47000 F.)
Silver	Ag	... . 1832° F.
Tin	Sn	... ... 455° F.
Tungsten (Wolfram)	W	... .. white heat, 2500° F.
Zinc	Zn	... ... 793° F.

Table of Temperatures Indicated by the Colour of Fire.

Incipient red	... 977° F.	Dull red	... 1292° F.
Cherry red	... 1652° F.	Clear cherry red	1832° F.
White heat	... 2372° F.		

These temperatures are according to Fahrenheit, but as the Centigrade thermometer is very commonly used you may wish to express the melting points according to that scale, and therefore I give you the rule for converting Fahrenheit to Centigrade :—

"Subtract 32, then multiply remainder by 5 and divide by 9." Thus, $C=(F-32)\frac{5}{9}$.

If you wish to turn Centigrade to Fahrenheit, proceed as follows : "Multiply the degree by 9, divide by 5 and add 32." Thus, $F=\frac{5}{9}C+32$.

CHAPTER VII.

WET TESTS.

In this chapter will be found a brief description of the method of determining the presence of minerals by means of various chemicals—called the "wet process." I have prominently in my mind the fact that your supply of chemicals is very limited, therefore I shall describe only such experiments as you will be able to perform. These experiments necessitate a knowledge of analytical chemistry, of which it has been said by some that a superficial knowledge is worse than no knowledge at all. This statement, at any rate, so far as testing for minerals is concerned, is absolutely wrong, as may be proved by anyone who will take pains to acquire the nutshell of knowledge contained in the following pages.

INSTRUCTIONS.—Reduce a small quantity of the specimen to be tested to fine powder, by means of a pestle and mortar, or anything else that may suggest itself; and if the tests already described have not enabled you to discover what the substance is, put a little of the powder into a test tube, and add some dilute nitric acid (HNO_3) mixed in the proportion of one part of acid to four or five of water: boil, and when evaporated down somewhat, add some strong nitric acid, and boil again.

Sometimes, especially with strong acid, a violent effervescence takes place, with an accompanying evolution of gas and rise in temperature—the result of the rapid combination of the metal with the acid. Sometimes no perceptible effect is produced. In either case you must subject the mixture to the action of heat, at first gentle, then gradually increasing. Care should be taken not to inhale the fumes, as they are poisonous. Always hold the tube in a slanting position while the gas is being evolved. Sometimes the sediment at the bottom of the tube will bump and spirt during the heating. Occasional shaking, in order to scatter the sediment through the liquid, will generally obviate this. If, when you first add the acid, such a violent effervescence takes place that the liquid is forced out of the tube, take a fresh lot of powdered ore, and add enough water to cover it, then add sufficient acid to make the mixture of acid and water the required strength.

If, after boiling for some minutes, the dilute nitric acid does not dissolve the mineral, try the effect of strong acid. If this fails, it will be well to try if hydrochloric acid (HCl.) will act upon it; and if not, try aqua regia, which is made up, as has been before explained, of three parts of strong hydrochloric acid, added, when required, to one part of nitric.

The method of dealing with these various solutions will be explained hereafter: my present object is to lead you to practise making these chemical solutions. It will, however, be found that nitric acid will dissolve most of the minerals which are described in this book.

While boiling the liquid you will not be able to hold the tube in your fingers, since it will get very hot; take, therefore, a strip of paper about 2 inches wide and 6 long, and, having doubled it twice, wrap it round the tube near the top, and hold the ends in your fingers. Always wash your tube before beginning a fresh test. In all testing operations a certain amount of care must of course be exercised, and cleanliness is indispensable. Careless manipulation will certainly lead to unreliable results.

It is sometimes necessary to use as a solvent some chemical which is not an acid at all. For example, if your specimen be a bromide or a chloride of silver, it will be necessary, in order to get the silver into solution, to use either ammonia (H_3N) or cyanide of potassium (KCN) as a solvent. The method of procedure in such a case will be found described on pages 51 and 52. Do not be too hasty in forming your decision as to whether or not the solution used has really acted. Though in some cases there appears to be no diminution in the quantity of powdered mineral, the solvent may have extracted a small quantity of something valuable, and this can only be determined by applying the tests.

EXPLANATION OF TERMS EMPLOYED.—I have used the terms *solution* and *solvent*, and shall have occasion by-and-by to use other terms, which, though quite familiar to chemists, may not be so to you. It will therefore be my duty, before proceeding any further, to make you acquainted with these terms and their meaning.

Solution means the perfect union of a substance, whether a solid, liquid or gas, with a fluid. A solution is more readily effected the more finely divided the substance is. The adjective *soluble* means that which is capable of solution.

The fluid by which the solution is effected is called the *solvent*, *e.g.*, water is a solvent for common salt, and aqua regia for gold. If the substance dissolves without undergoing any change, except in form, it is called a *simple* solution, *e.g.*, common salt dissolved in water remains common salt and the water remains water, and both may be obtained as such by evaporating the solution ; but gold dissolved in aqua regia undergoes a chemical change, being no longer pure gold but chloride of gold, part of the chlorine of the hydrochloric acid having united with the gold Thus both the substance dissolved and the solvent have been changed. This is called *chemical* solution. Most of the substances which we require to dissolve form chemical solutions. Both simple and chemical solutions are accelerated by heat.

Saturation.—This term has already been used in speaking of the borax bead test (p. 34). As applied to solution it simply means that the solvent has taken up as much of the substance as it can possibly hold. A hot solution holds more than a cold one, but when cooled down it deposits the excess in solid form, generally in crystals.

Precipitation.—This term is exactly the opposite of solution. It means that the substance is thrown down from the solution in solid form. This precipitation is generally caused by the addition of some other chemical, called a *re-agent*, though sometimes by the immersion of some solid substance, *e.g.*, knife-blade in a solution of copper. (See Tests for Copper.) Sometimes shaking or gentle heating promotes precipitation. The substance employed for the purpose of throwing down a solid from a solution is called the *precipitant*, and the solid thrown down by its means is called the *precipitate*. This latter is generally abbreviated thus—pp.

Decantation and Filtration.—It is often necessary to separate the precipitate from the solution: this may be done by either pouring off the liquid when the pp. has settled at the bottom of the tube, which operation is called *decantation* or by passing the liquid containing the suspended precipitate through a piece of white blotting paper or filter paper placed in a funnel, which operation is called *filtration*. In conducting this operation the filter paper must be double-folded with the folds at right angles. This admits of your placing the paper in the funnel in such a way that it lies close against the side of the funnel Before filtering it is better, having placed the paper in the filter, to wet it with a little clean water. The solution which passes through the filter is called the *filtrate*. Decantation is generally resorted to when the pp. is heavy or when it is of a slimy nature. It is frequently necessary to deal with the precipitate in some way; *e.g.*, it may be necessary to weigh or dissolve it. In such cases it must be washed with pure water. If decantation is the method adopted, the pp. should be shaken up two or three times with pure water and allowed to settle. If filtration is adopted water must be poured on to the pp. in the filter and allowed to filter through.

Wash bottle.—It is frequently necessary to wash and collect the pp. from the filter paper. This can be best effected by directing a gentle stream of water on to it by means of a WASH-BOTTLE, as it is called. The illustration (fig. 6) gives a good idea of what this piece of apparatus is like. By blowing in at the opening *a*, a fine stream of water is thrown out through *b*. A wash-bottle can be bought for a couple of shillings, but if you have a wide-necked bottle fitted with a cork and some glass tubing you can easily make one for a few pence. Heat a piece of glass tubing in the flame of the spirit lamp, and, when soft, gently draw it out to a point. You will thus get a fine aperture at the end of *b*. Cut it off a sufficient length by drawing a file across the tubing, and then taking it in both hands and snapping it. Next heat it in the spirit lamp, and gently bend it as shown in the engraving. Make the tube *a* in the same way. A set of cork borers for boring holes in corks can be bought for 1s. 6d., but, doubtless, a thin wire nail, heated to redness, will serve your purpose.

FIG 6—WASH BOTTLE.

Evaporation.—It is sometimes necessary to concentrate the solution before adding the precipitant. This is generally done by gently boiling the liquid until its bulk is reduced to a third or half of the original quantity. This operation is called *evaporation*, or evaporating down.

EXPERIMENTAL TEST.

Example—Testing for Silver.—As an illustration of the manner in which we apply the wet tests we will take an ore supposed to contain silver and deal with it. First let us take a case in which silver exists in some form other than that of a chloride or a bromide. The general appearance of the ore will in most cases enable us, after a little experience, to determine in what form the silver exists. Select a fair sample of the ore. Be careful in your sampling. The best way is to take a few pounds weight, and having broken it up to the size of beans, put it in a heap and quarter it by drawing a piece of hoop iron across it, thus: Take opposite quarters, say *a* and *b*, and again quarter. Crush finer, and repeat the quartering till you have reduced the sample to about half a pound. Then grind it to fine powder.

Case I.—Take about a teaspoonful of this—more or less according to the size of the tube—and boil it in strong nitric acid for about 10 minutes, using sufficient acid to allow for evaporation. The mixture must not be thick. If during boiling it becomes so add more acid. Carry out instructions on pages 45-46. After boiling for several minutes add as much water as there is acid, and boil again for a few minutes; then decant or filter into another tube and add drop by drop some hydrochloric acid (HCl) or common salt ($\mathrm{Na\ Cl}$) dissolved in water, and shake the tube to ensure complete admixture.

Result.—A white curdy precipitate is produced. On holding the tube in the sunlight this precipitate acquires first a violet tint and then turns black. This precipitate is chloride of silver ($\mathrm{Ag\ Cl}$). It will be well for beginners to confirm their results in this way: for if the specimen under consideration contains lead or mercury, the hydrochloric acid or salt solution will throw down a white precipitate of chloride of lead or chloride of mercury.

Neither of these will, however, turn black when exposed to sunlight. If there be but little silver present, and no lead or mercury, the addition of the hydrochloric acid or salt will impart at first simply a bluish-white opalescent appearance to the fluid : but after long standing in a warm place the chloride of silver collects at the bottom of the vessel. If the specimen contains much lead, and only a little silver, both will of course be thrown down by the hydrochloric acid or salt, and you may not be quite sure about the presence of the silver ; or you may wish to get an idea of the quantity of silver present Therefore act as follows :—Allow the precipitate to settle, and then carefully pour off the liquid. Add a little clean water, shake, and again allow the solid matter to settle ; pour off the water ; repeat this, add a fresh lot and boil. Hot water dissolves chloride of lead, but not chloride of silver or mercury, so whatever is left is chloride of silver if it turns black on being exposed to sunlight, or chloride of mercury if it still remains white. Pour off the water while hot, for the lead appears again as it cools unless the quantity of water be sufficiently large to retain it in solution.

If you wish to be particular, I would recommend the following plan :—Filter the contents of the tube containing the nitric acid solution and the precipitate by means of a small glass funnel and white blotting paper. Wash the solid part that remains on the paper by pouring a little water on it—or, better still, by means of a wash-bottle described on page 49—and allow the water to filter through. Now put the paper containing the precipitate into the bottom of a tube, add a little ammonia, and gently heat the mixture.

The ammonia will dissolve the chloride of silver present, but cannot act upon the chloride of lead The liquid will therefore contain all the silver that is present. Decant it very carefully into another tube—or, what is better, filter it into another tube—and add a few drops of nitric acid.

A white, curdy precipitate will be formed, which will turn black on exposure to sunlight. This is also chloride of silver, $Ag\,Cl$.

N.B.—Should mercury be present in the original precipitate as a chloride, the ammonia will blacken it when added as above directed.

It is not very likely, however, that mercury will be present in the mineral which you are testing for silver, because nitric acid only dissolves mercury when in the form of amalgam, which is a mixture of silver and mercury, and is by no means a metal of common occurrence, though it has been fonnd in considerable quantities in some of the silver mines in Chili.

Case 2.—The original specimen may, however, contain silver in the form of a chloride ($Ag\,Cl$) or a bromide ($Ag\,Br$). In this case it will not be brought into solution by means of nitric or any other acid, for acids do not act upon chlorides or bromides of silver.

How then are we to test for silver when it occurs in these forms? It fortunately happens that although acids will not dissolve it out, other chemicals will. Ammonia, as we have seen, will dissolve chloride of silver readily, and it will to some extent dissolve bromide of silver, but not entirely. It is therefore better to use something that will act upon both chloride and bromide of silver equally well. Cyanide of potassium (KCN) is the desired substance. By using this you will spare yourself the trouble of performing an additional experiment; for although ammonia may be used for dissolving the specimen, if it is a chloride of silver, yet it does not answer very well for dissolving a bromide of silver. You do not know whether the mineral is a bromide or chloride, and therefore if with ammonia you get no result, you will still have to try the cyanide of potassium before rejecting the specimen. By using this at first, you will dissolve out the silver whether it exists in the form of a chloride or a bromide or a mixture of these, as in the chloro-bromides of Broken Hill, N. S. Wales.

Therefore dissolve a little cyanide of potassium in water, and add a small quantity of the powdered specimen. Apply heat for several minutes, and allow the liquid to become clear. Decant or filter a little into another tube, and add a few drops of nitric acid. A white curdy precipitate of chloride of silver, which turns black on exposure to sunlight, indicates the presence of silver.

These tests are quite sufficient for proving the existence of silver, in whatever form it may occur, even though the ore containing it is, as is often the case, most complex in its character.

N.B.—If you are dealing with a nitric acid solution, you may, after testing for silver, test portions of the same solution for other metals according to the directions given under each. The fact of the hydrochloric acid being added will not interfere with the action of the other reagents to be employed.

ESTIMATION OF THE PERCENTAGE OF SILVER AND OTHER METALS.

I will now give a brief description of a simple means of estimating with tolerable accuracy the amount of silver contained (per ton) in a given sample. For this you will require a pair of accurate scales and weights and also some small filter papers.

We will take the first case we have supposed, viz., that the nitric acid solution contained silver which, on the addition of the hydrochloric acid (HCl) or common salt solution ($NaCl$), was thrown down as a white curdy precipitate of $AgCl$, *i.e.*, chloride of silver.

The action that took place is represented by the following equations which the observations made in Chap. I. will enable you to understand:—

$$4\ Ag+6\ HNO_3=4\ Ag\ NO^3+N_2O_3+3\ H_2O$$
$$Ag\ NO_3+H\ Cl=Ag\ Cl+HNO_3$$
$$Ag\ NO_3+Na\ Cl=Ag\ Cl+Na\ NO_3.$$

Weigh accurately 100 grains of the powdered mineral and boil it for a few minutes in strong nitric acid as above described. Dilute with a little water, filter very carefully, and add hydrochloric acid, drop by drop, till a precipitate no longer forms, taking care to agitate the mixture. Then filter, and while the filter paper is still in the filter pour upon the precipitate boiling water to dissolve out the chloride of lead, should any be present. Now dry, and weigh very carefully, the precipitate remaining on the filter paper, for this is chloride of silver. It will greatly simplify matters, though it may somewhat impair the accuracy of the result, if you place in the scale pan with the weights a dry filter paper to balance the one on which the precipitate is lying and which must be perfectly dry. Suppose you have to add to the pan in which the unused filter paper is lying two grains. You conclude that the precipitate lying on the other filter paper weighs two grains. Now what have we? 100 grains of the mineral under examination produces two grains of chloride of silver, which is represented by Ag Cl, and which is a chemical combination of silver and chlorine. On referring to the table of atomic weights given in the first chapter (p. 5) it will be found that the atomic weight of silver (Ag) is 108, and that of chlorine (Cl) is 35·5, *i.e.*, 35½.

Having made a note of this, let us see how many grains of Ag Cl a ton of the specimen will give. Remembering that there are 7000 grains in a pound avoirdupois, we get, if there are 2 grains of Ag Cl obtained from 100 grains of mineral, 140 grains of Ag Cl from 1lb. of the mineral. That multiplied by 112 gives 15,680grs. from 1cwt., or

313,600grs. from a ton. Now, since out of $108+35\frac{1}{2}$, *i.e.*, $143\frac{1}{2}$ parts of Ag Cl, 108 parts are pure silver, it is a very easy matter to ascertain how many grains out of the 313,600 grains of silver chloride will be pure silver.

Thus, as $143\frac{1}{2} : 313{,}600 :: 108$.

This will give 236,019grs. of pure silver, or nearly 492ozs. to the ton, as may be verified by dividing the 236,019grs. by 480, the number of grains in 1oz. Troy. You may, however, prefer the following method of calculation: Multiply the weight of Ag Cl by $\frac{3}{4}$, or, correctly, ·75174, which is its coefficient, as it is called. This will give you the quantity of pure silver in 100 grains of ore; then multiply the result by 156,800, *i.e.*, the number of times 100 grains of ore is contained in one ton, and divide the answer by 480. The answer will be ozs. Troy. Thus:

$$\frac{2}{1} \times \frac{3}{4} \times \frac{156800}{1} \times \frac{1}{480} = \frac{940800}{1920} = 490 \text{ ozs.}$$

It will at once be seen that such a rough method as that above described will only answer in the event of the ore being tolerably or very rich, for the scales you have will probably not be very accurate, and even if they are, you will not have weights less than $\frac{1}{2}$gr., $\frac{1}{4}$gr., &c. I merely mention it here to help you to arrive at some rough idea of the value of the ore you may be fortunate enough to meet with. Knowing that if 100 grains of ore yield 2 grains of Ag Cl, the yield per ton is 490ozs. of silver, it is easy, in the event of 100 grains yielding more or less than 2 of Ag Cl, to approximately estimate the amount of pure silver.

I suppose, however, that most people will be perfectly satisfied if on trying the tests given in this chapter they get a heavy precipitate, for this would show that the specimen is a good one, and this being so they will gladly pay a qualified analyst his fee to know the exact percentage of silver.

N.B.—If you have a chloride or bromide of silver, and you deal with it as I have directed in this chapter, obtaining a precipitate by means of nitric acid, that precipitate is also chloride of silver. Wherever simple methods of estimating the percentage of other metals, *e.g.*, copper, antimony, bismuth, &c., can be given, they will be found under the headings of the various metals.

The following table of weights may be of service :—

TROY WEIGHT.

24 grains = 1 pennyweight (dwt.)
20 pennyweights = 1 ounce (oz.) (480 grains).
12 ounces = 1 pound (lb.) (5,760 grs.)

AVOIRDUPOIS WEIGHT.

16 drams = 1 oz. (437½ grains).
16 ounces = 1 lb. (7,000 grains).
28 lbs. = 1 quarter (qr.)
4 qrs. = 1 hundredweight (cwt.) 112 lbs.
20 cwt. = 1 ton (2,240 lbs.)

As the French measure of weights is very commonly employed I will mention it here :—

Milligramme $\frac{1}{1000}$ of a gramme = ·0154 grains.
Centigramme $\frac{1}{100}$,, ·1544 ,,
Decigramme $\frac{1}{10}$,, = 1·544 ,,
Gramme (unit of weight) = 15·44 ,,
Decagramme (10 grammes) = 154·4 ,,
Hectogramme (100 grammes) = 1544 ,,
Kilogramme (1,000 grammes) = 34½ ounces.
Myriagramme (10,000 grammes) = 22·57 lbs.

We shall now proceed to the consideration of such wet tests for the various minerals as it is desirable to be familiar with. Under the head of each mineral described will be found observations respecting the rock formations in which it generally occurs together with other matters of interest; and, in order that you may form some idea of the probable composition of the mineral from a consideration of its physical properties, a brief description will be given of the appearance it possesses in consequence of its chemical union with other substances.

These minerals will be dealt with in the following order: Gold, Platinum, Iridosmine, Silver, Mercury, Copper, Bismuth, Graphite, Lead, Antimony, Zinc, Tin, Cobalt, Nickel, Iron, Arsenic, Manganese, Molybdenum, Tungsten, Titanium, Uranium, Tellurium, Aluminium, Magnesium, Thorium, Calcium, Barium, Asbestos, Mica, Coal, Clay.

GOLD—AU.

OBSERVATIONS.—No metal is perhaps more widely disseminated in nature than Gold. It exists in rocks of all ages and in sea water to the extent of one grain to the ton. Until recently it has been held that gold occurs mostly native, either pure or alloyed with silver and occasionally with other metals such as copper, iron, bismuth, tellurium, rhodium, &c., but I am convinced that more gold exists in the form of these and other chemical compounds than in the native state. The average of Australian gold is 93½ per cent. gold. The colour is, when pure, dark yellow, but it becomes paler with the increase of silver. Hardness, 2·5 to 3. Specific gravity ranges from 12 to 19·5 depending upon the amount of foreign metal alloyed with it.

Where it occurs in the form of scales, crystals, and nuggets, in the alluvial drifts, it is called "alluvial" gold to distinguish it from "reef" gold. These alluvial drifts—which are composed of boulders, gravels, sands and clay—belong for the most part to the Tertiary and Post-Tertiary periods, and have been derived from the breaking up or disintegration of pre-existing rocks. It has generally been held that the gold came into these drifts from reefs that have existed or that still exist in the country rocks around, and no doubt this is sometimes, perhaps generally, the case; but many hold—myself among the number—that it is more than probable that in some cases alluvial gold has been brought into the drift by water charged with gold in solution, which, in the presence of organic matter, has been deposited on particles of pyrites, gold, or other solid substances. Hence it is quite possible that nuggets may have "grown" in the spot where the lucky digger has found them.

The rocks in which auriferous veins, reefs, or "ledges," as they are called in the States, are most commonly met with are altered clay slates of the lower and upper Silurian and Devonian formations—especially where they are associated with greenstone dykes; also in metamorphic rocks, in chloritic, micaceous, talcose and other schists; in granite and with serpentine; but any rock formation through which quartz reefs run, especially when these contain metallic sulphides, may yield payable gold.

In Hauraki Peninsula, N. Zealand, and also at Cripple Creek, Colorado, U.S.A., the reefs mostly exist in *propylite*, *i.e.*, decomposed andesite, and in breccias, both of tertiary age.

The chief associated metallic minerals are pyrites (mostly iron pyrites, though sometimes copper), iron oxide, zinc-blende, galena, mispickel, and stibnite, but tellurium, manganese, &c., also occur. The principal non metallic associated minerals are quartz, clays, chlorite, and calcite; though barytes and fluor also occur.

The quartz which is the usual matrix of gold is frequently honeycombed and rusted at the surface over the upper part of the vein, owing to decomposition of the pyrites and other sulphides, which are converted into oxides. A honeycombed rock, brown with oxide of iron, is considered a good surface indication.

The occurrence of gold in the motherly embrace of iron sulphide or oxide is somewhat remarkable, inasmuch as an attempt to unite these artificially in our laboratories will prove unsuccessful. Into this question I will not enter now. The practical inference is that in auriferous regions it is advisable to try ironstone of the less compact varieties for gold; for what has probably happened is this: the gold was in the pyrites from which the sulphur has been driven off by heat—in reality, roasted by nature—leaving oxide of iron containing metallic gold in so finely divided a state as to be invisible to the naked eye.

At Mount Morgan Gold Mine, Rockhampton, Queensland, the gold occurs in stalactitic and other ironstone, deposited apparently, in part at least, by thermal springs. It is a noteworthy fact that the Mount Morgan gold is the finest the world has yet produced, containing nearly 99·7 per cent. of pure gold.

With reference to the gold in pyrites, I may remark that in my opinion the metal frequently exists partly in combination with sulphur, *i.e.*, as a sulphide of gold, and not, as is generally supposed, scattered through the pyrites in the metallic state only. When this is the case the gold sulphide cannot be dissolved by nitric acid, though it is soluble in aqua regia, and may be precipitated by ferrous sulphate or stannous chloride, as will be described presently. Gold also exists as a telluride, a silicate, and in various other forms.

TREATMENT OF "REFRACTORY" OR "REBELLIOUS" GOLD ORES.—More gold exists in combination with pyrites, antimony, arsenic, zinc, galena, tellurium, &c., than exists "free;" and the question of the economical extraction of the precious metal from these "refractory" ores is one of the greatest commercial importance. It is one to which I have given special attention, with, I am pleased to say, very satisfactory results

The methods hitherto adopted for the extraction of gold from refractory ores are *Cyanidation*, *Chlorination* and *Smelting*.

