

# THE ELEMENTS OF BLOWPIPE ANALYSIS

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## ELEMENTS OF BLOWPIPE ANALYSIS

*BY*

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## PREFACE

These few pages are intended to serve a twofold purpose,—to give the student a general outline of Blowpipe Analysis, and to introduce him to the methods of Determinative Mineralogy.

Every effort has been made to simplify details so that the book may be used in both High Schools and Colleges.

Tables for "systematic" examination have been intentionally omitted, for in the author's estimation these tend to dull the student's power of observation, and to make him place little value upon minute details.

The alphabetic arrangement has been followed for the sake of convenience when referring to the book.[Pg vi]

The last chapter is not intended to serve as a key to determining the minerals therein described, but rather it is added to give the student exercise in Blowpipe Analysis, and at the same time to point out the *methods* of Determinative Mineralogy.

Finally, the author would acknowledge his indebtedness to the following works: "Manual of Qualitative Analysis," Fresenius; "Qualitative Chemical Analysis," Venable; Roscoe and Schorlemmer's "Treatise on Chemistry"; Foye's "Hand-Book of Mineralogy"; Dana's "Mineralogy"; Kobell's "Tafeln zur Bestimmung der Mineralien"; etc.

FREDERICK HUTTON GETMAN.

STAMFORD, CONN.,

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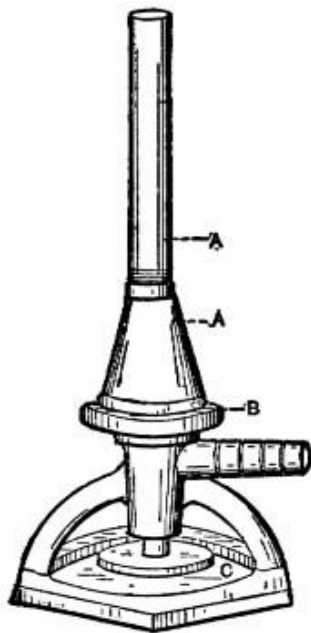
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BUNSEN BURNER  
Fig. 2



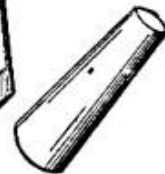
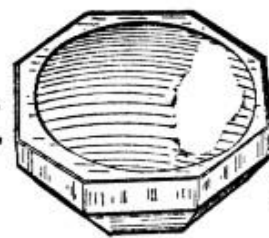
THE BLOWPIPE  
Fig. 1



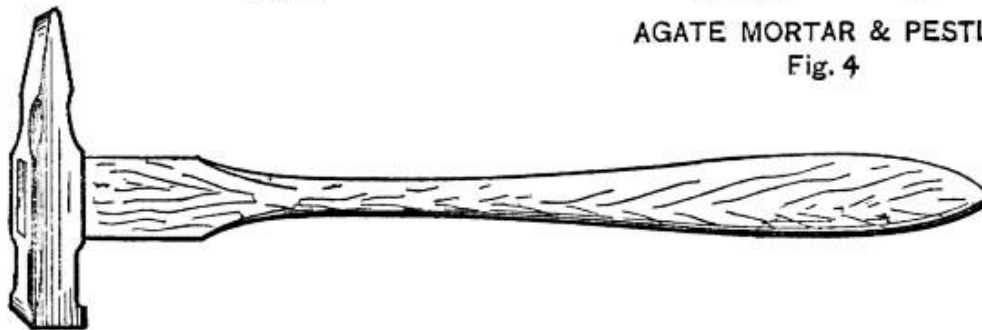
CHARCOAL BORERS  
Fig. 3



FORCEPS  
Fig. 5



AGATE MORTAR & PESTLE  
Fig. 4



HAMMER  
Fig. 6



3 - CORNERED FILES  
Fig. 7

## BLOWPIPE ANALYSIS

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### CHAPTER I

The blowpipe was first applied to mineral analysis in 1733 by Anton Swab, and its applications have since been improved and extended by various chemists, among whom may be mentioned Bergmann, Cronstedt, Gahn, Berzelius, and Plattner.

**Blowpipe.**—The common blowpipe of the jeweller is not particularly well suited to the operations of blowpipe analysis, since the flame has often to be kept playing upon the assay for some time, and the condensed moisture of the breath would seriously interfere with the passage of the[Pg 2] air through the jet. One of the best and least expensive forms of blowpipe is shown in Fig. 1. This consists, as is seen from the illustration, of a conical-shaped tube of tin closed at the wide end and formed into a mouthpiece at the small end; soldered into the tube at the large end, and at right angles to its axis, is a small brass tube which terminates in a conical tip pierced with a very fine hole. With this pipe it is possible to perform all of the operations of mineral analysis.

Some little practice is necessary to keep the flame steady and to take the breath at the same time.

No rule can well be given to the beginner, but his experience becomes his best guide.

**Bunsen Flame.**—Any kind of flame can be used for the blowpipe, provided it be[Pg 3] not too small; but since almost every laboratory to-day is furnished with gas and the Bunsen burner (Fig. 2), it will only be necessary to describe the use of the flame from this source. Upon examining the Bunsen flame with care, it will be seen that the flame consists of three distinct parts.

A dark inner cone which consists of gas not yet raised to the ignition point. Beyond this there is a luminous cone, where combustion is incomplete owing to lack of oxygen, and outside of this we find the non-luminous cone where the gas is completely burned.

This outer envelope is the hottest portion of the flame, and is known as the "oxidizing" flame because there is an excess of oxygen which is imparted to substances placed therein.



The luminous cone is known as the "reducing" flame, for in it metallic oxides[Pg 4] are reduced, the oxygen being taken up by the small incandescent particles of carbon.

If the air-holes at the base of the Bunsen burner be opened, the two inner cones become elongated, and the flame appears almost colorless.

The blowpipe enables us to get an oxidizing and a reducing flame of better form and greater power. To do this we cut off the air supply at the base of the burner and turn off the gas until the flame is about 1 cm. high; then upon introducing the blowpipe, and blowing a strong continuous jet of air across the Bunsen flame, we produce an oxidizing flame about 4-5 cm. in length. If the tip of the blowpipe be held outside of the Bunsen flame, and the pressure of the stream of air be diminished, we obtain a reducing flame.[Pg 5]

**Supports.**—For supports, charcoal, platinum, and glass are chiefly used. The charcoal should be made from some light wood, such as alder. It should be well burnt, and should not scintillate or smoke.

The platinum supports are generally in the form of wire and foil. Platinum-tipped forceps are frequently employed in blowpipe analysis.

Glass is used in the form of tubing.

Hard glass tubing, 3 mm. bore, is drawn off into ignition tubes 7-8 cm. in length. Several dozen of these tubes should be made before commencing the tests of the next chapter.

**Apparatus.**—A small agate mortar, 4-5 cm. in diameter, should be provided in which to grind the samples to be examined.

The pestle, which should also be of agate,[Pg 6] must be adapted to the mortar in shape and size.

Two pairs of forceps will also be needed.

One pair should be of steel, and the other pair of brass, with fine points.

Of other apparatus, the most necessary is:—

A small hammer and anvil.

Two three-cornered files.

Small piece of cobalt glass, about 5 × 10 cm.

Pocket magnifying lens.

Several small watch glasses—for metallic beads, etc.

**Chemicals.**—A list of the principal chemicals is here given:—

Sodium carbonate,  $\text{Na}_2\text{CO}_3$ .

Borax,  $\text{Na}_2\text{B}_4\text{O}_7 + 10 \text{H}_2\text{O}$ .

[Pg 7]Microcosmic salt,  $(\text{HNaNH}_4)\text{PO}_4 + 8 \text{H}_2\text{O}$ .

Cobalt nitrate,  $\text{Co}(\text{NO}_3)_2 + 5 \text{H}_2\text{O}$ .

Potassium cyanide, KCN.

