GILBERT

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MINERALOGY

FUN WITH MINERALS

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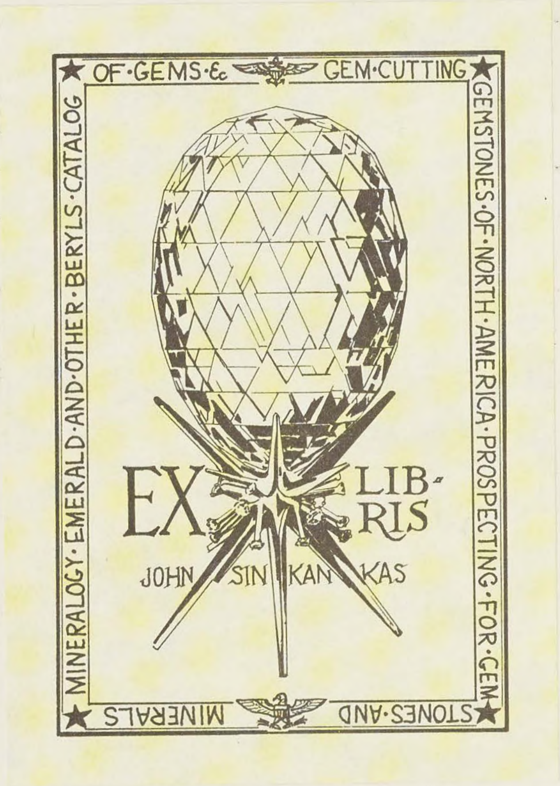
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GILBERT MINERALOGY

By

Alfred C. Gilbert

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INTRODUCTION

As you may know, naturally occurring materials are commonly divided into three kingdoms; that is, animal, vegetable and mineral. Minerals are those materials that make up the bulk of the earth's crust and are called inorganic materials because they have not been made by any of the processes of life. A mineral may be described as a naturally occurring substance of definite and uniform chemical composition and of characteristic physical properties. Mineralogy is that branch of science which has for its object the accurate investigation of these naturally occurring products as regards their physical and chemical properties, their economic importance and their uses in the arts.

Of the naturally occurring inorganic products two classes are recognized, and these are known as minerals and rocks. Minerals, as we have already stated, are definite chemical compounds. A few of the following minerals with their chemical name and formula may serve as examples:

Galena, sulphide of lead, PbS
Magnetite, oxide of iron, Fe_3O_4
Orthoclase, silicate of potassium and aluminum, $KAISi_3O^8$.

There are today between eight and nine hundred minerals known, although only a few are common minerals and important as rock making minerals, as ores of the useful metals or otherwise important in the industries.

Rocks are often used in a general way for designating any portion of the earth's crust. Rocks, however, contain certain minerals. For example, the rock known as granite contains the minerals, orthoclase $KAISi_3O^8$, albite $NaAISi_3O^8$, quartz SiO_2 and quite often several others in small amounts. Sometimes rocks consist of only one mineral, for example, quartzite. This is a rock containing only one mineral, namely, quartz SiO_2.

Since minerals have a definite chemical composition which is known to be true by chemical analysis, it is often easy to distinguish between the different species of minerals. Many minerals differ from each other in their composition, and consequently minerals behave quite differently when treated with the various chemical reagents. These differences in behavior when minerals are treated with chemical reagents furnish one important means of identifying minerals and determining the percentages or the amounts of the different constituents which go to make up the mineral.

The other important means of identifying minerals has to do mainly with the physical properties of minerals. Minerals differ widely in their physical properties, such as crystallization, luster, color, hardness, fusibility and specific gravity, and

The Atomic Weight of an element is the weight of an atom of the element compared with the weight of an atom of hydrogen, which is unity and the lightest element known.

The Molecular Weight of a substance is the sum of the atomic weights taken as many times as they occur in the molecule. For example, the atomic weight of lead is 207, of sulphur 32; therefore the molecular weight of lead sulphide is $(207+32) = 239$.

By Valency is meant the combining power of an atom of an element, or in other words the number of atoms of an element which will unite with or replace one atom of hydrogen. For example, chlorine is monovalent, that is, it combines with one atom of hydrogen to form the molecule HCl, hydrogen chloride. Oxygen is bivalent, that is, it combines with two atoms of hydrogen to form a molecule of H_2O (water).

Acids are compounds which are formed by the union of hydrogen with a non-metal or group of non-metallic elements in which the hydrogen atoms may be replaced by metals. Acids have a sour taste and turn blue litmus red. These properties are due to the replacable hydrogen (H) which they contain. HCl hydrochloric acid, H_2SO_4 sulphuric acid and HNO_3 nitric acid are a few examples of some of the common acids.

Bases are compounds formed by the union of metals with hydrogen and oxygen. They are also called alkalies or hydroxides. They have a soapy taste and turn red litmus blue. These properties are due to the (OH) hydroxyl group which they contain. $NaOH$ sodium hydroxide, KOH potassium hydroxide and $Ca(OH_2)$ calcium hydroxide are a few examples of some of the common bases.

Salts are compounds formed by the action of an acid on a base in which part or all of the hydrogen of the acid is replaced by the metal of the base. For example, the action of sodium hydroxide ($NaOH$) on hydrochloric acid (HCl) produces the salt sodium chloride $NaCl$ and water H_2O. Similarly, the salt sodium sulphate would be formed by the action of sulphuric acid on sodium hydroxide. Most of the minerals are salts and are therefore classified in groups according to the acid radical which they contain; for example, the silicates, salts of silicic acid in one group, the sulphates, salts of sulphuric acid in another group, and so on.

Oxides are compounds formed by the union of oxygen with metals or non-metals. For example, the union of the metal aluminum with oxygen gives a metallic oxide called aluminum oxide and is found in nature as the mineral corundum (Al_2O_3). Other examples are tin oxide known as tinstone (SnO_2) and silicon dioxide, known as quartz (SiO_2). On the other hand, non-metallic oxides are formed by the union of non-metals like sulphur, phosphorous, carbon, etc., with oxygen. Sulphur dioxide (SO_2) and carbon dioxide (CO_2) are some examples of non-metallic oxides.

By Oxidation is meant a chemical change in which oxygen is added to an element or compound. For example, when the metal zinc is heated in the air it takes up oxygen from the air to form a white compound, zinc oxide. This may be expressed in the form of an equation as follows:

$$\underset{\text{Zinc}}{2\,Zn} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Zinc Oxide}}{2\,ZnO}$$

Reduction on the other hand is applied to a chemical reaction in which oxygen is removed from a compound. For example, if hydrogen is passed over hot zinc oxide the oxygen is removed by the hydrogen to form water, the other product being metallic zinc. This reaction may be expressed as follows:

$$\underset{\text{Zinc Oxide}}{ZnO} + \underset{\text{Hydrogen}}{H_2} = \underset{\text{Water}}{H_2O} + \underset{\text{Zinc}}{Zn}$$

It can be seen from the above that oxidation is the opposite of reduction. It is important to get these two chemical changes clearly in mind, as they are of very great importance in the blowpipe analysis of minerals.

A Chemical Equation is a way of expressing in an abbreviated form what takes place in a chemical reaction when substances react with or unite with one another. For example, when the mineral calcite, calcium carbonate ($CaCO_3$), is dissolved in hydrochloric acid (HCL) the reaction may be expressed very clearly in the form of an equation as follows:

$$\underset{\text{Calcite}}{CaCO_3} + \underset{\substack{\text{Hydrochloric}\\\text{Acid}}}{HCL} = \underset{\substack{\text{Calcium}\\\text{Chloride}}}{CaCL_2} + \underset{\text{Water}}{HO} + \underset{\substack{\text{Carbon}\\\text{Dioxide}}}{CO_2}$$

Practically every chemical change therefore can be expressed by means of an equation in a similar way.

Water-of-crystallization is the water combined with a compound when it crystallizes out in nature. This water can usually be driven off from the compound by heating it. For example, the mineral gypsum as it is found in nature contains two molecules of water-of-crystallization. Similarly the mineral borax contains ten molecules of water.

In determining what elements are contained in an unknown mineral and in what amounts, the mineralogist employs what is known as a qualitative and quantitative analysis. He first runs a kualitative analysis on the mineral and in this way finds what the elements are which go to make up the mineral. He then runs a quantitative analysis, which gives him the necessary data for figuring out the percentages of the different elements in the mineral. From the percentages of the different constituents he can readily calculate by means of the atomic weights of the elements the ratio of the constituents, and in this way establish the formula for the unknown mineral. This is the manner in which the formulae for all the known minerals have been worked out.

Apparatus and Reagents and Their Uses in Testing Minerals

THE BLOWPIPE

The blowpipe (Figure 1) is a very useful and convenient instrument for making several tests on minerals. It consists essentially of a tapering tube with a very small opening at one end through which air can be forced from the lungs in a small stream under pressure. By means of the blowpipe it is possible to convert a small luminous flame into a very hot flame, and in this way many important tests can be made. A gas flame is very convenient for blowpipe experiments, but the flame from a candle or alcohol will answer the purpose just as well.

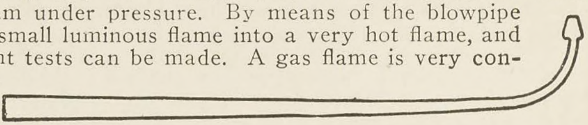

Fig. 1

THE BLOWPIPE FLAME

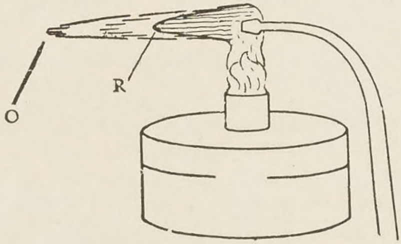

Fig. 2

In blowpipe analysis it is important that you recognize two types of flame, that is, the oxidizing flame and the reducing flame. Fig. 2 represents a blowpipe flame in which **O** is the oxidizing flame and **R** the reducing flame. The oxidizing flame which is a nearly invisible cone is the hottest part of the flame and is formed by the complete combustion of the gases from the flame. The reducing flame is bluish-violet in color and is that part of the flame where combustion of the gases takes plac.e The inner cone **S** which is light blue in color is composed of unburned gas mixed with air from the blowpipe. The gases in this cone are comparatively cool. The gases in this cone, carbon and hydrogen, are burned in the cones **R** and **O** to the gases carbon monoxide, carbon dioxide and water.