The Cyanide Process.—In this the ore is crushed fine and is subjected for some 12 to 40 hours to the action of a weak solution of cyanide of potassium (KCN), strength from ¼ to ¾ per cent., which penetrates the ore, finds the gold, and, aided by the oxygen of the air, brings it out in solution, the action being, according to "Elsner's Equation"—

$2Au + 4K\,CN + O + H_2O = 2(Au\,KCN_2) + 2KHO$

The gold from this cyanide of gold ($Au\,KCN_2$) solution is collected by passing the solution through troughs or boxes filled with zinc shavings, which precipitate the gold in a finely divided state. The gold is then freed from all impurities by melting it in a crucible with sand, bi-carbonate of soda and borax.

The Bromo-Cyanide Process.—It is claimed that this is an improvement on the Cyanide Treatment, as it overcomes some of the difficulties attending the application of that process, *e.g.*, the formation of compounds such as KHO, which, in the presence of sulphides of the baser metals, *e.g.*, Copper, Antimony, Arsenic, Zinc, Tellurium, &c., consume the cyanide, and result in the failure to obtain a fair per centage of the gold. Instead of aerating the cyanide solution, a compound is added holding a reserve of Cyanogen (C_2N_2)—the active solvent principle in potassium cyanide—which can be chemically disengaged in the solution at the point of actual contact with the gold in the ore. Bromo-Cyanide ($Br\,CN$) is the desired substance. It is added in the proportion of about half the quantity of Potassium Cyanide employed, *e.g.*, 0·5 per cent. Potassium Cyanide with 0·25 per cent. Bromo-Cyanide, or one per cent. KCN with 0·5 per cent. Br CN. It appears to me that the process has much to commend it.

The Chlorination Process.—In chlorination the ore is first roasted in order to get rid of the sulphur, arsenic, &c. It is then placed in immense vats furnished with false bottoms, moistened, and subjected for from 24 to 48 hours, according to the fineness of the gold and the temperature employed, to the action of chlorine gas (Cl) which is generated in airtight vessels of lead. The reaction is $Au + 3Cl = Au\,Cl_3$. Water is then added to wash out the soluble chloride of gold formed This operation is called *leaching*. The solution is then conveyed to the precipitating vats, and sulphate of iron ($Fe\,SO_4$) is added to throw down the gold. The reaction is $2Au\,Cl_3 + 6FeSO_4 = Fe_2\,Cl_6 + 2Fe_2\,(SO_4)_3 + 2Au$ The liquid is allowed to stand for 48 hours, and is then syphoned off, when the precipitated gold (Au) is collected, dried carefully, and fused in graphite pots with salt, sand, nitre, borax, &c.

Smelting.—In *smelting*, the ore is first crushed and then roasted. It then passes into a slagging furnace, where it is mixed with slag in order to prepare it for the blast furnace; for if not consolidated in some way, the fine particles of ore would be driven off by the blast. The prepared ore is then mixed with the necessary fluxes, and subjected to an intense heat in the blast furnace, the result being a regulus, or matte, in which the gold is concentrated and from which it must afterward be separated.

The Thermo-Hyperphoric Process.—It is not my intention to discuss the advantages or disadvantages of the various methods of gold extraction above described. With some classes of ore they answer very well indeed, with others they absolutely fail; but even where successful, the length of time occupied and the manifold operations involved increase the expense of treatment to such an extent that some improvement on these methods seems very desirable.

Having devoted several years to this question I may be allowed to speak with some authority, and I am very pleased to be able to say that all refractory ores, whether amenable to the above methods of treatment or not, can be made to yield 90 to 95 per cent of their gold at a cost of from 5s. to 10s. per ton by treating the ore previous to amalgamation with what is popularly known as *water-gas* in closed furnaces.

This treatment, partly the invention of Mr Alf. A. Lockwood, M.I.M.E., was submitted to me for examination in 1890. It was then in a very crude state, but, as I was convinced of its value, I bestowed careful attention upon the matter, and having fully demonstrated the efficacy of the treatment, applied it on a large scale to ores containing 20 per cent. of arsenic and zinc, lead, copper and iron sulphides, with the result that I saved 95 per cent. of the assay value, viz., 1oz. 15dwt. against 11dwt. by battery or pan amalgamation.

Having recently brought the furnace in connection with the process to perfection, I took out patents for the treatment in every country of importance, and applied to it the distinctive name of "Thermo-Hyperphoric Treatment," which correctly describes the action—viz., that heat is employed, and that the base elements that interfere with the amalgamation of the gold with quicksilver are eliminated by the agency of the water-gas.

By a very simple arrangement steam is conveyed over red-hot coke (carbon), and the products, consisting chiefly of hydrogen (H) and carbonic oxide (CO), which together make up water-gas, are conducted to closed furnaces into which the crushed ore is automatically fed These are raised to a temperature of about 1200° F. to 1800° F., by means of gaseous or solid fuel; and, after treatment lasting from two to four hours, depending on the complexity of the ore, all impurities which interfere with the amalgamation of the gold are removed or are so modified by the chemical action of the gases, that the precious metal is left quite pure. The ore is then crushed and amalgamated by an improved method. The complete treatment costs less than 10s. per ton—in ordinary cases only 5s.—and, by reason of its simplicity, its effectiveness, and its cheapness, it cannot fail to become the popular method of dealing with refractory gold-bearing ores. This is the opinion of the English metallurgists to whom I have recently submitted the process.

Tests for Gold.—Minute specks of sulphide or of oxide of iron in quartz and other stone are sometimes mistaken for gold. Holding the specimen in such a way as to let the light fall direct upon the speck from all directions, turn it round; if the colour and lustre remain uniform and unchanged, we may reasonably conclude that the speck is gold, for particles of sulphide and oxide of iron reflect light more strongly from one side than from another. If possible, press the speck with the point of your knife: if it is iron it will not be impressed, but if gold it will be. Should you still be uncertain as to the speck being gold, reduce the stone to a fine powder and wash it in a pan. Examine the pan, if necessary with the aid of a lens, to see if there be any specks of gold in it, remembering what has been said about the reflection of light in the case of those particles likely to be mistaken for gold. If you require a confirmatory test, or should you prefer to apply the wet test without going through the washing process, you may act as follows:—Powder the specimen as finely as possible, and boil a small quantity of it for ten minutes or so in aqua regia, prepared by adding one part of strong nitric acid to three parts of strong hydrochloric acid, when required. This mixture readily dissolves gold, the explanation being that chlorine, which is one of the solvents for gold, is formed by the mutual action of the nitric and hydrochloric acid, and produces chloride of gold, $Au\,Cl_3$. The action is expressed by the following equation: $2Au+3HNO_3+9H\,Cl=2Au\,Cl_3+3NO\,Cl+6H_2O$.

N.B.—If the ore contains much oxide of iron, this ought first to be dissolved by boiling gently with hydrochloric acid. Pour off and wash; then boil with aqua regia. If the ore contains much pyrites it must be ground to powder and gently warmed with pure (colourless) nitric acid (added little by little five or six times) till all the fumes have disappeared, and then washed and treated with aqua regia. Or the pyrites may be carefully roasted on a shovel or clay tray till it ceases to smell of sulphur, and the oxide of iron, into which the sulphide is thus converted —(see page 33)—gently warmed with hydrochloric acid till the ore is dissolved Then proceed with the aqua regia treatment. If the ore contains much antimony deal with it as directed on page 85.

Having boiled the powdered ore for about ten minutes, proceed as follows :—

Method I.—Filter and boil the filtrate in a tube or a small china dish until the liquid has nearly all evaporated, add a little hot water, say about a wineglassful, and again filter. Boil down to half the quantity ; add four drops of hydrochloric acid, then add one-fifth of its bulk of clear ferrous sulphate solution, made by shaking up some crystals of ferrous sulphate with water and filtering. If gold be present, a precipitate of metallic gold is produced, which appears brown when the tube containing it is held in front of some dark object (*i.e.*, when viewed by reflected light) ; but bluish-green when held up to the light (*i.e.*, when it is examined by transmitted light) This brown or bluish-green colour is obvious even when 40,000 parts of the liquid are present. If the liquid amounts tō 80,000 parts it it coloured sky-blue ; with 160,000 parts it becomes violet ; with 320,000 parts of liquid the violet tint is still very obvious.

By taking a known quantity of ore, say half a pound, and performing the experiment carefully and collecting the precipitate, which is metallic gold, and weighing it, a very fair estimate of the number of ounces per ton can be obtained.

Or Method II.—Having boiled the ore in aqua regia for ten minutes, filter, and to a portion of the clear solution add a few drops of stannous chloride. Even in extremely dilute solutions of gold, a purple-red precipitate (or coloration at least), which sometimes inclines rather to violet or brownish-red, is produced. This precipitate has been called "purple of Cassius."

It may here be useful to describe how stannous chloride is prepared, as it is sometimes difficult to procure in the country districts. Take a piece of metallic tin and reduce it to powder either by filing or scraping with a knife Boil the powder for some time (say for fifteen minutes) with concentrated hydrochloric acid in a wide tube, taking care always to have an excess of tin in the vessel; dilute the solution with four times the quantity of water to which has been added enough hydrochloric acid in it to make it slightly acid, and filter. Keep the clear solution for use in a well-stoppered bottle containing small pieces of metallic tin or some pure tin foil. If this be not attended to, the stannous chloride will absorb oxygen from the air, and become so changed in its nature as to prevent its being used for the purpose for which it was intended. Should you procure the stannous chloride in the solid form from the chemist, it must be dissolved by boiling in strong hydrochloric acid. Boil till no more of the salt will dissolve, then add to the solution four times as much pure water. Bottle as above.

P.S.—Miners sometimes desire to ascertain the value of quartz specimens. I will therefore furnish a simple method of ascertaining the weight of gold in a given specimen. Weigh it in air; next find its specific gravity as described on page 18. Knowing the specific gravity of gold, which may safely be taken at 17, and the specific gravity of quartz, viz, 2·5, we can by the following formula ascertain the weight of gold contained in the specimen—

$$g = n\frac{(N-Q)\ G}{(G-Q)\ N}$$

in which g = weight of gold in specimen. G = the specific gravity of gold, Q = specific gravity of quartz;

n = the weight of specimen, and N = the specific gravity of specimen.

Gold Ores.—Under Tellurium, p. 101, will be found a brief description of telluride gold ores, which are attracting great attention just now in Western Australia, the United States, and New Zealand. Antimonial ores, iron pyrites, arsenical pyrites, &c., also contain gold free, and as a sulphide, sometimes in payable quantities. These will be dealt with under their respective heads.

PLATINUM,—Pt., AND IRIDOSMINE.

Observations.—This metal occurs in the native state usually in flattened grains though sometimes in masses weighing several pounds. It is generally more or less alloyed with gold, iridium, osmium, iron and other metals. This has the effect of darkening its colour, which is naturally silver-white; but it becomes steel-gray when thus alloyed. Its hardness is 4 to 5 : sp. gr. : 16 to 19 It is malleable *i.e.*, it may be flattened out. It is found in some of the gold-bearing alluvial deposits. Another metal commonly found in these deposits and sometimes associated with Platinum, is a compound of iridium and osmium to which the name of *Iridosmine*, and sometimes *Osmiridium*, has been given. This metal occurs in the form of flattened grains of a steel-gray colour, and much resembles platinum, than which, however, it is much harder, having a hardness of 6·7. Its sp. gr. 19·5 to 21·1. When Iridosmine is alloyed with gold as is sometimes the case it injures its quality owing to the fact that being very hard it destroys the dies used for coining. The value of Platinum is from 20s. to 26s. an ounce. It is infusible before the blowpipe, and hence is used in testing for minerals by means of borax bead. It is also made into vessels for chemical purposes.

Tests.—If, when panning off, you observe steel-gray or silver, white grains remaining at the bottom of the prospector's dish, you may be tolerably sure they are platinum or iridosmine, their colour and weight being the tests applied. But you may wish to apply confirmatory tests, therefore I furnish the following. Both are unchanged before the blowpipe. Both are insoluble in any single acid, but Platinum slowly dissolves in boiling aqua regia, forming a yellowish solution which becomes bright red on the addition of stannous chloride. If, after long boiling in aqua regia, some flattened steel-gray or tin-white grains remain they are Iridosmine. Platinum is often slightly magnetic, but this is probably due to the presence of iron.

SILVER,—Ag.

Observations.—Silver is found native, and also in combination with various substances forming sulphides, chlorides, &c. The various ores of silver are found in rocks of all ages, except the carboniferous, from the granite and metamorphic slates, porphryies, schists, to the beginning of the tertiary. It also exists in sea water as a chloride. The principal silver ores do not resemble silver at all, but contain such large quantities of lead, arsenic, iron or other minerals as to completely mask the silver. Some of the silver-bearing ores are very refractory, but it will be found that the treatment by water-gas referred to on p. 61 will also prove effective in dealing with such silver-bearing ores. The tests described on p. 50—53 will never fail to detect the presence of silver, even when it exists in a very small quantity.

Description of Silver Ores.

Native Silver (Symbol Ag).—In some cases native silver is found associated with silver ores. It occurs occasionally in the regular form of crystals (cubical system), but chiefly in irregular grains and formless masses. It has been found in New South Wales in thin plates, and in bundles of fine fibres, like hairs, growing from a common centre.

The natural colour of silver is white and shining; but owing to its great affinity for sulphur, which blackens its bright surface, it is mostly found in black masses imbedded in the silver ores, filling fissures in veins, or appearing as a black vegetation in cavities or on the surface of veins. It is malleable, and may easily be cut with a knife, having a hardness from 2½ to 3. Its specific gravity is 10·1 to 11·1.

CONFIRMATORY TEST.—Dissolve in nitric acid and add hydrochloric acid or common salt solution. A white curd which turns black on exposure to sunlight, or which dissolves in ammonia, proves the presence of silver.

All native or manufactured silver contains a minute quantity of gold, copper, iron, or arsenic. These metals have a great affinity for silver, and cannot be entirely separated from it in the smelting operations.

Some have been deceived by a mineral known as arsenical-iron pyrites, or mispickel, which has a silvery appearance and is commonly associated with ores of silver, see page 97. This ore may readily be distinguished from native silver, not only by the above confirmatory test, but by its brittleness, its want of sectility, or incapability of being cut with a knife, and the white arsenical fumes it gives off under the blowpipe, when it yields black specks of iron which are magnetic. The smell of the fumes is somewhat like that of onions.

Sulphide of Silver, or Argentite, or silver glance; symbol Ag_2S when pure; hardness, from 2 to 2½, hence it is easily cut with a knife; specific gravity 7 to 7·4; colour, blackish lead-gray; streak, shining. One hundred parts of pure Ag_2S contain sulphur 12·9, silver 87·1; but generally the proportion of Ag_2S to the mass of ore is but small. Sulphide of Silver has been found in many parts of the colony, but in most cases intimately mixed with galena (sulphide of lead), so that really the ore should be termed argentiferous galena (see under Lead, page 83).

TEST.—To test for silver when occurring in this form, whether alone, or associated with galena, act as follows :—Pulverise the mineral and boil it for a few minutes in strong nitric acid. In the event of admixture with galena, a white powder (sulphate of lead) will appear in the solution as the result of the action of the strong nitric acid on the sulphur and lead ; but it will not interfere with the solution of the silver should any be present. Its presence may therefore be disregarded. Now dilute with water and filter the solution, and to the clear liquid add hydrochloric acid or common salt solution. A white curd, which turns black on exposure to sunlight, proves the presence of silver. This curd is chloride of silver, Ag Cl. By taking a known quantity of ore, and weighing the Ag Cl obtained from it, the amount of silver per ton may easily be calculated, as exemplified on pages 53 to 55.

Antimonial Silver Ores.—Of these ores two forms are well known, viz., Stephanite, Ag_5S_4Sb, or as it is sometimes called, Black silver; and Pyrargyrite or Ruby silver, Ag_3S_3Sb. It will be seen from the formulæ that each of these contains antimony, Sb. and Sulphur, S. Their hardness, specific gravity and streak are as follows :—Stephanite ; H, 2 to 2¼, specific gravity 6·27, streak iron-black ; and Ruby silver ; H, 2 to 2½, specific gravity 5·7 to 5·9, streak cochineal-red. The colour of Ruby silver embraces all the shades of red, but it is sometimes of an iron-gray. It is rarely found of any other colour. The lustre of this ore is remarkable, being metallic, and in many instances nearly as brilliant as that of a diamond.

There is also another Antimonial silver ore called Dyscrasite, which is a crystallised ore of whitish or yellowish blue colour. Streak silver-white. It resembles arsenical iron very much, but it is easily distinguished from that ore by its crystals being longer, and by its being sectile—*i.e.*, capable of being cut with a knife. It consists of silver and antimony.

TEST.—To test silver when occurring in this form, proceed as follows:—First pulverise the mineral and boil in strong nitric acid for a few minutes, and then add as much water as there is acid, and boil again. The white powder that forms is an oxide of antimony. This dissolves on adding tartaric acid and boiling; but as its presence does not interfere with the testing for silver, you need simply filter and add to the clear solution hydrochloric acid, as described in the former cases. The resulting precipitate is $Ag\,Cl$ (chloride of silver).

Proustite, or light-red silver ore.—This is a valuable ore of silver closely related to pyrargyrite. Its composition is Ag_3S_3As, from which it will be seen that the arsenic has replaced the antimony of pyrargyrite. The hardness of proustite is about 2½, and streak light red.

TEST.—Proceed as in Sulphide of Silver.

Fahlore or Fahlerz.—Symbol $Cu_8S_7Sb_2$. It will be seen from this that the ore is a mixture of copper, sulphur, and antimony; but, inasmuch as part of the copper is frequently replaced by silver, it is right to mention it when speaking of the silver ores. Its colour varies from steel-gray to iron-black; its hardness ranges from 3 to 4·5, and its specific gravity from 4·5 to 5·12; streak nearly the same as the colour, sometimes inclined to brown and cherry-red. The proportions of the constituents, as indeed the constituents themselves, vary much. Sometimes part of the antimony is replaced by arsenic, in which case the ore is paler in colour, and contains no silver. The dark-coloured ore contains from 25 to 28 per cent. of antimony, and is richest in silver. The percentage of silver in fahlerz generally varies from 0 to 10, but some specimens have been known to contain as high as 30 per cent. of silver.

TEST.—To detect the presence of silver in fahlerz, act as in the other cases mentioned. It will be noticed that the solution becomes a brownish-green colour; this is owing to the presence of copper. The white powder caused by the nitric acid oxidising the antimony will also appear, but its presence may be disregarded, as it can be got rid of by filtering.

Arsenide of Silver.—This occurs at Sunny Corner and elsewhere in New South Wales. The ore containing it somewhat resembles porous ironstone; indeed, it is one of the iron ores, viz., Hæmatite. It would appear as if the silver, with a little lead, was originally present in Arsenical Pyrites (Mispickel) which is made up of arsenic, iron, and sulphur, and which often contains lead and silver as arsenical sulphides of those metals. This has been acted on by heat which has driven off all the sulphur and most of the arsenic and has allowed the oxygen of the air to unite with the iron, forming an oxide of iron. The silver and lead have probably been left in combination with some of the arsenic as arsenides.

TEST.—Act as in the case of Sulphide of Silver.

Hessite or Telluride of Silver, Ag Te, 100 parts being composed of 37·2 tellurium and 62·8 of silver. This is a heavy sectile, metallic-looking, steel-gray, or lead-gray mineral, sp. gr., 8·3 to 8 6; hardness, 2 to 3·5. I mention this ore because it is, in small quantities, frequently mixed with sulphide of silver in galena and blende. It dissolves in boiling nitric acid, and hence the presence of silver in this form will be detected during the test for sulphide of silver.

Silver Chloride, or horn silver. Symbol, Ag Cl. This ore occurs chiefly at the out-crop of veins of silver, along with the sulphide or silver-glance; indeed, it appears in almost every place where silver is found. It is a somewhat horny or waxy-looking substance, and is so soft that it may be cut by the finger-nail. Hardness, 1 to

1·5; sp. gr., 5·5 to 5·6; streak, shining. 100 parts of pure $AgCl$ contain, chlorine 24·7 and silver 75·3. Its colour is gray, though occasionally it is bluish or greenish. It is often so mixed with clay that it does not present the appearance of pure horn silver, but looks much like clay. In this case its presence can only be determined by testing. Clay resulting from the decomposition of felspar in granite and other felspar-bearing rocks is called *kaolin*, which consists of silica 46·4, alumina 39·7, and water 13·9=100 parts. At Broken Hill chloride of silver exists in this, scattered through it in grains or streaks. This is known as "kaolin ore." Pure horn silver fuses in the flame of a candle, and emits acrid fumes. It is very easily reduced to metallic silver by means of the blow pipe.

TEST.—This ore is not affected by acids. Ammonia and potassium cyanide both dissolve it; and from the solution obtained by either of these, nitric acid throws down a white curdy precipitate of chloride of silver, which turns black on exposure to sunlight, as described on page 50.

Silver Bromide, or Bromite. Symbol, $AgBr$; colour, olive-green or yellow. H, 1 to 2; sp. gr., 5·8 to 6. No specimens of pure bromide have as yet been discovered in New South Wales.

Silver Chloro-Bromide, or Embolite. Symbol, $2AgBr+3AgCl$. This ore, which, as will be seen from the formula, is a mixture of chloride and bromide, somewhat resembles the latter. Its colour is asparagus to olive-green. H, 1 to 1·5; sp. gr., 5·1. 100 parts contain 51 of chloride of silver and 49 of bromide.

This ore has been found at Silverton, in the Barrier Ranges, and at Broken Hill.

TEST.—Bromide of silver is scarcely dissolved by ammonia, so that, in order to get all the silver contained by a specimen of chloro-bromide in solution, it is necessary to use potassium cyanide as a solvent. From the solution nitric acid throws down a white precipitate of Ag Cl, which turns black on exposure to sunlight, as explained on page 50.

MERCURY—Hg.

Observations.—The ores of mercury (quicksilver) are found in veins in sedimentary rocks of all ages, but chiefly in the clay-slates and mica-schists; also scattered in grains through sandstone.

Tests.—All the ores of mercury may easily be distinguished by their volatile (easily evaporating) character, and by coating a piece of copper white when rubbed upon it. They all, if pure, evaporate when thrown upon a red-hot iron, and those containing sulphur emit a strong smell of sulphur under this treatment.

The following test may be tried:—Reduce the ore to powder, and mix it intimately with about an equal quantity of quicklime. Place the mixture in a tube, and apply a gentle heat. After a short time the sulphur will unite with the quicklime, and a globule of mercury will be found at the bottom of the tube, or condensed in minute globules on the sides of the tube. By fitting the glass tube with a cork and piece of tubing, bent and having its end immersed in cold water, all the mercury, which by heat is reduced to vapour, can be collected in a condensed form as a globule. See also glass-tube test, page 24.

Wet Test.—Dissolve in nitric acid; add hydrochloric acid. A white precipitate forms; collect this, and add ammonia to it. If it becomes black, mercury is present.

This test does not apply in the case of sulphide of mercury (Cinnabar) since it is insoluble in nitric acid. It, however, dissolves in aqua regia, forming mercuric chloride with separation of sulphur. Evaporate nearly to dryness and add water. Filter and add a little stannous chloride; a white precipitate of sub-chloride of mercury ($Hg_2 Cl_2$) is thrown down. On adding more stannous chloride this precipitate is reduced to metallic mercury, and acquires a gray tint. If it be allowed to subside, it may be united into globules of metallic mercury by boiling with hydrochloric acid and a little stannous chloride. By taking 100 grains and in this way collecting the mercury it contains, a fair idea of the value of the ore can be arrived at.