Hydrochloric acid, (dilute),  $\text{HCl} + n\text{H}_2\text{O}$ .

Litmus paper, red and blue.

Brazil-wood paper.

Any other special reagents which may be needed will be mentioned as required.

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[Pg 8]

## CHAPTER II

### GENERAL OUTLINE OF BLOWPIPE ANALYSIS

[ABBREVIATIONS: O. F. for oxidizing flame, R. F. for reducing flame, Ch. for charcoal, Ct. for coating, Bp. for blowpipe.]

In order to examine a substance before the blowpipe to determine the presence or absence of certain elements, it becomes necessary to arrange a systematic method. As with all branches of chemical work, one's success is largely dependent upon neatness of manipulation and carefulness of observation.

The following order of observation is essentially that given by Berzelius:—

1. Examination on charcoal by itself.

[Pg 9]2. Examination on charcoal with  $\text{Na}_2\text{CO}_3$ .

3. Examination in ignition tube with  $\text{Na}_2\text{CO}_3$  and charcoal.

4. Examination on platinum wire.

5. Examination in borax bead.

## 6. Examination with $\text{Co}(\text{NO}_3)_2$ .

After having examined a body in these six different ways, we shall be able to say what are its principal constituents.

Before describing the method of carrying out these six different operations, it will be necessary to give a few definitions of terms which we shall have frequent occasion to employ.

**Definitions.**—*Ignition* is the heating of a substance to a high temperature.

*Fusion* is the heating of a substance to the melting-point.

*Intumescence* is the swelling of the substance upon heating.[Pg 10]

*Decrepitation* is the crackling of a substance due to the sudden expansion of combined water upon heating.

*Deflagration* is the burning of a substance with explosive violence, generally due to excess of oxygen.

*Incandescence* is the white light emitted by a substance that is infusible when subjected to a high temperature.

**Examination on Charcoal alone.**—The size of the assay should be about that of a mustard seed. This is sufficiently large to show all of the reactions clearly, and though a larger piece would exhibit the characteristic phenomena, yet much more effort is required. A very small, shallow hole should be cut in the Ch. to receive the assay. The Bp. flame should be directed at an angle of about  $30^\circ$  with the surface of the Ch. Considerable care must be taken lest the hole in[Pg 11] the Ch. is burned too deep and the assay lost in the coal.

The force of the air from the jet must also be borne in mind for a strong blast, or sudden puffs may blow the substance away.

The following changes are to be looked for:—

a. Whether the substance is volatile or non-volatile.

*Illustrations.* Examine before the Bp. on Ch. some arsenious oxide,  $\text{As}_2\text{O}_3$ , also some alumina,  $\text{Al}_2\text{O}_3$ .

b. Whether the substance is fusible or infusible.

*Illustrations.* Examine before the Bp. on Ch. some silver oxide,  $\text{AgO}$ , also some zinc oxide,  $\text{ZnO}$ .

c. Whether the substance is alkaline or non-alkaline when placed upon moistened red litmus.[Pg 12]

*Illustrations.* Ignite some calcium carbonate,  $\text{CaCO}_3$ , before the Bp. on Ch., and place residue on moistened red litmus. In like manner, examine some magnesium carbonate,  $\text{MgCO}_3$ .

d. Color of coating on Ch. caused by combination of metal and oxygen due to heat of Bp. flame.

*Illustrations.* Examine some oxide of lead,  $\text{PbO}$ , before the Bp. on Ch., also some oxide of cadmium,  $\text{CdO}$ .

e. Decrepitation.

*Illustration.* Examine some sodium chloride,  $\text{NaCl}$ , before the Bp. on Ch.

f. Deflagration.

*Illustrations.* Examine some potassium nitrate,  $\text{KNO}_3$ , before the Bp. [Pg 13]on Ch., also some ammonium nitrate,  $\text{NH}_4\text{NO}_3$ .

g. Intumescence.

*Illustration.* Examine some alum,

$\text{K}_2\text{Al}_2(\text{SO}_4)_4$ ,

before the Bp. on Ch.

h. Incandescence.

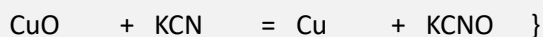
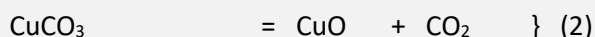
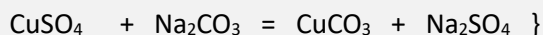
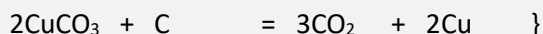
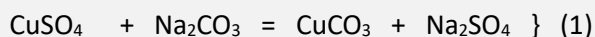
*Illustration.* Examine some oxide of barium,  $\text{BaO}$ , before the Bp. on Ch.

i. Formation of a metallic bead—color and malleability.

*Illustration.* Examine some silver oxide,  $\text{AgO}$ , before the Bp. on Ch.

**Examination on Charcoal with  $\text{Na}_2\text{CO}_3$ .**—Metallic compounds are often difficult to reduce with the blowpipe flame alone, and hence no bead is obtained. In order to facilitate reduction and the obtaining of a metallic bead, the substance in a finely powdered condition is mixed [Pg 14]with four parts of sodium carbonate,  $\text{Na}_2\text{CO}_3$ , and ignited before the Bp. on Ch. The metallic compound is decomposed, the metal being transformed into the carbonate, which in turn, through the agency of the Ch. and the heat of the flame, is reduced to the free metal. Sometimes the reduction is made easier by adding to the substance about its own bulk of potassium cyanide,  $\text{KCN}$ , which takes up oxygen from the compound and is converted into potassium cyanate,  $\text{KCNO}$ .

The reactions in reducing copper sulphate,  $\text{CuSO}_4$ , with  $\text{Na}_2\text{CO}_3$  and with KCN before the blowpipe, are here given:—



[Pg 15]

After obtaining beads, it is well to obtain their coatings, for oftentimes it is only in this way that we can distinguish between the metals.

**Examination in Tube with  $\text{Na}_2\text{CO}_3$  and Charcoal.**—If the substance in a finely pulverized condition be mixed with twelve parts,  $\text{Na}_2\text{CO}_3$ , and six parts of charcoal powder and the mixture be placed in an ignition tube and subjected to heat, the acid of the substance combines with the soda and the metal is set free.

If this metal is volatile, a sublimate is formed in the upper end of the tube.

Mercury deposits in minute globules, which may be seen with the magnifying glass. Arsenic forms a ring, which, when examined with the magnifying glass, is seen to be made up of minute crystals. Ammonia is recognized by its characteristic[Pg 16] odor, and also by its turning a slip of moistened red litmus (held over the mouth of the tube) blue.

**Examination on Platinum Wire.**—Many substances possess the property of imparting to the colorless flame of the Bunsen burner characteristic colors.

The chlorides of these substances exhibit these flame reactions best, and hence before applying the flame tests we dip the wire which serves as a support into hydrochloric acid and then into the substance. When the substance has been taken up on the wire, it is placed in the edge of the long colorless flame of the Bunsen burner near the apex, when instantly the flame becomes tinged with the characteristic color of the substance.

*Illustrations.* Sodium compounds color the flame yellow, and a crystal of potassium[Pg 17] dichromate appears colorless in the sodium light.

This sodium reaction is extremely delicate, it being possible to detect with ease a quantity of a sodium salt less than 1/3000000 of a milligram in weight.

Potassium colors the flame purplish-violet.

Barium colors the flame apple-green.

Strontium colors the flame crimson.

Calcium colors the flame orange-red, distinguished from strontium, by appearing gray when seen through blue glass.

Boracic acid colors the flame green when the substance has been moistened with glycerine.

**Examination in Borax Bead.**—Borax,  $\text{Na}_2\text{B}_4\text{O}_7$ , and microcosmic salt,

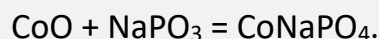
$\text{NaNH}_4\text{H} . \text{PO}_4$ ,

possess the property of dissolving many of [Pg 18] the metallic oxides at the temperature of the Bunsen flame.