HEATING MINERALS IN THE BLOWPIPE FLAME

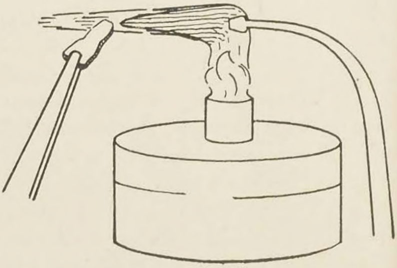

Fig. 3

Whether a mineral fuses or melts easily in the blowpipe flame is an important means of identification of the mineral. The test is usually made by holding a sharply pointed fragment of the mineral by means of the forceps just beyond the tip of the inner blue cone, as shown in Figure 3. This is the reducing flame and if a mineral fuses or melts in it the mineral is said to be fusible in the blowpipe flame. This furnishes us a means of dividing minerals into two classes; those that are fusible and those that are infusible in the blowpipe flame. The minerals that are fusible are further classified as to whether they are easily fusible in the blowpipe flame or fusible with difficulty. In the reducing flame the mineral is converted into the metallic state, while in the oxidizing flame it is converted into the oxide.

THE USE OF CHARCOAL IN BLOWPIPE ANALYSIS

Charcoal blocks are used frequently in blowpipe tests. In heating a mineral on charcoal with the blowpipe flame, place the mineral or a mixture of the mineral and other reagents in a small hollow scraped in the charcoal by means of a spoon. (See Figure 5.) This hollow should be about ¾ of an inch in diameter and about ⅛ of an inch deep.

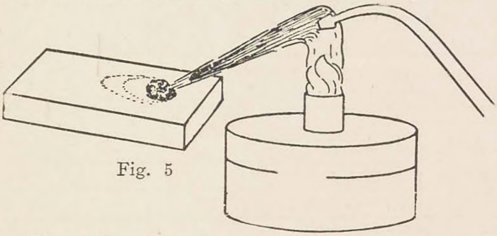

Fig. 5

Some minerals when heated alone on charcoal by means of the oxidizing flame of the blowpipe give characteristic oxide coatings. Other minerals when mixed with powdered charcoal and sodium carbonate and heated in the reducing flame on charcoal are reduced with the formation of globules of the metal present in the mineral.

The following table gives a list of the elements which give characteristic oxide coatings when their minerals are heated alone in the oxidizing flame on charcoal:

Oxide Coatings on Charcoal

ELEMENT	COLOR AND CHARACTER OF COATING
Lead	Yellow near mineral and white farther away. Coating is due to formation of lead oxide and sometimes lead sulphite and lead sulphate.
Zinc	Yellow when hot and white when cold. Coating is very close to the mineral and is non-volatile in the oxidizing flame. Coating turns green when moistened with cobalt nitrate and heated intensely.
Antimony	White. Coating is volatile and is deposited close to the mineral.
Arsenic	White. Coating is volatile and is deposited away from the mineral. Usually accompanied by garlic odor.
Bismuth	Yellow near mineral and white farther away. Distinguished from lead-oxide coating by fusing on charcoal with potassium iodide and sulphur. Coating is yellow near mineral and brilliant red farther away. Under similar conditions lead would give a solid yellow coating.
Molybdenum	Light yellow when hot and white when cold. Coating is non-volatile in the oxidizing flame. Coating becomes dark blue when heated for a second in the reducing flame.
Sulphur	Odor of burning sulphur or sulphur dioxide.

The following table gives a list of the important elements which give metallic globules when their minerals are mixed with powdered charcoal and sodium carbonate and heated in the reducing flame on charcoal:

Metallic Globules on Charcoal

ELEMENT	GLOBULES
Silver	Silver-white globule — malleable.
Lead	Soft metallic globule — malleable — easily fused and marks paper.
Bismuth	Silver-white globule — brittle.
Tin	Tin-white globule — soft and malleable — does not mark paper.
Gold	Yellow globule — soft and malleable.
Copper	Red spongy mass.
Nickel	Residue — slightly magnetic.
Cobalt	Residue — slightly magnetic.
Iron	Residue — slightly magnetic.

NICKEL-STEEL WIRE

Nickel-steel wire, which is an alloy of the metals nickel and steel, may be used in place of platinum for making certain tests in mineralogy. (See Fig. 6.)

Some metals when dissolved in certain compounds called fluxes give a characteristic color to the fused mass. Borax and sodium carbonate are two compounds which are used as fluxes. By means of these color reactions it is quite often possible to tell what metal is present in a mineral.

Fig. 6

One end of the wire is bent into a loop, which should be about ¼ of an inch long and ⅛ of an inch wide. The loop is first heated in the blowpipe flame, dipped into the flux which is then fused into a bead on the loop by heating again in the flame. A small amount of the mineral about the size of a pin head is now placed on the bead and the bead heated in the flame until the mass is well fused. On cooling, the characteristic color of the metal present in the mineral will be imparted to the bead. The color of the bead will depend on whether it was heated in the oxidizing or reducing flame. The following table gives a list of the important bead tests of several of the metals:

Borax Bead Test

ELEMENT	OXIDIZING FLAME	REDUCING FLAME
Copper	Blue	Opaque red
Iron	Yellow	Bottle-green
Manganese	Reddish-violet	Colorless
Cobalt	Deep blue	Deep blue
Chromium	Green	Green
Nickel	Reddish-brown	Opaque gray
Uranium	Yellow	Pale green

Certain elements give characteristic flame color tests when heated on nickel-steel wire in the blowpipe flame. One end of the wire is first cleaned by scouring it with sea sand. It is then heated in the blowpipe flame until the flame from the wire becomes nearly colorless. The wire is then touched to some of the finely pulverized mineral, and then introduced into the blowpipe flame. The following table gives a list of the important elements with their flame colors:

Flame Color Tests for Metals

ELEMENT	COLOR OF FLAME
Copper	Emerald green from oxide of copper.
Copper	Azure blue from chloride of copper
Sodium	Yellow
Strontium	Crimson
Lithium	Crimson
Calcium	Orange
Barium	Yellow-green
Boron	Yellow-green
Zinc	Bluish-green
Lead	Pale azure-blue
Molybdenum	Yellow-green

Where two or more elements give the same color flames other tests have to be applied in order to satisfactorily distinguish between these elements.

TESTING WITH OPEN AND CLOSED TUBES

Open and closed tubes are often used for testing materials. The open tube (Fig. 7) should be from 6 to 8 inches in length and have an inside diameter of about ¼ of an inch. This tube is used ordinarrily for making oxidation tests. A small amount of the powdered mineral is placed in the tube about one-third of the way by using a narrow strip of paper folded together to serve as a boat for introducing the mineral. The tube is then inclined slightly and heated gently at first at a point just above the mineral, and finally directly under the mineral. By heating in this manner, the mineral is oxidized by a current of air which passes up through the tube. In most cases a deposit called a sublimate will be formed on the upper, cooler portion of the tube. It is often possible to tell by the nature and color of this sublimate what metal is present in the mineral. Again a gas may be formed by oxidation, the odor of which makes it possible to tell one or more of the elements which are present. The following table gives a list of the elements and a description of their behavior when heated in an open tube:

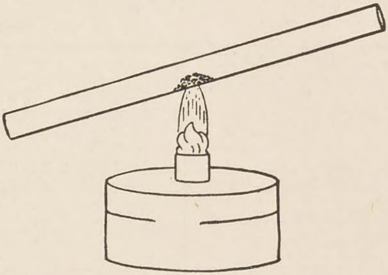

Fig. 7

Open Tube Tests

ELEMENT	BEHAVIOR ON HEATING
Sulphur	Characteristic fumes of burning sulphur or sulphur dioxide. A piece of moistened blue litmus paper held over the upper end of the tube turns red, due to the acid reaction.
Antimony	Volatile white ring or sublimate close to the mineral.
Arsenic	Volatile white sublimate far from the mineral. Odor of garlic.
Mercury	Forms minute gray globules of metallic mercury.
Molybdenum	Pale yellow sublimate close to the mineral.

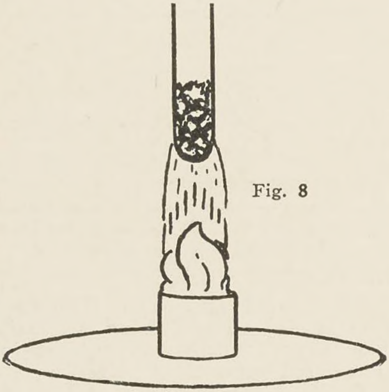

Fig. 8

Closed end tubes (Fig. 8) are easily made by heating a piece of soft glass tubing about 8 inches long in the center and pulling it apart when soft. A little of the powdered mineral is then introduced into the tube and the tube heated over a hot flame. Heating a mineral in a closed tube prevents the mineral from reacting with oxygen from the air. In this way the mineral ordinarily breaks down into simpler parts or fuses together. The following table gives a list and description of some of the important closed tube tests:

Closed Tube Tests

SUBSTANCE	TEST
Water	Minerals containing water-of-crystallization will give a deposit of minute drops of water on the upper portion of the tube.
Sulphur	Minerals containing an excess of sulphur give an orange colored sublimate when hot and a yellow sublimate when cold.
Arsenic	Arsenic and arsenic containing sulphur gives a reddish-yellow sublimate when cold and deep red when hot.
Antimony	Antimony containing sulphur gives a brownish red sublimate when cold and a black sublimate when hot.
Mercury	Mercury containing sulphur gives a black sublimate. When heated with sodium carbonate and charcoal gives globules of metallic mercury.

PULVERIZING MINERALS. Minerals may be broken up into the form of a powder by placing them in a small cloth bag or by wrapping them in several folds of thick paper and pounding the mineral on an anvil or on a piece of iron with a hammer. Use may be made of a mortar and pestle for grinding minerals which are not too hard.

FORCEPS... Forceps or ordinary tweezers are useful for holding fragments of minerals when fusing in the blow pipe.

HORSESHOE MAGNET... A common horseshoe magnet will be found to be very useful for recognizing certain bodies possessing magnetic properties.

MEASURING SPOON. A measuring spoon is useful for measuring small amounts of powdered minerals and dry reagents.

TEST TUBES... Test tubes are important pieces of apparatus for carrying out chemical reactions in the wet way. Uses of the above apparatus are mentioned in the tests in which they are needed.

PART II.

PHYSICAL PROPERTIES OF MINERALS

In Part I minerals were regarded from the standpoint of their chemical properties. They also possess certain physical properties which may be very useful for their identification and recognition. Some of the most important of these are structure, cohesion. tenacity, hardness, luster, color and specific gravity. It is important to have clearly in mind the meaning of these physical properties before endeavoring to make a study of any of the common minerals.

STRUCTURE OF MINERALS

By structure of minerals is meant the outward form and shape of minerals. The following terms with their definitions are used to describe the structure of minerals:

Granular—When a mineral consists of grains either fine or coarse as marble and some forms of galena.

