CHEMICAL EXAMINATION OF MINERALS.

462. The complete investigation of the chemical composition of a mineral includes, first, the identification of the elements present by qualitative analysis, and, second, the determination of the relative amounts of each by quantitative analysis, from which last the formula can be calculated. Both processes carried out in full call for the equipment of a chemical laboratory. An approximate qualitative analysis, however, can, in many cases, be made quickly and simply with few conveniences. The methods employed involve either (*a*) the use of acids or other reagents "in the wet way," or (*b*) the use of the blowpipe, or of both methods combined. Some practical instructions will be given applying to both cases.

EXAMINATION IN THE WET WAY.

463. Reagents, etc.—The most commonly employed chemical reagents are the three mineral acids, hydrochloric, nitric, and sulphuric acids. To these may be added ammonia, also solutions of barium chloride, silver nitrate, ammonium molybdate, ammonium oxalate; finally, distilled water in a wash-bottle.

A few test-tubes are needed for the trials and sometimes a porcelain dish with a handle called a casserole; further, a glass funnel and filter-paper. The Bunsen gas-burner (p. 256) is the best source of heat, though an alcohol lamp may take its place. It is unnecessary to remark that the use of acids and the other reagents requires much care to avoid injury to person or clothing.

In testing the powdered mineral with the acids, the important points to be noted are: (1) the degree of solubility, and (2) the phenomena attending entire or partial solution; that is, whether (*a*) a solution is obtained quietly, without effervescence, and, if so, what its color is; or (*b*) a gas is evolved, producing effervescence; or (*c*) an insoluble constituent is separated out.

464. Solubility.—In testing the degree of solubility hydrochloric acid is most commonly used, though in the case of many metallic minerals, as the sulphides and compounds of lead and silver, nitric acid is required. Less often sulphuric acid and aqua regia (nitro-hydrochloric acid) are resorted to.

The trial is usually made in a test-tube, and in general the fragment of mineral to be examined should be first carefully pulverized in an agate mortar. In most cases the heat of the Bunsen burner must be employed.

(*a*) Many minerals are completely *soluble without effervescence;* among these are some of the oxides, as hematite, limonite, göthite, etc.; some sulphates, many phosphates and arsenates, etc. Gold and platinum are soluble only in aqua regia or nitro-hydrochloric acid.

A yellow solution is usually obtained if much iron is present; a blue or greenish-blue solution (turning deep blue on the addition of ammonia in excess) from compounds of copper; pink or pale rose from cobalt, etc.

(*b*) *Solubility with effervescence* takes place when the mineral loses a gaseous ingredient, or when one is generated by the mutual reaction of acid and mineral. Most conspicuous here are the *carbonates,* all of which dissolve with effervescence, giving off the odorless gas *carbon dioxide* (CO_2), though some of them only when pulverized, or, again, on the addition of heat. In applying this test dilute hydrochloric acid is employed.

Sulphureted hydrogen, or hydrogen sulphide (H_2S), is evolved by some sulphides when dissolved in hydrochloric acid: this is true of sphalerite, stibnite, etc. This gas is readily recognized by its offensive odor.

Chlorine is evolved by oxides of manganese and also chromic and vanadic acid salts when dissolved in hydrochloric acid.

Nitrogen dioxide (NO_2) is given off, in the form of red suffocating fumes, by many metallic minerals, and also some of the lower oxides (cuprite, etc.), when treated with nitric acid.

(*c*) The *separation of an insoluble ingredient* takes place: With many silicates, the *silica* separating sometimes as a fine powder, and again as a jelly; in the latter case the mineral is said to *gelatinize* (sodalite, analcite). In order to test this point the finely pulverized silicate is digested with strong hydrochloric acid, and the solution afterward slowly evaporated nearly to dryness. With a considerable number of silicates the gelatinization takes place only after ignition; while some others, which ordinarily gelatinize, are rendered insoluble by ignition.

With many sulphides (as pyrite) a separation of *sulphur* takes place when they are treated with nitric acid.