For example, with oxide of cobalt, the following reactions take place with the two fluxes:—



On heating,  $\text{NaNH}_4\text{H} . \text{PO}_4$ , it is decomposed into the metaphosphate of sodium,  $\text{NaPO}_3$ ,



Now in such cases of solution the metallic oxides impart a characteristic color to the flux.

The platinum wire is the best support,—it is heated to incandescence in the Bunsen flame, and then is quickly dipped into the borax, when a small globule will adhere,—this is removed to the flame again when the borax melts to a clear glassy bead. While the bead is still melted, touch it to [Pg 19] the finely pulverized substance and replace in the flame. In a few seconds the small particles of the substance will have dissolved, and the bead will be seen to have assumed the color characteristic of the substance. Note the color when hot and then when cold; often there is a wide difference. Then, too, the test should be made in both O. F. and R. F.

Some analysts prefer to make a small loop in the end of the wire before taking up the borax to make the bead. Care should be taken to see that the bead is colorless before bringing it in contact with the substance.

As the depth of color produced is largely dependent upon the amount of substance taken, some little caution should be exercised to insure taking up about the same quantity each time.

*Illustrations.* Make several beads, and [Pg 20] note the colors characteristic of the following oxides: cobalt, nickel, iron, manganese, chromium, and copper.

The microcosmic salt bead dissolves almost every oxide except silica,  $\text{SiO}_2$ , and this is seen to float about in the melted mass. This is used as a test for silica.

**Examination with  $\text{Co}(\text{NO}_3)_2$ .**—If after examination on the Ch. *per se*, a white infusible residue remains, it is moistened with a drop of cobalt nitrate  $\text{Co}(\text{NO}_3)_2$  and re-ignited before the Bp., when a change of color will be observed. This change in color is owing to the fact that the heat of the Bp. flame decomposes the cobalt nitrate, nitric acid being driven off, and the remaining  $\text{CoO}$  forming with the oxide of the residue a colored mass.

*Illustrations.* Ignite before the Bp. on Ch. the following [Pg 21]oxides,—allow to cool, add a drop of  $\text{Co}(\text{NO}_3)_2$ , re-ignite, and note color,—aluminum, magnesium, zinc, and calcium.

Care should be taken to thoroughly ignite before adding the cobalt nitrate solution.

With the six methods of examination just given almost every simple substance can be detected, but should any doubt remain, a few simple tests in the "liquid way" will be sufficient to substantiate the blowpipe examination.

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[Pg 22]

## CHAPTER III

GENERAL REACTIONS FOR THE DETECTION OF THE METALLIC ELEMENTS IN SIMPLE COMPOUNDS

For the sake of convenience, rather than for scientific reasons, the following compounds have been arranged in alphabetic order. Also the oxides of the elements have been taken, since they exhibit the reactions to best advantage.

The student should work through carefully each one of the tests and satisfy himself as to the characteristic reactions of the various elements, for only in this way can he expect to recognize the substances when presented to him as "unknowns." It is advisable to provide a note-book and rule it as follows:[Pg 23]—

1. **Aluminum,  $\text{Al}_2\text{O}_3$ .**—Before the Bp. on Ch. Infusible. No change.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Forms an infusible compound with slight intumescence.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. No change. Moisture driven off.

In flame on platinum wire. No change. Becomes incandescent.

In flame with borax bead. In O. F.[Pg 24] dissolves slowly, forming a colorless glass which remains so on cooling.

With  $\text{Co}(\text{NO}_3)_2$ . Mass becomes blue upon re-ignition.

2. **Antimony,  $\text{Sb}_2\text{O}_3$ .**—Before the Bp. on Ch. In O. F. volatilizes without change. In R. F. is reduced and volatilized. White coating of antimonious oxide deposited on Ch. Blue tinge imparted to flame.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Readily reduced. White brittle bead. Very volatile, giving characteristic white coating.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Volatilized.

In flame on platinum wire. Volatilized. Colors flame greenish blue.

With borax bead on platinum wire. In O. F. dissolves to a colorless glass.



With  $\text{Co}(\text{NO}_3)_2$ .\_\_\_\_\_

3. **Arsenic,  $\text{As}_2\text{O}_3$ .**—Before the Bp. on Ch. Very volatile. Strong garlic odor to fumes.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Reduced with emission of arsenical fumes.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Volatilizes, forming a mirror-like deposit of metallic As in the cooler part of tube.

In flame on platinum wire\_\_\_\_\_

With borax bead on platinum wire\_\_\_\_\_

With  $\text{Co}(\text{NO}_3)_2$ .\_\_\_\_\_

4. **Bismuth,  $\text{Bi}_2\text{O}_3$ .**—Before the Bp. on Ch. Yields a coating—orange-yellow when hot, lemon-yellow when cold. The yellow coating usually has a white outline.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Easily reduced to metallic bismuth. Yellow bead brittle, but less so than antimony.

[Pg 26]

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch.\_\_\_\_\_

In flame on platinum wire\_\_\_\_\_

With borax bead on platinum wire. In O. F. small quantity dissolves to a clear yellow glass, which becomes colorless when cold.

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

5. **Cadmium,  $\text{CdO}$ .**—Before the Bp. on Ch. Gives a coating on the coal. Reddish-brown when cold. Very volatile.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Readily reduced. The metal volatilizes easily, giving the characteristic coating.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch.\_\_\_\_\_

In flame on platinum wire\_\_\_\_\_

With borax bead. In O. F. dissolves to a clear yellowish bead, colorless when cold.

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

[Pg 27]

6. **Chromium,  $\text{Cr}_2\text{O}_3$ .**—Before the Bp. on Ch. No change.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Cannot be reduced. Soda sinks in Ch. and a green colored mass remains.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_

**With borax bead.** Dissolves slowly but colors intensely. Yellow while hot, green when cold.

With microcosmic salt bead. Colors red when hot, green when cold.

With  $\text{Co}(\text{NO}_3)_2$  \_\_\_\_\_

**7. Cobalt,  $\text{CoO}$ .**—Before the Bp. on Ch. In O. F. unchanged. In R. F. is reduced to the metal and is magnetic.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Reduced to a gray magnetic mass.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_ [Pg 28]

With borax bead on platinum wire. In O. F. colors very intensely blue, both hot and cold.

With  $\text{Co}(\text{NO}_3)_2$  \_\_\_\_\_

**8. Copper,  $\text{CuO}$ .**—Before the Bp. on Ch. Fuses to a black globule, which can be reduced with some difficulty.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Readily reduced to metallic bead, which is red in color, hard, malleable.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire. Colors flame emerald-green.

With borax bead on platinum wire. In O. F. green when hot, blue when cold.

With  $\text{Co}(\text{NO}_3)_2$  \_\_\_\_\_

**9. Iron,  $\text{Fe}_2\text{O}_3$ .**—Before the Bp. on Ch. In O. F. unchanged. In R. F. becomes black and magnetic. [Pg 29]

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  Reduced to a metallic powder, magnetic.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_

With borax bead on platinum wire. In O. F. red while hot, yellow when cold.

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

**10. Lead,  $\text{PbO}$ .**—Before the Bp. on Ch. Easily reduced to the metal, bead very malleable. Coating yellow, surrounded by white ring.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Instantly reduced. Coats the Ch. upon further blowing.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Reduced to the metal.

In flame on platinum wire. Tinges flame blue.

With borax bead on platinum wire.[Pg 30] In O. F. dissolves easily, forming a limpid glass.

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

**11. Manganese,  $\text{Mn}_2\text{O}_3$ .**—Before the Bp. on Ch. At high temperature turns red.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Is not reduced.

Before the Bp. in O. F. on platinum foil with  $\text{Na}_2\text{CO}_3$ . Transparent green mass when hot. Opaque, bluish-green when cold.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Not reduced.