DESCRIPTION OF ORES —*Native Mercury.*—This occurs in small globules scattered through the containing rock; colour, tin-white. Sp. gr., 13 56. It has been met with in New South Wales, but it is a rare mineral.

Native Amalgam.—This is a compound of silver and mercury; Symbol $Ag\ Hg$ and $Ag_2\ Hg_3$. Hardness, 3 to 3·5; sp. gr. 10 5 to 14·1. It is silver-white in colour, and is rather brittle. It sometimes contains more than 35 per cent. of silver.

Cinnabar.—Symbol $Hg\ S$. This ore has been met with in New South Wales. Its colour varies from bright-red to brownish-black. Its streak is scarlet-red. Hardness, 2 to 2 5; sp. gr. 8·5 to 9. It often contains impurities such as carbon and clay, in which case it has a brownish streak and colour.

It is easily distinguished from red iron ore (red hæmatite) by the tests given above.

COPPER—Cu.

OBSERVATIONS.—The ores of copper are very widely distributed They are fairly abundant in quantity, and varied in appearance, being of various shades of colour, from a brilliant red to velvet black, also of a beautiful green and sky-blue. Their bright colour distinguishes them from other ores. The geological position of copper varies, but the more extensive deposits occur among the old slates Devonian and Silurian, the metamorphic rocks as, for example, gneiss, altered Devonian sandstones, schists, porphyry, granite and others; especially in the neighbourhood of dykes of igneous rocks.

TESTS. 1 —See Borax Bead test, page 35; also Reduction Test, chapter VI., page 42.

2. Powder the ore and dissolve it in boiling nitric acid. Dilute the solution with water, and add ammonia drop by drop. If copper be present a greenish-blue precipitate forms, and this re-dissolves upon further addition of ammonia, to a perfectly clear fluid of a magnificent azure blue, the intensity of the colour depending upon the amount of copper present. This test also produces a blue colour, inclining, however, to violet, when applied to nickel ores; but the following confirmatory test is satisfactory. In the solution place the clean blade of your pocket knife. If much copper be present the blade will be speedily coated with a copper-red coating of metallic copper. If the percentage be small, the blade will become coated slowly; and, of course, should copper be absent, no such effect will be produced upon the blade. If iron be present with the copper, the blue liquid forms, after allowing the contents of the tube to settle, at the top of the reddish-brown (foxy-red) precipitate of iron ($Fe\ O,\ HO$) thrown down by the ammonia.

If you wish to estimate the percentage of copper in an ore, take 100 grains of powdered ore, and boil it in enough nitric acid to enable the mixture to boil conveniently. Add enough ammonia to cause the precipitate to dissolve, forming the blue colour. Filter and boil the blue liquid. While boiling add an excess of caustic potash dissolved in water. The whole of the copper will then be thrown down as a black precipitate Copper Oxide ($Cu\ O$). Boil for a few minutes and collect the precipitate on a filter paper. Wash it by pouring clean water upon it. Dry and weigh 100 parts of the precipitate ($Cu\ O$) contain roughly 80 parts of pure metallic copper.

Suppose the 100 grains of ore yield 20 grains of $Cu\ O$. As 100 grains of $Cu\ O$ contain 80 of copper, the 20 grains

CuO would contain 16 grains of copper, *i.e.*, the ore contains 16 per cent.

Rule for Obtaining the Percentage of Copper.—Multiply the number of grains of CuO obtained as above from 100 grains of ore by $\frac{4}{5}$. This will give you the number of grains of pure copper in 100 grains of ore, that is, the yield per cent.

3. If you please you may test for copper by simply dissolving the ore in some *dilute* nitric acid, and placing in the solution the clean blade of your pocket knife. If copper be present it will be deposited on the knife-blade.

Description of Ores.—Native copper has been met with in many parts of the colony. It occurs massive, in plates, threads, wires, and in leaf-like forms. Hardness, 2·5 to 3; sp. gr. 8·8. The following ores have also been met with, in some places in large quantities:—

Fahlerz or Gray Copper or Tetrahedrite.—This ore is a mixture of Cu, Sb, and S, and, as has been explained on page 70, frequently contains silver. For description of ore see page 70. Boiled in nitric acid the powdered ore forms a brownish green solution, and gives the azure blue with ammonia.

Copper Pyrites.—Symbol $CuFeS_2$. This ore, which is the most abundant of copper ores, is never found entirely free from iron. It is of a brass-yellow colour and somewhat resembles iron pyrites, but may be distinguished from that mineral by its inferior hardness, which is only 3·5 to 4, whereas that of iron pyrites is from 6 to 6·5. Its sp. gr. is 4·1 to 4·3. It forms a green solution of nitric acid. While dissolving it gives off abundant brown poisonous fumes. The richness of copper pyrites may, in general, be judged of by the colour: if of a fine yellow hue and yielding readily to the hammer, it may be considered a good ore; but, if hard and pale yellow, it is a poor one, being mixed with iron pyrites.

There is another form of copper pyrites called Bornite or peacock ore, from the beautiful blending of colours which its surface presents. Its composition is much the same as that of the yellow copper pyrites. Symbol $Cu_3 Fe S_3$. Streak, pale grayish black. H 3; sp. gr. 5.

Red Copper Ore or Cuprite.—Symbol $Cu_2 O$, red oxide of copper. Colour, deep red of various shades. Streak, brownish-red. Distinguished from oxide of iron by its lively red colour, which is more brilliant than that of iron, and also of course by the test for copper given above. It is a brittle ore, with a hardness of from 3·5 to 4, and sp. gr. 5·85 to 6·15. Forms a bluish solution when dissolved in nitric acid.

Black Oxide of Copper or Melaconite.—Symbol $Cu O$. This results from the decomposition of the sulphide and other ores. It generally occurs in veins, or along with other copper ores, as a black powder, or in dull black masses. In some places it is found in abundance. Its colour is frequently a velvet black, often inclining to blue or brown. It yields from 60 to 70 per cent. of copper, according to the amount of impurities present. If quite pure it would contain nearly 80 per cent., as remarked on p. 75.

Carbonate of Copper.—This is either of a green colour, when it is called Malachite, or of a blue colour, when it is called Azurite. Both kinds dissolve in nitric acid with effervescence, as all carbonates do. The chemical composition of Malachite is $Cu_2 CO_3 + H_2 O$, *i.e.*, carbonate of copper and water. 100 parts contain—Copper oxide, 71·9; carbonic acid, 19 9; water, 8·2.

Its colour varies from pale emerald to deep green. It is sometimes earthy, in which case the colour is dull; and sometimes solid and compact, with a beautiful silky lustre. Its hardness is 3·5 to 4, and sp. gr. 3·7 to 4. It is a valuable ore when abundant.

The chemical composition of azurite is $2 Cu CO_3 + Cu H_2O_2$. 100 parts contain—copper oxide 69·2, carbonic acid

25·6, and water 5·2 Its colour varies from azure blue to indigo. It occurs both massive and crystallised, though often earthy. Hardness, 3·5 to 4·5. Sp. gr. 3·5 to 3·85.

Redruthite, or Vitreous copper ore, or copper glance; symbol, Cu_2S. This ore is a lead gray colour, often tarnished blue or green. Streak, blackish lead-gray. Its hardness is 2·5 to 3, and sp. gr. 5·5 to 5·8. Dissolves readily in nitric acid with separation of sulphur, and the solution covers a knife-blade with copper.

A few other forms of copper are found, but they are of little importance.

The water that collects in copper mines frequently contains in solution sulphate of copper which has been formed by the oxidation of the sulphide, thus: $Cu\,S + 4O = Cu\,SO_4$. If scrap iron be thrown into this solution the dissolved salt of copper will change places with the iron, the copper being collected in the solid form as Cu, and the iron going into solution, thus: $Cu\,SO_4 + Fe = Fe\,SO_4 + Cu$.

Bismuth—Bi.

Observations.—This metal occurs in larger quantities native than in form of ores, although the sulphides, carbonates, and oxides are also met with. It occurs in veins of gneiss and other crystalline rocks, *e.g.*, granite, and magnesian limestone; also in clay slate. In New South Wales most of, if not all, the veins of Bismuth ore which have been discovered, occur in granite in proximity to altered slate. The mineral is associated with molybdenite, wolfram, arsenical pyrites and tin ore, &c. Its value is about 7s. 6d. per lb.

Tests. 1—See Blowpipe Test, Chapter VI., page 39. I cannot do better than refer you to the above test. The bead is easily produced, and the confirmatory test is a very striking one.

2. The presence of bismuth may also be determined as follows:—

Powder the ore and place in a wide-mouthed test tube as much as will lie on the point of the small blade of a knife and add about ½ a teaspoonful of strong nitric acid. Dissolve the ore by boiling, and allow the boiling to continue till the acid evaporates to about half its original bulk. Now take a tumbler of pure water and add the solution to it. A white precipitate *perhaps* forms. I say perhaps, for even though bismuth be present, it will not be precipitated if there be any free acid present. To make quite sure add about a teaspoonful of salt water. A white precipitate, appearing either immediately, or after standing for a few minutes, shows the presence of bismuth.

DESCRIPTION OF ORES.—NATIVE BISMUTH has been found in a few places in New South Wales. It has a reddish tin-white colour, though often tarnished; streak, silver-white. Its hardness is 2·3, and specific gravity 9·6 to 9·8.

The following also occur in the colony:—

BISMUTH SULPHIDE.—Symbol, Bi_2S_3, called BISMUTHITE. The form this assumes is either granular or massive, the mass being made up of long prismatic or needle-like crystals and containing 81 per cent. of pure Bismuth. The colour is lead-gray to tin-white, with a yellow tarnish. Hardness 2 to 2·5, specific gravity 6 4 to 6·6.

BISMUTH OXIDE OR OCHRE.—Symbol, $Bi_2 O_3$, called BISMITE. This ore, which occurs massive or earthy, is very soft and friable. Its specific gravity is 4 36 to 4·7 Its colour varies from straw-yellow to light gray or green.

BISMUTH CARBONATE—This is an earthy-looking ore, with a colour varying from gray or yellow to a dirty green. Its hardness is 4 to 4·5; specific gravity 6·8 to 6·9. It effervesces in nitric acid, and in hydrochloric acid forms a deep yellow solution.

It may be useful here to give a method of estimating the percentage of Bismuth present in a sample of ore.

Weigh out a given quantity, say 100 grains of powdered ore, and dissolve it in strong nitric acid. Filter, and add a solution of carbonate of soda, or better still, of carbonate of ammonia in *excess*, *i.e*, in sufficient quantity to render the solution alkaline. A white precipitate forms of carbonate of bismuth, the symbol of which is $Bi\ O_3CO_2$. Heat the mixture nearly to boiling. This ensures the precipitation of all the Bi present. Collect the precipitate by filtering, dry it, and placing it on a piece of platinum foil, hold it in the flame of a spirit lamp for some minutes. This drives off the carbonic acid (CO_2) present, leaving ter-oxide of bismuth $Bi\ O_3$. Weigh this. 100 parts contain 81·25 parts of the pure metal

N.B.—Should, on the addition of the carb. of ammonia, a reddish-brown precipitate appear, this proves the presence of iron. To avoid its appearance, take a fresh lot of the solution and add to it a considerable quantity of tartaric acid. This will prevent the iron falling when carb of ammonia is added, and the resulting white precipitate is Carbonate of Bismuth.

GRAPHITE OR PLUMBAGO—G.

OBSERVATIONS.—This mineral occurs in granite, gneiss, mica-slate, clay-slate, granular and other limestone. Very few good specimens have yet been found in the colony. Black clay, containing a small percentage of carbon, and which makes a mark on paper, is often mistaken for graphite by miners. This is of no value, but a deposit of good graphite would be extremely valuable—worth perhaps £20 per ton. It is used for making lead pencils and crucibles; also, as a lubricating agent, for polishing stoves and the manufacture of foundry facings, &c.

Graphite consists of carbon mixed more or less with foreign matter. It is usually foliated and massive, though sometimes granular and compact. When foliated it somewhat resembles molybdenite, which see. It has a greasy feel. It makes a mark on paper like that of a black-lead pencil: hence sometimes called "black-lead." H. 1 to 2; sp. gr. 1·9 to 2·2. It is not soluble in acids and remains unchanged before the blowpipe.

LEAD—PB.

OBSERVATIONS.—The ores of lead are found in rocks of all ages, *e.g.*, in granite, gneiss, limestone, schists, clay-slates, trachyte, various sandstones, &c. All lead ores contain more or less silver and gold. Those found in the oldest rocks are generally the richest in precious metal. The most common ore is galena, the sulphide of lead. The richest deposits of lead ore are found in and near limestone rocks, though such are generally poor in silver: this is especially the case with those actually in the limestone, while those in slate are generally the richest in silver. Lead occurs in many rare and unimportant forms not worth working, but though you may not value these ores, yet it is to be remembered that the country in which they are met with is worth examining for the more useful ores. The following combinations have all been met with in N.S.W., viz., arseniate of lead, carbonate, molybdate, oxide (red lead), phosphate, sulphate, and sulphide of lead or glance.

TESTS.—From any of these lead ores the globule of lead may easily be obtained by means of the blowpipe. [See chapter VI., page 40.]

If, however, you prefer the wet test, you may act as follows:—To the powdered ore add diluted nitric acid and boil. Filter and add a little hydrochloric acid or common salt solution. A white crystalline precipitate ($Pb\ Cl$), which does not turn black on exposure to sunlight, indicates **lead.** This precipitate is soluble in a large amount of water, especially upon application of heat.

N.B —In order to obtain in solution the whole of the lead contained in a sample of galena, *i.e.*, sulphide of lead, you must use weak acid, say one part of strong acid diluted with twelve parts of water. In this case the whole of the lead present is obtained in solution as nitrate of lead, and sulphur separates and floats on the surface. If strong acid be used, a white insoluble powder (sulphate of lead) is obtained. If acid of medium strength be used, some of the lead will be dissolved as nitrate, and some will separate as insoluble sulphate of lead with some sulphur.

The above tests will always enable you to say definitely whether or not the specimen under examination contains lead.

RULE FOR ESTIMATING PERCENTAGE OF LEAD.—Take 100 grains of ore and get all the lead in solution as above. Carefully collect the pp. got by adding hydrochloric acid; dry and weigh, multiply weight by $\frac{17}{20}$. The answer will give you roughly the percentage of lead.

DESCRIPTION OF ORES —Galena, Sulphide of Lead; Symbol Pb S.—This is the most common ore of lead, and as it is widely distributed over this colony, it will be advisable to give a brief description of it here. It generally occurs crystallised in small cubes, which may easily be separated by a slight blow from a hammer. Occasionally its occurs massive, but in this case the crystalline structure prevails, and the crystals may be detected by the aid of a lens. More rarely it is granular. Its colour is lead-gray, with a shining metallic lustre on newly fractured surfaces, but these eventually become tarnished on exposure to the air; streak lead gray. It may easily be cut with a knife. Its hardness is 2·5, and its sp. gr. ranges from 7·2 to 7·6. Sometimes galena has a peculiar bluish tinge, often inclining to black. This consists of a compound of sulphides of lead, zinc, copper, and iron, sometimes with the addition of tin, silver, and a little gold.

Argentiferous Galena.—Galena usually contains a little silver, ranging from 1 to 3 or 5 parts in 10,000; rarely one per cent. or more. Wherever, therefore, galena is found, it is advisable to try it for this metal, which occurs as a sulphide mixed with the lead. The method of testing for silver in the presence of lead has been fully described under Silver, pages 50—51. Generally speaking, poor galena is comparatively rich in silver, and *vice versa*. In some parts of the world argentiferous galena which only contains seven or eight ounces to the ton is profitably worked, but in the Colonies it appears that nothing under 20 ounces to the ton will pay, unless under very exceptional circumstances.

Carbonate of Lead (Cerussite).—Symbol, Pb CO_3. Hardness, 3 to 3·5; sp. gr. 6·46 to 6·48. Colour white, grayish, light or dark. Occurs both in crystallised and massive form. Effervesces in nitric acid. The ore is of frequent occurrence with other ores, but it rarely forms a vein of itself.

Sulphate of Lead (Anglesite).—Smybol, Pb SO_4. In the massive state this ore closely resembles the carbonate of lead, but may be distinguished from it by the fact that while the carbonate dissolves in nitric acid with effervescence, the sulphate dissolves silently. Colour white or slightly gray or green. Hardness, 2·75 to 3; sp. gr. 6·1 to 6·4.

Phosphate of Lead (Pyromorphite).—Symbol (Pb_3 O_{12} P_3Cl.) The composition of this ore varies somewhat, but in round numbers it consists of lead oxide, 75 per cent; phosphoric acid, 15 per cent.; and chloride of lead, 10 per cent. Hardness, 3·5 to 4; sp. gr. 6·5 to 7·1. Colour, bright green to brown or wax yellow, or even orange yellow. Streak white, inclining to yellowish; lustre more or less resinous; brittle.

All the lead ores may be determined with so much ease by means of a blowpipe and the acid test that they cannot be mistaken for any other ore. It is therefore not necessary to devote any more space to their description.

ANTIMONY—SB.

OBSERVATIONS.—Antimony occurs sparingly native and also in combination with various substances, chiefly Sulphur and Oxygen, forming sulphides and oxides. These ores occur in slates of the Devonian age, in granite and some of the metamorphic rocks, *e.g.*, limestones, mica-schists, &c. It is largely used as an alloy. Value £30 to £40 per ton.

TESTS.—The blowpipe test given in chapter VI., page 39, is really the best for antimony; still, as some of my readers may prefer the wet tests, I will furnish them.

1. If on attempting to dissolve the mineral under examination in nitric acid a white precipitate is formed which is dissolved on boiling it in a solution of tartaric acid, you may be sure that your specimen is **antimony.** The easiest way to apply the test is simply to put some tartaric acid into the tube in which the precipitate has formed, and notice if the latter disappears on boiling.

2. The ores of antimony are soluble in warm hydrochloric acid; therefore dissolve a little of the mineral by boiling it with this acid. When clear, decant a little of the solution into a tube and add a quantity of water. A white precipitate, which dissolves on being heated with tartaric acid, proves the presence of **antimony.** This precipitate after a time assumes a fawn colour.

RULE FOR ESTIMATING THE PERCENTAGE OF ANTIMONY.—If you wish to ascertain the percentage of antimony contained in an ore, collect the precipitate produced by adding water to the acid solution, obtained from 100 grains of ore as above described, and weigh it. Roughly, 70 per cent. of the white precipitate is pure metallic antimony. Therefore to get the percentage simply multiply the weight of the dried precipitate by $\frac{7}{10}$.

The method of dealing with an antimony ore in which silver is present has already been described on page 70.

Description of Ores.—The most common antimony ore is the sulphide, **stibnite**, or Antimony-glance (Symbol Sb_2S_3). Its hardness is 2, and specific gravity 4·6 to 4·7. It is brittle though easily cut with a knife, and melts slowly when held in thin pieces in the candle flame. Its colour and streak are both lead-gray with a blackish or irridescent tarnish. It is frequently fibrous and sometimes fine granular. When boiled in H Cl it gives off a gas with a very disagreeable smell (sulphuretted hydrogen)

Cervantite.—Symbol, $Sb\ O_4$, oxide of antimony. This is a yellow mineral which is frequently found with the sulphide (stibnite) from which it has been formed by oxidation. It is sometimes found massive. H. 4 to 5; sp. gr., 4. It dissolves with great difficulty in hot hydrochloric acid.

N.B.—Some of the sulphide of antimony contains gold. To prove the presence of this metal in such an ore it is necessary to remove the sulphide before applying the test on page 64. Act as follows :—Powder the ore and boil in strong H Cl. This converts the antimony into a soluble chloride. Decant; wash repeatedly with water containing tartaric acid. Then add aqua regia and test for gold as directed.

Zinc—Zn.

Observations.—Zinc ores occur in rocks of all ages, but principally in limestones, old and new, and in altered rocks. It is generally associated with ores of lead; also with copper, tin, iron and silver ores. Native Zinc has not been met with. The metal has such an affinity for oxygen and other matter that it cannot exist long in its pure state. It is found in the form of sulphide, carbonate, silicate, oxide and arseniate.

USES.—Thousands of tons of Zn are annually used for galvanising iron; for roofing instead of lead; for case lining; for the manufacture of white paint, which, however, does not combine properly with the oil, and hence is more liable to peel of; for the manufacture of glass for optical purposes; in medicine and in calico printing.

The value of 30% ore is not more than £7 or £8 per ton.

TESTS.—See blowpipe tests, chap. VI., page 38.

2. The following wet test may be appled: Powder the ore, dissolve by boiling in nitric acid; filter and add solution of Ferrocyanide of potassium; a white slimy precipitate shows the presence of zinc. No satisfactory simple tests, other than these, can be given, so I must refer the reader to the descriptions of each ore given below.

DESCRIPTION OF ORES.—Zinc-blende, or sulphide of zinc (mineralogical name *Sphalerite*), Symbol, Zn. S. This, in small fragments, in which form it often occurs, is often mistaken for coarse stream tin. See tin, page 90. It is frequently found crystallised, though it is sometimes found massive. Its colour is generally a bright or yellowish-brown; streak, white to reddish-brown. The true colour of pure Zn S is white; the dark shade that it usually has is due to the presence of sulphide of iron. The lustre is resinous or waxy, which is characteristic. The name blende is derived from the German blenden, to dazzle, in allusion to the brilliancy of the crystals. Hardness 3·5 to 4, sp. gr. 3·9 to 4·2. Mixed with carbonate of soda, on charcoal, its powder before the BP flame yields fumes of zinc, and these, condensing, form a coating which is yellow while hot, and white on cooling; and which, when moistened with nitrate of cobalt solution, becomes green. Zinc blende dissolves in nitric acid, emitting a gas which has the smell of rotten eggs (sulphuretted hydrogen). This ore is worth testing for silver and gold. It is sometimes mixed with galena (sulphide of lead); indeed it has frequently been mistaken for that mineral. It may, however, easily be distinguished by its greater hardness, and generally by yielding a reddish-brown powder when scratched with a knife. It will be remembered that the hardness of galena is only 2·5; it therefore may be easily cut with a knife, and the cut or scratch is bright.

Instances are not uncommon in which the zinc-blende has run into galena bearing payable silver.

ZINCITE.—Red Zinc Ore; Symbol Zn. O.—Colour, deep or bright red; streak, orange yellow; lustre, brilliant. Splits up into plates, or, in other words, its cleavage is perfect like that of mica. Hardness, 4 to 4·5; sp. gr. 5·4 to 5·7. In borax bead in the oxidising flame the powder forms a glass, yellow while hot, and colourless when cold. On charcoal it is infusible, but yields coating as with blende. Dissolves in nitric acid without effervescence.

CALAMINE.—This name has been applied to two kinds of zinc ore, viz., the carbonate and one of the silicates, viz., the hydrated silicate. By English Mineralogists the use of the term *calamine* is restricted to the former; by American Mineralogists to the latter, carbonate of zinc being called by them Smithsonite.

CARBONATE OF ZINC, $Zn\ CO_3$, is of an impure white, or yellowish-gray; sometimes green or brown colour, with a somewhat pearly lustre; streak, uncoloured. Hardness 5; sp. gr. 4·1 to 4·5 It contains, when pure, 52 per cent. of metallic zinc. It is usually associated with blende and galena. It effervesces in nitric acid; and on charcoal, with soda before the blowpipe in *R* flame, yields coating as with blende. This coating, and also the powdered mineral when moistened with nitrate of cobalt solution and heated under the O flame, gives a green colour.

THE SILICATE OF ZINC occurs in two forms—the difference between the two being that one contains water, making it what is known as a Hydrated Silicate, and the other does not. In appearance they are much alike. In the R flame on charcoal with soda both yield a white incrustation which, when moistened with nitrate of cobalt solution and treated in the O flame, becomes bright green; and both, when powdered, dissolve in strong hydrochloric acid and gelatinise on cooling.