Massive—A mineral composed of compact material with an irregular form. It does not have any crystal faces but may possess crystalline structure. For example, some varieties of quartz, chalcopyrite, etc.

Compact—Earthy—A mineral consisting of a uniform mass of very minute particles.

Amorphous—Minerals possessing no trace of crystalline structure.

Columnar—Minerals possessing a columnlike structure usually in parallel groupings of prisms, or columns. For example, some varieties of hornblende, beryl and wollastonite.

Fibrous—Minerals consisting of fine thread-like strands which may be separated or pulled apart. (Fig. 12). Illustrated by such minerals as serpentine, amphibole (asbestos) and gypsum (satin-spar).

Foliated—A mineral which may easily be separated into plates; for example, some varieties of serpentine and brucite.

Micaceous—Similar to foliated minerals but in which the mineral can be easily split into very thin sheets like muscovite (common mica).

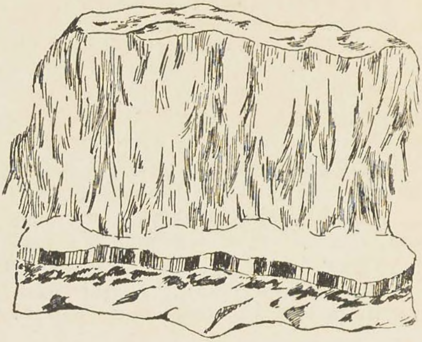

Fig. 12

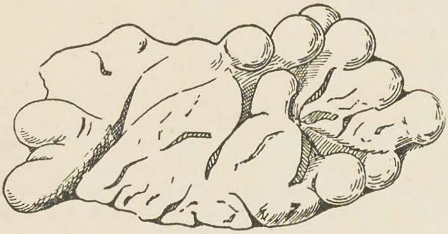

Fig. 13

Botryoidal and Globular—Applied to minerals possessing small rounded or spherical aggregations, such as some varieties of hyalite, opal and smithsonite. (Fig. 13).

Reniform and Mammillary—Kidney shaped minerals, such as some varieties of hematite and malachite. (Fig. 14).

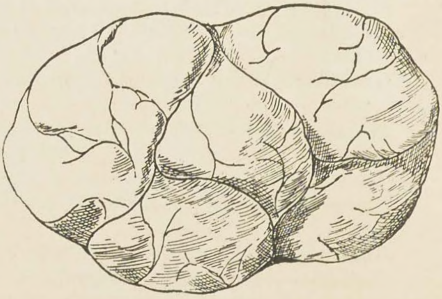

Fig. 14

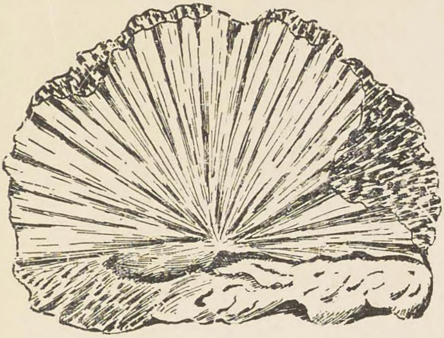

Fig. 15

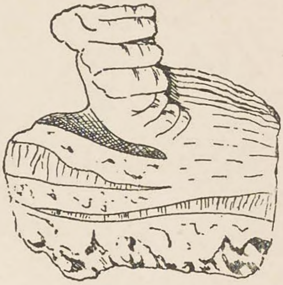

Fig. 16

Radiated—When fibres or crystals radiate from a central point, as illustrated in some varieties of stibnite and pectolite. (Fig. 15).

Stalactitic—Minerals having icicle-like forms and usually found in the roof of some cavity and formed from dripping water. For example, some varieties of limonite and calcite. (Fig. 16).

COHESION OF MINERALS

Cleavage—A mineral is said to possess cleavage when it shows definite plane surfaces resembling crystal faces when the mineral is broken. (Fig. 17). The directions of cleavage are always parallel to some possible crystal face. Only a few minerals possess perfect cleavage, while many do not possess any cleavage and in others the cleavage is poor. The cleavage of a mineral is described according to the crystal face to which it is parallel; for example, cubic cleavage (halite and galena), octahedral cleavage (calcite) dodecahedral cleavage (sphalerite), prismatic cleavage (amphibole), basal cleavage (topaz) and pinachoidal cleavage (stibnite).

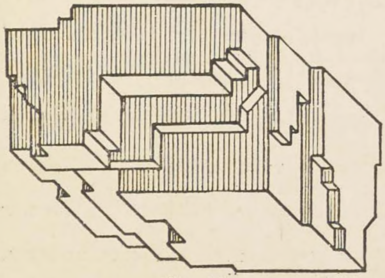

Fig. 17

Parting—Some minerals when subjected to a strain break or part along certain plane surfaces. When minerals exhibit this property they are said to have a parting. It resembles cleavage somewhat but differs from it in that cleavage can take place as readily in one part of a crystal as in another. Magnetite sometimes shows a perfect octahedral parting but has no apparent cleavage. (Fig. 18.)

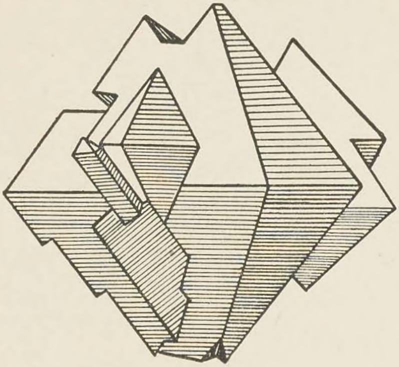

Fig. 18

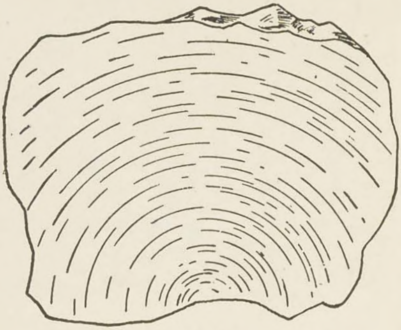

Fig. 19

Fracture—When a mineral breaks and does not show plane surfaces as in cleavage or parting, it has what is known as fracture. When a mineral breaks and shows a smooth curved surface like the interior surface of a shell, it has a conchoidal fracture. (Fig. 19). This fracture is found in amorphous substances, such as glass and in minerals as quartz. Fracture of minerals is said to be uneven or irregular when the mineral breaks into rough or irregular surfaces. Fracture is splintery when the mineral breaks into splinters or needles.

TENACITY OF MINERALS

Minerals possess certain properties which depend upon their tenacity. The following terms are used to describe the various kinds of tenacity:

Brittle—When a mineral crumbles or powders easily. Example: Iron pyrites, apatite, fluor spar, etc.

Ductile—When a mineral can be drawn out into a wire. Example: native metals.

Flexible—When a mineral bends but does not resume its former shape when the pressure is released. Example: talc, selenite, etc.

Elastic—When a mineral, after being bent, will spring back to its former position. Example: mica.

Malleable—When a mineral can be flattened out into thin sheets under a hammer. Example: native silver, gold, copper, platinum, etc.

Sectile—When a mineral can be cut into thin shavings with a knife. Example: graphite, steatite, etc.

HARDNESS OF MINERALS

Minerals vary widely in their hardness. By hardness is meant the resistance which a mineral offers to being scratched. A scale of hardness is usually represented by crystallized varieties of the following minerals:

1. **Talc**—Very soft, easily scratched by the thumb nail.
2. **Gypsum**—Scratched by the thumb nail, but much less readily.
3. **Calcite**—Scratched by a cent and very easily by a pocket knife.
4. **Fluorite**—Scratched by a pocket knife without difficulty.
5. **Apatite**—Scratched easily by window glass, but with difficulty with a knife.
6. **Orthoclase**—Scratched by window glass.
7. **Quartz**—Scratches window glass readily.
8. **Topaz**—
9. **Corundum**—
10. **Diamond**—Very hard.

The finger nail is a little over 2 in hardness, since it scratches gypsum but not calcite. A cent is about 3 in hardness, for it just scratches calcite. An ordinary pocket knife is just over 5, and window glass a little harder, about 5.5.

Sometimes a softer mineral will leave a mark on a harder mineral and this must not be mistaken for a scratch. A mark made in this manner can be easily rubbed off while a scratch will be permanent. On testing a mineral for hardness always use a fresh surface of the mineral as an old surface may be somewhat changed and softer than a fresh surface.

LUSTER OF MINERALS

The term luster as applied to minerals is the appearance of the mineral due to the effect of light upon it. Minerals come under one of three classes: those that have metallic luster, those that have a non-metallic luster and those that have a sub-metallic luster.

By metallic luster is meant having the appearance of a metal. Most minerals that come under this class are opaque and their powders are black or dark colored. Examples: galena and pyrite. The luster of a mineral is usually determined by rubbing the mineral across a piece of unglazed white porcelain. The mineral leaves a streak which gives the color of the finely powdered mineral.

Minerals with a non-metallic luster are transparent to light on their thin edges. These minerals are in general light colored and their streaks are colorless or very light colored. The following terms are used to further describe the appearance of minerals having a non-metallic luster:

Adamantine—Hard, brilliant luster like the diamond.

Greasy—As if covered with a layer of oil. Example: certain specimens of sphalerite and quartz.

Pearly—Appearance of pearl. Examples: talc, brucite and selenite.

Resinous—Like resin. Examples: sphalerite, opal and amber.

Silky—Like silk. This appearance is peculiar to minerals having a fibrous structure. Examples: gypsum (satin-spar), malachite and serpentine.

Vitreous—Like glass. Example: quartz and rock salt.

Those minerals which lie between the minerals having a metallic and nonmetallic luster are said to have a submetallic luster. They have a light colored streak. Limonite and some specimens of sphalerite are examples of minerals which have submetallic luster.

COLOR OF MINERALS

Color is a very important property of minerals and serves as an important means of identification. Since the color on some mineral surfaces changes somewhat on long exposure, it is always essential to examine a fresh surface of the mineral before noting the color. The color of a mineral is a very definite and constant property. For example, the black color of magnetite, the bluish-gray of galena, the brass yellow color of chalcopyrite, and the green of malachite are all characteristic colors of these minerals. Many minerals vary in color, however, in different specimens. This is due sometimes to impurities in the mineral. For example, sphalerite is sometimes brown and black, due to the presence of iron as an impurity. Again quartz which is usually colorless may be colored red, due to the presence of a small amount of hematite. Fluorite is found in many different colors, such as white, pink, yellow, green and blue.