In flame on platinum wire\_\_\_\_\_

With borax bead on platinum wire. In O. F. violet-red while hot, amethyst-red when cold.

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

**12. Mercury,  $\text{HgO}$ .**—Before the Bp. on Ch. Instantly reduced. Very volatile.

[Pg 31]

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Reduced and volatilized.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Sublimes condensing in the upper part of the tube as a metallic ring which is seen with the lens to consist of minute globules of mercury.

In flame on platinum wire\_\_\_\_\_

With borax bead on platinum wire\_\_\_\_\_

With  $\text{Co}(\text{NO}_3)_2$ \_\_\_\_\_

13. **Nickel, NiO.**—Before the Bp. on Ch. In O. F. unchanged. In R. F. reduced to metal, slightly magnetic.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Easily reduced to the metal.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_

With borax bead on platinum wire. In O. F. violet while hot, reddish-brown when cold.

[Pg 32]

With  $\text{Co}(\text{NO}_3)_2$  \_\_\_\_\_

14. **Silver, AgO.**—Before the Bp. on Ch. Easily reduced to the metal. White, malleable, hard bead. Coats the coal dark red near assay.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Instantly reduced to metallic globule.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. Reduced to the metal.

In flame on platinum wire \_\_\_\_\_

With borax bead on platinum wire. In O. F. partially dissolved. Bead becomes milk-white.

With  $\text{Co}(\text{NO}_3)_2$  \_\_\_\_\_

15. **Tin, SnO<sub>2</sub>.**—Before the Bp. on Ch. Coats the coal yellow while hot, dirty white when cool. Not reduced.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Reduced to metallic tin. White, hard, malleable bead. Coating white and close to assay.[Pg 33]

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_

With borax bead on platinum wire. In O. F. small quantity dissolves to limpid glass.

With  $\text{Co}(\text{NO}_3)_2$ . Greenish-blue color.

16. **Zinc, ZnO.**—Before the Bp. on Ch. Upon ignition becomes yellow. Is not reduced.

Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$ . Reduced to metal. Rapidly volatilized, coating the coal white.

In ignition tube with  $\text{Na}_2\text{CO}_3$  and Ch. \_\_\_\_\_

In flame on platinum wire \_\_\_\_\_

With borax bead on platinum wire. In O. F. yellow while hot, limpid glass when cold.

[Pg 34]

With  $\text{Co}(\text{NO}_3)_2$ . Green mass.

Having now given the principal reactions for the most important metals, we will proceed to the examination of the alkali metals, the alkaline earths, and some of the acid elements.

#### THE ALKALI METALS

**17. Ammonium,  $\text{NH}_4$ .**—This hypothetical compound is commonly classed among the alkali metals from its close resemblance to the members of this group.

To detect the presence of this hypothetical metal, mix the assay with about four parts of  $\text{Na}_2\text{CO}_3$ , place in an ignition tube, and apply heat. The odor of the evolved gas will be recognized, and if a piece of red litmus paper be moistened and held at the mouth of the tube, it will be turned blue by the escaping ammonia gas.

We are not authorized to infer the pre-existence of ammonium, however, from the [Pg 35] appearance of this reaction, for the presence of nitrogenous organic matter in the substance, which would be decomposed by this treatment, would give rise to such a reaction.

**18. Potassium.**—Potassium is recognized by the color which its salts impart to the Bunsen flame. If a portion of a salt of potassium be held on a platinum wire in the flame, it imparts a blue-violet tint which rapidly disappears.

**19. Sodium.**—Like potassium, this alkali metal is detected by the color which its salts give to the flame.

If a sodium salt be held on the platinum wire in the flame, it imparts an intense yellow color.

The extreme delicacy of this reaction has been mentioned elsewhere. The value [Pg 36] of this test is really lessened by its great delicacy, for it is possible to detect minute quantities of sodium in almost all substances, although it may not be in chemical combination. As an example, draw the platinum wire between the fingers, and then place in flame, and note presence of sodium.

**20. Lithium,  $\text{Li}_2\text{O}$ .**—In the Bunsen flame on the platinum wire it imparts a carmine-red tinge.

Hydrochloric acid on the sample augments the coloration.

## THE ALKALINE EARTHS

21. **Barium, BaO.**—In the Bunsen flame on the platinum wire it imparts an apple-green coloration. This reaction is intensified by moistening the sample with hydrochloric acid.[Pg 37]

22. **Calcium, CaO.**—In the Bunsen flame on the platinum wire it imparts an orange-red color, which appears gray when seen through blue glass.

Hydrochloric acid on the sample makes the color more intense.

23. **Strontium, SrO.**—In the Bunsen flame on the platinum wire it imparts an intensely red color, which is increased by converting the substance into the chloride.

## THE ACID ELEMENTS

24. **Borates.**—If the substance be finely powdered, moistened with glycerine, and then placed on a platinum wire in the Bunsen flame, it imparts a brilliant green color.

If turmeric paper be dipped into a solution of a borate, and then be dried at 100° C., it is turned to a peculiar red[Pg 38] color. These two reactions are extremely delicate.

25. **Bromides.**—Bromides treated with microcosmic salt and oxide of copper on platinum wire impart to the flame a greenish-blue color, the edges being decidedly green.

26. **Chlorides.**—Chlorides are treated in the same way as bromides. The color imparted to the flame is azure-blue.

To discriminate between bromides and chlorides more clearly, the substance is mixed with anhydrous potassium bisulphate and fused in an ignition tube.

Bromine and sulphur dioxide are evolved (if the substance be a bromide), the tube being filled with a yellow gas possessing the characteristic odor of bromine.

27. **Fluorides.**—A small portion of the substance in a finely powdered condition is[Pg 39] placed in one of the ignition tubes, a strip of moist Brazil-wood paper is introduced into the open end, and heat is applied. Hydrofluoric acid is evolved, and the red color of the paper is changed into a straw-yellow.

Mica, containing only 0.75% of fluorine, shows the reaction clearly.

28. **Iodides.**—Iodides are treated, as the bromides and chlorides, in a bead of microcosmic salt with oxide of copper. The flame is colored green.

Fused with potassium bisulphate in an ignition tube the violet vapors of iodine are evolved, and thus iodides may be distinguished from chlorides and bromides.

29. **Nitrates.**—If a nitrate be heated upon charcoal before the Bp., violent deflagration occurs. If the substance containing[Pg 40] the nitric acid be mixed with a *very small* quantity of finely powdered potassium cyanide, the deflagration is accompanied with ignition and detonation.

If the substance be mixed in a dry condition with dry potassium bisulphate, and is then heated in an ignition tube, red-brown nitrous fumes are evolved. This reaction takes place if there is but a small quantity of nitrate present.

30. **Phosphates.**—Phosphates impart to the flame a bluish green color. The color is made more intense by moistening the substance with sulphuric acid, and then taking the paste so formed on the platinum wire and placing it in the Bunsen flame.

31. **Silicates.**—Silicates, when treated with microcosmic salt on a platinum wire,[Pg 41] suffer decomposition; the bases unite with the phosphoric acid to form a transparent glass in which the silica may be seen floating as a cloudy mass.

The bead must only be examined for silica while hot, since on cooling it becomes opaque.

32. **Sulphides.**—Many sulphides, when heated in an ignition tube, volatilize and give a sublimate of sulphur in combination with the metallic portion of the substance.

A very delicate test for sulphur in whatever combination it may be found in a substance, and which may be performed with great ease, is to mix the finely powdered assay with four parts,  $\text{Na}_2\text{CO}_3$ , and fuse in an ignition tube. When thoroughly fused the tube is broken, and the fused mass is placed on a bright silver coin, and a drop[Pg 42] of water is added. If the substance contains sulphur, a black spot will be observed on the coin where the fused mass was placed.

Before going on to the next chapter, the student should assure himself of his familiarity with the reactions just given, and he should practise with various substances, the nature of which is unknown to him.