WILLEMITE.—Symbol, $Zn\ Si\ O_3$. Colour whitish, greenish-yellow, flesh-red, or yellowish-brown; streak uncoloured- H. 5·5; sp. gr. 3·89 to 4·18. Brittle; with soda before blowpipe yields coating as in other zinc ores. On being boiled in hydrochloric acid it gelatinises.

GALMEY.—Symbol, $Zn_2SiO_4 + H_2O$ (Water)—a hydrated silicate, sometimes called electric calamine, because it becomes electrified when heated. Colour whitish, sometimes greenish, brownish or even bluish; streak uncoloured. H. 4·5 to 5; sp. gr. 3·16 to 3·9. Brittle; infusible before the blowpipe; but the powder dissolves in boiling sulphuric or hydrochloric acid, and, on cooling, gelatinises.

TIN—SN.

OBSERVATIONS.—This ore, as a source of wealth to the colony of New South Wales, ranks next to gold and coal. The deposits are of two kinds, alluvial and veins in reefs. Alluvial or stream tin has been derived from the palæozoic and associated rocks and occurs in the beds of ancient water courses in some cases covered up by basalt, sometimes to a depth of 200 feet or more, thrown out during the earlier tertiary period. Reef tin occurs in veins traversing felspar and quartz porphyry, gneiss, mica-schist, and the old slates. Stream tin is associated with sapphires, topazes, beryl, tourmaline, zircons and other gems; reef tin with mispickel, wolfram, iron pyrites, blende, tourmaline, fluorspar, &c.

TEST.—To test for tin, act according to instructions given in blowpipe test (chapter VI., page 40). This is the best test that can be applied, and it is not by any means difficult.

Description of Ore.—It is doubtful whether tin really occurs native. Indeed, we may say that the only ore is the binoxide, $Sn\ O_2$, containing in 100 parts 78·67 of tin and 21·33 of oxygen; for, although a sulphide has been found in Cornwall, yet it is not common, and moreover it is so adulterated with foreign matter, as iron, copper, lead, &c., that the smelting of tin from it is impracticable. It cannot, therefore, be regarded as an ore of tin.

Cassiterite or Tin Stone, Symbol $Sn\ O_2$, binoxide of tin. It occurs massive in reefs, as rolled pebbles occasionally weighing many pounds, and as rounded fragments and small grains known as "stream tin." Well-developed crystals in the form of short prisms, with four or eight-sided pyramidal summits, are by no means rare. It is also sometimes met with in fibrous form, when it is known as "wood tin." Its hardness is from 6 to 7; specific gravity, 6·4 to 7·1; colour, generally black and opaque, with a high adamantine lustre when in crystals, though sometimes it is brown, red, yellow, gray, white, and even colourless. Occasionally two or more of these colours are to be seen in the same specimen, and then the effect is very beautiful, especially when there is an admixture of the ruby-red and translucent amber colours. Streak, when pure, almost white, but sometimes grayish, or even brownish, according to the amount of impurity it contains.

There are a few substances which are sometimes mistaken for Tin ore, viz., wolfram, which bears a somewhat close resemblance to lode tin; and black-jack, or sulphide of zinc, and iron sand, which are frequently mistaken for stream tin by the inexperienced. It may be useful to point out the difference between these substances. There are three marks by which lode tin may be distinguished from wolfram, viz.:—1st. Wolfram has a hardness of 5 to 55, whereas that of lode tin is from 6 to 7. Hence wolfram may be easily scratched with a knife, while tin is only just scratched, or not scratched at all. 2. Reduced to powder, mixed with carbonate of soda, or better, potassium cyanide, and brought under the blowpipe flame, the wolfram gives a magnetic globule, which is soluble in hydrochloric acid, leaving a yellow residue, while lode tin similarly treated gives a white shining bead. 3. The powder, or streak, of wolfram varies from black to reddish-brown, while that of lode tin is light-gray or brown.

The distinction between stream tin and some kinds of iron-sand is striking; a magnet will readily attract the iron-sand, but will not act at all upon the stream tin, Titaniferous iron-sand is not, however, attracted so readily by the magnet; but in this case the borax bead test will be conclusive. (p. 35.)

With black-jack (sulphide of zinc) there is a little more trouble; for it is not attracted by the magnet, and the colour of its powder is sometimes the same as that of tin. There is, however, this distinction, viz., having reduced the black-jack to powder it will, on heating, dissolve readily in strong nitric acid, leaving sulphur, and emitting an odour of rotten eggs (sulphuretted hydrogen), whereas powdered stream tin will not dissolve at all. Then again, black-jack has a peculiar waxy lustre, which tin has not, and it is also softer and lighter than tin—its specific gravity being from 3·9 to 4·2, and hardness 3·5 to 4. Compare these with those of tin given above.

COBALT—Co.

OBSERVATIONS.—This is not a widely distributed ore. It usually occurs in veins accompanying ores of copper, iron Manganese, and silver; but in such small quantities as to be of little value. No pure ores of cobalt have as yet been found in New South Wales. It is principally used for painting porcelain and pottery. The pure oxide is worth from 10s. to 12s per lb.

TESTS.—1. See borax bead test, page 35; also reduction test, page 42. The former is especially characteristic.

2. Powder a fragment of the mineral, and divide it into two parts. Boil one part in a little strong hydrochloric acid. A green solution, which disappears on diluting with water, proves the presence of cobalt.

Boil the other portion in strong nitric acid. A light red or pink solution, which does not disappear on diluting with water, proves the presence of cobalt.

DESCRIPTION OF ORES.—SMALTINE or Cobalt Glance. This ore is tin-white in colour, sometimes inclining to steel-gray. Streak, grayish-black: brittle, the facture being fine granular. Sp. gr. 6·4 to 7·2. H. 5·5 to 6. The chemical composition is (Co, Ni.) As_2. It sometimes contains as much as 24 per cent. of cobalt. Smaltine somewhat resembles mispickel, but the borax bead test is decisive

COBALINE.—A silver white ore crystallising very much like iron pyrites. Its colour is slightly tinged with red: streak, grayish-black. H. 5·5; sp. gr. 6 6. Its composition is Co., As., S.

COBALT BLOOM or Erythrine, or Hydrous Cobalt Arseniate.—This ore occurs both crystallised and massive; when in the former state the crystals have a highly perfect cleavage like that of mica. Its composition is Co_3, O_8, $As_2 + 8\ H_2\ O$. In colour it is peach red, crimson red, and rarely grayish or greenish: streak a little paler; the dry powder is lavender blue. H. 1·5 to 2; sp. gr. 2·9. A valuable ore when abundant.

NICKEL—NI.

OBSERVATIONS.—Nickel ores occur with Copper, Silver, and Lead, Iron, &c., in gneiss, serpentine, and various other metamorphic rocks. Nickel occurs alloyed with Iron in Meteorites sometimes to the extent of 15 per cent., though generally from 8 to 10 per cent. In examining for nickel it is almost always the case that some of the masses, pieces or specimens will show to the naked eye or under the magnifying glass characteristic apple-green specks or streaks of some of the salts of nickel.

Nickel is mostly used at the present time for nickel-plating, for the manufacture of philosophical instruments, for coins as in U.S.A., and for making German silver, which is an alloy of copper, nickel, and zinc. The ores used to be valuable, but owing to the abundance and the modern improved methods of extracting the metal, the price of nickel has fallen to a few pence per lb.

TESTS.—See borax bead test, page 35; also reduction test, chapter VI., page 42. Powder the specimen, and boil it in nitric acid. Add ammonia drop by drop. If nickel be present a trifling greenish turbidity is produced, which dissolves on adding more ammonia, and forms a violet-blue liquid. A blue colour is also produced by copper, but there is a distinction, viz., in the presence of copper a knife-blade becomes coated, but nickel produces no such effect; and, moreover, the blue produced by copper is azure, while that produced by nickel is violet-blue.

DESCRIPTION OF ORES.—Niccolite, Kupfernickel, or arsenical, or copper nickel, so called from its pale copper-red colour, has been met with in New South Wales. Its symbol is Ni As—a combination of nickel and arsenic. It is a brittle ore, with a metallic lustre; streak, pale brownish-red. Its hardness is 5 to 5 5 and sp. gr 7·3 to 7 7.

There is also a silicate of nickel found in New Caledonia called NOUMEAITE, which sometimes yields as much as 12 per cent. of nickel. Its colour is light or dark green. H. 2·5; sp. gr. 2 2 to 2·86. Sometimes the nickel is replaced by cobalt.

IRON—FE.

OBSERVATIONS.—Iron is one of the most widely distributed metals in nature, its ores being found in rocks of all ages, and its salts even in most mineral springs, which have sometimes been the source of iron deposits now being worked, or to be worked. The ores ordinarily worked for the extraction of the iron, viz., oxides and carbonates, chiefly occur in the carboniferous and other coal-bearing formations; though there is no occasion to restrict ourselves to these, as extensive beds of the purest ore occur in the metamorphic rocks.

TESTS.—1. See borax bead test, page 35. 2. Powder the ore, and apply a magnet. If strongly attracted, it is magnetic iron ore; if slightly attracted, it may be magnetic iron pyrites, titanic iron, chromic iron, or some other form. It must not, however, be supposed that all iron ores are attracted by the magnet, for upon some it does not act at all. Dissolve the powder in nitric acid by boiling; add to the clear solution a little solution of potassium ferrocyanide. A beautiful blue precipitate of Prussian blue is immediately thrown down if iron be present. Ammonia also produces a reddish-brown precipitate. Sometimes the precipitate for the first moment appears almost white; then after a short time it becomes a dirty green, and finally it turns reddish-brown (foxy-red), owing to absorption of oxygen from the air.

N.B —There are some forms of iron, viz., titanic, chromic, and magnetic, also Franklinite, which are not soluble in nitric acid. For the means of testing these, the reader is referred to the description of each ore.

DESCRIPTION OF ORES.—IRON PYRITES, or sulphide of iron. Symbol $Fe\ S_2$. There are two kinds of this ore. The one is bronze yellow, inclining to gold-yellow; streak, brownish-black, called simply pyrites, or pyrite, and occurs in cubes the faces of which are often striated; the other is generally white, of a silvery lustre, though sometimes it is a pale bronze-yellow or greenish-gray; streak, greenish-gray to brownish-black. It is called MARCASITE or white iron pyrites. Both kinds have nearly the same chemical composition, more than half their weight being sulphur, and the remainder metallic iron. Both are brittle, with a hardness of 6 to 6·5. The sp. gr. of the yellow iron pyrites is 4·8 to 5·1, and that of marcasite is 4·65 to 4 9. Before the blowpipe both give off sulphur, and afford magnetic globules. Both are soluble in nitric acid with deposition of sulphur. The yellow iron pyrites is distinguished from copper pyrites by its hardness; it is the "mundic" of miners. Marcasite is very liable to decomposition by the atmosphere, when it forms a sulphate of iron. This is sometimes met with in course of formation in many drives and shafts of mines.

MAGNETIC PYRITES.—Symbol, $Fe S$. This is another form of iron sulphide. It contains less sulphur than the others, and is slightly attracted by the magnet—hence its name. Its colour is between bronze-yellow and copper-red; streak, grayish-black. H. 3·5 to 4·5, and sp. gr. 4 4 to 4·65; it somewhat resembles copper pyrites, but the test for copper by means of ammonia will remove all doubt. It frequently contains nickel—sometimes as much as from 3 to 5 per cent. It dissolves in nitric acid.

CARBONATE OF IRON, or spathic or sparry iron, siderite or chalybite; symbol, $Fe CO_3$. Colour generally yellowish-gray, or yellowish-brown; streak uncoloured. Its texture in the fresh fracture is always decidedly crystalline, and of silky lustre. H. 3 to 4·5; sp. gr. 3·7 to 3 9; dissolves in heated nitric acid with *effervescence.* This ore may be regarded as indicative of the presence of valuable minerals, for it associates with all kinds of metallic ores, changing the character of a vein from one kind of ore to another.

There is another variety of carbonate of iron, called clay-ironstone, and which is abundant as nodules and layers in coal formations. Its colour is sometimes white, but generally of a dirty-gray, a yellowish-brown, or of a faint brick-red appearance. It dissolves with *effervescence* in nitric acid, which serves to distinguish it from other iron ores of similar appearance.

LIMONITE OR BROWN HÆMATITE, or brown oxide of iron; symbol, Fe_2O_3. This ore is so widely distributed, and appears under so many different forms, that it is difficult to describe it. Sometimes it is earthy and sometimes solid and compact. The best way to decide whether an iron ore belongs to this variety is to reduce it to powder; if this is yellow, the ore may be called brown hæmatite.

SPECULAR IRON ORE, or red hæmatite or iron glance; symbol, $Fe_2 O_3$. The appearance of this ore varies from a dull brownish powder, like reddle, to the lustre and colour of polished steel or Plumbago. Its powder or streak is always *red* when rubbed on white paper or porcelain, hence the name hæmatite for the Greek *haima*, blood.

MAGNETIC IRON ORE.—Magnetite, lode-stone, or black oxide of iron. Symbol, $Fe_3 O_4$. The colour of this ore is generally iron-black, but sometimes it is pitch-black. H. 5·5 to 6·5; sp. gr. 5. It is strongly magnetic. Its powder (streak) is always *black*. It is soluble in hot hydrochloric acid, but not in nitric. From the solution potassium ferrocyanide throws down a blue precipitate.

TITANIC IRON, OR ILMENITE.—Symbol, variable. —Chemical composition, iron and titanic acid; colour, iron-black, often inclining to brown. It has a somewhat metallic lustre. H. 5 to 6; sp. gr. 4·6 to 5. Sometimes the powdered ore is slightly attracted by a magnet. It will not dissolve in nitric acid; but after long boiling, nearly an hour, will dissolve in hydrochloric acid, and from the solution iron is thrown down by potassium ferrocyanide as a blue precipitate. Titaniferous iron-sand is sometimes mistaken by the unexperienced for stream-tin, but the borax bead test (p. 35) which proves iron, is conclusive.

FRANKLINITE.—This is an ore composed of 66 to 69 parts of iron, 15 to 18 of manganese peroxide, and 10 to 27 zinc oxide. It is a brittle ore of iron-black colour; streak, dark reddish-brown. Hardness 5 5 to 6·5; sp. gr. 5 to 5·3. Usually attracted by the magnet

The powdered ore boiled in hydrochloric acid, dissolves and gives off pungent fumes of chlorine. From the solution potassium ferrocyanide throws down the blue precipitate of iron. And if some of the powdered ore be mixed with soda and placed on charcoal before the blow-pipe flame a coating of zinc oxide will form, yellow while hot and white when cold.

CHROMIC IRON, OR CHROMITE.—Symbol $Fe\,Cr\,O_4$. Colour, iron black and brownish-black, like a hard brown iron-stone; streak, dark brown. It has a semi-metallic or resinous lustre. In the mass it is brittle. H. 5·5; sp. gr. 4·4 to 4 5. The powdered ore is generally attracted by the magnet, but is scarcely affected by acids.

The best test is the borax bead test, which gives in oxidising flame when cold, grass-green, and in reducing flame emerald-green, page 35.

It usually occurs massive, but also as small crystals (cubical) and water-worn grains in gold and gem-bearing sands.

Chromic iron containing about 50% of Sesqui-oxide of Crominum is worth between £3 and £4 a ton in London. It is used for making some preparation for tanning purposes; also for the manufacture of potassium bichromate, &c.

ARSENIC—As.

OBSERVATIONS.—Arsenic occurs native, and in combination with substances forming ores. The rocks in which the deposits and veins are found are mica-schists, granite, and various other crystalline and metamorphic rocks.

TEST.—See glass tube test, page 25; also blowpipe test, page 38.

DESCRIPTION OF ORES.—Native As. has been met with in the colony. Its colour is whitish-gray, but after a few hours' exposure it becomes tarnished and appears grayish-black. H. 3·5, and sp. gr. 5·7 to 5·8. When heated, it gives an order of garlic, and evaporates, yielding dense white vapours.

ORPIMENT, $As_2\ S_3$ and REALGAR, As. S, are both sulphides of As. The former is of fine yellow colour; the latter a fine clear red colour, aurora red, with an orange-yellow streak. The H. and sp. gr. of each are about the same, viz., H. 1·5 to 2, and sp. gr. 3·5. Before the blowpipe both wholly evaporate, and on charcoal give white fumes and burn with a blue flame. In closed tubes both yield a yellow sublimate, page 25.

ARSENICAL IRON PYRITES.—This ore, called also mispickel, is a compound of arsenic, iron and sulphur, its symbol being Fe As. S. It somewhat resembles As., but its H. is much greater, viz., 5·5 to 6; sp. gr. 6·3. Its colour is silver white; streak, dark grayish-black. It dissolves in nitric acid, with separation of sulphur. In a tube it gives, when heated, a yellow sublimate, and on charcoal before the blowpipe, white fumes. This latter feature distinguishes it from white iron pyrites, which it closely resembles, although the latter is a little harder. Arsenical iron pyrites sometimes contain silver, gold, or cobalt.

MANGANESE—MN.

OBSERVATIONS.—Manganese is a very widely distributed mineral, being generally found associated with iron. Its ores sometimes contain cobalt and nickel. The most valuable deposits occur in rocks older than the mesozoic. The value of an ore depends not only upon the proportion of the oxide it contains, such oxide being used extensively for colouring glass, for bleaching and for the production of oxygen gas; but as manganese is also used as an addition to iron, low-grade ores are also valuable, provided they are comparatively rich in iron. The earthy varieties are used for making umber paint. Good samples of manganese, containing about 40 per cent. of the metal, are worth about £2 per ton.

Tests.—1. See borax bead test, page 35, which is very characteristic.

2. Dissolve by aid of heat in nitric acid. Filter, and to the clear solution add a few drops of ammonia. If Mn be present a whitish precipitate will be produced, which, upon exposure to the air, speedily acquires a brownish, and finally a deep blackish-brown colour, owing to its absorbing oxygen from the air.

Description of Ores.—Pyrolusite, or black oxide of manganese. Symbol $Mn O_2$. It is sometimes found crystallised in small prisms, but more often massive. Sometimes it is fibrous and sometimes earthy. Its colour is iron-black, dark steel gray or bluish. When reduced to powder it is black and soils the fingers. H. 2 to 2·5; sp. gr. 4·8 to 5. If heated with hydrochloric acid, it gives off a very pungent irritating gas called chlorine.

Psilomelane.—This is a manganese ore resembling Pyrolusite in its composition, though in addition to oxide of Mn it sometimes contains barium, potassium, cobalt and nickel. It is much harder than Pyrolusite, its hardness being 5 to 6; sp. gr. 4 to 4·4; colour, iron-black or greenish-black to dark steel-gray with a sub-metallic lustre; streak, reddish or brownish-black, shining.

Rhodonite.—Manganese Spar or Fowlerite; symbol, $Mn O_3 Si$. This is, as will be seen from the formula, a silicate of manganese. Its colour is reddish, usually deep flesh red; also brownish, greenish, yellowish, when impure; lustre vitreous. H. 5·5 to 6·5; sp. gr. 3·4 to 3·7.

Test.—Violet colour with borax bead.

Wad or Bog Manganese.—This is an impure oxide of Mn—a hydrated form. It is sometimes mixed with iron, copper, or cobalt. It is formed in low places from the decomposition of minerals containing Mn; hence its name, *bog* manganese. Its colour is black or brownish-black; generally massive, also scaly or earthy. It is usually very soft and easily cut with a knife, but some specimens are hard. Its sp. gr. varies from 1 to 6·7. It is generally so light that it floats when put into water.

MOLYBDENUM—Mo.

OBSERVATIONS.—Molybdenum, in the form of a sulphide is found in many parts of the New England district associated with Bismuth, tin, and sometimes with galena, pyrites and gold, &c. At Kingsgate some exceptionally fine specimens occur with the bismuth, in the quartz veins traversing granite.

DESCRIPTION OF ORE—MOLYBDENITE.—This substance, which is a sulphide of Molybdenum, $Mo\ S_2$, somewhat resembles graphite. Its colour is pure lead-gray; streak the same. It makes a mark on paper like that of graphite; but the mark it makes on porcelain is slightly greenish. H., 1 to 1·5; sp. gr., 4·15 to 4·8. It has a greasy feel, and splits up into thin leaves something like tinfoil. Dissolves in nitric acid, leaving a gray residue. On charcoal, with blowpipe flame, the sulphur is driven off, and the flame is tinged with green. In boiling sulphuric acid it forms a blue solution. All these features serve to distinguish molybdenite from graphite. USE.—It is used for preparing the chemical known as Molybdate of Ammonia, and also blue carmine for colouring porcelain. It is, however, of no commercial value at present.

TUNGSTEN (WOLFRAM)—W.

OBSERVATIONS.—Tungsten occurs in the metamorphic and granitic rocks associated with bismuth, tin, antimony, and other ores. Two forms of this mineral are met with in New South Wales, viz., wolfram (tungstate of iron and manganese) and scheelite (tungstate of lime). The word tungsten is the Swedish word for heavy stone. It is a valuable ore, being largely used in the preparation of certain pigments and a particular kind of steel called musket steel, which is the hardest steel made. A compound, made by fusing it with carbonate of soda, is also employed by calico printers as a mordant, and it is sometimes applied to muslin and woodwork to render them uninflammable. Another compound has been employed as a substitute for white lead paint.

The value of the ore depends upon the amount of tungstic acid it contains. Wolfram, containing 60 per cent. tungstic acid, is worth £15 to £25 a ton. Scheelite is worth about £30 per ton.

DESCRIPTION OF ORES – WOLFRAM.—It has already been said that this substance is sometimes mistaken for tin ore. For the distinguishing marks the reader is referred to Tin, page 89.

The chemical composition of wolfram is (Fe Mn) WO_4 —a tungstate of iron and manganese. It is found in rolled masses with tinstone, and also massive in reefs. The cleavage in one direction is very perfect. Its colour is brownish-black. When pulverised, the powder, *i.e.*, the streak, is black if it contains much iron, and reddish-brown if it contains much manganese. Its hardness is 5 to 5·5, and sp. gr. 7·1 to 7·5.

Before the blowpipe the powdered wolfram, mixed with soda, fuses to a magnetic globule. It dissolves in warm hydrochloric acid, or aqua regia, leaving a yellow residue which is soluble in ammonia.

SCHEELITE.—This is tungstate of lime; its symbol is $Ca\,WO_4$. Its colour is white, yellowish-white, pale yellow, brownish, greenish, or reddish; lustre, vitreous; streak, white. It is a brittle ore, with a hardness of 4·5 to 5, and tolerably heavy, its sp. gr. being 5·9 to 6. When pure it contains 80 per cent tungstic acid. In nitric or hydrochloric acid it is decomposed, leaving a yellow residue which is soluble in ammonia.

TITANIUM—Ti.

OBSERVATIONS.—The minerals containing **titanium** are Rutile, Anatase (or Octahedrite), and Brookite, which are chemically identical, being merely dioxide of titanium, though crystallising in different ways. Titanium also exists in combination with iron in the ore Ilmenite (p. 95) and in titaniferous ironsand.

TEST.—See blowpipe test (p. 35), and also p. 37.

DESCRIPTION OF ORE.—The only ore we need describe here is *rutile* ($Ti O_2$), which is a reddish-brown mineral passing into red; sometimes yellowish, bluish, violet, or black. It is brittle, with a hardness of from 6 to 6·5; sp. gr., 4·18 to 4·25. It is not affected by any acids. Sometimes it is found in needle-like crystals penetrating quartz crystals and resembling grass. Indeed, we have frequently experienced some difficulty in persuading miners that it was not grass. It is of no value. Water-worn pieces are sometimes found in gem sand and drifts.

URANIUM—U.

OBSERVATIONS.—Uranium is not an abundant ore, nor is it important. It is sometimes found associated with silver and lead ores, also with Arsenic and Antimony.

TESTS.—1. Borax bead test (p. 35).