SPECIFIC GRAVITY OF MINERALS

By specific gravity of a mineral is meant the relation between the weight of the mineral and the weight of an equal volume of water. For example, quartz is known to have a specific gravity of 2.65, which means that quartz is 2.65 times as heavy as the weight of an equal volume of water. In obtaining the specific gravity of a mineral it is essential that the mineral be pure and crystalline, otherwise the specific gravity will vary. If the mineral contains cracks or holes, it is necessary to boil the mineral in water for several minutes to displace the air contained in the cracks, as the air tends to make the mineral lighter.

The method usually applied for obtaining the specific gravity of a mineral is to weigh the mineral in air and then in water. The differences in weight is the weight of a quantity of water equal to the volume of the mineral, because when a body is immersed in water it is buoyed up by a weight which is equal to the weight of the water displaced. If (**x**) is the weight of the mineral in air and (**y**) is the weight when immersed in water, then the specific gravity may be expressed as follows:

$$\text{Specific gravity} = \frac{\mathbf{x}}{\mathbf{x\ y}}$$

A very convenient piece of apparatus for obtaining the specific gravity of a mineral is that known as the Spring or Jolly Balance. By means of this apparatus (Fig. 20) the weights of the mineral in the air and in water are determined by the stretch of the spiral spring. Two small metal pans **A** and **B** are suspended one above the other from the spring. The lower pan **B** is always in the water which is contained in a vessel resting on a movable

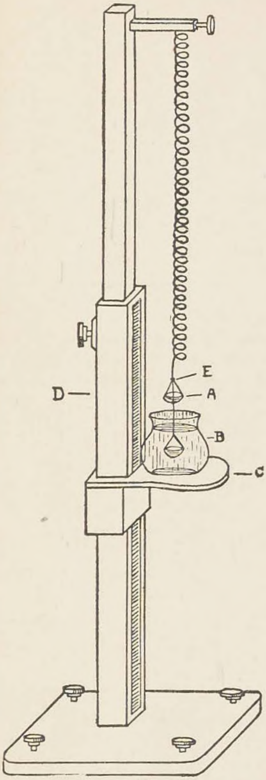

Fig. 20

platform **C**. On the front side of the upright **D** there is a mirror and graduated scale. There is a small bead at **E** which serves as a mark for noting the position of the spring in regards to the graduated scale.

Three readings are taken: first, the position of the balance in regards to the scale with the lower pan in the water; second, the position of the balance in regards to the scale when the mineral is placed in the upper pan or when weighed in the air; third, the position of the balance when the mineral is placed in the lower pan or when the mineral is immersed in water. The difference between the first and second reading gives the weight of the mineral in air and the difference between the first and third reading gives the weight of the mineral in water. From these two weights the specific gravity can readily be calculated, using the formula described on the previous page.

MAGNETISM

There are a few of the common minerals which are attracted by a magnet. Some minerals containing iron, nickel and cobalt are attracted by a strong electro-magnet, and this test sometimes affords a convenient means of recognizing these minerals. Other minerals are attracted only after strong heating (ignition) in the air. This is also used as a valuable test in recognizing certain minerals.

PART III.

DESCRIPTION OF MINERALS AND MEANS OF IDENTIFICATION

The more important common minerals are classified into two groups according as they have large economic importance as ores or are useful in the arts or are important as rock forming minerals. Let us now examine a few of these minerals and see if we cannot learn a little more about them.

MINERALS OF ECONOMIC IMPORTANCE

(Minerals with Metallic Luster)

A. GALENA

Taken from the Greek galene, meaning tranquility. It was supposed to have certain soothing medicinal properties. It is often called blue ore or blue lead by miners. Sometimes called galenite.

Composition — Sulphide of lead, PbS. Sulphur = 13.4 per cent, lead = 86.6 per cent. Often carries small amounts of silver sulphide and is sometimes valuable as a silver ore. When it contains enough silver to be worth extracting it is called "argentiferous galena." Whether galena contains silver or not can be told only by chemical analysis. Galena also contains at times small traces of zinc, cadmium, antimony, iron. copper, bismuth, selenium and gold.

Crystal System—Common form is the cube. (Fig. 21).

Structure—Occurs commonly crystallized or massive cleavable; also occurs coarse or fine grained.

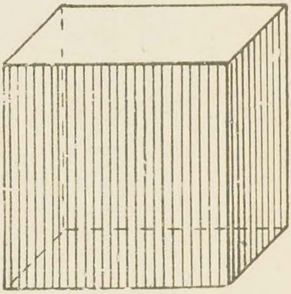

Fig. 21

Physical Properties

Cleavage—Cubic and perfect, specimens breaking into small cubes when rubbed or struck.

Hardness—2.5 to 2.75. Can be scratched easily by a cent.

Luster—Bright metallic.

Color—Lead gray.

Streak—Lead gray.

Experiment 1. How to Test for Galena—Powder some of the mineral by breaking it up in a small cloth bag by means of a hammer. Now mix a small amount of the powdered mineral with an equal amount of sodium carbonate and heat the mixture on charcoal in the reducing flame of the blowpipe. Notice that a metallic globule of lead is formed, which is bright lead color when hot but covered with a dull oxide coating when cold. Notice that a coating of lead oxide is also formed, which is yellow near the globule and white farther away. Remove the lead globule and notice that it is malleable and can be hammered out into a thin sheet.

Place a little of the powdered mineral in an open tube and heat slowly over a gas flame if such is handy. Do you recognize the odor of burning sulphur? Nearly all sulphides when heated this way or when roasted on charcoal in the oxidizing flame give this same characteristic pungent odor of sulphur dioxide.

Galena is recognized chiefly by its cubic cleavage, high specific gravity or weight, softness and black streak.

Occurrence—A common metallic sulphide and found associated with such minerals as pyrite, chalcopyrite, sphalerite, anglesite, cerussite, quartz, dolomite, calcite, barite and fluorite. Also found with silver minerals and sometimes contains silver in sufficient quantity to make it an important silver ore.

It is found in Missouri occurring in the form of beds. disseminated through limestone and also associated with zinc ores. It is found as lead-silver deposits in Idaho, Utah and Colorado. Important deposits are also found in Germany and England.

Uses—It is the most important lead ore and an important ore of silver. Metallic lead finds may important uses, some of which are as follows: as sheets and pipes; in making shot, bullets and weights, in some alloys as solder (tin and lead) type metal (antimony and lead) and low fusing alloys (bismuth, tin and lead) commonly called Wood's metal; large amounts are used in the form of basic lead carbonate, commonly known as white lead, in paint making; in the form of litharge (PbO) and red lead (Pb_3O_4) for making fine grades of glass, for glazing earthenware and as pigments; in the form of lead chromates for making red and yellow paints; in many industries in the form of lead acetate (sugar of lead). Galena is also used as a detector in wireless sets.

B. STIBNITE

Sometimes called gray antimony, antimony glance or antimonite.

Composition—Antimony trisulphide Sb_2S_3 Antimony = 71.4 per cent, sulphur = 28.6 per cent. Occasionally contains silver and gold.

Crystal System—Usually in the form of elongated prisms vertically striated. Crystals sometimes bent or curved and steeply terminated. (Fig. 22.)

Structure—In radiating crystal groups or in bladed forms with prominent cleavage. Sometimes massive, coarse to fine granular.

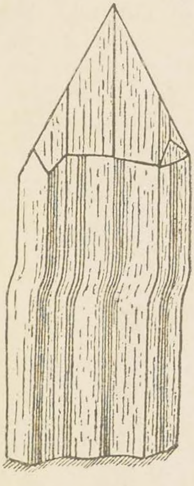

Fig. 22

Physical Properties

Cleavage—Perfect.

Hardness—2. Can be scratched with the finger nail.

Specific Gravity—4.5 to 4.6. Fairly heavy.

Luster—Metallic, splendent on fresh surface.

Color—Lead gray.

Streak—Lead gray.

Experiment 2. How to Test for Stibnite—Heat a small piece of the mineral in a gas or candle flame and notice that it fuses or melts very easily.

Heat a small amount of the mineral on charcoal in the oxidizing flame of the blowpipe and notice that a heavy white coating of antimony oxide is formed a short distance from the mineral and the burning mineral gives the irritating odor of burning sulphur.

Heat a little of the powdered mineral in an open tube and notice that two sublimates are formed, one a white non-volatile sublimate on the bottom of the tube and the other a white volatile sublimate in the form of a ring around the tube. Heat a little of the powdered mineral in a closed tube and notice that the mineral gives a faint ring of sulphur and a red deposit of antimony oxysulphide when cold.

Stibnite is usually recognized by its bladed structure. perfect cleavage, soft black streak and lead-gray color.

Occurrence—Found usually in beds or veins of quartz, granite and gneiss. It occurs associated with other antimony ores and with calcite, barite, galena, cinnabar, sphalerite and occasionally gold. Found in China, Japan, Mexico, New South Wales, Saxony, Bohemia and in small deposits in California. Nevada and Idaho.

Uses—Metallic antimony is used in several alloys such as type metal (antimony, bismuth and lead), britannia metal (antimony and tin), babbitt or antifriction metal (antimony. tin and lead) and pewter (antimony and lead). Antimony sulphide is used in fireworks, in safety matches, percussion caps and in the vulcanization of rubber. Antimony trioxide is used as a pigment and in the glazing of enameled ware. Other compounds of antimony like tartar emetic are used in medicine.

C. CHALCOPYRITE

Sometimes called copper pyrites and yellow copper ore. Derived from the Greek word meaning brass.

Composition—Sulphide of copper and iron, $CuFeS_2$. Sulphur = 35 per cent, copper = 34.5 per cent, iron = 30.5 per cent.

Crystal System—Usually wedged shaped in the form of sphenoids. (Fig. 23.)

Structure—Occasionally in crystals, but more often massive and compact.

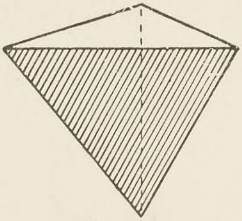

Fig. 23

Physical Properties

Fracture—Uneven, conchoidal.

Hardness—About 3.5. Can be scratched with a knife.

Specific Gravity—4.1 to 4.3. Fairly heavy.

Luster—Metallic and opaque.

Color—Brass yellow, often tarnished to bronze.

Streak—Greenish-black and slightly shining.

Experiment 3. How to Test for Chalcopyrite—Powder a little of the mineral and heat a small amount mixed with a little sodium carbonate and a little borax on charcoal in the reducing flame of the blowpipe. Notice the smell of burning sulphur and the formation of metallic globules of copper. Remove the globule from the charcoal and notice that it is somewhat magnetic, for it is attracted by the magnet. Also notice that the globule has the characteristic red copper color and is malleable, for it can be hammered out into a thin sheet.