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[Pg 43]

## CHAPTER IV

### BEHAVIOR OF SOME OF THE PRINCIPAL ORES BEFORE THE BLOWPIPE

For the sake of practice, and as a fitting introduction to "Determinative Mineralogy," this chapter is appended. It is not intended to give a detailed account of the minerals,

but rather to set before the student the most marked characters, such as hardness, specific gravity, color, lustre, etc.

To determine the hardness of a mineral, we try to scratch it with the minerals forming an arbitrary "scale of hardness," proceeding successively from the softest to the hardest. When we say that a certain mineral has hardness = 4, we mean that the mineral is scratched by 4 on the scale, and[Pg 44] that 4 on the scale is scratched by the mineral. The scale of hardness chiefly in use is the Mohs-Breithaupt scale, which is as follows:—

1. Talc, common laminated light green variety.
2. Gypsum, crystallized.
3. Calcareous spar, transparent variety.
4. Fluor spar, crystalline.
5. Apatite, transparent.
6. Orthoclase, white cleavable variety.
7. Quartz, transparent.
8. Topaz, transparent.
9. Sapphire, cleavable variety.
10. Diamond.

It seldom happens in determining the hardness of a mineral that its hardness exactly conforms to that of some one member of the scale. In such cases we generally estimate the hardness. For example, suppose[Pg 45] a mineral was harder than 4, but softer than 5, and that it was nearer 5 than 4, then we would call its hardness  $4\frac{3}{4}$ .

In order to preserve the scale some operators use a three-cornered file, first cutting the mineral and then the scale until a number is found, which is abraded to about the same depth as the mineral under examination.

Since a set of minerals forming a scale of hardness is not always at hand, the following scale given by Chapman is appended:—

1. Yields easily to the nail.
2. Yields with difficulty to the nail or just receives an impression from it. Does not scratch a copper coin.
3. Scratches a copper coin but is also scratched by it, being of about the same degree of hardness.[Pg 46]



4. Not scratched by a copper coin. Does not scratch glass.
5. Scratches glass with difficulty, leaving its powder on it. Yields readily to the knife.
6. Scratches glass easily. Yields with difficulty to the knife.
7. Does not yield to the knife. Yields to the edge of a file, though with difficulty.
- 8, 9, 10. Harder than flint.

Specific gravity cannot well be determined without the aid of a balance, and hence its value here is not great.

As in the preceding chapter, alphabetic arrangement will be employed.

#### ORES OF ANTIMONY

**Stibnite**,  $\text{Sb}_2\text{S}_3$ , Sb . 71, S . 29.—[\[A\]](#)H = 2, G = 4.52-4.62. Of lead-gray color and metallic lustre. Consists of a large number[Pg 47] of needle-shaped crystals. Brittle. Fuses in candle flame. In an ignition tube yields a sublimate of sulphur. On Ch. before the Bp. it is volatilized, giving antimony coating and tinges the flame pale blue.

[\[A\]](#)H = Hardness, G = Specific Gravity.

#### ORES OF ARSENIC

**Native Arsenic, As.**—This contains traces of Sb, Ag, Fe, Co, and Ni.

H = 3.5, G = 5.7-5.8. Dark gray in color. Fracture tin-white, tarnishing rapidly. Volatilizes before the Bp. on Ch. without melting, giving white coating of arsenious acid and characteristic garlic odor. In ignition tube it sublimes, giving arsenical ring.

**Realgar**,  $\text{AsS}$ , As . 70, S . 30.—H = 1.5-2, G = 3.56. Bright red to orange-red color and resinous lustre. In an ignition tube it fuses and finally sublimes. The sublimate[Pg 48] when cool is red and transparent. Fuses readily before the Bp. on Ch. and burns with pale yellowish flame, emitting gray-white fumes having garlic odor.

**Orpiment**,  $\text{As}_2\text{S}_3$ , As . 61, S . 39.—

H = 1.5-2.0, G = 3.4-3.5.

Lemon-yellow in color and resinous or pearly lustre. Sectile. Before the Bp. on Ch. behaves like realgar, but in an ignition tube it gives a dark yellow sublimate which is transparent.

#### ORES OF BISMUTH

**Native Bismuth, Bi.**—This contains traces of As, Te, and S.

H = 2.0-2.5, G = 9.7-9.83. Color, silver-white, slightly tinged with red. Metallic lustre. Brittle when cold, but may be laminated when hot. Before the Bp. on Ch. behaves like pure Bi.[Pg 49]

**Bismuthite**,  $\text{Bi}_2\text{O}_3$  . 90,  $\text{CO}_2$  . 7,  $\text{H}_2\text{O}$  . 3,—

H = 4.0-4.5, G = 6.9-7.8.

Usually of a white or light greenish color and vitreous lustre, in acicular crystallizations. In an ignition tube decrepitates, yielding water and turning gray. Before the Bp. on Ch. it fuses easily and is reduced to metallic globule, coating the Ch. with  $\text{Bi}_2\text{O}_3$ . With  $\text{Na}_2\text{CO}_3$  it occasionally gives the sulphur reaction.

#### ORES OF CHROMIUM

**Chromic Iron Ore**,  $\text{FeO}$  . 32,  $\text{Cr}_2\text{O}_3$  . 68.— $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MnO}$ , and  $\text{MgO}$  are commonly present. H = 5.5, G = 4.32-4.57. Occurs usually massive. Color, iron-black to brownish black. In many varieties strongly magnetic. Lustre, shining and somewhat metallic. Heated in an ignition tube, remains unchanged. Infusible before the Bp. on Ch.[Pg 50] Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and  $\text{KCN}$  yields metallic iron. In borax bead it slowly dissolves to a clear transparent glass, which is a beautiful green when cool.

#### ORES OF COBALT

**Smaltite**,  $\text{Co}(\text{Fe}, \text{Ni}) \text{As}_2$ , Co . 28, As . 72.—H = 5.5, G = 6.37-7.30. Color, tin-white or steel-gray. Lustre, metallic. When heated to redness in an ignition tube it yields a sublimate of metallic arsenic. Before the Bp. on Ch. it fuses readily, with emission of arsenical fumes, to a grayish black magnetic globule. This globule may be examined for iron, cobalt, and nickel with the borax bead.

**Cobaltite**,  $\text{CoS}_2 + \text{CoAs}_2$ , Co . 36, As . 45, S . 19.—H = 5.5, G = 6.0-6.3. Color, silver-white tinged with red. Metallic lustre. Before the Bp. on Ch. fuses easily, with[Pg 51] emission of copious arsenical fumes, to a gray magnetic globule. Remains unchanged in the ignition tube.

**Linnaeite**,  $(\text{Co}, \text{Ni})_3\text{S}_4$ , (Co, Ni)58, S . 42.—H = 5.5, G = 4.8-5.0. Color, bright steel-gray, sometimes reddish. Lustre, metallic. Crystallizes in the regular octahedron. Before the Bp. on Ch. fuses to a metallic globule which is attracted by the magnet. With borax bead gives reaction for cobalt.

**Erythrite**,  $\text{Co}_3\text{O}_8\text{As}_2 + 8 \text{H}_2\text{O}$ ,  $\text{As}_2\text{S}_5$  . 38.4,  $\text{CoO}$  . 37.6,  $\text{H}_2\text{O}$  . 24.0.—

H = 1.5-2.0, G = 2.95.

Color, crimson to peach-red. When crystallized, of pearly lustre, but frequently dull and earthy. Heated in ignition tube gives off water, and color changes to blue or green. Before the Bp. on Ch. in R. F. it [Pg 52] emits arsenical fumes and melts to a dark gray globule which with the borax bead reacts for cobalt.

#### ORES OF COPPER

##### **Native Copper, Cu.—**

H = 2.5-3, G = 8.5-8.9.

Color, copper-red. Lustre, metallic. Occurs usually massive and very arborescent. Before the Bp. on Ch. it fuses, and if the heat is sufficiently high it assumes a bright bluish-green surface; on cooling it is covered with a coat of black oxide. In the borax bead it reacts for copper.