2. Dissolve the powdered ore by boiling in nitric acid. Filter, and to the clear solution add a few drops of potassium ferrocyanide. If uranium be present, a reddish-brown precipitate will be thrown down. This is a most delicate test, and serves to distinguish between uranium and iron, which both give with the borax bead the same colours.

DESCRIPTION OF ORE.—Uranium oxide or pitch-blende (U_3O_4). Colour, grayish, brownish, or velvet-black; streak, black. H., 5 to 6; sp. gr., 6·4 to 6.8. Used in painting on porcelain.

TELLURIUM—TE.

OBSERVATIONS.—Tellurium has hitherto been considered a rare mineral, but its presence in connection with gold and silver ores is, in my opinion, so much more general than is supposed, that it is very desirable that some description of it should be given here. Not only have rich deposits of telluride ores been found in Colorado, Dakota, and other parts of the United States, and at Kalgurlie and Coolgardie in Western Australia, but I have myself determined its existence among the low-grade ores of the Hauraki Peninsula, New Zealand, as well as in other parts of the colonies. I am disposed to think that extensive deposits of these valuable ores will be found in many places, and I wish miners and prospectors to be on the alert. It is to be remembered, however, that telluride ore does not always appear at the surface, nor is it met with at any given depth, as it sometimes occurs at the grass roots and sometimes comes in at 90, sometimes 200, and even 300 feet levels. Where free gold is found running at a depth into telluride ores, it is probably explained by the fact that the ore in the upper portion of the vein has been oxidised or decomposed under atmospheric influences, which exert themselves even to the depths above mentioned, and thus the gold has been set free. The formations in which telluride ores exist are certain tertiary igneous rocks, such as phonolite, andesite, propylite, breccia, and granite, where this is in contact with these rocks. The ores are not always confined to the veins, but are sometimes scattered through the country rock for some distance on each side of the veins.

DESCRIPTION OF ORES—NATIVE TELLURIUM.—Tellurium is a metal, though classed by some chemists among the metalloids or non-metallic elements, such as sulphur. Its colour in the native state, in which it is occasionally found in six-sided prisms or granular massive, is tin-white. It is very brittle. Its hardness is 2 to 2·5, and specific gravity 6·1 to 6·3. It is principally found in combination with lead, bismuth, silver, gold, and sulphur; but there are reasons for supposing that it exists in combination with several other substances.

There are about six well-known varieties of telluride ore, though more than double that number have been met with in small quantities.

CALAVERITE.—Symbol Au Te_2. This is a telluride of gold. Colour, bronze-yellow. H., 2·5; sp. gr., 9. It sometimes occurs in small, imperfect crystals imbedded in quartz, but is generally found massive. Its composition is tellurium 55·5 per cent. and gold 44·5 per cent., corresponding to the formula above given. It takes its name from Calaveras, in the State of California. There is also another telluride of gold called

SYLVANITE.—Symbol (Au Ag) Te_3. This ore is sometimes called graphic tellurium, from its occasional fancied resemblance to Hebrew characters. H., 1·5 to 2; sp. gr., 5·7 to 8·3. Lustre, metallic. Sometimes massive granular, sometimes fibrous or columnar, like stibnite; streak and colour pure steel-gray to silver-white, though sometimes nearly brass-yellow; fracture uneven. Its composition is, roughly: tellurium, 58 per cent.; gold, 24 per cent.; and silver, 24 per cent., though sometimes it contains a little antimony or lead.

HESSITE.—This is a telluride of silver (see p. 71).

PETZITE.—This ore closely resembles Hessite, being a telluride of silver, in which some of the silver is replaced by gold. Some samples have yielded tellurium, 32·68 per cent.; silver, 41·86 per cent.; and gold, 25·60 per cent. The colour is between steel-gray and iron-black; streak, iron-black. It is a brittle ore, having hardness 2·5 and sp. gr. 8·7 to 9·4.

NAGYAGITE, or Foliated Tellurium. This ore very much resembles graphite. It is generally foliated, though sometimes massive. It has a metallic lustre, and is easily cut with a knife. Its streak and colour are both blackish lead-gray. Some specimens have yielded tellurium, 32 per cent.; lead, 54 per cent.; and gold, from 6 to 13 per cent Others have shown the presence of silver, copper, sulphur, and antimony.

TETRADYMITE (symbol, Bi_3 Te_3).—This is an ore of tellurium containing Bismuth. It occurs massive, foliated, and granular. H., 1·5 to 2; sp. gr., 7·2 to 7·9. Lustre, metallic. Its colour is pale steel-gray; soils paper when rubbed upon it; not very easily cut with a knife. It consists of tellurium 48 per cent. and bismuth 52 per cent., but it sometimes contains sulphur and selenium. When these elements form a considerable proportion, the ore is called joseite, or wehrlite. Another altered form of tetradymite is called montanite.

TESTS FOR TELLURIUM.—See blowpipe test, page 39, which is very characteristic.

By dissolving tellurium in nitric acid, and, after remaining a few minutes, pouring it into a large quantity of water, a somewhat bulky precipitate of tellurous acid, H_2TeO_3, is formed. Bismuth also gives this result, but the blowpipe test will enable you to distinguish between the two.

The following test may be applied to all ores of tellurium:

1 Powder the ore very fine indeed, and mix intimately with an equal bulk of carbonate of soda and a little charcoal. Fuse the mixture in a closed tube, and, when cold, add a little hot water. If tellurium be present, a purple-red colour will be produced, owing to the presence of telluride of sodium.

2. Powder the ore and heat with strong sulphuric acid. If tellurium be present, the solution will become purple or carmine-red. On adding water this coloration disappears, and a blackish gray precipitate is formed.

TREATMENT OF TELLURIDE ORES.—Owing to the important discoveries of valuable telluride ores from which gold cannot be extracted by the ordinary methods of amalgamation or concentration, it becomes a most important matter to know how to treat them. Cyanidation, chlorination, and smelting have all been tried, but with results not altogether satisfactory. The high-grade ores are generally smelted; but this method involves considerable loss due to volatilisation. The low-grade ores are generally cast on one side awaiting the discovery of some cheap method of treatment. The intermediate ores are treated by cyanide and chlorination, but as it is deemed advisable to roast before treatment, and as this roasting means a loss of gold, it is clear that both these methods leave much to be desired. The Thermo-Hyperphone process, or treatment by water gas in closed furnaces, described on p. 61, is the best and cheapest method. This treatment will save full assay value at a cost of 5s to 10s. per ton, and admits also of the saving of the tellurium as a by-product. By this treatment the thousands of tons of low-grade ores of Cripple Creek, Colorado, now lying at the dumps, and those of New Zealand, West Australia, and other parts, can be profitably worked.

ALUMINIUM.—AL.

OBSERVATIONS.—Aluminium occurs as an oxide, alumina, Al_2O_3, entering largely into the composition of rocks. It is never found in the native state; but is very extensively diffused in nature in the various compounds of alumina, from some of which it is extracted, generally from CRYOLITE and BAUXITE. Common Clay contains about one-tenth of its own weight of the metal. As a metal it is silvery-white in appearance. Its sp. gr. is only 2·56; and this extreme lightness, combined with its tenacity, its resistance to oxidation, and other chemical properties, causes it to be largely used in Scientific Apparatus, and for various ornamental purposes. Various processes for the extraction from its ores on a large and cheap scale have been adopted, especially in the United States, and the metal is now being extensively used.

The Alum of commerce is derived from some form of Alumina—generally the Sulphate. This frequently occurs in a kind of brown or black shale, which is hence called Alum-shale, or Slate. It also occurs in Alum-stone, or *Alunite*.

TESTS.—Many compounds of Aluminium—*e.g.*, Cryolite, Alunite, &c.—may be distinguished by grinding the substance to powder, moistening with solution of nitrate of Cobalt, and treating it in the blowpipe flame on platinum wire, when a fine blue colour is produced (see p. 37).

A rock containing a fair proportion of Alum generally exhibits its presence by a whitish or yellowish-white efflorescence of the salt, readily distinguished by its sweetish, astringent taste—the taste peculiar to common Alum.

DESCRIPTION OF ORES.—Alum-shale, or Slate. This is a dark carbonaceous slate which often occurs among the shales of coal regions, and among other rocks, and contains pyrites, the oxidation of which affords Sulphuric Acid, which combines with the Alumina of the Shale, forming Sulphate of Alumina. The Shale is gently roasted, and digested in water, which is then evaporated, and the crystals of Alum obtained.

ALUNITE, OR ALUM-STONE.—This is a grayish or reddish rock, with a vitreous lustre, found in volcanic districts, among trachytic and allied rocks, and containing much Alum in earthy form, which, on being roasted, is converted into Soluble Alum, and may easily be dissolved out. Sp. gr., 2·58 to 2·75; hardness, 4. It contains 30 to 40 per cent. of Alumina.

Near the village of Bulladelah, about 35 miles from Port Stephens, N.S.W., there exists an enormous deposit of Alum-stone, 1,000 tons of which yields 220 tons of Alum.

MAGNESIUM—MG.

OBSERVATIONS —This mineral is very largely distributed in nature in combination with substances forming rocks, earths, and clay. In the form of carbonate it occurs as *Magnesite*, a white or grayish substance breaking with a flat conchoidal fracture, with a hardness of 3·5 to 4·5 and sp. gr. of 3.

TEST.—It adheres to the tongne, and has a cold feel like that of porcelain. Magnesium also occurs as a Silicate in the mineral Meerschaum, &c., and as an Oxide (Magnesia) in Talc, Serpentine, &c. Magnesia, moistened with Nitrate of Cobalt, gives under the blowpipe flame a pale-pink or brown-pink colour. This serves to distinguish Magnesia from Alumina. Any clay containing much Magnesia adheres to the tongue. The metal, which is extracted from some of its compounds, burns at a low red heat with a dazzling white light.

THORIUM—TH.

OBSERVATIONS.—This is a rare metal, somewhat resembling Aluminium and Magnesium in appearance, but differing vastly from them in weight, having a specific gravity of 9 4. Minerals yielding Thorium are much sought after just now, as the metal is valuable, owing to its being largely used, in the form of a nitrate, in the production of incandescent gas light.

TESTS.—No simple test can be given for its identification. It is, however, found in the minerals Monazite and Thorite, of which a brief description is given.

MONAZITE.—This generally occurs in a crystallised form, rather brittle, of a yellowish-brown or brownish-hyacinth colour The lustre inclines rather to resinous. H., 5 to 5·5, and sp. gr., 4·9 to 5·3. The name, derived from a Greek word signifying *to be solitary*, would suggest that it is of very rare occurrence. It has, however, been met with in Tasmania. It consists of Phosphate of Thorium and some other rare elements.

TEST.—Reduce to powder, moisten with sulphuric acid, take up on platinum wire and heat in the blowpipe flame. It will colour the flame dull-green, owing to the presence of phosphorus (see p. 22). With borax on platinum wire it gives a bead yellow while hot, and nearly colourless when cold.

THORITE.—This is a Silicate of Thorium, found crystallised and massive sometimes in Syenite. Its colour is black, brown, and brownish-yellow, with a vitreous lustre. H., 4·5 to 5; sp. gr., 4·3 to 5·4. With borax it gives a bead which is orange when hot and grayish on cooling. It dissolves with difficulty in hydrochloric acid and forms a jelly.

CALCIUM.

OBSERVATIONS.—This is another very abundant metal. We shall only consider three forms in which it occurs, viz., Calcite, Fluorite, and Gypsum. These often occur as matrices of veins carrying metallic ores.

CALCITE, OR CALC-SPAR, is carbonate of lime, $Ca\,CO_3$. It occurs in rhomb-shaped and other crystals, also in the form of chalk, limestone, stalagmites, &c. The crystallised varieties always break up into little rhombs when struck with a hammer. Calcite is easily scratched, having a hardness of 3 to 3·5, and it may always be distinguished by effervescing when acids are applied; sp. gr., 2·5 to 2·8.

TEST.—Dissolve in hydrochloric acid and add sulphuric acid. A dense white precipitate of sulphate of lime proves Calcite in its various forms.

FLUORITE, or FLUORSPAR, is fluoride of calcium. Symbol, $Ca\,F_2$. It generally occurs in cubes of various colours, white, purple, and green being the more common. It is slightly harder than most specimens of calcite, having a hardness of 4; sp. gr., 3 to 3·25. It does not effervesce when acid is applied. If powdered and treated with sulphuric acid, it gives off vapours of hydrofluoric acid, which etch glass.

Gypsum.—The chemical composition of this substance is $Ca\ SO_4,\ 2\ H_2\ O$, *i.e.*, hydrated calcium sulphate. Its colour is white, but sometimes gray or brown, owing to the presence of iron oxide. It occurs both crystalline and crystallised. The former resembles some limestones and the latter resembles calcite in appearance, but both may easily be distinguished from these by the fact of their not effervescing when acid is applied The crystallised variety is distinguished also by breaking into plates by reason of its easy cleavage, the surface having a glistening or pearly appearance. The H. of gypsum is 1·5 to 2. It is of commercial value for agricultural purposes, *e.g.*, in the manufacture of artificial fertilisers, and for the manufacture of "Plaster of Paris" and other cements. The name *Alabaster* is given to the massive form of gypsum when pure white. The crystallised variety is known as *Selenite*.

Barium.

Observations.—Such compounds of barium as are used in the arts are chiefly prepared from sulphate of B, which has been found in New South Wales. Quite enough is, however, found in the north of England to supply the present demand.

Artificial sulphate of baryta is used to adulterate white lead; and, as it prevents the white lead from blackening by the sulphur vapours, the mixture is preferred for certain kinds of painting. It is also used for glazing cards. Artificial carbonate of baryta is used in the manufacture of some kinds of glass, of certain compounds used in chemistry, of fireworks, and some kinds of blasting powder.

TEST.—No characteristic chemical test can be given for barium compounds, excepting that they tinge the blowpipe flame green. They are distinguished by their great weight from all non-metallic minerals to which they bear a resemblance, and they are not likely to be confounded with the metallic minerals: hence their weight is the best simple test to apply.

DESCRIPTION OF ORES.—Barium Sulphate, or barytes, or heavy-spar (symbol, $Ba\ S\ O_4$) occurs crystallised in tabular crystals and also massive, sometimes very fibrous, sometimes granular and compact. Its colour is white, though sometimes tinged yellow, red, brown, blue, or dark-brown. Its hardness is 2·5 to 3·5; sp. gr., 4·3 to 4·7. Hence it may easily be distinguished from Calcite and Gypsum by its weight.

The powdered ore will not dissolve in acids. Placed on charcoal it imparts a green colour to the blowpipe flame.

BARIUM CARBONATE, or Witherite (symbol, $Ba\ CO_3$).—Generally found massive, of a yellowish or grayish-white colour. H., 3 to 4; sp. gr., 4·29 to 4·35. It is a brittle substance. The powder dissolves with effervescence in nitric acid, as all carbonates do. Before the blowpipe it decrepitates (*i e.*, flies off in small splinters), and fuses easily to a transparent globule, which becomes opaque when cold: tinges flame green.

ASBESTOS.

OBSERVATIONS.—This is a name given to the fibrous varieties of tremolite, actinolite, and other members of the hornblende family, which consist chiefly of Silicate of Magnesia and a little Lime, &c. Asbestos is mostly found imbedded in Serpentine rock, mica slate, and other metamorphic rocks. It sometimes occurs in long fibres with a silky lustre to which the name *Asbestos* is applied, sometimes like kid-leather (called nountain leather), sometimes with the appearance and flexibility of cork (mountain cork), and sometimes compact and hard, of a brownish or yellowish colour, resembling petrified wood. It is used largely for making incombustible cloth, packing for steam engines, cement, &c.

TEST.—Perfectly infusible before the blowpipe and not affected by acids.

MICA.

OBSERVATIONS.—This mineral is well known as a constituent of granite It is readily distinguished by splitting up into thin plates, which are easily scratched by the fingernail and are elastic. It is of various kinds, but I shall not enter into a description of them here; but see granite (p. 151). I mention the mineral because it is of considerable value when found in large-sized pieces. It will be found in some of the granitic regions, especially where the rock is coarsely-crystalline in its texture. It is largely used in lamps, in Electrical Science, &c. It is, therefore, of considerable value. To command good prices, however, it must be free from colour and clear when split, and must be free from holes and cracks; but tinted varieties are also in demand.

HYDROCARBON COMPOUNDS.

COAL, &C.

OBSERVATIONS.—It is quite beyond the scope of this book to enter into a lengthy description of coal; nor is it necessary to do so. Everybody knows the mineral when he sees it. Practically, any rock that will make a fire without the addition of any other substance is called a coal, but the varieties are not all of equal quality. The true value is represented by the amount of combustible matter present. The better known kinds of coal are

Anthracite, *Bituminous Coal*. *Brown Coal* or *Lignite*, and *Cannel Coal* or *Torbanite* (*Kerosene Shale*). They occur in beds interstratified with shales, sandstones, and conglomerates. These different classes of coal have probably been determined by the varieties of vegetation out of which they were originally formed.

ANTHRACITE has a high lustre. It is compact and hard. It consists chiefly of pure carbon. It does not burn well unless it has a strong draft to support combustion, since it contains but a small quantity of volatile matter (hydro-carbons.) It is well adapted to smelting operations. Anthracite generally occurs in strata that have been disturbed by the intrusion of metamorphic or igneous rocks; sp. gr., 1·3 to 1 75.

BITUMINOUS COAL.—The ordinary coal used for domestic purposes. It contains more volatile matter than Anthracite. Sp. gr., 1·27 to 1·5. Generally speaking, the lower the sp. gr. the better the quality.

LIGNITE, OR BROWN COAL.—This is an imperfect coal occupying an intermediate position between wood and coal. It is characterised by its making a brown powder when crushed. It is not much in favour as a fuel excepting where bituminous coal cannot be obtained.

CANNEL COAL.—Torbanite, or Kerosene Shale. This is a very compact kind of coal, even in texture, with little or no lustre. It generally breaks with a broad conchoidal fracture. When struck it emits a dull wooden sound. It burns very easily, as its volatile hydro-carbons amount to between 50 and 80 per cent. When of good quality it yields from 150 to 180 gallons of mineral oil per ton. Sp gr. from 1·06 to 1·313. That with the lower sp. gr. is the better in quality. Its average value is about 37s. per ton.

ELATERITE or Elastic Bitumen, Ozokerite or Mineral Wax, Bitumen (both fluid and solid), and Asphaltum (mineral pitch), may all be recognised by their bituminous odour and freedom with which they burn.

The following is an analysis of some of the best and poor qualities of each kind of coal :—

—	Fixed Carbon.	Hydro-carbons.	Water.	Ash.
Anthracite—Best...	91·44	6·25	0·75	1·56
Poor	84·12	1·96	1·80	12·12
Bituminous—Best	58·33	34·17	1·83	5·67
Poor	53·34	26·66	3·33	16·67
Brown—Best	49·99	35·42	11·79	2·80
Poor	38·29	32·43	17·50	11·78
Cannel Coal—Best	8·035	83·861	0·44	7·664
Poor	32·72	43·61	2·74	20·93

TO TEST THE HEATING POWER OF COAL.

To give a lengthy description of the various kinds of coal is by no means so important as to furnish some simple method of ascertaining the value of the coal. That value, of course, depends upon its heating or, as it is called, its calorific power. I propose to give the details of a simple piece of apparatus for determining that value with sufficient accuracy for all practical purposes. The apparatus (fig. 7) can be made by any tinsmith, and need not cost more than a few shillings. A, which we will call the *furnace*, is a piece of stout copper tubing 3in. long and $\frac{3}{4}$in. in diameter. It is soldered on to a disc of lead, E. Over this is placed a cylinder, B, two inches in diameter and four high, the bottom of which is perforated to allow the products of furnace combustion to escape. This has a piece of $\frac{1}{4}$-inch copper tubing, C, soldered on to the top and fitted with a small stopcock, D. This cylinder is fixed to the lead disc, E, by means of a spring catch. This is all placed in a glass or copper vessel, FF, about 11in. high and 4in. in diameter.

Now, what we desire to do is to burn a sample of our coal in such a way that we can estimate its heating power. We will make it heat a given quantity of water. We must, however, supply it with some oxygen-yielding substance, or it will not be able to burn in the cylinder, B. This oxygen-yielding mixture is made by pounding up in a pestle and mortar three parts of chlorate of potash to one of nitrate and well mixing it. This can be kept in a stoppered bottle. We shall also require some fuse. And this we make by boiling cotton cord in a saturated solution of nitrate of lead, and drying it at a temperature of 212° F. This may also be kept in a stoppered bottle.

We are now ready to test the heating power of our sample of coal. Powder it very fine and weigh out a convenient quantity, say 15 grains. Mix thoroughly with this 10 times its weight of the oxygen-producing mixture, viz., 150 grains. Put this in the furnace, causing it to settle by gently tapping it. Insert a short length of fuse in it. Pour into the vessel a thousand times as much water as you have taken fuel, viz., 15,000 grains, which will be $1\frac{3}{4}$ pint, less one small tablespoonful. Take a note of the temperature of the water.

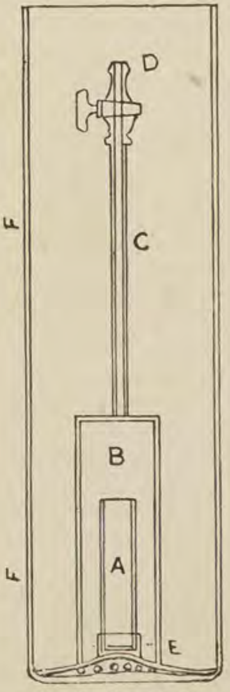

FIG 7.—SECTION OF CALORIMETER.

Now light the fuse and put the cylinder over it, seeing that the stopcock is shut. It may then be immersed in the vessel containing the water without wetting the furnace charge. The fuse is meanwhile burning down to the mixture, and when it reaches it the charge goes off like a squib. The products of combustion bubble out through the holes, and when the bubbling ceases turn the stopcock open and let the water rush into the heated furnace. Now take the temperature of the water, which will be considerably increased. Add 10 per cent. of the increase for loss.

This temperature may be said to represent the calorific or heating power of the sample of coal. You have found out what rise in temperature, when burnt under certain conditions, it is capable of producing in one thousand times its own weight of water. You can perform the experiment under exactly similar conditions with a sample of coal the quality of which is recognised, and thus can estimate the value of your own.

Take an example by way of illustration. The initial temperature of the water is (say) 60° F.; after the experiment it is 70½° F.; add 10 per cent. of the increase—viz., 1. The theoretical calorific or heating power of your sample is thus 11½. This would be a good sample of household coal, and will be a guide for you in your work. I say the *theoretical* heating power is 11½, or 11·5. In actual practice, however, only half the theoretical heating power is utilised.

CLAY.

Clay is derived from the decomposition of felspathic rocks, and consists chiefly of hydrated Silicate of Alumina, with a little oxide of iron and some alkalies. When pure it is of a snow-white colour. To the touch it has a soft, unctuous feeling, and is very easily broken. It adheres to the tongue and gives off a singular smell when breathed upon, which has been designated the argillaceous odour.

When moistened with water it absorbs it and becomes *plastic* or dough-like, in which state it can easily be moulded.

The purest clay found in nature is kaolin, or potter's clay (see p. 152). Clay is, however, seldom found pure, because in the rocks from which it is formed are minerals containing protoxide of iron which, under atmospheric action, become altered to higher states of oxidation and give to all clays various shades of colour from the finest yellow to the deepest brown.

BRICK CLAY.—Good brick clays contain from 20 to 30 per cent. alumina and 50 to 60 per cent. silica, the remainder consisting principally of carbonate of lime, magnesia, potash, and oxide of iron. These latter substances are fusible, and in brickmaking serve to bind the mass together.

FIRE CLAY.—This is usually in the coal measures, just beneath the seams of coal.

Objectionable ingredients are oxides of iron, if the percentage exceeds 6 per cent., and alkalies—*e.g.*, magnesia, lime, soda, or potash—when their combined weight exceeds 3 per cent., because with this amount the bricks would tend to fuse under the great heat to which the fire bricks are subjected.