Heat a small amount of powdered mineral in an open tube and notice the odor of burning sulphur. Heat a little of the powdered mineral in a closed tube and notice the separation of sulphur.

Chalcopyrite is usually recognized by its brass-yellow color. softness and greenish-black streak. It is distinguished from iron pyrites in that it crumbles when cut with a knife while iron pyrites is not affected by the knife blade. Copper pyrites does not give off any sparks when struck with steel while iron pyrites does. It is distinguished from gold in that it is brittle and non-malleable, gold being malleable. soft and easily cut by a knife.

Occurrence—Most common ore of copper. Found widely distributed in metallic veins and associated with such minerals as pyrite, chalcocite, malachite, azurite, sphalerite, galena, quartz, calcite, etc. Sometimes carries gold and silver, in which case it is mined for these metals.

Found widely associated with other copper minerals in the United States, as in Montana, Utah. Colorado, California and Arizona. Also found in England, Spain, Sweden, Canada, Mexico, Alaska, Chile, etc.

Uses—Most important copper ore. Copper has many varied and important uses as follows: in wire, sheet and nails; in various alloys as brass (copper and zinc), German silver (copper, zinc and nickel), bronze (copper, tin and zinc), gold coin, silver coin, and nickel coin. Copper sulphate, commonly known as blue vitriol, is used in calico printing and in galvanic cells.

D. PYRITE

Commonly called iron pyrites. Name derived from Greek word meaning fire, probably because of the fact that the mineral gives off sparks when struck with steel.

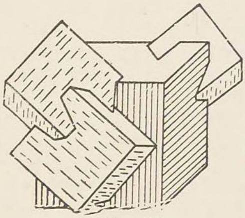
Fig. 24

Composition — Iron disulphide, FeS_2. Iron = 46.6 per cent, sulphur = 53.4 per cent. Contains occasionally small amounts of copper, nickel and cobalt. Sometimes carries small amounts of gold and is then called auriferous pyrite.

Crystal System — Common crystal forms are the cube with striated faces (Fig. 24) and pyritohedron (Fig. 25).

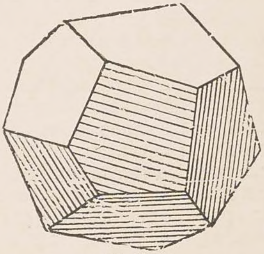
Fig. 25

Structure—Commonly found in crystals. Also found massive, granular, stalactitic, globular and reniform.

Physical Properties

Hardness—6 to 6.5. Rather hard, also brittle.

Specific Gravity—4.95 to 5.1. Fairly heavy.

Luster—Metallic, splendent, opaque.

Color—Pale brass yellow to bronze yellow, due to tarnish.

Streak—Greenish or brownish-black.

Experiment 4. How to Test for Pyrite—Heat a small fragment of the mineral, held in the forceps, in the reducing flame of the blowpipe and notice that the mineral fuses easily. When the fragment has become cold, test it with the magnet. Notice that the fragment is magnetic and is attracted by the magnet.

Break a little of the mineral up into the form of a powder and heat a little of the powder in a closed tube. Notice the formation of a large amount of sulphur in the tube. Heat a little of the powder in an open tube. Do you recognize the odor of burning sulphur? This same odor is obtained when a little of the powdered mineral is heated on charcoal in the oxidizing flame.

Make a loop on one end of nickel-steel wire by bending it around the sharpened end of a lead pencil. Heat the loop in the oxidizing flame of the blowpipe for several moments. Then dip the loop into borax and again heat carefully in the blowpipe or gas flame. Notice that the borax puffs up and soon melts. On cooling, you should have a thin, clear transparent bead. Now place a bit of the powdered mineral about the size of a pin head on the bead and heat the bead for several minutes in the reducing flame. Notice that the bead on cooling is bottle green in color. If heated in the oxidizing flame. the bead would be yellow on cooling. This is the borax bead test for iron.

Pyrite is usually distinguished from gold in that it is brittle; from chalcopyrite by the fact that it cannot be scratched by a knife and is of paler color.

Occurrence—Pyrite is a very common occurring mineral and is found in many parts of the world. It occurs commonly as a vein mineral and is found widely as an accessory mineral in several kinds of rocks. It occurs associated with many different minerals. Important deposits of pyrite are found in Virginia, New York, Massachusetts, California, Portugal and Spain.

Uses—Pyrite is frequently mined because of the gold or copper that is found associated with it. It is never mined as an iron ore because of the large amount of sulphur which it contains. It has an important use, however, in the manufacture of sulphuric acid and sulphate of iron or ferrous sulphate (copperas). Sulphuric acid is probably the most important technical acid and finds many uses in the industries, such as manufacture of other mineral acids, preparation of fertilizers and as a dehydrating or drying agent in many chemical reactions. Sulphur dioxide obtained by burning or roasting pyrite finds an important use as a bleaching agent in the preparation of wood pulp in paper making. Ferrous sulphate is used in the manufacture of inks, in dyeing, in preserving wood and as a disinfectant. Pyrite is also used as a detector in wireless sets.

E. MAGNETITE

Commonly known as magnetic iron ore. The name was probably derived from a certain locality in Macedonia called Magnesia or to a shepherd named Magnes who is said to have discovered the mineral by noticing that the nails of his shoe and the ferrule of his staff adhered to the ground over which he walked.

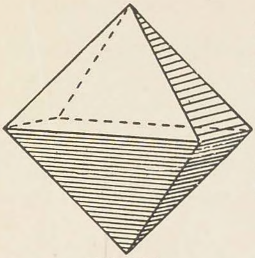

Fig. 26

Composition—Oxide of iron Fe_3O_4. Iron = 72.4 per cent, oxygen = 27.6 per cent. The ferrous iron is sometimes replaced by small amounts of magnesium or titanium.

Crystallization—Usually in the form of octehedrons when crystallized (Fig. 26).

Structure—Frequently found crystallized. Other forms are granular and massive, coarse and fine grained.

Physical Properties

Cleavage—Sometimes develops octehedral parting when pressure is applied to the mineral.

Hardness—6. Can be scratched by window glass.

Specific Gravity—5.2. Rather heavy.

Luster—Metallic.

Color—Iron black.

Streak—Black.

Magnetism — Strongly magnetic. The variety known as lodestone is a natural magnet.

Experiment 5. How to Test for Magnetite—Magnetite cannot be fused or melted in the blowpipe flame. Try fusing a small fragment in the reducing flame of the blowpipe.

Break a little of the mineral up into the form of a powder and make a borax bead test as described under the mineral pyrite. Notice that in the oxidizing flame the bead is yellow, while in the reducing flame the bead is bottle-green.

Try the effect of the magnet upon one or two fragments of the mineral and notice that the mineral is readily attracted by the magnet.

Magnetite is recognized chiefly by its strong magnetism. its hardness, black color and black streak.

Occurrence—Common ore of iron. Found in many rocks and in some cases in the form of large ore bodies. Also occurs in beds and sometimes found in the black sands of the seashore. Often associated with such minerals as corundum, mica, diabase, gabbro and peridotite.

Found in large beds in Northern New York State. Also found in Pennsylvania, New Jersey and England. It constitutes the chief iron ore in Norway and Sweden. The variety known as lodestone is found in Siberia, Germany and Arkansas.

Use—Important iron ore.

F. PYROLUSITE

Named from the Greek word meaning fire and wash, because of its power of removing the colors from green or brown glass.

Composition—Manganese dioxide, MnO_2. Sometimes contains a little water.

Crystal System—Usually takes the crystal form of some other mineral, especially manganite.

Structure—Usually occurs massive or reniform; sometimes with a fibrous and radiating structure.

Physical Properties

Fracture—Splintery, mineral breaking into needles.

Hardness—2 to 2.5. Soft, often soils the fingers like carbon.

Specific Gravity—4.75.

Luster—Metallic.

Color—Iron black.

Streak—Iron black.

Experiment 6. How to Test for Pyrolusite—Heat a small piece of the mineral, held in the forceps, in the blowpipe flame and notice that the mineral is infusible and does not melt.

Make a borax bead as described under the tests for the mineral pyrite and heat a small amount of the mineral about the size of a pinhead on the bead in the oxidizing flame of the blow-pipe. Notice after cooling that the bead is colored reddish-violet. If heated this way in the reducing flame, the bead would be colorless.

Repeat the above test, using a sodium carbonate bead in place of the borax bead. The sodium carbonate bead is made similar to the borax bead. Notice that the mineral imparts a bluish green opaque color to this bead when heated in the oxidizing flame.

Place a small amount of the powdered mineral in a closed tube and heat over a hot flame. While heating, insert into the tube a toothpick or match which has a spark on one end. Notice that the spark glows brightly and in some cases takes fire and burns with a flame. This is because the mineral gives off oxygen when heated.

Occurrence—Found in beds or nests as manganese ores enclosed in clays. Also found occurring in veins with quartz and various metallic minerals.

Occurs in Virginia, California, Arkansas, Georgia, Australia, Japan, India. Nova Scotia, etc.

Uses—Most important ore of manganese. Manganese is used chiefly in the form of alloys, the most important being those containing iron and manganese. The alloy known as spiegeleisen contains iron and manganese and is used extensively in the manufacture of steel. Manganese dioxide is used as an oxidizing agent in the manufacture of chlorine, bromine and oxygen; as a decolorizer of glass; as a drier in paints, and in the dry-cell battery. Potassium permanganate is used as a disinfectant. Manganese is also used for coloring glass, pottery and bricks and in calico printing.

Minerals With Non-Metallic Luster

G. SPHALERITE

Commonly known as zinc blende or black jack. The name blende is German, meaning blind or deluded because it resembles galena. Sphalerite is Greek, meaning treacherous.

Composition—Zinc sulphide, ZnS. Zinc = 67 per cent, sulphur = 33 per cent. Part of the zinc is sometimes replaced by iron and often small amounts of cadmium, manganese, etc.

Crystal System — Tetrahedrons are the common form. (Fig. 27). Also found in the form of cubes. Crystals are often twinned and modified so that is is difficult to determine the forms present.

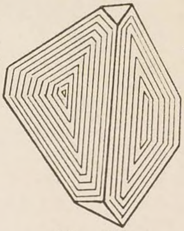

Fig. 27

Structure—Usually massive and compact, coarse to fine granular but sometimes botryoidal or fibrous.

Physical Properties

Cleavage—Perfect.

Fracture—Conchoidal, brittle.

Hardness—3.5 to 4. Can be scratched with a knife.

Specific Gravity—4 to 4.1.

Luster—Resinous and adamantine. Non-metallic.