**Chalcopyrite**,  $\text{CuFeS}_2$ , Cu . 35, Fe . 30, S . 35.—H = 3.5-4, G = 4.1-4.3. Color, brass-yellow, often golden-yellow. Lustre, metallic. Occurs crystallized, but is generally found massive. Is easily scratched [Pg 53] with a knife. Heated in an ignition tube decrepitates, and occasionally yields a faint sublimate of sulphur. Before the Bp. on Ch. it blackens, but becomes red again on cooling. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and KCN it is reduced, and the metals are obtained in separate masses. It reacts with the borax bead for copper and iron.

**Copper Glance**,  $\text{Cu}_2\text{S}$ , Cu . 80, S . 20.—H = 2.5-3.0, G = 5.5-5.8. Color, dark blue to steel-gray. Occurs in compact masses, often very shining. Before the Bp. on Ch. fuses to a globule which boils and emits glowing drops. Sulphur dioxide escapes abundantly, and the outer flame is colored blue. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  yielding a metallic globule.

**Tetrahedrite**,  $4\text{CuS} + \text{Sb}_2\text{S}_3$ .—Frequently contains silver, iron, mercury, and zinc. [Pg 54] H = 3.0-4.0, G = 4.5-5. Color, steel-gray to iron-black. Heated in an ignition tube fuses and gives a sublimate of antimonious oxide. When mercury is present this condenses in the upper part of the tube, forming the characteristic mirror. Before the Bp. on Ch. it fuses readily to a metallic globule, emitting dense white fumes; zinc and antimony coatings are deposited on the Ch. After long ignition before the Bp., if the mineral is finely powdered and mixed with  $\text{Na}_2\text{CO}_3$  and KCN, the ore is reduced to the metal.

**Cuprite**,  $\text{Cu}_2\text{O}$ , Cu . 89, O . 11.—

H = 3.5-4.0, G = 5.5-6.15.

Color, intense crimson-red. Before the Bp. on Ch. blackens and fuses quietly, and finally yields a metallic globule of copper. Before the Bp. [Pg 55] on Ch. with  $\text{Na}_2\text{CO}_3$  and KCN it is easily reduced.

**Malachite**,  $2 \text{CuO} + \text{CO}_2 + \text{H}_2\text{O}$ , CuO . 72,  $\text{CO}_2$  . 20,  $\text{H}_2\text{O}$  . 8.—

H = 3.5-4.0, G = 3.90-4.03.

Color, bright green. Occurs generally in mammillated concretions. Lustre, shining and fracture, silky. Heated in an ignition tube yields water and blackens. Before the Bp. on Ch. it fuses to a metallic globule. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and KCN it is easily reduced. With borax bead gives characteristic coloration.

**Azurite**,  $3 \text{CuO} + 2 \text{CO}_2 + \text{H}_2\text{O}$ , CuO . 69,  $\text{CO}_2$  . 26,  $\text{H}_2\text{O}$  . 5.—

H = 3.5-4.0, G = 3.77-3.83.

Color, azure-blue. Occurs usually in crystallized or globular masses. Lustre, earthy or vitreous. Before the Bp. and with other reagents behaves like malachite.[Pg 56]

**Chrysocolla**,  $\text{CuO} + \text{SiO}_2 + 2 \text{H}_2\text{O}$ ,  $\text{SiO}_2$  . 34.2, CuO . 45.3,  $\text{H}_2\text{O}$  . 20.5.—H = 2.0-3.0, G = 2. Color, bluish-green, closely resembling malachite. Occurs usually as an incrustation, its surface being very smooth, like enamel. In an ignition tube it blackens and yields water. Before the Bp. on Ch. in O. F. it blackens, coloring the flame bright green; in the R. F. it turns red. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  yields metallic copper. In borax bead it reacts for copper.

**Atacamite**,  $\text{CuCl}_2 + 3 \text{CuO}_2\text{H}_2$ —Cl . 16.6, O . 20.3, Cu . 50.1,  $\text{H}_2\text{O}$  . 13.0.—

H = 3.0-3.5, G = 3.75-3.77.

Color, green to blackish green. Lustre, adamantine to vitreous. In an ignition tube yields water. Before the Bp. on Ch. colors flame blue. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and KCN is reduced to the metal. In borax bead it reacts for copper.[Pg 57]

#### ORES OF IRON

**Limonite**,  $2 \text{Fe}_2\text{O}_3 + 3 \text{H}_2\text{O}$ ,  $\text{Fe}_2\text{O}_3$  . 86,  $\text{H}_2\text{O}$  . 14.—H = 5.0-5.5, G = 3.6-4.0. Color, brown to ochre-yellow. Earthy or semi-metallic in appearance. In an ignition tube yields water. Before the Bp. on Ch. infusible. In borax bead reacts for iron.

**Hematite**,  $\text{Fe}_2\text{O}_3$ , Fe . 70, O . 30.—

H = 5.5-6.5, G = 4.9-5.3.

Color, dark steel-gray to iron-black. Lustre, metallic. When pulverized yields a red powder. Before the Bp. on Ch. infusible. After long roasting becomes magnetic. In borax bead gives usual indications of iron.

**Magnetite**,  $\text{Fe}_3\text{O}_4$ ,  $\text{FeO}$  . 31,  $\text{Fe}_2\text{O}_3$  . 69.—

H = 5.5-6.5, G = 5.17-5.18.[Pg 58]

Color, iron-black. Lustre, shining and metallic. Pulverized, its powder is black. It is strongly magnetic. Fuses with difficulty before the Bp. on Ch. In borax bead reacts for iron.

**Pyrites**,  $\text{FeS}_2$ , Fe . 47, S . 53.—

H = 6.0-6.5, G = 4.95-5.20.

Color, brass-yellow. Lustre, metallic. Occurs commonly in cubes. It often contains small quantities of Au, Ag, Cu, As, Co, and Mn. Heated in an ignition tube gives a sublimate of sulphur, the residue becoming magnetic. Before the Bp. on Ch. in O. F. sulphur is burned off and the red oxide remains. This residue may then be examined for iron, etc.

**Marcasite** (White Iron Pyrites).—Having the same general composition as pyrite, but much lighter in color. Crystals, prismatic. Before the Bp. on Ch. behaves like pyrite.[Pg 59]

**Pyrrhotite**,  $\text{Fe}_7\text{S}_8$ , Fe . 60.5, S . 39.5.—

H = 3.5-4.5, G = 4.58-4.64.

Color, bronze-yellow. Closely resembles pyrite, but may be distinguished from it by being feebly magnetic. Heated in an ignition tube yields no sublimate. Before the Bp. on Ch. fuses to a magnetic globule, which exhibits a yellowish crystalline structure when fractured.

**Mispickel**,  $\text{FeAsS}$ , Fe . 34, As . 46, S . 20.—H = 5.5-6.0, G = 6.0-6.2. Color, silver-white. Lustre, metallic; very brittle. Often associated with it we find small quantities of Co, Ag, and Au. Heated in an ignition tube it first yields a red sublimate of sulphide of arsenic, and then afterward a crystalline sublimate of metallic arsenic. Before the Bp. on Ch. emits dense fumes of arsenic and deposits a coating on the[Pg 60] coal; it then fuses to a globule which behaves like pyrrhotite.

**Siderite**,  $\text{FeCO}_3$ ,  $\text{FeO}$  . 62,  $\text{CO}_2$  . 38.—H = 3.5-4.5, G = 3.7-3.9. Color, grayish yellow to reddish brown. Lustre, pearly. Crystallizes in rhombohedrons with curved faces; these crystals are distinctly cleavable and massive. Heated in an ignition tube it decrepitates with evolution of carbon dioxide. Before the Bp. on Ch. infusible. Before

the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  it fuses to a magnetic mass. With borax bead it reacts for iron and sometimes for manganese.