The growth of vegetation, out of which the coal was formed, used up the alkalies and iron, and thus rendered the clay infusible. The following is an analysis of some of the very best fire clay from Stourbridge, England :—

Silica	73·82	per cent.
Alumina	15·88	,,
Oxide of Iron	2·95	,,
Alkalies	·90	,,
Water	6·45	,,
	100 00	

For the sake of comparison I give the following analysis of a colonial fire clay which I have used with fairly satisfactory results in furnace work, but as the alkalies exceed 3 per cent. it could not be regarded as a first-class clay :—

Silica	67·64	per cent.
Alumina	19·18	,,
Oxide of Iron	1·39	,,
Alkalies	4·45	,,
Water	7·34	,,
	100·00	

CHAPTER VIII.

PRECIOUS STONES.

"The Flowers of the Mineral Kingdom."

Observations.—The term "Precious" is only applied to those stones which are beautiful, sufficiently hard to resist scratching by constant use, and which are of rare occurrence. Precious stones are generally met with in granite, greisen, and other eruptive rocks, in the older metamorphic rocks, *e.g.*, gneiss, hornblendic, chloritic, and talcose schists and other allied rocks, or in gravel drifts derived from the disintegration of the same. Their formation was probably due to chemical action under long-continued and immense pressure in the presence of moisture. Of all mineral substances known to us, comparatively few enter into the composition of precious stones. These are Carbon, Silica, Magnesia, Alumina, Lime, Fluorine, Zirconium, Iron, Glucina, and a little colouring matter of various kinds, *e.g.*, Chromium, Manganese, Copper, &c.

Some precious stones are made up of but one of these substances, while others are composed of several. The composition of each will be mentioned.

Tests - Crystal Form.—It has been explained on p. 11 that nearly all mineral substances have their own particular form of crystallisation, by means of which they can be identified. This is so with regard to Precious Stones, but the subject is too intricate to attempt to deal with it here

Colour.—The colour of precious stones is doubtless regarded by many as an important test; but inasmuch as among white stones we have the diamond, sapphire, and topaz; among red stones the sapphire (ruby), garnet, hyacinth; among green stones, the diamond, sapphire, garnet, &c., &c., it is clear that the colour alone can be no certain guide; for colour depends merely upon the colouring matter that happened to be present when the stone was being formed.

Specific Gravity.—This is an important test, and I must refer the reader to my remarks on the subject on pages 18 and 19. Mention is there made of a particular solution, viz., "Sonstadts," which is useful in determining the sp. gr. within certain limits. The stones that sink in that solution (the sp. gr. of which is 3·17) are Diamond, Sapphire, Ruby, Topaz, Peridot, Spinel, Chrysoberyl, Garnet, Zircon. Those that float are Tourmaline (not always, however), Phenakit, Turquoise, Emerald, Aquamarine, Quartz, Moonstone.

Hardness.—This is a most important test, and one which can be applied by everybody. By it is simply meant the capability of being scratched by other bodies. The degree of hardness is shown in the following scale:—

Diamond, 10.
Sapphire, 9.
Topaz, 8.
Quartz, 7.
Felspar, 6.
A good steel knife or file, 6 to 6½.
Window glass, 5 to 5½.

The application of this test is described on p. 16.

If scratched by a quartz crystal the stone has a hardness of 7 or less; if by a topaz, 8 or less; if by a sapphire, 9 or less; if by a diamond, 10 or less. It is a good plan to keep for the purpose of testing stones a small rock crystal, topaz, sapphire, and a diamond, or fragments of these with angular corners.

Lustre.—Closely connected with the hardness of precious stones is their lustre. As a rule it may be said that the harder the gem the greater the lustre. As a means of comparing the brilliancy of the various stones to be described, the following table will be of interest :—

ADAMANTINE.—Possessing the brilliancy of the diamond, *e.g.*, diamond and zircon.

VITREOUS.—Resembling the surface of glass, *e g.*, garnet.

RESINOUS —Shining as if rubbed with an oily substance, *e.g.*, emerald.

PEARLY.—Exhibiting the peculiar lustre of a pearl, *e.g.*, moonstone.

SILKY.—Having a fibrous reflection similar to that of silk, *e.g.*, crocidolite.

The carat, which is the weight used in weighing diamonds and other precious stones, is divided into 4 grains, which are a little lighter than grains Troy. The carat=3·17 grains.

DESCRIPTION OF PRECIOUS STONES.

THE DIAMOND.—The diamond is pure crystallised carbon. Its colour is white, straw-yellow, red, orange, green, blue, pink, brown, or black. It may readily be distinguished from all other precious stones by its adamantine lustre, and by its superior hardness, being the only gem that a sapphire will not scratch. Its hardness is 10, and sp. gr. 3·48 to 3·55.

A green diamond is said to be the rarest of all gems. One weighing 1½ carats was sold for £300. The pink is perhaps equally valuable. The blue is prized only for its rarity, as the colour is seldom pure. The black diamond is not by any means beautiful, still it is so rare that it is highly prized by collectors. The brown, gray, and yellow diamonds are the least valuable.

The value of the best diamonds when cut is from £10 to £30 per carat. Mixed uncut stones, varying from less than ½ to about one carat, and slightly off colour, are worth from 5s. to 25s. per carat.

The diamond generally occurs crystallised, though sometimes in pebbles or masses called *carbonado*. Fractured or coarse diamonds unfit for jewellery are called *bort*, and are used for cutting glass, for drills of various kinds, and also for cutting gems. For the last purpose they are reduced to powder, which is spread upon a rotating circular plate of soft iron.

THE SAPPHIRE.—The sapphire is pure crystallised alumina, *i.e.*, oxygen and aluminium. Its colour is blue and grayish-blue; also red, green, yellow, violet, or amethyst, brown, and nearly black. Sometimes also it is nearly white, or of a milky-white tint. Lustre, vitreous; sometimes pearly on the basal plane, exhibiting a star. Hardness, 9; sp. gr., 3·9 to 4 10. The crystals of bright blue colours only are called sapphires; the dull, dingy-coloured crystals are called *corundum*. The blackish and bluish gray varieties frequently found in granular masses are called *emery*. The yellow sapphires are called by jewellers oriental topaz. When cut and polished the sapphire almost equals the diamond in brilliancy. The white sapphire when cut and polished has been mistaken for the diamond. The hardness test will, however, always decide.

The amethyst, or violet variety of corundum, is termed oriental amethyst. It is a gem of rare occurrence, and is likely to be mistaken for the common amethyst, than which, however, it is much harder and of greater value.

The value of the best blue sapphires cut, and of a fair size, is from £20 to £30 per carat. Many of our Australian sapphires are not worth, in their rough state, more than 2s. to 5s. per carat, owing to their very dark colour, though, of course, some are worth much more. When cut they might be worth from £2 to £4 per carat. Dirty green sapphires are worth not more than 3d. per carat, and opaque sapphires 2s. per lb.

THE RUBY.—The true ruby, or, as it is called, the oriental ruby, is simply a red sapphire. Its composition and hardness are the same as those of the sapphire. It is said that next to the diamond the ruby is the most precious of gems. Indeed, it is said that a perfect stone commands a higher price than a good diamond. It is infusible and unchanged before the blowpipe. The value of the best stones weighing ½ carat and upwards is, when cut, £20 per carat. A 1½ carat ruby, perfect and of pigeon-blood colour, is valued at £200 per carat.

SPINEL.—This stone is composed of alumina and magnesia. It has been called a second cousin to the ruby. It is remarkable for its range of colour, which, though generally red, is sometimes blue, green, yellow, or brown. Its lustre is vitreous. The red spinel, called "Balas ruby," is sometimes sold for the true ruby, but may easily be distinguished from it by its inferior hardness. It has a hardness of 8, whereas that of the true ruby (red sapphire) is 9. Sp. gr. of spinel is 3·5 to 4·1. When heated before the blowpipe it darkens, but regains its colour on cooling. The finer varieties are much valued as gems. It sometimes resembles the garnet, but the hardness test will serve to distinguish between them. Compare.

THE GARNET.—This gem is a mixture of silicates of alumina, magnesia, lime, and iron. It is generally crystallised, but sometimes occurs massive—*e.g.*, as garnet-rock. The colour is deep red to a cinnamon colour; also brown, black, green, emerald-green, and white. Lustre, vitreous to resinous; sp. gr., 3·1 to 4·3; hardness, 6·5 to 7 5. It is, therefore, easily scratched by a topaz, and this serves to distinguish it from the spinel, which is only just scratched by a topaz, being of equal hardness with the topaz.

Most garnets, too, are fusible before the blowpipe; but spinel is infusible, and temporarily darkens under the operation.

Pyrope, Almandine, Cape Ruby, Essonite or Cinnamon Stone, are all varieties of garnet. There is also a green garnet found in the "Urals" which is called the "Bobrowska" garnet.

By many in Australia garnets are mistaken for rubies; but the test of fusibility is quite conclusive, as is also that of the hardness.

From the brilliancy and richness of their colour garnets are much used in jewellery. The red garnet was the carbuncle of the ancients.

THE ZIRCON.—This stone is a mixture of silica and zirconia Its colour is generally brownish-red, brown, and red, of clear tints; also yellow, green, gray, sometimes opaque, and more rarely white; lustre, adamantine. Hardness, 7·5, and sp gr., 4 to 4·8. The colour and hardness of the zircon are frequently the same as that of the garnet; but the crystal form is very different. It is of square prismatic form, whereas the garnet is more globular; and, further, before the blowpipe the red zircon is infusible, but becomes permanently colourless; whereas the garnet blackens and fuses readily. The lustre, too, of the zircon more nearly approaches that of the diamond than does that of the garnet. Indeed, some of the colourless varieties are sold for diamonds, from which, however, they may be distinguished by their inferior hardness. The more brilliantly-coloured stones are named hyacinth.

LAPIS-LAZULI (Ultra-marine).—Composed chiefly of silica, alumina, soda, lime, and sulphuric acid. Its colour is rich Berlin or azure-blue, on account of which it might be mistaken for other gems, as, for example, the sapphire; but its hardness is vastly inferior to those gems it resembles, being only 5·5. It may therefore be scratched by a knife, and very easily by quartz crystal; sp. gr., 2·3 to 2·5. This was probably the sapphire of the ancients. It is sometimes found in crystals, though usually massive, and is highly esteemed for costly vases and for manufacturing mosaics.

The Topaz.—This stone consists of silica, alumina, and fluorine. It is commonly called by jewellers the occidental topaz, to distinguish it from the yellow sapphires, which are called oriental topaz The topaz varies in colour ; sometimes it is pale-yellow, sometimes white, greenish, bluish, and reddish, and very rarely pink. Its sp. gr. is 3·4 to 3·65, and hardness 8. It will, therefore, scratch everything but sapphires and diamonds. Water-worn specimens of white topaz often resemble pebbles of rock crystal but may easily be distinguished from such by their superior lustre, by their perfect cleavage, their specific gravity, by their becoming electric when heated or rubbed, and, chiefly, by their superior hardness—the rock crystals having only a hardness of 7.

The value of the Australian topaz, which in colour is generally white or with a greenish tint, is for stones weighing about an ounce and upwards from 10s. to 20s. per ounce.

Beryl.—Under this name are included the *Emerald* and the *Aqua Marine*, the former possessing a beautiful brilliant green colour, whilst the latter is of a sea-green colour. Beryl, however, occurs of every shade of greenish-blue to brown. This gem is a mixture of silica, alumina, and glucina, which is an oxide of the comparatively rare element glucinium. Occasionally it is colourless or white. Lustre, vitreous and inclining to adamantine. The green colour possessed by some of the stones is due to organic matter, and not to the presence of chrome oxide, as generally supposed. This organic colouring matter is probably derived from the decomposition of the animals, whose remains are now found fossilised in the rock in which the emeralds are found imbedded. They have apparently been deposited from chemical solution. The pale-bluish, or bluish-green tinted beryls, are called aqua-marine ; the paler varieties are called simply beryl. The beryl is rarely found without a flaw, and is extremely brittle. It crystallises in six-sided prisms. Its sp. gr. is 2·6 to 2·8, and hardness 7·5 to 8, which is the same, or nearly the same, as that of the topaz, but it may be distinguished from the latter by its inferior weight or sp. gr.; also by the absence of the development of electrical properties by heat.

The value of the best emeralds is, when cut, from £10 to £40 per carat, exceeding that of the diamond.

TOURMALINE.—The chemical composition of this stone is very varied; but it chiefly consists of silica, alumina, boracic acid, magnesia, and iron. Its lustre is vitreous. Its colour varies according to its composition. Sometimes it is black, blue-black, and dark-brown; these are the most common, but it is also met with white or colourless, bright and pale-red, grass-green, cinnamon-brown, yellow, and gray. Occasionally it is found to be red within and green externally, or with one colour at one extremity and another at the other. The ruby-red tourmaline is valuable as a gem, and so also is that which has a dark olive tint. Tourmaline occurs as three, six, nine, or twelve-sided prisms, but the sides of the prisms are often rounded. Its sp. gr. is 3 to 3·3, and hardness 7 to 7·5. It is brittle; the crystals are often fractured across and break very easily. It becomes electric when heated. Tourmaline cut into thin plates possesses the property of polarising light, and large crystals would be valuable for cutting such plates from. Its use is confined to scientific circles. The black opaque variety is called *schorl*. Water-worn crystals are commonly found associated with gold, diamonds, and other gems in drifts and river deposits.

CHRYSOBERYL.—This is the true Cat's-eye. It is one of the few gems composed of glucina, its composition being alumina, glucina, and ferrous oxide, and other colouring matter. Its colour is red, yellow, greenish-yellow, or brownish-yellow, and occasionally white. Its sp. gr. is from 3·68 to 3·75, and its hardness 8·5. It is therefore scratched by a sapphire, but itself scratches topaz with a little difficulty and quartz easily. The lustre is vitreous. The transparent yellow stones are used in jewellery, but they are not very fashionable. They bring about 6s. to 25s. per carat. The *Alexandrite* is a variety of chrysoberyl appearing leaf green by reflected light and raspberry-red by transmitted light, and also by candle light. This ranks amongst the finest and rarest of gems. The specimens known as Cat's-eyes owe their resemblance to a cat's eye to the fact of the reflection of light from minute internal striations.

PHENAKIT, or *Cite.*—This stone is interesting because it contains the rare earth glucina, its composition being Silica 54·2 and Glucina 45·8, but it is rarely used as a gem stone. Its hardness is 7 5 to 8, and sp. gr. 2 96 to 3; lustre, vitreous. Its colour varies from colourless to bright wine-yellow, inclining to brown.

PERIDOT (Olivine).—Olivine is one of the constituents of that important and widespread series of volcanic rocks known as basalt. It is commonly of a yellowish-green or bottle-green colour. The varieties which are used in jewellery are styled *precious* olivine, and are distinguished by the names *chrysolite*, when of a yellow or greenish-yellow colour, and *peridot*, when possessing that peculiar green colour which is observed on looking through a delicate green leaf. Its composition is Silica 41, Magnesia 50, and Ferrous Oxide 9. It may be decomposed into a kind of jelly by boiling in Hydrochloric or Sulphuric Acid. Lustre, vitreous; sp. gr., 3·3 to 3·5; hardness, 6 to 7. It may, therefore, be easily scratched by a topaz, and even by a rock crystal; hence its value is small. Peridot closely resembles tourmaline, but may easily be distinguished from it by its not becoming electric when heated, as tourmaline does, and by its inferior hardness.

TURQUOISE.—This is a stone composed of Phosphorus, Alumina, a little copper, and water. Its colour varies from sky-blue, bluish-green, to apple-green. Its lustre is somewhat waxy; hardness, 6; sp. gr., 2·6 to 2·83.

QUARTZ.—It may seem strange that this should be included amongst the precious stones, but some of the varieties of quartz are so beautiful, and so closely resemble gems, that they are of great value. Quartz is simply *silica*, *i.e.*, oxide of silicon ($Si\,O_2$). Its sp. gr. is 2·5 to 2 8, and hardness 7. The crystals are always in the form of six-sided prisms, terminating in six-sided pyramids. They vary much in colour, sometimes being colourless, sometimes topaz yellow, amethyst, rose, smoky, milky, and greenish. The names given to quartz of various colours are as follow :—

1. ROCK CRYSTAL.—The colourless variety. When perfectly clear and in large crystals it is used for spectacles and optical instruments.

2. AMETHYST.—So called from its violet-blue colour, which is caused by the presence of a trace of oxide of manganese. The finely-coloured specimens are highly esteemed as gems.

3. ROSE QUARTZ.—Pink or rose-coloured; seldom occurs in crystals, but generally in fractured masses. The colour, which is probably due to the presence of a slight trace of oxide of manganese, fades on long exposure to light.

4. FALSE-TOPAZ.—This is the name given to the yellow crystals. They are often cut and set as topaz, from which, however, they may be distinguished by their inferior hardness.

5. CAIRNGORM STONE.—This is the name given to the yellow-brown variety of quartz.

6. SMOKY QUARTZ.—Crystals of quartz of a brown or smoke-coloured tint. Passes into the Cairngorm.

7. MILKY QUARTZ.—Milky-white, and slightly opalescent. Occurs massive, and is common.

8. PRASE.—A dull-green, impure, translucent variety of quartz. Occurs massive.

9 CHALCEDONY.—This is only a variety of quartz with a somewhat waxy lustre, and which, being tinted with small particles of iron and other substances, presents great variety of colours; *e.g.*, it is called—

(*a*) *Carnelian*, when of bright-red colour.
(*b*) *Sard*, when of deep brownish-red colour.
(*c*) *Agate*, when variegated. The colours of agate may be improved by steeping in hot oil or honey, and afterwards boiling in strong sulphuric acid.
(*d*) *Onyx*, when occurring in alternate stripes of black and white.
(*e*) *Sardonyx*, when consisting of alternate parallel layers of white and red.
(*f*) *Cat's-eye*, when it is of a yellowish-green or greenish-gray colour, and presents, on being cut, glaring internal reflections of light resembling the contracted pupil of a cat's eye. This peculiar effect is supposed to be due to the presence of small parallel fibres of asbestos.

10. JASPER.—This is another variety of quartz. It is generally of a dull-red colour, but sometimes yellow, brown, and more rarely blue or black. It admits of a high polish, and is used for inlaid work.

11. BLOODSTONE.—This is a green jasper, spotted with red spots, which are caused by iron.

12. SILICIFIED OR PETRIFIED WOOD.—This consists of quartz which has taken the place of the wood. Sometimes the quartz is in the form of chalcedony or agate.

OPAL.—This is one of the very few mineral substances which are never found crystallised, and which are therefore classed as Amorphous. It is the same in composition as quartz, but contains several per cent. of water, so that it would be called a hydrated silica. Its colour is sometimes white, red, brown, green, or yellow. Some varieties are semi-transparent, and others are almost opaque. The sp. gr. of opal is 1·9 to 2·3, and its hardness is 5·5 to 5·6; it may therefore easily be scratched by quartz, which distinguishes it from some varieties of chalcedony and siliceous stones, for which it is liable to be mistaken.

NOBLE OPAL.—The external colour of this is usually milky, but within there is a rich play of the prismatic colours, green, yellow, red, blue, and violet.

The value of the best cut opals ranges from £3 to £8 per carat, but inferior stones can be purchased at prices from 2s. upwards

WOOD OPAL.—This is produced by water containing opal in solution percolating through wood and petrifying it. The original structure of the wood is frequently preserved.

MOONSTONE.—This is a variety of felspar, one of the constituents of granite. It consists chiefly of silica, alumina, and potash. It presents a pearly or silvery play of colour, not unlike that of the moon, which gives it its name. Its sp gr. is 2 53 to 2·58 and hardness 6, which serves to distinguish it from certain forms of quartz to which it bears a slight resemblance.

CROCIDOLITE.—This is a mineral which has sometimes been called Cat's-eye, to which when properly cut it bears a striking resemblance; but it is merely a mineral similar to hornblende, and is composed of Silica, Oxide of Iron, and a little Soda, &c. Its hardness is about 7; sp. gr., 3·2 to 3 265. Lustre, silky. Colour, brownish-yellow or gold, indigo or greenish-blue, and dull-red. It is an ornamental rather than a precious stone.

CHAPTER IX.

SUMMARY OF THE PRINCIPAL TESTS GIVEN IN THIS WORK.

In this summary will be given some of the leading characteristics of certain minerals; and if the substance you desire to identify appears to possess these characteristics, the next step will be to refer to the fuller description given on the page indicated, and see if the mineral under examination answers to it. If necessary, you must apply the test furnished. A summary like the following can of course only be expected to give a very general idea of what the mineral really is.

TESTS FOR MINERALS.

A.—The appearance, hardness, and streak (pp. 15, 16, and 17), will first be considered.

1. If metallic, yellow, and too hard to be scratched with point of knife, or only just scratched, it is probably *Iron Pyrites* (p 93).

2. If metallic, very pale yellow, and too hard to be scratched with point of knife, it is probably *Marcasite, White Iron Pyrites* (p. 93).

3. If metallic, yellow, and easily scratched, it is probably *Copper Pyrites* (p. 76).

4. If slightly bronze-yellow, easily cut, heavy, and brittle, it may be *Calaverite* (Tellurium, p. 102).

5. If black and very heavy, and too hard to be scratched with knife, and on being powdered is pale-gray to light-brown, it is probably *Lode Tin* (p. 89).

6. If black and very heavy, and can be scratched, streak being dark reddish-brown, it is probably *Wolfram* (p. 83); but if not so very heavy, and scratches with greater pressure, it is *Franklinite* (p. 95).

7. If iron-black in colour, tolerably heavy, strongly attracted by the magnet, having a black streak and not able, or only just able, to be scratched with knife, it is *Magnetite, i.e., Magnetic Iron* ore (p. 95).

8. If dark steel-gray or iron-black in colour, and, when crystallised, having a fine lustre, tolerably heavy, able with more or less pressure to be scratched with knife, streak, *i.e.*, the powder being cherry-red or reddish-brown, it is probably *Hæmatite* (specular iron, p. 95).

9. If dark-brown and black to ochre-yellow in colour, able with tolerable ease to be scratched with a knife, of medium weight, having a yellowish-brown to dull-yellow streak, it is probably *Limonite, i.e., Brown Hæmatite* (p. 94).

10. If black and tolerably heavy, and able with very considerable pressure to be scratched with knife, streak being dark-brown, lustre metallic or resinous, it is probably *Titanic Iron* (p. 95), or if brittle *Chrome Iron* (p. 96), or *Psilomelane* (p. 98).

11. If of bright lead colour, consisting of a mass of cube-like crystals, easily cut, brittle and heavy, streak lead gray, it is probably *Galena, i.e.*, Sulphide of Lead (p. 82)

12. If wax-yellow, brownish-yellow to black in colour, with a waxy lustre, and fairly easily scratched with a knife, streak white to reddish-brown, not very heavy, it is *Blende, i.e., Zinc Sulphide* (p. 86).

13. If of lead-gray colour, consisting of a mass of long prismatic or needle-like crystals, heavy, easily cut, and omewhat brittle, it is probably *Sulphide of Antimony* p. 85), or *Sulphide of Bismuth* (p. 79), or possibly *Sylvanite Tellurium*) p. 103.

14. If of lead-gray colour, very soft, moderately heavy, scratched by finger-nail, flexible, and splitting into thin

eaves, it is probably *Molybdenite* (p. 99). If whitish or tinted and very light, it is *mica* (p. 111).

15. If of reddish-white colour, very heavy, crystallised, and easily cut, it is probably *Native Bismuth* (p. 79).

16. If silver-white to steel-gray in colour, with grayish or yellowish tarnish, and able with difficulty to be scratched with a knife, it is probably *Mispickel, i.e., Arsenical Iron Pyrites* (p. 97).

17. If the colour is steel-gray or inclining to iron-black, brittle, easily cut, it is probably *Fahlerz, i.e.,* gray copper ore (p. 76 and 70).