Color—White when pure. More often black, brown and yellow. Brown and black color due to the presence of iron.

Streak—White to yellow or brown.

Experiment 7. How to Test for Sphalerite—Heat a small fragment of the mineral in the reducing flame of the blowpipe and notice that the mineral is infusible or nearly so.

Break a little of the mineral up into the form of a powder and heat a small amount of the powder on charcoal in the oxidizing flame of the blowpipe. Then heat in the reducing flame. Notice the odor of burning sulphur and the formation of a coating of zinc oxide which is yellow when hot and white when cold. If this coating is moistened with a drop of cobalt nitrate solution and heated in the reducing flame, it will turn dark green in color.

Mix a little of the powdered mineral with a little sodium carbonate and charcoal and heat on charcoal in the reducing flame of the blowpipe. Notice the bluish green flame that is produced by the mineral. This is the flame color test for zinc.

Sphalerite is usually recognized by its characteristic resinous luster and perfect cleavage.

Uses—Most important zinc ore. Metallic zinc is used chiefly in making brass (an alloy of copper and zinc), in making galvanized iron, in electric batteries and as sheet zinc. The compound zinc oxide or zinc white is used extensively in making paints. Zinc sulphate is used in medicine and in dyeing. Zinc chloride is used as a preservative for wood. The metal cadmium is often obtained from sphalerite.

H. MALACHITE

Commonly called green copper carbonate. Name is derived from the Greek word mallows on account of its green color.

Composition—Basic carbonate of copper $(CuOH)_2CO_3$. Copper = 57.4 per cent, water = 8.2 per cent, cupric oxide = 71.9 per cent, carbon dioxide = 19.9 per cent.

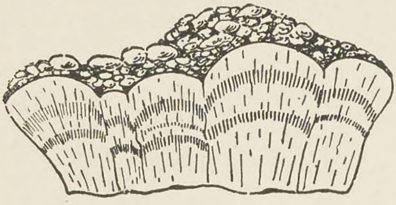

Fig. 28

Crystal System—Crystals usually found in slender prismatic forms.

Structure—Commonly radiating fibrous with botryoidal or stalactitic surface (Fig. 28). Also found granular or earthy.

Physical Properties

Cleavage—Perfect.

Hardness—3.5 to 4. Can be scratched by a knife.

Specific Gravity—3.7 to 4.

Luster—Adamantine to vitreous in crystals. Silky in fibrous varieties. Dull in earthy variety.

Color—Bright green.

Streak—Pale green.

Experiment 8. How to Test for Malachite—Heat a small fragment of the mineral, held in the forceps, in the blowpipe flame and notice that it fuses or melts, giving an emerald green flame.

Break a small amount of the mineral up into a powder and place a little of the powder in a closed tube. Heat the tube over a hot flame and notice that water is given off which condenses in the form of drops on the sides of the tube. Also notice that the mineral turns black.

Mix a little of the powdered mineral with a little sodium carbonate and borax and heat the mixture on charcoal in the reducing flame of the blowpipe. Notice the formation of red metallic globules of copper.

Prepare a borax bead as described under the mineral pyrite and heat a little of the powdered mineral about the size of a pinhead on the bead in the blowpipe flame for several minutes. Notice that on cooling the bead is colored green. This is the borax bead test for copper.

Malachite is recognized generally by its green color and radiating fibrous structure.

Occurrence—Usually occurs in copper veins that are found in limestones. An important and widely distributed ore of copper. Found in the Ural Mountains of Russia. Africa, Chile. Arizona and New Mexico.

Uses—Important copper ore. Used somewhat as ornamental material for vases and veneer for table tops.

J. CALCITE

Commonly called calc spar or carbonate of lime. Name derived from Latin word calx, meaning lime.

Composition—Calcium carbonate, $CaCO_3$. Calcium oxide = 56.0 per cent. carbon dioxide = 44.00 per cent. Calcium sometimes replaced by small amounts of magnesium, iron, manganese and zinc.

Crystal System—Good crystals very common. Figures 29 and 30 illustrate two of the more important types of crystallization. Some crystals are very complex.

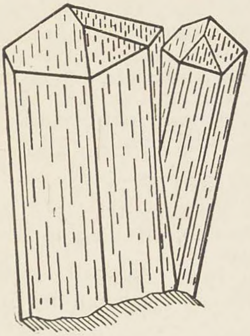

Fig. 29

Structure — Found fibrous, stalactitic, coarse to fine granular, compact and earthy.

Cleavage—Perfect.

Hardness — 3. Can be scratched by a cent, easily by a knife.

Specific Gravity—2.72. Not very heavy.

Luster—Vitreous to earthy.

Color — Usually white or colorless. Sometimes colored gray, red, green. yellow, blue, brown and black. Usually transparent, but opaque when impure.

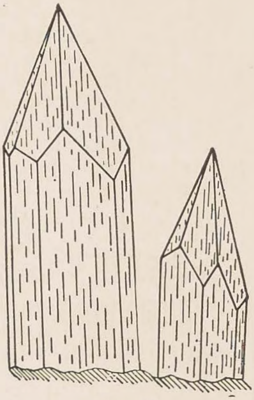

Fig. 30

Experiment 10. How to Test for Calcite—Heat a fragment of the mineral, held in the forceps, in the reducing flame of the blowpipe for several minutes and notice that it does not fuse or melt. Moisten a piece of yellow turmeric paper and touch it to the fragment that has been heated. Notice that the turmeric paper turns brown. This is a test for calcium oxide, which gives an alkaline reaction and is present in calcite. If this fragment is moistened with hydrochloric acid and heated, it gives an orange-red flame which is the flame color test for the metal calcium. Small pieces of the mineral also effervesce or give off the gas carbon dioxide, freely, when dissolved in cold hydrochloric acid.

Occurrence—Calcite is a very common and widely diffused mineral. It occurs in very large masses in many rocks. The common rock materials known as limestones, marbles, chalk, calcerous marls, etc., consist essentially of calcium carbonate. A large amount of these carbonates has been formed by the gradual deposition of shells and the skeletons of sea animals which consist mainly of calcium carbonate. It is found also as a vein mineral occurring with all sorts of metallic ores.

Calcite in its various forms is found widely distributed in many localities. Some notable deposits occur in England, Iceland, Mexico, Missouri, Michigan, and New York.

Uses—Calcite is used chiefly in the manufacture of lime for mortar and cement. By heating limestone to about 1000 degrees Fahrenheit, carbon dioxide, a gas, is driven off and the limestone is converted into quicklime (CaO). Whitewash is made by mixing quicklime with water, while mortar is made by mixing it with sand and water. Portland cement is made by mixing lime with silica and alumina.

Chalk is used for whiting, whitewash, crayons and as a fertilizer. Large deposits of it are found in the famous chalk cliffs of Dover. England.

Limestone is used chiefly as a building material. Also as a flux for smelting certain metallic ores. The chief occurrences in the United States are in Indiana, Pennsylvania, Illinois, Ohio, New York, Missouri and Wisconsin.

Marbles are used primarily as ornamental and building material. Important quarries of marble are found in Vermont, New York, Georgia and Tennessee.

Iceland spar is a valuable variety and is used for making optical instruments in the form of the Nicol prism to produce polarized light. Found in Iceland.

K. FLUORITE

Commonly known as fluor spar and derived from the Latin. fluo, meaning to flow. being used as a flux.

Composition—Calcium fluoride, CaF_2. Fluorine = 48.9 per cent, calcium = 51.1 per cent.

Crystal System—Common form is the cube. (Fig. 31).

Structure—Crystallized. Also found massive and columnar, coarse to fine granular.

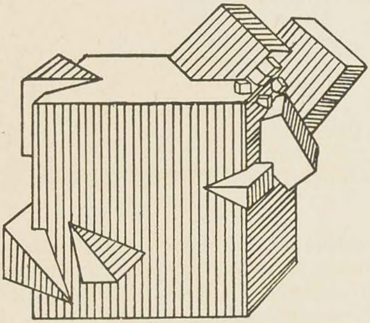

Fig. 31

Physical Properties

Cleavage—Perfect octahedral.

Fracture—Conchoidal, brittle.

Hardness—4. Can be scratched with a knife.

Specific Gravity—3 to 3.25.

Luster—Vitreous.

Color—Colorless, white, green, blue, purple, yellow, rose and brown.

Streak—White.

Experiment 11. How to Test for Fluorite—Heat a small fragment of the mineral, held in the forceps, in the blowpipe flame and notice that it fuses or melts. Also notice that the mineral colors the flame orange. This is the flame color test for the metal calcium. Moisten a small piece of turmeric paper with water and place it on the fragment that has been heated. Notice that the yellow turmeric paper turns brown. This is a test for an alkali. the alkali present being calcium oxide (CaO).

Test for fluorine is as follows: break a little of the mineral up into the form of a powder and mix a small amount of the powdered mineral with an equal amount of sodium bisulphate. Place some of this powdered mixture, about ½ inch, in a closed tube and heat over a hot flame, preferably a gas flame. Notice that after a short while a white sublimate or deposit of silicon dioxide is formed on the walls of the tube. When the mixture was heated, sodium bisulphate was converted into sodium sulphate and sulphuric acid. The sulphuric acid reacted with the mineral calcium fluoride to form hydrofluoric acid which in turn acts upon the glass and etches it. A secondary reaction then sets in with the formation of a white deposit of silica on the glass tube. This is the test that is usually applied to the element fluorine.

Fluorite is usually recognized by its cubic crystals, octehedral cleavage, vitreous luster, color and by its being scratched with a knife.

Occurrence—Common mineral and widely distributed. Usually found in veins or associated with metallic ores such as tin and lead. Also associated with dolomite, limestone, calcite, gypsum, barite, galena, quartz. cassiterite, sphalerite, topaz, apatite, etc.

Fluorite is found as important deposits in Illinois and Kentucky. Also in England and Saxony.

Uuse—The better grade of fluorite is used in the manufacture of opalescent glass. Other grades are used in enameling cooking utensils, as a flux in steel making, in the preparation of hydrofluoric acid and sometimes as ornamental material in the form of vases and dishes.

L. HALITE

Commonly called rock salt or common salt.

Composition—Sodium chloride, NaCl. Sodium = 39.4 per cent, chlorine = 60.6 per cent. Often contains impurities such as calcium and magnesium chlorides and calcium sulphate.

Crystal System—Usually in the form of cubes (Fig. 32). Other forms rare.

Structure—Usually in crystals showing cubical cleavage and known as rock salt. Sometimes occurs massive and granular.