#### ORES OF LEAD

**Galena**,  $\text{PbS}$ , Pb . 87, S . 13.—

H = 2.5, G = 7.4-7.6.

Color, bluish gray, slowly tarnishing. Lustre, metallic. Crystals in the form of cubes.[Pg 61] Heated in an ignition tube it sometimes decrepitates and yields a sublimate of sulphur. Before the Bp. on Ch. easily reduced to the metallic state, the Ch. becoming coated with sulphate and oxide of lead. The metallic globule usually contains a little silver. To separate this, the process known as "cupellation" is employed. A hole is bored into the Ch. about 1 cm. in diameter and about 6 mm. deep. Into this hole is placed a stiff paste made by mixing finely pulverized bone-ash with a little soda and water. This paste is pressed in hard, and then the surface is smoothed off, and the centre is slightly depressed with the rounded end of a glass rod. The charcoal so prepared is set in a warm place to allow the paste to dry. When the paste is quite dry the small globule of lead is placed in the depression in the centre of the bone-ash "cupel," and is there exposed to the[Pg 62] O. F. from the Bp. The lead is oxidized and is absorbed by the bone-ash, while any silver present will remain in the central depression as a bright shining bead.

**Cerussite**,  $\text{PbCO}_3$ , PbO . 84,  $\text{CO}_2$  . 16.—H = 3.0-3.5, G = 6.46-6.57. Color, white, gray, or yellow. Lustre, adamantine. Crystallizes in prismatic needles. When heated in an ignition tube carbon dioxide is evolved and the residue turns yellow. Before the Bp. on Ch. readily reduced to metallic lead.

**Anglesite**,  $\text{PbSO}_4$ , PbO . 74,  $\text{SO}_3$  . 26.—H = 2.0-3.0, G = 6.12-6.39. Color, yellow, gray, and brown. Lustre, adamantine, resinous. Heated in an ignition tube decrepitates, and sometimes yields a little water. Before the Bp. on Ch. fuses to a clear bead, which on cooling becomes[Pg 63] opaque. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  is reduced to the metal giving a yellow coating. The  $\text{Na}_2\text{CO}_3$  absorbed by the coal reacts for S.

#### ORES OF MANGANESE

**Pyrolusite**,  $\text{MnO}_2$ , Mn . 63.2, O . 36.8.—H = 2.0-2.5, G = 4.82. Color, iron-black to steel-gray. Lustre, non-metallic. Heated in an ignition tube yields generally a little water, and if the temperature be high enough, oxygen is evolved. Before the Bp. on Ch. infusible. In borax bead gives characteristic color.

**Psilomelane**,  $\text{Mn}_2\text{O}_3 + \text{H}_2\text{O}$ .—

H = 5.5-6.0, G = 3.7-4.7.

Color, iron-black to steel-gray. Generally resembles pyrolusite, but is distinguished from it by its superior hardness. It frequently [Pg 64] contains BaO and Li<sub>2</sub>O. It behaves before the Bp. like pyrolusite.

**Wad** (Bog Manganese).—This mineral is essentially MnO<sub>2</sub>, MnO, and H<sub>2</sub>O, with small quantities of Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, BaO, SiO<sub>2</sub>, etc., associated with it.

H = 0.5-6.0, G = 3.0-4.2. Color, dull black. Heated in an ignition tube yields water in abundance, otherwise it behaves like pyrolusite.

#### ORES OF MERCURY

**Native Mercury, Hg.**—G = 13.5-13.6. Color, silver-white. Is liquid at all ordinary temperatures. Heated in an ignition tube is volatilized, the vapors condensing in the upper end of tube to small metallic globules of Hg. Before the Bp. on Ch. it is volatilized. Frequently contains Ag. [Pg 65]

**Cinnabar, HgS<sub>2</sub>, Hg . 86, S . 14.**—

H = 2.0-2.5, G = 8.0-8.2.

Color, scarlet-red to brick-red. Lustre, non-metallic. When pulverized yields a powder of vermilion-red color. Heated in an ignition tube it volatilizes, yielding a black sublimate, which by friction becomes red. Before the Bp. on Ch. it is wholly volatilized. Heated in an ignition tube with Na<sub>2</sub>CO<sub>3</sub> metallic mercury sublimes, condensing in the upper portion of the tube in minute globules.

#### ORES OF NICKEL

**Millerite, NiS, Ni . 64.4, S . 35.6.**—

H = 3.0-3.5, G = 5.2-5.6.

Color, brass-yellow. Brittle. Before the Bp. on Ch. it fuses to a magnetic, metallic globule. The roasted mineral gives in the borax bead the color reaction characteristic [Pg 66] of nickel, and sometimes that of cobalt, which is often associated with it.

**Niccolite, NiAs, Ni . 44, As . 56.**—

H = 5.0-5.5, G = 7.35-7.67.

Color, pale copper-red. Lustre, metallic. Very brittle. Heated in an ignition tube yields a copious sublimate of arsenious oxide, the residue falling to a greenish powder. Before the Bp. on Ch. fuses to a white brittle globule emitting arsenical fumes. In borax bead gives color characteristic of nickel. Frequently in this mineral a portion of the arsenic is replaced by antimony.

## ORES OF SILVER

### **Native Silver, Ag.—**

H = 2.5-3.0, G = 10.1-11.0.

Color, silver-white. Lustre, metallic. Ductile and malleable. Usually occurs associated[Pg 67] with Au, As, Sb, Cu, Fe, etc. Before the Bp. on Ch. easily fuses to a globule which is surrounded with a dark red coating on the coal.

### **Argentite, Ag<sub>2</sub>S, Ag . 87.1, S . 12.9.—**

H = 2.0-2.5, G = 7.20-7.36.

Color, blackish lead-gray. Lustre, metallic. Very sectile. Before the Bp. on Ch. in O. F. intumescs with evolution of sulphur dioxide, finally yielding a metallic globule of Ag.

**Pyrargyrite, Ag<sub>3</sub>SbS<sub>3</sub>, Ag . 59.8, Sb . 22.5, S . 17.7.—**H = 2.5, G = 5.77-5.86. Color, black to dark cochineal-red. Lustre, metallic, adamantine. In an ignition tube it yields on continued heating a sublimate of antimony sulphide. Before the Bp. on Ch. it gives a coating [Pg 68]of antimony trioxide. Before the Bp. on Ch. with Na<sub>2</sub>CO<sub>3</sub> is reduced to metallic silver.

**Proustite, Ag<sub>3</sub>S<sub>3</sub>As, Ag . 65.5, As . 15.1, S . 19.4.—**H = 2.0-2.5, G = 5.57-5.64. Color, light red. Lustre, splendent, adamantine. Before the Bp. on Ch. it behaves like pyrargyrite, save that it gives off arsenical fumes instead of antimonious oxide.

**Stephanite, Ag<sub>5</sub>S<sub>4</sub>Sb, Ag . 68.5, Sb . 15.3, S . 16.2.—**H = 2.0-2.5, G = 6.2-6.3. Color, iron-black to blackish gray. Lustre, metallic. Very brittle and fragile. In an ignition tube it decrepitates, fuses, and finally yields a slight sublimate of antimony trisulphide. Before the Bp. on Ch. gives a coating of antimonious oxide. Before the Bp. on Ch. with Na<sub>2</sub>CO<sub>3</sub> a globule of metallic silver is obtained. The mineral frequently contains copper and iron.[Pg 69]

**Kerargyrite, AgCl, Ag . 75.3, Cl . 24.7.—**H = 1.0-1.5, G = 5.52. Color, white, gray, yellowish, greenish to blue. Lustre, resinous, adamantine. Soft like wax. Fuses easily in a candle-flame. Before the Bp. on Ch. it is readily reduced to metallic silver.

## ORES OF TIN

### **Cassiterite, SnO<sub>2</sub>, Sn . 79, O . 21.—**

H = 6.0-7.0, G = 6.8-7.0.