18. If copper-red colour with lead-gray tarnish, brittle, and able to be scratched easily with a knife, it is probably *Red Copper Ore, i.e., Oxide of Copper* (p. 77).

19. If bright-red to brownish-black in colour, heavy, easily cut, streak scarlet red, it is *Cinnabar* (p 74) or ruby silver (p 98). If light red in colour, streak light red, may be Proustite, another form of silver (p 70). If reddish, moderately heavy, scratched with difficuly, it is probably Rhodonite (p. 77).

20. If green or blue, compact or earthy, easily cut or scratched, it is probably *Malachite* (p. 77) or *Azurite* (p. 78), *i.e.*, green or blue carbonate of copper.

21. If exhibiting a beautiful play of colours as in the peacock's tail, easily cut, it is probably *Peacock Ore*, a sulphide of copper (p. 77).

22. If of white or grayish colour, light or dark, heavy and easily cut, crystallised or massive, it is probably *Cerussite, i.e.*, lead carbonate (p. 83). Do not confuse with Barytes (p 110) and No 27. If not quite so easily cut it may be Scheelite (p. 100).

23. If of iron-black colour, either powdery or solid, but capable of being cut, it is probably either *Manganese* (p. 98) or *Black Oxide of Copper* (p. 77).

24. If yellowish like clay on surface and appearing like horn on being cut, it is probably *Horn Silver, i.e.*, *Chloride* (p 71)

25. If the mass is made up of rhomb-shaped crystals, or if the crystals are dog-toothed in shape, easily scratched, non-metallic in appearance, of whitish, light-grayish, or yellowish tint, effervescing in acid, it is *Calcite* (p 108).

26. If crystals are cubical, non-metallic, not so easily scratched, colour white, yellowish, purple, greenish, not effervescing in acid, it is *Fluorspar* (p 108).

27. If it splits into flakes, pearly lustre, easily scratched, does not effervesce, it is gypsum (p. 109), if not so easily scratched, and nearly twice as heavy, and does not effervesce, it is *Barytes* (p. 110)

B.—Powder the mineral, and draw the magnet through it.

1. If strongly attracted, it is *Magnetite*, *i e.*, magnetic iron ore (p. 95).

2. If slightly attracted, it is *Magnetic Iron Pyrites*, *Titanic Iron* or *Franklinite*, *Chromic Iron* (p. 94 to 96).

C.—If not attracted, powder a little very finely and try :—

1. The borax bead test, described in Chapter VI., p. 35

2. Or the reduction test, described in Chapter VI., p. 37.

D.—If not yet satisfied as to the identity of the mineral, crush it up and dissolve a little of the powder by the aid of heat in a small quantity of dilute or strong nitric acid. Boil well, and when most of the acid has evaporated, add a little water and boil again. Note directions on page 46.

1. A white powder forms at the bottom of the tube. Filter, or pour off the clean solution into another tube, and boil the white powder with tartaric acid ; if it dissolves, the mineral is *Antimony* (p. 84). If a yellow residue is left, and which is soluble in Ammonia, it is probably *Scheelite* (p 100).

2. If the white powder does not dissolve it is *Lead* (p. 81); for the strong acid has thrown down some of the lead as a white powder and has dissolved the rest.

3. To the clear nitric acid solution add hydrochloric acid or common salt solution. If a white, curdy precipitate is formed which turns purple and then black on exposure to sunlight, the mineral contains *Silver* (p. 68).

4. If the precipitate is white and crystalline, and does not turn black on exposure to sunlight, the specimen contains *Lead* or *Mercury* (p. 81 and 73).

5. There may be silver mixed with the lead. In this case a portion of the precipitate will turn, or perhaps the whole mass will become slightly darkened. This would be caused by the presence of a little silver. To separate it from the lead act as follows:—Allow it to settle, and pour off the liquid. Add clean water and shake. The lead, or a portion of it, dissolves. Pour off the water and add ammonia to the precipitate, if any remains. Heat and filter. Whatever silver was present will be in the clear solution which has filtered through. If the portion insoluble in the ammonia remains white, it is *Lead*; if turns black, it is *Mercury*. Refer to pages 81 and 73.

6. Add to the clear solution obtained as above a few drops of nitric acid. A white, curdy precipitate proves the presence of *Silver* (p. 69).

7. If the hydrochloric acid or common salt solution does not produce any effect, or if you wish to detect the presence of substances other than silver, add, to another portion of the clear nitric acid solution, ammonia, drop by drop.

Result—

(*a*) A greenish-blue precipitate forms, dissolving, on the addition of more ammonia, to a magnificent azure-blue solution. This proves *Copper* (p 75).

(*b*) If the blue inclines to violet it indicates *Nickel* (p. 97). If not quite sure about it, place the clean blade of your knife in the weak acid solution; if copper be present it will coat the blade.

(c) A whitish precipitate forms, which, upon exposure to the air, becomes a brownish, and finally, a deep blackish-brown colour. This indicates *Manganese*. Verify by borax bead, which gives an Amethyst colour (p. 98).

(d) A foxy-red feathery precipitate forms. This proves *Iron* (p. 93).

8. The solution resulting from the boiling of the mineral in nitric acid is greenish. Inference, *Copper* is present, *e.g.*, Fahlerz (p. 76). Prove by adding ammonia as above.

9. The solution resulting from the boiling of the mineral in nitric acid is light-red, and retains its colour on adding water. Inference, *Cobalt* (p. 91), Confirm by borax bead, which gives beautiful *blue* (p. 90).

10. The whole, or greater part, of the powdered mineral dissolves in boiling nitric acid. Throw a little of the solution into a tumbler full of water. A white precipitate proves *Bismuth* (p. 79). If it does not appear, add a little salt water. This will produce it, either immediately or in a few minutes, if Bismuth be present.

11. The powdered mineral dissolves in boiling nitric acid, giving off an unpleasant odour like that of rotten eggs (Sulphuretted Hydrogen). Inference, *Sulphide of Zinc* (p. 86) Confirm by blowpipe test (p. 86).

12. To the clear nitric acid solution add a little Potassium Ferrocyanide solution. A beautiful blue precipitate (Prussian blue) proves *Iron* (p. 93), the amount of the precipitate being indicative of the quality of the ore.

Note.—Any powdered mineral which, on the addition of dilute nitric acid, effervesces, is a carbonate of some kind, *e.g.*, Calcite (p. 108); Copper (p. 77); Bismuth (p. 79); Lead (p. 83); Zinc (p. 87); Iron (p. 94); or Barium (p. 110).

E.—1. The mineral does not dissolve in nitric acid. It is a horny substance and may be cut with a knife, like horn; or it is yellowish, somewhat resembling clay; or perhaps it is greenish and crystalline. It may be *chloride* or *chlorobromide of silver* (p. 72). Pulverise a little of it, and boil it with a little Potassium Cyanide and water. Filter, and to the clear solution add nitric acid A white precipitate proves *Silver*. (See pp. 50, 53, and 68.)

2. The mineral is black and heavy, and the powder is not magnetic, and will not dissolve in boiling nitric acid. It may be *Tin* or *Wolfram*. See tests for these under Tin (pp. 89, 90). But it may be some form of iron, as Chromic or Titanic Iron. Try by the borax bead test (p. 35).

F.—The mineral is supposed to contain gold. Dissolve by boiling in aqua regia—made up by adding 3 parts of hydrochloric to 1 of nitric acid. Filter, and add stannous chloride solution. A brownish-red precipitate inclining to purple, or, if only a little gold be present, a coloration is produced. This is called Purple of Cassius, and is a delicate test for *Gold*. Or add to the aqua regia solution a few drops of ferrous sulphate dissolved in water. If gold be present a brown precipitate of metallic gold will be produced, which appears bluish-green when held up to the light. See pp. 63, 64.

N.B.—The weight of pure gold in a given specimen of quartz may easily be obtained by means of the formula given on page 65.

SUMMARY OF TESTS FOR PRECIOUS STONES.

The following table will furnish some clue as to what the precious stone under examination is; and its identity may be established by reference to the description given of each in Chapter VIII., page 118.

Notice the scale of hardness, page 15.

Colour.	Hardness.	Inference.
Colourless, straw-yellow, black, green, red, pink. Very brilliant lustre.	10	Diamond.
Blue, greyish-blue, red, yellow, amethyst, green, brown or black.	9	Sapphire.
Red.	9	True Ruby (Red Sapphire.
Red, green, yellow, brown and black.	8	Spinel.
Deep-red to crimsom, brown, black, green, emerald-green, or white. Shape, globular.	6·5 to 7·5	Garnet.
Brownish-red, brown, red, yellow and gray. Of square, prismatic form; brilliant lustre.	7·5	Zircon.
Clear red and brilliant lustre.	7·5	Hyacinth (Zircon)
Rich Berlin, or azure-blue.	5·5	Lapis-lazuli.
Pale-yellow, white, greenish, bluish, reddish, very rarely pink.	8	Topaz.
Green, yellow, smalt-blue, or colourless.	7·5 to 8	Beryl, or Emerald.
Black, blue-black, dark-brown, occasionally colourless, bright, or pale red, greenish, brown or gray. In 3, 6, 9, or 12 sided prisms; often rounded at corners and ends.	6·5 to 7·5	Tourmaline.
Colourless, pink, yellow, yellow-brown, smoke-coloured, milky-white, dull-green, bright and dull red, variegated, greenish-gray.	7	Quartz, of which there are numerous forms.
White, red, brown, green, yellow; sometimes semi-transparent, sometimes opaque.	5·5 to 7·5	Opal.
Milky, but with an internal play of colours.	6·5	Noble Opal.
Pearly, or silvery play of colour like moon.	5	Moonstone.

PART II.

ON ROCKS.

THE MINERS' GUIDE;

OR,

WHERE TO LOOK FOR MINERAL WEALTH.

Having given tests by which the various minerals of commercial value may be identified, I propose to make some remarks concerning those rock formations in which it is worth while to look for them; for valuable minerals are not distributed over the earth's surface irregularly: there is something approaching to a system in their distribution, the knowledge of which furnishes us with a rule by which we decide whether a particular kind of mineral may be expected to be found in a given spot. Our guide in this matter is the nature of the rock formations. The study of these belongs to Geology, which is that branch of science which investigates the structure of the earth and the causes which have led to that structure. It is not my intention to attempt to teach systematic geology in these pages, but merely to make such remarks about rocks as may help you in your search after mineral wealth.

Valuable minerals are always associated with certain rock formations, and it is absolutely necessary that the practical mineralogist should be able to recognise these when he meets with them. You must, however, learn to determine them not so much by written descriptions as by handling actual specimens; and therefore I must refer you to the various public and private collections to which you may have access. And here I will venture to remark for the benefit of all whom it may concern, that the authorities should no longer delay the establishment of small Schools of Mines in all the important mining centres. To provide all that is really necessary need not cost the country very much, and, if nothing else can be done, at least small collections of typical rocks and minerals can be supplied to each Mechanics' Institute or School of Arts. These collections would be exceedingly useful to miners and others interested in mining.

Now it is usual to divide the rocks of the earth's "crust," by which term is meant that part of the earth's surface which is accessible to human observation, into *three* great divisions, viz. :—

I. **Sedimentary,** Stratified, or Aqueous; II. **Igneous,** or Eruptive rocks; and III. **Metamorphic,** or altered rocks. It is to be remembered that all accumulations of earthy matter, whether hard or soft, and also certain chemically and organically formed deposits, are termed by geologists "*rocks.*"

The following table of rock formations of the earth is furnished for the purpose of showing how the rocks of the earth are classed, and to give a general idea of the extent to which the geological series is represented in Australia. It does not in any sense profess to be complete; nevertheless it is instructive, and sufficient for all practical purposes.

TABULAR ARRANGEMENT OF ROCKS AND ROCK SYSTEMS.

PERIODS.	SYSTEMS.	FORMATIONS.
Post Tertiary or Quarternary	Recent	Deposits of gravel, sand, loam, and mud now accumulating.
	Pleistocene or Post Pliocene	Alluvial flats along the course of creeks and rivers; newer gold and tin drifts; lavas.
Tertiary or Cainozoic *i.e.*, Recent Life	Pliocene	Older gold and tin drifts capped with basalt; rich basaltic downs.
	Miocene	Portland and Murray River beds.
	Eocene	Represented in Victoria; not in N.S.W
Secondary or Mesozoic *i.e.*, Middle Life	Cretaceous	Desert Sandstone, Maryborough beds, Q.; Rolling Downs of Q
	Jurassic or Oolitic	Clarence River Series, and in Victoria.
	Triassic	Wianamatta Shales, Hawkesbury Sandstone and Narrabeen Series.
Primary or Palæozoic *i e.*, Ancient Life	Permian	Newcastle and E. Maitland Coal Measures.
	Carboniferous	Lower Coal Measures (Wollongong); Upper Marine Series (Branxton).
	Devonian	The gold-bearing Slates; Wallerawang and Rydal Series.
	Silurian Cambrian	Gold-bearing Slates; Yass and Hume beds, Victorian Schists, &c.
Archæan or Azoic *i.e.*, Nolife Period	Metamorphic	Clay Slate, Gneiss, Schists, Serpentine, &c.
	Igneous	Includes the great variety of granites porphyries, greenstones, basalts, &c.. found so widely distributed.

The full consideration of these systems does not fall within the province of the economic geologist and practical mineralogist, and hence I shall devote but little space to their description. Should you desire more information concerning them, I must refer you to one of the many excellent text books on geology, *e.g*, that by Geikie or Bird.

The table, however, calls for a few remarks. First, let us glance at the *sedimentary* or *stratified* rocks. These have chiefly been deposited in water and are therefore sometimes called *aqueous* rocks. Some, however, are *chemically* formed, *e.g.*, many limestones, some iron deposits, &c.; and some are *organically* formed, being composed of plants, *e.g*, coal and certain limestones; or of animals, *e.g*, some limestones, flints, &c. We need not discuss these now: it is sufficient to say that the sedimentary rocks consist principally of **sand, clay, and lime.**

The sandy rocks are masses of sand and gravel; sandstones, consisting of fine grains of sand cemented together; grits, in which the component grains of very coarse sand are cemented together; and conglomerates, or puddingstone, which consist of rounded stones of small or large size cemented together. The cementing medium is sometimes iron oxide, sometimes clay or carbonate of lime, and occasionally silicious or flinty matter.

The clayey rocks are clay, *i.e.*, silicate of alumina, which is soft; marl, which is clay containing carbonate of lime; shales, which are hardened clay, with a tendency to split into slices or laminæ along the lines of deposit; and slate, *i.e.*, hardened clay, altered somewhat by heat and pressure, and characterised by "cleavage," *i.e.*, a tendency to split into thin slices or laminæ in directions other than that of the original bedding. Shale, when much hardened, passes into slate.

The limestone rocks are principally chalk, marble, limestones, all of which are made up of carbonate of lime; and dolomite, which consists of carbonate of lime and magnesia.

All these rocks have been gradually and successively deposited in water through an immense series of ages. Excepting the lime rocks, they are made up of material derived from the breaking up of older rocks which formed the original crust of the globe; hence they are often spoken of as "derivative rocks." None of these old original rocks have yet been discovered, nor is it likely that they will be; but they must have closely resembled our igneous rocks, inasmuch as they were formed by the hardening of the molten matter of which the primeval globe was composed. A reference to the foregoing table of rocks will show that those first deposited are called *Primary*; those formed in succeeding ages are known as *Secondary*; while to the third, or more recent, set the names *Tertiary* and *Post Tertiary* have been given.

Nearly all these rocks contain fossils, *i.e.*, the remains of plants and animals, such as the leaves and stems of trees, shells, fish, &c., and bones of animals. By means of these fossils the *relative* ages of the rocks of each set are determined, the most ancient forms of life being in the primary rocks, which are hence called *Palæozoic*, from two Greek words meaning "ancient life" The secondary rocks are called *Mesozoic*, which term means "middle life;" and the tertiary are called *Cainozoic*, *i.e.*, "recent life."

Of the Sedimentary Rocks, the Post Tertiary, Tertiary, and the Palæozoic are the most interesting to us; the former, because they yield the chief supplies of alluvial gold and tin, which are frequently covered up by basalt which flowed out from great vent holes or craters at or towards the close of the Pliocene period; the latter, because in them, and in the associated rocks, lodes or reefs are the most numerous.

But what are these associated rocks? Some are igneous, others are metamorphic. This will lead us to the consideration of these two classes. First, the *igneous*. These are rocks which have been forced out from the heated interior of the earth by those great disturbing agencies of which the earthquake and volcano are indications. They were all originally molten or pasty, the result of the action of heat—either dry or moist heat. They are almost all very hard, and their internal structure is usually crystalline. These igneous rocks have been divided into *hydrothermal, trappean, and volcanic*; but for our purpose it will be sufficient to divide them into **Plutonic**, *i.e.*, those which have cooled and solidified at some depth below the surface, and whose appearance at the surface *is in all cases due to the planing off or denuding of the superincumbent rocks*; and the **Volcanic**, *i.e.*, those which have cooled at or near the surface. Broadly speaking, it may be said that all coarsely crystalline rocks are Plutonic. They cannot, as a rule, be easily scratched with the point of a knife excepting when partly decomposed or "weathered," as it is called. As examples of these Plutonic rocks we may mention Granite of various kinds, Syenite, Felsite (called also Felstone and Eurite), Porphyry, Greisen, Diorite or Greenstone, Diabase, Gabbro, Dolerite, &c. Of the Volcanic rocks we may mention as examples Trachyte, Phonolite, Andesite, Basalt, Anamesite, Obsidian, Pumice, &c.

The **Metamorphic** rocks are intermediate between the sedimentary and the igneous rocks, and their origin is in many cases due to the action of the latter upon the sedimentary; though not in all cases, for sometimes the igneous rocks are themselves altered by chemical action or by heat from other igneous rocks. The study of these metamorphic rocks in Australia presents a most inviting, and hitherto almost untouched, field of research.

You will easily understand that when great masses of igneous or molten rock were thrust in among or protruded through the sedimentary rocks, the latter would be considerably acted on by the intense heat of the former. A familiar example of such action is exhibited in an over-burnt brick, which is an instance of metamorphism by dry heat. Now, had we saturated the clay, previous to burning, with water containing certain chemicals in solution, and then raised it to red heat, we should have obtained a different result—a mass of clay altered in a different manner. This would furnish an instance of metamorphism by moist heat and chemical action. So in nature, the sedimentary rock has, through the intense heat of the eruptive or igneous rock, entirely lost its original characteristics, and itself become in appearance more like an igneous rock.

The Metamorphic rocks whose origin is clearly traceable are for the most part either (1) *altered primary sedimentary rocks;* or (2) *altered igneous rocks.* Any of the sedimentary rocks of either period may of course be altered; but the lowest being nearest the source of heat, will stand the greatest chance of being altered. Hence the metamorphic rocks are for the most part associated with, or lie at the bottom of, the Primary rocks. The most general characteristic of the altered sedimentary rocks is their tendency to split, not along the grain of their bedding, but in some given general direction across the bedding. This tendency to thus split is called the *Cleavage.* The altered igneous rocks are mostly Plutonic, though some are Volcanic.

The following list includes the leading altered rocks, whether altered from sedimentary or igneous rocks, though the origin of some cannot always with certainty be traced:—

Clay Slate and other slate, *e.g.*, micaceous, chloritic, talcose, &c., have been formed from altered slate rocks.

Marble.—Altered limestone.

Dolomite.—Sometimes altered limestone with the addition of magnesia, which, in solution, has soaked through the limestone.

Quartzite, Quartz Schists, and Hornstone.—Altered sandstone.

Gneiss.—Sometimes altered granite, from which it differs in no way except in the structure; sometimes an altered sedimentary rock.

Granulite.—Sometimes an altered eruptive; occasionally an altered sedimentary rock.

Mica Schists.—An altered sedimentary rock.

Hornblende Schists.—Sometimes altered syenite and sometimes diorite, &c.

Serpentine.—An altered eruptive rock.

We are now in a position to explain the occurrence of **mineral veins and lodes or reefs** in the primary strata and in certain igneous rocks. First, let us take the primary strata.

Bear in mind that these were formed from pre-existing rocks through which the vein stuff and other mineral substances were scattered in various chemical combinations, or, possibly, in veins or bunches. When these rocks were disintegrated, or broken up, by the action of the tides (which were in those days hundreds of times as high as they are now, owing to the greater proximity of the moon), by the atmosphere and other agencies, *e.g.*, ice, frost, &c., the material composing them was conveyed to some sea of tranquil deposit, and there laid down in horizontal strata. In time, by pressure of sand and water above, they became indurated or hardened. Some mineral matter was scattered throughout these sedimentary rocks, having been washed along with the material composing them, or having been deposited by the infiltration of the ocean waters, which contained minerals in solution in much larger quantities than they do now, though even now they contain gold and silver in minute proportions.

In order, however, to collect these mineral substances in the form of ores and reefs, at least two conditions are required, viz., space in which to accumulate, and the means of collecting together or accumulating in these spaces.

Let us see how these two requirements are fulfilled.

When the igneous rocks were forced against or amongst the sedimentary rocks, lifting them up or pushing through them, they naturally caused cracks and fissures to run in various directions. To many of these cracks and fissures, molten or pasty rock gained access and filled them up, forming what are called "dykes" when large and regular, and "rock veins" when small and less regular; others, however, were not immediately filled up, but remained more or less open until subsequently filled with mineral substances accumulated by a more slow and gradual process, as for example deposition from aqueous solution, as will presently be explained. It is quite clear that in many cases the dykes have had much to do with the deposit of these minerals. As the igneous rocks cooled, moreover, they themselves cracked, or were acted on by subsequent disturbing forces (*e.g.*, earthquakes) which caused fissures to run through them, as well as through the surrounding sedimentary rocks There will probably be several, perhaps many, of these "cracks" parallel to one another; but only one may be a true fissure, large and deep, while the others are small and superficial. All these fissures or cracks have since been filled by minerals in a more or less pure or unmixed state, and frequently in a crystalline form. Of these minerals quartz is probably the most abundant, being the almost universal matrix in a mineral country; but fluorspar and calcite also occur as matrices. In these matrices (vein stuff, or gangue as it is called) are mixed various metals, such as lead, tin, copper, silver, gold, &c., either in the native state, or mixed with other substances forming *Ores* or *Lodes*. These are called "Mineral Veins," and must not be confounded with "rocks veins." They are also called reefs in the colonies and "ledges" in the United States.

The above explanation of fissures or cracks will show why a fissure reef is thought so much more of than any other; but let it be remembered that where there is one reef there will probably be others, so that it is not wise to fix your affections too much on any particular one, until you have thoroughly prospected the ground.

Sometimes the principal reefs are crossed at right angles by other reefs, but when this is the case their contents are either of a different nature or poorer in quality. But now arises the question—how came these substances into the cracks? Well, remember they were either (1) in the original rock in which the crack was caused by the igneous rocks in the manner above described; or (2) in another not so very far away which was acted on by the same, or possibly some other heating agency, and was connected with the crack by channels of some sort; or (3) they came up from greater depths in the form of vapour or aqueous solution. Heat is the great expansive force in nature. In the sedimentary rocks, and in some of the igneous, is contained a large quantity of water called "interstitial water." This is not apparent to the senses, but it is nevertheless there in the proportion of 2·67 per cent., which would correspond to two quarts of water for every cubic foot of rock. This water contained various chemicals in solution, which it gathered as it soaked through the rock. Well, when under the influence of heat and pressure, this water expanded and was forced along, it changed the character of the rock, converting by means of its chemicals in solution a limestone into a dolomite, or a clay slate into a crystalline rock, and so forth; but it did more than this. By a system of exchange, or give and take, it derived from the rock certain mineral substances, and burdened with these it moved gradually along until it reached one of these cracks. Here it perhaps evaporated, leaving crystals mixed with other substances on the sides of the fissure. This might continue till the fissure was filled. It is not unlikely, however, that on reaching the crack or fissure it would meet with water which had reached the same spot from another direction, and which in its course had picked up different substances, and the constituents or component parts of these two mixtures, acting on one another, would cause metals or other minerals to be precipitated, *i.e.*, thrown down, and mixed with what had been previously, or was then being, deposited. It is needless to give here the chemical reactions that take place, but it is perfectly easy to reproduce in our laboratories on a small scale what nature does in her laboratory on a large scale, *e.g.*, gold (p. 64), or silver (p. 50). You will easily perceive how, in the event of your reef passing from one kind of rock into another, it is quite natural to expect to find different ores, for the constituents of one rock through which the water passed might be favourable for the deposition of a certain kind of ore, while those of the neighbouring rock were not quite favourable.