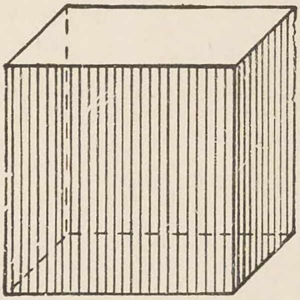

Fig. 32

Physical Properties

Cleavage—Cubical and perfect.

Fracture—Conchoidal, brittle.

Hardness—2.5. Can be scratched with a cent.

Specific Gravity—2.1 to 2.6. Rather light. **Luster**—Vitreous.

Color—White or colorless and, when impure, yellow, blue, purple or red.

Taste—Salty. **Solubility**—Readily soluble in water.

Experiment 12. How to Test for Halite—Heat a small piece of the mineral, held in the forceps, in the blowpipe flame and notice that the mineral fuses or melts very easily. Also notice that it gives a strong yellow flame. This is a test for the metal sodium. Moisten a small piece of yellow turmeric paper and place it on the mineral after it has been heated. Notice that the yellow turmeric paper turns brown, proving that an alkali is present in the mineral.

Break a little of the mineral up into the form of a powder and try to dissolve a little of the powder in some water in a test tube. Notice that the mineral dissolves readily in water. Taste a little of this solution. Do you recognize the salty taste? If this solution was treated with a solution of silver nitrate you would obtain a white precipitate of silver chloride. This is the test for chlorine in a soluble compound.

Occurrence—A common and widely occurring mineral. Occurs extensively in beds of great thickness. Found also in springs, salt seas and in the ocean.

Salt beds were originally formed by the gradual evaporation and drying up of salt water which had been shut out from the sea. These beds have then become covered by other deposits of sediment so that salt beds are found to a depth of two thousand feet below the surface of the ground. These salt beds range from a few feet to a hundred feet in thickness.

Salt is produced in the United States either by mining by means of shafts and galleries or by pumping the salt brine from the salt bed to the surface and evaporating off the water. Many important deposits are found in the United States, especially in New York, Michigan, Ohio, Kansas and Louisiana. Important deposits are found also in Great Britain, Poland, Hungary, Germany and Spain.

Uses—Rock salt is used chiefly for culinary and preservative purposes. Also used in manufacture of sodium carbonate for glass making, soap making and bleaching. Also used in the preparation of sodium compounds and in the extraction of gold by the chlorination process.

IMPORTANT ROCK MAKING MINERALS

Minerals With Non-Metallic Luster

The rock maknig minerals are in most cases complex silicates of such metals as aluminum, magnesium, calcium, iron. sodium, potassium and hydroxyl (OH). The physical properties of these minerals usually afford sufficient means for their identification.

M. ORTHOCLASE

Commonly known as potash feldspar. The name orthoclase refers to the right-angled cleavage which the mineral has. Feldspar is taken from the German word feld, meaning field. Orthoclase belings to a class of rock-making minerals called the feldspars. They are complex silicates of aluminum with sodium potassium or calcium and sometimes barium.

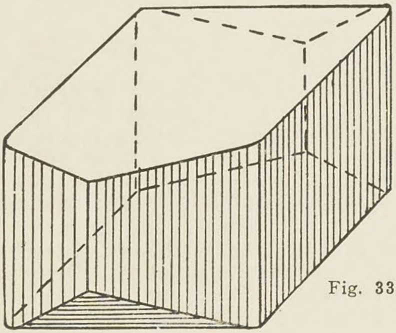

Fig. 33

Composition—Potassium aluminum silicate, $KAlSi_3O^8$. Aluminum oxide = 18.4 per cent, potash = 16.9 per cent and silicon dioxide = 64.7 per cent. Soda sometimes replaces part of the potash.

Crystal System—Crystals usually prismatic in habit. (Fig. 33-.

Structure—Crystals common. Also occurs massive and with granular structure.

Physical Properties

Cleavage—Two kinds, perfect and good.

Fracture—Conchoidal to uneven and splintery.

Hardness—6 to 6.5. May be scratched by glass or may scratch glass.

Specific Gravity—2.5 to 2.6. Rather light. **Luster**—Vitreous.

Color—Colorless, gray, white, flesh-red and gray or greenish gray.

Streak—White.

Experiment 13. How to Test for Orthoclase—Heat a small splinter or fragment of the mineral in the reducing flame of the blowpipe and notice that the mineral does not fuse or melt easily. It melts only on the edges of thin fragments.

If the powdered mineral is mixed with powdered gypsum and heated on platinum or nickel-steel wire, the flame will be colored purple, which is the flame test for the mineral potassium.

Orthoclase is usually recognized by its hardness, color and cleavage.

Occurrence—A very common rock-forming mineral. It occurs widely distributed in all types of rocks and is found associated with the minerals quartz, albite and muscovite. It is largely a vein mineral and is found in New England and Middle Atlantic States, chiefly in Connecticut, Maine, New York, Maryland and Pennsylvania. Feldspar is quarried in large amounts in some of these localities.,

Uses—Orthoclase finds an important use in the manufacture of porcelain. The finely ground mineral is mixed with clay (kaolin- and quartz and, when heated to a high temperature, the feldspar fuses and acts as a cement to bind the material together. Fused feldspar is one of the chief ingredients of the glaze on porcelain.

N. TALC

Commonly called steatite or soapstone.

Composition—Silicate of magnesium, $H_2Mg_3(SiO_3)_4$. Magnesium oxide = 31.7 per cent, silicon dioxide = 63.5 per cent, water = 4.8 per cent.

Structure—Usually massive. with foliated structure. Can be split into thin plates, which are flexible but not elastic when found in this form. Also compact. **Crystal System**—Crystals rare.

Physical Properties

Cleavage—Perfect, giving thin plates. Can be cut with a knife.

Hardness—1. Very soft mineral, will make a mark on paper or cloth.

Specific Gravity—2.8. Rather light.

Luster—Pearly, feels greasy. **Color**—White, apple-green and gray.

Experiment 14. How to Test for Talc—Heat a small piece of the mineral, held in the forceps, in the reducing flame of the blowpipe and notice that it is difficult to fuse or melt the mineral. It fuses to an enamel on the edges only.

If a small piece of the mineral is moistened with a solution of cobalt nitrate and heated in the blowpipe flame the mineral will become pale violet in color.

Talc is usually recognized by its resemblance to mica in structure and cleavage, and by its softness and greasy feel.

Occurrence—Talc is usually found as a mineral formed by the alteration of magnesium silicates such as chrysolite, pyroxene, amphibole, etc.

Soapstone quarries are found in the United States chiefly in Vermont, Massachusetts, Rhode Island. New York, New Jersey, Pennsylvania, Maryland, North Carolina, Virginia and Georgia.

Uses—Soapstone has many uses. In the form of slabs it is used extensively for making wash tubs, sinks, table tops, electrical switchboards, furnace linings, hearthstones, etc. The compact variety is used as tailor's chalk, slate pencils, gas burners, etc. Finely divided talc is used in paper making as a filler to give weight, as a lubricant, as toilet powders (talcum powder, in paints, as a heat insulator and in several other things.

O. APATITE

Name taken from the Greek word apatao, meaning to deceive.

Composition—Phosphate and fluoride of calcium, $Ca_4(CaF)\ (PO_4)_3$ or phosphate and chloride of calcium $(Ca_4)\ (CaCl)\ (PO_4)_3$. The first is called fluor-apatite while the second is called chlor-apatite.

Fig. 34

Crystals System—Crystals usually long prismatic in habit. Sometimes found in short prisms. (Fig. 34).

Structure—Usually found in crystalline form. Also found massive, granular to compact.

Physical Properties

Cleavage—Very poor.

Fracture—Conchoidal and uneven, brittle.

Hardness—5. Can be scratched by a knife, better with glass. **Specific Gravity**—3.15.

Luster—Vitreous to subresinous.

Color—Usually some shade of green or brown. Also white, colorless, blue, violet and gray. Transparent to opaque.

Streak—White.

Experiment 15. How to Test for Apatite—Heat a small fragment of the mineral, held in the forceps, in the reducing flame of the blowpipe for several minutes and notice that it does not fuse or melt easily. Notice the orange colored flame produced by the mineral when heated in this way. This is the flame test for the metal calcium.

The powdered mineral dissolves in concentrated hydrochloric acid and gives a white precipitate of calcium sulphate when a drop or two of sulphuric acid is added.

The mineral is usually recognized by its hardness, color and crystal forms.

Uses—Apatite is used chiefly as a fertilizer on account of the phosphorous which it contains. Transparent varieties are used somewhat as gems.

P. MUSCOVITE

Also known as muscovy-glass or common mica. The name was derived from the mineral muscovy-glass which was used as a substitute for glass in Russia. Mica is derived from the Latin word micare, meaning to shine.

Composition—A complex silicate of potassium, aluminum and hydrogen, $H_2KAl_3(SiO_4)_3$. Frequently contains traces of iron, magnesium, calcium, sodium, lithium, fluorine and titanium.

Crystal System—Usually in the form of six-sided plates (Fig. 35). Also massive and in scales.

Structure—Large and small sheets foliated. Sometimes in scales. Distinct crystals rare.

Physical Properties

Cleavage — Extremely perfect, mineral can be easily separated into thin sheets. Sheets are flexible and elastic.

Hardness—2 to 2.5. Can be scratched by copper coin.

Specific Gravity—2.76 to 3.

Luster—Vitreous, silky and pearly.

Color—White, yellow, brown, black and green. In thin sheets the mineral is transparent and almost colorless.

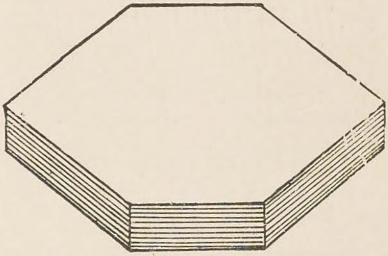

Fig. 35

Experiment 16. How to Test for Muscovite—Heat a small piece of the mineral, held in the forceps, in the blowpipe flame for several minutes and notice that the mineral does not fuse or melt very readily.

Muscovite is usually recognized by its light color and mica-like structure.

Occurrences—A very common and widely distributed rock-making mineral. It is found in many types of rocks. Muscovite is found in veins associated with quartz, feldspar, tourmaline, beryl, garnet, fluorite and apatite.

Muscovite is found in the United States chiefly in the Appalachian and Rocky Mountain regions. It occurs in pegmatite veins in North Carolina and South Dakota. Deposits are also found in Connecticut, Maine, New Hampshire. Colorado, Alabama and Virginia. Also found in large deposits in Canada and India.

Uses—Mica is used extensively as an insulating material in the construction of electrical apparatus. Used to take the place of windows (isinglass), for stove doors, lanterns, etc. Powdered mica is used to give wall paper a shiny luster, as a non-conductor of heat, as a lubricant in oils, and as a fireproofing material.