Color, brown, black. Lustre, adamantine, brilliant. Occurs crystallized in square prisms. Reentrant angles characteristic. Before the Bp. on Ch. with Na<sub>2</sub>CO<sub>3</sub> and KCN reduced to a metallic globule of tin. In the borax bead gives characteristic reaction.



**Stannite**,  $2 \text{ Cu}_2\text{S} \cdot \text{SnS}_2 + 2 (\text{FeS} \cdot \text{ZnS}) \text{ Sn} \cdot \text{S}_2$ .—H = 4.0, G = 4.3-4.5. Color,[Pg 70] steel-gray to iron-black. Lustre, metallic. Occurs usually massive and disseminated. Heated in an ignition tube it yields sulphur dioxide. Before the Bp. on Ch. it emits sulphur dioxide and becomes covered with oxide of tin. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and KCN it gives an impure globule of copper. A very difficult mineral to determine.

#### ORES OF ZINC

**Calamine**,  $\text{H}_2\text{Zn}_2\text{O}_5\text{Si}$ ,  $\text{SiO}_2 \cdot 25.0$ ,  $\text{ZnO} \cdot 67.5$ ,  $\text{H}_2\text{O} \cdot 7.5$ .—H = 4.5-5.0, G = 3.4-3.5. Color, white, gray, bluish, or brown. Lustre, vitreous. Brittle. In an ignition tube yields water when heated and becomes milky white. Before the Bp. on Ch. practically infusible. With  $\text{Co}(\text{NO}_3)_2$  it assumes a green color which passes into a fine blue when the heat is increased.[Pg 71]

#### **Smithsonite**,

$\text{Zn} \cdot \text{CO}_3$ ,  $\text{ZnO} \cdot 64.8$ ,  $\text{CO}_2 \cdot 35.2$ .—

H = 5, G = 4.30-4.45. Color, gray, yellow, brown, and green. Lustre, vitreous, pearly. Heated in an ignition tube  $\text{CO}_2$  is evolved, residue appearing white. It often contains impurities of Cd, Pb, Fe, Mn, Ca, and Mg. When these are present the residue in the ignition tube becomes dark on cooling. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  and exposed to the R. F. it is decomposed. It gives the characteristic reaction for zinc with  $\text{Co}(\text{NO}_3)_2$ .

**Zincite**,  $\text{ZnO}$ ,  $\text{Zn} \cdot 80.3$ ,  $\text{O} \cdot 19.7$ .—

H = 4.0-4.5, G = 5.43-5.70.

Color, blood-red. Lustre, brilliant, subadamantine. Before the Bp. on Ch. infusible. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  gives coating of [Pg 72]zinc oxide. Gives characteristic reaction with  $\text{Co}(\text{NO}_3)_2$ . It frequently contains a small quantity of  $\text{Mn}_2\text{O}_3$ , which may be detected in the borax bead.

**Sphalerite**,  $\text{ZnS}$ ,  $\text{Zn} \cdot 67$ ,  $\text{S} \cdot 33$ .—

H = 3.5-4.0, G = 3.9-4.1.

Color, yellow to black. Lustre, resinous, brilliant, and sometimes submetallic. Heated in an ignition tube sometimes decrepitates. Before the Bp. on Ch. infusible. Before the Bp. on Ch. with  $\text{Na}_2\text{CO}_3$  easily reduced. With  $\text{Co}(\text{NO}_3)_2$  gives the characteristic reaction. It frequently contains small quantities of Cd, Hg, Sn, Pb, Au, Ag, etc.[Pg 73]

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## I

*TABLE OF COLORS OF COATINGS ON CHARCOAL*

Element	Color Hot	Color Cold
Antimony	(Rather volatile)	White
Arsenic	(Very volatile)	White
Bismuth	Orange-Yellow	Lemon-Yellow
Cadmium	Brownish Yellow	Reddish Brown
Lead	Lemon-Yellow (volatile)	Lemon-Yellow
Silver	Dark Red	Dark Red
Tin	Faint Yellow	White
Zinc	Yellow	White

## II

*TABLE OF FLAME COLORATIONS*

Red	Yellow	Green	Bluish Green	Blue	Violet
Calcium	Sodium	Barium	Bromine	Chlorine	Potassium
Lithium		Boron	Copper		
Strontium		Iodine	Phosphorus		

[Pg 74]

## III

*TABLE OF COLORS OF BORAX BEADS IN OXIDIZING FLAME*

Element	Color Hot	Color Cold
Aluminum	Colorless to Cloudy	Colorless to Cloudy
Antimony	Yellowish	Colorless

Barium	Colorless to Opaque	Colorless to Opaque
Bismuth	Yellow	Colorless
Cadmium	Yellow	Colorless to White
Calcium	Colorless	Colorless
Chromium	Reddish Yellow	Yellowish Green
Cobalt	Blue	Blue
Copper	Green	Greenish Blue
Iron	Orange	Yellow
Lead	Yellow	Colorless
Magnesium	Colorless	Colorless
Manganese	Violet	Reddish Violet
Nickel	Violet	Reddish Brown
Silver	Colorless	Milk-White
Strontium	Colorless to Opaque	Colorless to Opaque
Tin	Colorless	Colorless
Zinc	Yellowish	Colorless

[Pg 75]

#### IV

##### *TABLE OF COLORS OF BORAX BEADS IN REDUCING FLAME*

Element	Color Hot	Color Cold
Aluminum	Colorless	Colorless
Antimony	Colorless	Cloudy

Barium	Colorless	Colorless
Bismuth	Colorless	Gray—Cloudy
Cadmium	Colorless	Gray—Cloudy
Calcium	Colorless	Colorless
Chromium	Green	Green
Cobalt	Blue	Blue
Copper	Colorless	Red
Iron	Yellowish Green	Yellowish Green
Lead	Colorless	Gray
Magnesium	Colorless	Colorless
Manganese	Colorless	Pink
Nickel	Colorless	Gray—Cloudy
Silver	Colorless	Gray
Strontium	Colorless	Colorless
Tin	Colorless	Colorless
Zinc	Colorless	Gray

[Pg 76]

V

*TABLE OF COLORS OF MICROCOSMIC SALT BEADS IN OXIDIZING FLAME*

Element	Color Hot	Color Cold
Aluminum	Colorless	Colorless
Antimony	Yellowish	Colorless

Barium	Colorless to Opaque	Colorless to Opaque
Bismuth	Yellow	Colorless
Cadmium	Yellowish	Colorless
Calcium	Colorless	Colorless to Opaque
Chromium	Reddish	Green
Cobalt	Blue	Blue
Copper	Green	Greenish Blue
Iron	Red	Brownish Red
Lead	Yellowish	Colorless
Magnesium	Colorless	Colorless
Manganese	Brownish Violet	Reddish Violet
Nickel	Reddish	Yellow
Silver	Yellowish	Yellowish
Strontium	Colorless	Colorless
Tin	Colorless	Colorless
Zinc	Yellowish	Colorless

[Pg 77]

# VI

## *TABLE OF COLORS OF MICROCOSMIC SALT BEADS IN REDUCING FLAME*

Element	Color Hot	Color Cold
Aluminum	Colorless	Colorless
Antimony	Colorless	Gray—Cloudy

Barium	Colorless	Colorless
Bismuth	Colorless	Gray—Cloudy
Cadmium	Colorless	Gray—Cloudy
Calcium	Colorless	Colorless
Chromium	Reddish	Green
Cobalt	Blue	Blue
Copper	Dark Green	Brownish Red
Iron	Red	Reddish
Lead	Colorless	Gray—Opaque
Magnesium	Colorless	Colorless
Manganese	Colorless	Colorless
Nickel	Colorless	Gray
Silver	Colorless	Gray
Strontium	Colorless	Colorless
Tin	Colorless	Colorless
Zinc	Colorless	Gray—Cloudy

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