Although the above explanation is quite satisfactory as far as some veins and reefs are concerned, yet there is no doubt that, in some cases, both vein stuff and the metallic contents of the same have come from great depths in the form of vapour or, possibly, dissolved in water, from which they have, on cooling and evaporating, been deposited. Reefs of this class would be described as being of hydrothermal origin. With reference to quartz reefs, I may remark that in no case has quartz been ejected from below in a molten state, for the point of fusibility of quartz being so much higher than that of other minerals, such as those of which the containing rock is made up, the heat required to maintain the quartz in a fluid state would melt the rock in which the quartz was being deposited; and this is rarely, if ever, found to be the case.

There are other theories put forth to account for the origin of mineral veins, but those which I have given you appear to me to be the most natural and the most satisfactory as applied to the majority of such veins.

We cannot now deal at greater length with this interesting subject; but I hope enough has been written to enable you to understand how it is that metalliferous reefs are found for the most part in the older strata and the metamorphic and igneous rocks. Of course, had suitable conditions obtained, they would also have been formed in newer rocks; but only in exceptional cases has this occurred. As a result of the disturbing action among the rocks which contain mineral wealth, and to which action the accumulation of such mineral wealth is due, a mining district is commonly a mountainous one.

Description of Rocks.

It will now be my aim to give such a description of those rocks with which valuable minerals are associated as may enable you to distinguish them, when you meet with them in the field. It is a difficult task, and one which cannot be performed satisfactorily. You must, by reference to some named collection, accustom your eye to the external characters of rocks, and then perhaps my description may be of some little service. Always take care when examining a rock to break a piece for examination from the solid rock, and not from the weathered crust, which is often misleading.

You will require a hammer, a small pocket lens, a knife to test the hardness, and a small bottle of dilute hydrochloric acid.

The various rock-forming minerals mentioned in the description, will be found enumerated on pages 161 and 162 in the system of classification of minerals. In order to determine the correct name of a rock, the different minerals composing it must be ascertained; and it often happens that these cannot be determined, excepting by the aid of a microscope or by chemical analysis. With a little practice we can, however, form a tolerably correct idea of what the rock is from a consideration of its physical characteristics, and in the following brief description I shall give such particulars as may be helpful to you.

We will begin with the *Sedimentary Rocks.*

SEDIMENTARY ROCKS.

SANDSTONE.—Composed of grains of sand more or less coloured by iron and cemented by this or some other substance. Some are very fine, others coarse. When very coarse the stone is called a *grit.*

MICACEOUS SANDSTONE.—A rock so full of mica flakes, that it splits readily into thin laminæ, each of which has a lustrous surface from the quantity of Silvery-mica.

ARKOSE (granitic) Sandstone.—Composed of disintegrated granite.

CONGLOMERATE (puddingstone).—A mass of various sized water-worn pebbles cemented together. When the fragments composing it are *angular* instead of rounded, the rock is called a *Breccia.*

SLATE (Argillite).—This is a hard rock, composed of argillaceous (clayey) material, compact in form, often with minute flakes of mica and fine grains of sand, and capable of splitting into slices. When the direction in which the rock splits is different from that of the original bedding—the result of great lateral pressure—it is called a *slate*, or clay-slate, and the tendency to split is called "cleavage." This cleavage is characteristic of slate. All slates can be easily scratched with a knife. They emit a peculiar "earthy or slaty" odour when breathed upon. They often contain fossils, by means of which their relative age can be determined. They are of various ages, and are often traversed by reefs and veins, especially when altered by contact with igneous rocks (see p. 146).

SHALE (from German word "to peel."—This term is applied to rock composed of the same material as slate, but generally less hard, and splitting into slices along the line of original deposit; often fossiliferous. Has a peculiar earthy or slaty odour when breathed on. Shales are sometimes called *Argillaceous Schists.*

Marl is clay, with the addition of one-tenth or more of its mass of lime. In a dry state it breaks up into cubical fragments. Effervesces with acid.

Limestone.—Varies much in texture. Sometimes hard, flinty, and close-grained, breaking with splintery or conchoidal fracture; sometimes crystalline, resembling loaf sugar; sometimes dull and earthy; sometimes resembling in appearance sandstone. The colour also varies from white to cream colour and blue-gray, yellow, brown, and black. May easily be scratched with a knife, and effervesces freely when acid is applied. Streak white.

Dolomite (Magnesian Limestone).—Usually crystalline in texture. Colour, white to yellowship or pale brown, according to the proportion of oxide of iron present. Easily scratched with knife, but requiring more pressure than when scratching limestone. Effervesces very slowly indeed, scarcely at all when acid is applied, unless it is powdered and heated.

THE IGNEOUS ROCKS.

I have already pointed out that these are divided into two classes, Plutonic and Volcanic (see p. 143). Some of each class will now be described.

The Plutonic Rocks.

Granite.—This rock consists of a crystalline granular admixture of quartz, felspar, and mica. Cannot be scratched with a knife. Sp. gr., 2·5 to 2·8. The quartz are the glassy, grayish-white, or smoky parts; the felspar the dusky-white parts—or pink, when stained with iron—with a waxy lustre. The mica is usually in small bright scales, which, if silver-white, are *muscovite* or potash mica; if brownish black or black, are *biotite* or magnesian mica.

Hornblendic Granite.—Sometimes black, or greenish-black, hornblende takes the place of mica, either wholly or in part. The rock is then called hornblendic granite or syenite granite. The hornblende must be picked out by the hardness of its prism, since the dull edges of biotite crystals (mica) often resemble fibrous hornblende.

PORPHYRITIC GRANITE is the name given to a fine-grained granite with large crystals of felspar scattered throughout the base.

PEGMATITE is the name given to granite when the crystals of felspar and plates of mica are very large.

Granite weathers chiefly by the decay of its felspars, often forming *Kaolin*, a white clay with a somewhat greasy feel. With cobalt solution a pale blue colour is produced by this when heated on a platinum wire (p. 37). The pure varieties are used for making porcelain; hence a deposit of this clay would be of value.

SYENITE.—A coarse crystalline-granular mixture of orthoclase (common felspar) and hornblende. It is often flesh-coloured. Usually occurs massive, but sometimes in dykes. Sp. gr., 2·7 to 2·9 Cannot be scratched with a knife.

FELSITE.—Called also eurite and felstone. A hard, very compact, flinty-like, though sometimes fine granular, rock breaking with an even fracture, composed chiefly of orthoclase felspar and quartz. Can with difficulty be scratched with a knife. Colour generally light gray, but sometimes red, brownish-red to black. Weathers white. Streak white. Sp. gr., 2·6 to 2·7. It may also be considered as granite in a very compact state without mica. The most compact varieties resemble flint. As well as being an eruptive igneous rock it is sometimes metamorphic.

PORPHYRY.—This is sometimes a metamorphic rock. It is a hard, compact, and flinty-like rock of varying composition, with distinct crystals embedded in the base. Can be scratched with a knife with difficulty. It is variously coloured and occurs massive and in dykes. When grains or crystalline blebs of quartz are scattered through the base the rock is called a *quartz-porphyry*, which is of various colours. When the crystals are felspar it is called *felspar-porphyry*. This rock is generally dark coloured.

NOTE.—It is only right to mention that the term "porphyry" is discarded by some petrologists, because, in reality, it is not a distinct class of rock that is signified thereby, but only a variety of another class. The term is, however, a convenient field term for the rock above described, and is sufficiently accurate for all practical purposes: hence I retain it here.

GREISEN.—This is really granite with the felspar left out. It consists of granular quartz and scales of mica, which is usually, though not always, white. Tin ore (cassiterite) is commonly met within this rock.

DIORITE (Greenstone).—The term greenstone has been applied not only to diorite, but also to various rocks with a greenish tint, concerning the nature of which doubt existed (see Dolerite). It is, therefore, a convenient field term, serving as a cloak for comparative ignorance, which in some cases, however, is pardonable. The use of the term is, nevertheless, restricted by some to *Diorite*, which is a very tough rock, consisting of a crystalline granular mixture of triclinic felspar (the whitish mineral) and hornblende (the greenish mineral). It differs from syenite in the nature of its felspar, that being the lime felspar, and not the common variety, which is a constituent part of syenite. The colour of diorite is often, for the coarser kinds, grayish-white to greenish-white, and, for the finer kinds, olive-green to blackish-green. It weathers brown, and the weathered crust effervesces with acid. It may, with some considerable pressure, be scratched with a knife. Specific gravity, about 2 95.

DOLERITE (from Greek word meaning "deceitful".—A crystalline-granular rock, of dark gray to black colour. It takes its name from the fact of its resembling granite to such an extent that, at first sight, it is apt to be mistaken for that rock. It may be scratched with a knife with moderate ease. It has the same composition as basalt, viz., labradorite, or anorthite felspar, and augite. The striated felspars and dark crystals are characteristic. Dolerite is sometimes included among the Volcanic Rocks; but as it is the deep-seated portion of basaltic rock, which has consequently solidified at a depth, and not at or near the surface, it should, I think, be classed among the Plutonic Rocks. The very close-grained and compact dolerites are known as *Aphanites*. When dolerite is altered it is called *Diabase*. All these rocks, in common with diorite, are called *greenstone*.

GABBRO.—A coarse, though sometimes fine, crystalline-granular rock, very tough, composed of triclinic felspar (usually labradorite) and diallage, which is a laminated variety of augite, usually of a greenish colour. Specific gravity, 2 85 to 3·10. The labradorite is usually pale gray or white, and easily fuses in the blowpipe flame. The diallage occurs in tabular or plate-like patches of a gray, brownish green or blackish-green colour, with a pearly lustre on the cleavage. Its weathered parts slightly effervesce with acid

NOTE.—Diorite, Dolerite, Basalt, and some other similar igneous rocks weather into rounded masses which appear to be made up of concentric layers like the coats of an onion. This is a somewhat characteristic feature.

THE VOLCANIC ROCKS.

TRACHYTE (from Greek word meaning "rough").—A light-coloured gray rock feeling rough to the finger when freshly broken, and consisting of a base of felspar in which glassy crystals of sanidine are often scattered. Frequently porous and makes good drip-stones.

BASALT.—A compact, dark grayish, bluish-black, or greenish-black rock often with crystalline grains scattered through it; the green crystals are olivine. Sometimes has little cavities containing mineral matter. Composed of labradorite, augite, olivine, and titaniferous iron. Weathers yellow or brown. The coarse varieties, the deep sealed portion of lava-flows, are called *dolerite*, and the intermediate varieties, *anamesite*.

MELAPHYRE is the name given to basalt when altered or decomposed The term "trap" is applied to some dark basaltic rocks which are spread out in great sheets over a large extent of country, as in Sweden, where they occur in great terrace or stair-like sheets—whence the name *trap* (from *trappa*, a stair) They are really not different from basalt.

ANDESITE.—A dark-coloured, compact, or vesicular rock, with small scattered crystals of felspar (plagioclase) and hornblende or augite. Colour, bluish or brownish-black to dark gray; rarely green. Weathers reddish-brown. The rock forms a connecting link between trachyte and basalt. When decomposed, it is called prophylite, and in some parts of the world—*e.g.*, New Zealand and Colorado, U.S.A. —carries gold reefs.

PHONOLITE OR CLINKSTONE.—A compact rock of grayish-blue and other shades, consisting of glassy felspar (sanidine) and nepheline with hornblende. It is generally somewhat slaty in structure, and occasionally resembles trachyte in appearance. When struck with a hammer it gives out a metallic clinking sound, whence its name, clinkstone. The weathered crust is white and distinct.

RHYOLITE (from Greek word signifying "flowing").—This is really a variety of basalt of somewhat recent origin which has rapidly hardened by being poured out at the surface and spread over a large area of cold rock. It consists of crystals (usually sanidine, the glassy variety of felspar), imbedded in a glassy sort of paste, which has a more or less streaky character—an evidence of its former viscous condition Though sometimes compact, it more often has a porphyritic structure.

OBSIDIAN.—A glassy brown or gray rock, resembling bottle glass, and breaking with a conchoidal fracture. It consists of felspar in a vitreous condition.

PUMICE.—A general term for spongy vesicular froth-like lava, consisting of felspar in cellular form.

BRECCIA.—This is a rock composed of volcanic fragments of andesite, &c., which have been hurled out by volcanic agency, and have been partially decomposed by atmospheric agencies, and eventually cemented together by percolating waters.

TUFA.—This is also a compound of volcanic fragments, chiefly ash, hardened together into rock. It has sometimes been laid down in water, in which case it might correctly be considered an aqueous rock.

THE METAMORPHIC ROCKS.

CLAY SLATE (ALTERED SLATE).—This is an easily recognised rock, with a "*cleavage*" structure, breaking with a hard and earthy-looking fracture, and of a dark gray to black colour. It is easily scratched with a knife, and emits an earthy smell when breathed upon. The term *altered slate* is somewhat indefinite, as geologists commonly talk about altered slates the moment they trace alteration from the normal or original condition; and, of course, there are many degrees of alteration. The term is, however, a convenient one to apply to those Silurian, Devonian, and other slates which are traversed by reefs or penetrated by igneous rocks.

MARBLE AND DOLOMITE are altered limestones, the latter having the addition of magnesia: easily scratched. Marble effervesces freely with acid; dolomite very slowly, unless powdered and heated in the acid.

QUARTZITE.—An altered and exceedingly hard sandstone, the grains of which are bound together by a cement formed by the dissolving action of the heated water on them. It breaks with a lustrous fracture. Any grit or sandstone with a silicious cement may be regarded as a quartzite. They vary much in hardness; some may be scratched, while with others the knife leaves a metallic streak of steel on the surface.

GNEISS.—A crystalline rock of a laminated nature, made up of layers of *quartz*, *felspar*, and *mica*, approximately parallel to one another. It differs in no way from granite except in point of structure.

GRANULITE —A variety of gneiss without mica, and containing, as a rule, small garnets.

MICA SCHIST.—A moderately hard and glistening rock, consisting largely of mica and some quartz, and splitting easily into laminæ or flakes. Its colour is dark gray. This is the most abundant metamorphic rock. If the quartz is very abundant and only a little mica, the rock passes into a *quartz schist.*

HORNBLENDE SCHIST.—This is a dark green or black rock, consisting of hornblende and quartz, the latter only in small quantity. If it loses its schistose structure it becomes a hornblende rock or *Amphibolite.*

TALC SCHIST.—This is a rock of a white or greenish colour, having a soapy feel, and a very pearly lustre. It consists of scales of talc (silicate of magnesia) with a little quartz. May be scratched with the finger-nail. The powdered rock, heated on platinum wire and moistened with cobalt solution, gives pink colour, owing to the magnesia (see p. 37).

HYDROMICA SCHIST.—This rock so closely resembles Talc Schist that they are frequently taken one for the other; in fact, it used to be called Talcose slate until it was discovered that there was no talc in its composition. Its colour is whitish, grayish, pale pinkish, and also darker colours. It has a smooth surface, feeling greasy to the fingers, and a somewhat pearly lustre. It, however, differs from Talcose Schist in composition, consisting of hydrous mica (chiefly silicate of alumina and water), with or without quartz. The white varieties can be tested for alumina by nitrate of cobalt solution (see p. 37), which gives a blue colour, and may thus be distinguished from Talc Schist.

CHLORITE SCHIST.—A dark green schistose rock with blackish-green scales of chlorite on the surface of foliation. Easily scratched with a knife.

SERPENTINE.—An altered eruptive rock, occurring in beds or masses among schistose rocks, and also in dykes and veins traversing other rocks. It is a compact or finely granular, faintly glimmering though sometime dull rock. Easily cut or scratched Its colour is pale to dark green or reddish, or with blotched and clouded mixtures of these colours. It has a somewhat soapy feel Does not effervesce with acids. It consists of hydrous magnesian silicate, which is the altered condition of the minerals which originally made up the eruptive rock out of which the Serpentine has been formed.

CONCLUSION.—It will not, I think, be necessary to weary the practical miner with descriptions of any other rocks. It has been my aim to give simple descriptions of those among which he probably works. It is very necessary to be familiar with the *Metamorphic Rocks*, as, *e.g.*, the *old slates*. the *Plutonic*, and the *Volcanic Rocks*; for, generally speaking, when a trace of something valuable is found among these, it is worth while spending a few pounds in prospecting. Hence, in reply to the question, where shall we look for mineral wealth? I say, leaving out coal, concerning which see Table of Rock formations (p. 140), and some deposits or iron (p. 93), among the Metamorphic rocks, as, for example, the altered slates, especially where these occur in close proximity to the Plutonic rocks; among the Plutonic rocks themselves; and also amongst certain of the Volcanic rocks, such as decomposed andesite, phonolite, &c.

APPENDIX.

ARRANGEMENT OF MINERAL COLLECTIONS.

Many miners, speculators, and others possess small collections of minerals, but how few arrange these in any order! Some picked specimens may be laid out on view, but the others are heaped up in a confused mass. This is a great pity since it detracts much from the value of a collection. I therefore recommend the reader to adopt some simple form of arrangement—some system of classification. Several systems have from time to time been suggested, depending in some cases upon the chemical composition or upon both chemical composition and crystalline form, or upon the metal prominent in the composition of each. I have, however, adopted a modification of these—a system which experience as a teacher and collector has taught me is best suited to the requirements of those who desire a thoroughly practical knowledge of the subject without regard to strictly scientific considerations. I have designated this the *Popular System*, and I give here a synopsis of it which I hope will enable you to arrange your collection in such a way that you may both systematise your own knowledge of the subject, and enable others to learn something by a brief inspection.

In **Division I.** I bring together all native metals; in **Division II.** are all the principal ores and the matrices or gangues of ores; in **Division III.** I place the varieties of Silica and the rock-forming minerals; in **Division IV.** the Precious Stones; and in **Division V.** Organic Products.

The tests in the foregoing pages will enable you to place under the head of the various metals all specimens with which you may meet; hence Divisions I. and II. will soon be represented, so also Divisions IV. and V. The third division will be found full of interest, especially in reference to the study of rocks. It is impossible in a small work like this to furnish means of testing these minerals; but you will probably find that any crystal or substance which you are not able to determine by means of the tests I have given you will rightly be placed in Division III., Sec. II. I therefore recommend you not to cast it on one side, but to place it in this division, and take the first opportunity, by comparison or otherwise, of determining its name. Especially should you do so with all crystals, whether they occur separately or fairly well defined in rock masses. Sec. III. may with advantage be furnished with small specimens of the minerals embraced by it, in order to make your collection of rock-forming minerals complete.

THE POPULAR SYSTEM OF CLASSIFICATION OF MINERALS.

DIVISION I. Native Elements.	SEC. I. METALLIC.—Gold, Silver, Platinum, Tellurium, Copper, Mercury, Bismuth, Arsenic, Antimony. SEC. II. NON-METALLIC.—Sulphur, Diamond, Graphite.
DIVISION II. Metals in combination with various elements forming ores, earths, &c.	SEC. I. METALLIC MINERALS Principal Ores, *i.e.*, Compounds of the following Metals:— Gold. Silver. Mercury. Copper. Bismuth. Lead. Antimony. Zinc. Tin. Cobalt. Nickel. Iron. Arsenic. Manganese. Molybdenum. Tungsten. Titanium. Uranium. Tellurium.

Division II.—*continued.*

Sec. II.

EARTHY MINERALS.

Compounds of Elements forming earths, clays, vein-stuffs, &c., excepting Silica :—

Aluminium.
Magnesium.
Calcium.
Thorium.
Barium.
Strontium.
Potassium.
Sodium.
Boron.
Ammonium.

Note.—We do not insist too strongly upon the division into *metallic* and *earthy* minerals, because some of the metallic occur in earthy form, *e.g.*, some Carbonate of Copper, Chloride of Silver, &c., and some forms of lead closely resemble Barytes. Other examples might be cited. The division is, however, a convenient one for all practical purposes. You will place under each metal the ores described in "Simple Tests for Minerals," pages 57 to 111.

DIVISION III.

Silica and the Silicates ; and other rock-forming minerals.

SILICA in its many varieties, p. 127 to 128.

Sec. I.

Quartz.
Chalcedony.
Jasper.
Agate.
Opal.
Trydimite.

Sec. II.

SILICATES, or ordinary rock forming minerals, *e.g.*:—

Felspars

Common, or Monoclinic, or Potash Felspars.

- Orthoclase.
- Adularia.
- Sanidine.

Triclinic, or Lime and Soda Felspars, called by the general term Plagioclase.

- Albite.

Sec. II.—*continued.*

- Oligoclase.
- Andesine.
- Labradorite.
- Anorthite.
- Microcline (a potash triclinic felspar).

Micas.

- Muscovite.
- Biotite.
- Lepidolite.

Hornblende (Amphibole).

- Common Hornblende.
- Tremolite.
- Actinolite.

Augite (Pyroxene).

- Common Augite.

Sec. II.—*continued.*

- Enstatite.
- Bronzite.
- Hypersthene.
- Diallage.
- Olivine.
- Leucite.
- Nepheline.
- Melilite.
- Haüyne.
- Nosean.
- Scapolite.
- Sodalite.
- Wollastonite.
- Epidote.
- Idocrase.
- Tourmaline.
- Andalusite.
- Sphene.
- Staurolite.
- Zeolites.
  - Several Varieties.
- Chlorite.
- Kaolin.
- Talc.
- Serpentine.

Sec. III.

OTHER ROCK FORMING MINERALS:—

- Iron.
  - Hæmatite.
  - Limonite.
  - Magnetite.
  - Ilmenite or Titanic Iron.
  - Siderite.
  - Pyrite.
  - Marcasite.
  - Vivianite.
- Manganese (oxide).
- Rutile.
- Lime.
  - Calcite.
  - Aragonite.
  - Dolomite.
  - Fluorspar.
  - Gypsum.
  - Anhydrite.
  - Apatite.
- Barytes.
- Sodium Chloride.
- Sulphur.
- Corundum.
- Garnet.
- Zircon.
- Spinel.

Note.—Besides Silica and the Silicates, rocks are largely made up of other minerals. These will be found in their proper divisions, but they are brought together in Sec. III., which is included here in order to show at a glance the chief minerals which combine together to make up the rocks of the globe. It is to be remembered that many of the Silicates of Sec. II. contain compounds of Aluminium, Magnesium, Potassium, &c.

DIVISION IV. PRECIOUS STONES. See pages 120 to 129.	Diamond — Sapphire — Ruby — Spinel — Garnet — Zircon — Lapis Lazuli — Topaz — Beryl (Emerald) — Tourmaline — Chrysoberyl — Phenacite — Peridot (Olivine) — Turquoise — Quartz and its varieties, *i.e.*, Amethyst, &c. — Opal — Moonstone — Crocidolite — Pearl; and fine specimens of the following:— Euclase — Spodumene — Iolite — Epidote — Axinite — Sphene Diopside.
DIVISION V. ORGANIC PRODUCTS. See pages 111 and 112.	**Graphite**, which should really be included in this division. **Coal** (varieties). — Anthracite — Bituminous or Common Coal — Cannel Coal or Torbanite or Kerosene Shale — Lignite or Brown Coal — Jet. Asphaltum — Bitumen — Elaterite (Elastic Bitumen) — Ozocerite (Mineral Wax) — Petroleum (Naphtha) — Amber — Gums of various kinds.

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