Q. GARNET

The garnets, of which there are six varieties, are complex silicates of the metals calcium, magnesium, iron, manganese, aluminum and chromium. The name garnet is derived from the Latin word granatus, meaning like a grain.

Composition—The variety of garnet known as almandite is a silicate of iron and aluminum, $Fe_3Al_2(SiO_4)_3$. The other varieties of garnet have a similar formula with the iron and aluminum replaced by some of the other metals mentioned above.

Crystal System—Usually as the rhombohedron (Fig. 36) and the trapezohedron (Fig. 37).

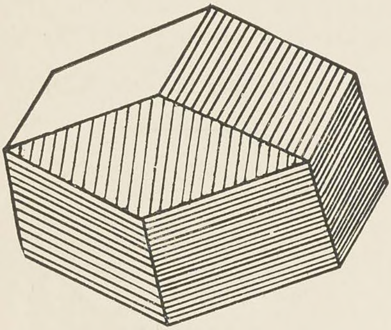

Fig. 36

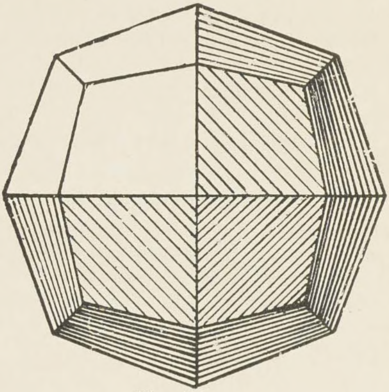

Fig. 37

Structure—Usually well crystallized. Also massive and coarse to fine grained.

Physical Properties

Hardness—6.5 to 7.5. Rather hard. Will scratch window glass.

Specifis Gravity—3.9 to 4.2.

Luster—Vitreous. Resinous in some varieties.

Color—Deep red in almandite. In other varieties, yellow, brown, black, green and white. **Streak**—White.

Experiment 17. How to Test for Garnet—Heat a small fragment of the mineral garnet (almandite), held in the forceps, in the reducing flame of the blowpipe and notice that the mineral fuses or melts.

Heat a small piece or fragment of the mineral on charcoal in the reducing flame of the blowpipe for several minutes. Allow the mineral to cool and notice that an iron globule has been formed. Try the effect of the magnet on the iron globule and observe that the globule is magnetic and is attracted by the magnet.

Garnets are generally recognized by their characteristic crystal forms, hardness and color.

Occurrence—The garnets are common minerals and very widely distributed. They occur as a constituent of many types of rocks. Sometimes found as rounded grains in stream and sea sands.

Almandite is found in India, Brazil, Australia, in the Alps and in Alaska. Some of the other varieties are found in Utah and Arizona, Bohemia, Ceylon, and in the Ural Mountains of Russia.

Uses—Some varieties of almandite are used as a gemstone. Garnets are sometimes used in the powdered state as abrasive material, as sand for grinding stone and for making sandpaper.

R. QUARTZ

Composition—Dioxide of silicon, SiO_2. Silicon = 46.7 per cent, oxygen = 53.3 per cent. Frequently contains various impurities.

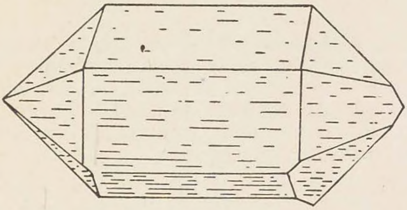

Fig. 38

Crystal System — Usually in the form of hexagonal prismatic crystals terminated by hexagonal pyramids. (Fig. 38). Sometimes the prism faces are missing, as in the form consisting of a doubly terminated hexagonal pyramid (Fig. 39).

Structure — Commonly found as crystals. Also found massive, coarse to fine grained. Sometimes mammillary and stalactitic.

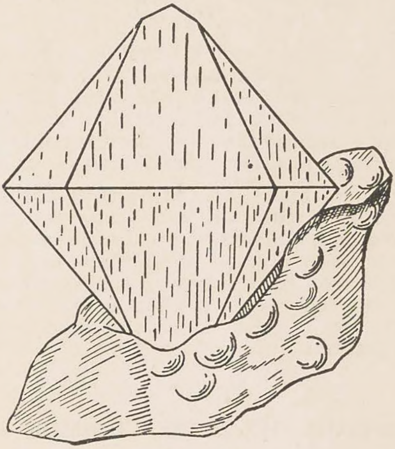

Fig. 39

Physical Properties

Fracture—Conchoidal.

Hardness—7. Rather hard. Easily scratches window glass.

Specific Gravity—2.65 to 2.66.

Luster—Vitreous, sometimes resinous or greasy, transparent to opaque.

Color—Colorless when pure. When impure colored red, pink, yellow, amethyst, blue, green, black and brown.

Experiment 18. How to Test for Quartz—Heat a small piece of quartz, held in the forceps, in the blowpipe flame for several minutes and observe that the mineral does not fuse or melt. If the finely powdered mineral is fused with sodium carbonate on platinum or nickel-steel wire a clear glass bead is obtained.

Quartz is usually recognized by its glassy luster, crystal form, hardness and conchoidal fracture.

Varieties—A great many different varieties of quartz are found, the colors of which are due to the different impurities which they contain. Some of these are rose quartz, rock crystal, amethyst, smoky quartz, milky quartz and cat's eye. Other varieties are known as chalcedony, carnelian, chrysoprase, agate, onyx, flint and jasper.

Occurrence—Quartz is the most common of all the minerals. It is a very important constituent of most rocks. It is a very common vein mineral. It is associated commonly with muscovite and feldspar. It often occurs as an important ore of gold. Found in large amounts as sand in stream beds and upon the seashore and as a constituent of soils.

Very good quartz crystals are found in Arkansas and New York. Rock crystal is found in Ural Mountains, Brazil, on the shore of Lake Superior, Maine, Pennsylvania and South Dakota. Smoky quartz is found in Switzerland, Colorado, North Carolina and Maine. Agate is found in Brazil, Uruguay and in several places in the United States. Massive quartz is mined for various purposes in Connecticut, New York, Maryland and Wisconsin.

Uses—Many of the various forms such as amethyst, rose quartz, agate, etc., find important uses as ornamental material. Used in the form of quartz sand or sandpaper as an abrasive material. Used for making mortar and cement in form of sand. Has an important use in the manufacture of glass, porcelain, as a wood filler, scouring soaps and in paints. Some of its various forms such as quartzite and sandstone are used as a building stone and as a paving material. Quartz sand is used in large amounts as a flux in several smelting operations.

LIST OF THE MORE COMMON ELEMENTS WITH THEIR SYMBOLS, ATOMIC WEIGHTS AND VALENCES

Element	Symbol	Atomic Wgt.	Valence
Aluminum	Al	27	3
Antimony	Sb	120	3, 5
Argon	A	40	
Arsenic	As	75	3, 5
Barium	Ba	137	2
Bismuth	Bi	208	3, 5
Boron	B	11	3
Bromine	Br	80	1
Cadmium	Cd	112	2
Calcium	Ca	40	2
Carbon	C	12	4
Chlorine	Cl	35	1
Chromium	Cr	52	2, 3, 4
Cobalt	Co	59	2
Copper	Cu	63	1, 2
Fluorine	F	19	1
Gold	Au	197	1, 3
Helium	He	4	
Hydrogen	H	1	1
Iodine	I	127	1
Iron	Fe	56	2, 3
Lead	Pb	207	2, 4
Lithium	Li	7	1
Magnesium	Mg	24	2
Manganese	Mn	55	2, 4
Mercury	Hg	200	1, 2
Nickel	Ni	59	2
Nitrogen	N	14	3, 5
Oxygen	O	16	2
Phosphorous	P	31	3, 5
Platinum	Pt	195	4
Potassium	K	39	1
Silicon	Si	28	4
Silver	Ag	108	1
Sodium	Na	23	1
Strontium	Sr	87	2
Sulphur	S	32	2, 4, 6
Tin	Sn	119	2, 4
Zinc	Zn	65	2

LIST OF SOME COMMON MINERALS WITH THEIR FORMULAE

Albite—sodium aluminum silicate, $NaAlSi_3O^8$.
Amphibole—calcium and magnesium silicate.
Apatite—fluoride and phosphate of calcium.
Arsenopyrite—sulpharsenide of iron, $FeAsS$.
Barite—barium sulphate, $BaSO_4$.
Biotite—complex silicate of aluminum, iron, magnesium and potassium.
Bornite—copper iron sulphide, Cu_5FeS_4.
Calamine—zinc silicate.
Calcite—calcium carbonate, $CaCO_3$.
Cassiterite—tin oxide, SnO_2.
Celestite—strontium sulphate, $SrSO_4$.
Cerussite—lead carbonate, $PbCO_3$.
Chalcocite—cuprous sulphide, Cu_2S.
Chalcopyrite—iron and copper sulphide, $CuFeS_2$.
Cinnabar—mercuric sulphide, HgS.
Corundum—aluminum oxide, Al_2O_3.
Cuprite—cuprous oxide, Cu_2O.
Dolomite—calcium magnesium carbonate, $CaMg(CO_3)_2$.
Epidote—complex silicate of calcium, aluminum and iron.
Fluorite—calcium fluoride, CaF_2.
Galena—lead sulphide, PbS.
Garnet—complex silicate of iron, magnesium, aluminum and calcium.
Graphite—carbon, C.
Halite—sodium chloride, $NaCl$.
Hematite—iron oxide, Fe_2O_3.
Kaolinite—complex aluminum silicate.
Limonite—iron oxide, $2Fe_2O_33H_2O$.
Magnetite—iron oxide, Fe_3O_4.
Malachite—basic copper carbonate, $CuCO_3Cu(OH)_2$.
Muscovite—complex silicate of potassium and aluminum.
Natrolite—complex silicate of sodium and aluminum.
Orthoclase—potassium aluminum silicate.
Pyrite—iron disulphide, FeS_2.
Pyrolusite—manganese dioxide, MnO_2.
Pyroxene—calcium magnesium silicate.
Quartz—silicon dioxide, SiO_2.
Serpentine—magnesium silicate.
Siderite—iron carbonate, $FeCO_3$.
Smithsonite—zinc carbonate, $ZnCO_3$.
Sphalerite—zinc sulphide, ZnS.
Staurolite—complex silicate of iron and aluminum.
Stibnite—antimony sulphide, Sb_2S_3.
Talc—magnesium silicate.
Tetrahedrite—antimony copper sulphide, $Cu^8Sb_2S^7$.
Tourmaline—complex silicate of boron and aluminum.