Some compounds of titanium and tungsten are decomposed by hydrochloric acid with the separation of the oxides of the elements named (TiO_2, WO_3). The same is true of salts of molybdic and vanadic acids, only that here the oxides are soluble in an excess of the acid.

Compounds containing silver, lead, and mercury give with hydrochloric acid insoluble residues of the *chlorides.* These compounds are, however, soluble in nitric acid.

When compounds containing tin are treated with nitric acid, the *tin dioxide* (SnO_2) separates as a white powder. A corresponding reaction takes place under similar circumstances with minerals containing arsenic and antimony.

Insoluble Minerals.—A large number of minerals are not sensibly attacked by any of the acids. Among these may be named the following oxides: Corundum, spinel, chromite, diaspore, rutile, cassiterite, quartz; also cerargyrite; many silicates, titanates, tantalates, and niobates; some of the sulphates, as barite, celestite; many phosphates, as xenotime, lazulite, childrenite, amblygonite; also the borate, boracite.

465. Examination of the Solution.—If the mineral is difficultly, or only partially, soluble, the question as to solubility or insolubility is not always settled at once. Partial solution is often shown by the color given to the liquid, or more generally by the precipitate yielded, for example, on the addition of ammonia to the liquid filtered off from the remaining powder. The further examination of the solution yielded, whether from partial or complete solution, after the separation by filtration of any insoluble residue, requires the systematic laboratory methods of qualitative analysis.

It may be noted, however, that in the case of sulphates the presence of *sulphur* is shown by the precipitation of a heavy white powder of barium sulphate ($BaSO_4$) when barium chloride is added. The presence of *silver* in solution is shown by the separation of a white curdy precipitate of silver chloride ($AgCl$) upon the addition of any chlorine compound; conversely, the same precipitate shows the presence of *chlorine* when silver nitrate is added to the solution.

Again, *phosphorus* may be detected if present, even in small quantity, in a nitric acid solution of a mineral by the fine yellow powder which separates, sometimes after standing, when ammonium molybdate has been added.

EXAMINATION BY MEANS OF THE BLOWPIPE.*

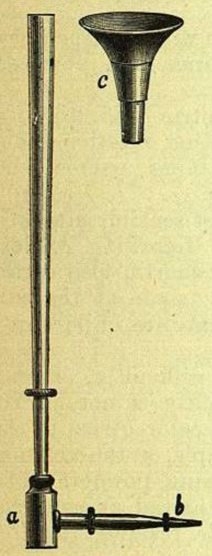
466. The use of the blowpipe, in skilled hands, gives a quick method of obtaining a partial knowledge of the qualitative composition of a mineral. The apparatus needed includes the following articles:

Blowpipe, lamp, platinum-pointed forceps, platinum wire, charcoal, glass tubes; also a small hammer with sharp edges, a steel anvil an inch or two long, a horseshoe magnet, a small agate mortar, a pair of cutting pliers, a three-cornered file.

Further, test-paper, both turmeric and blue litmus paper; a little pure tin-foil; also in small wooden boxes the fluxes: borax (sodium tetraborate), soda (anhydrous sodium carbonate), salt of phosphorus or microcosmic salt (sodium-ammonium phosphate), acid potassium sulphate ($HKSO_4$); also a solution of cobalt nitrate in a dropping bulb or bottle; further, the three acids mentioned in Art. **463**.

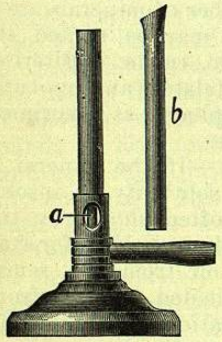
467. Blowpipe and Lamp.—A good form of *blowpipe* is shown in Fig. 570. The air-chamber, at *a*, is essential to stop the condensed moisture of the breath, but the tip (*b*), of platinum or of brass, though convenient is not essential, and many will prefer to do without the mouthpiece (*c*).

570.



The most convenient form of *lamp* is that furnished by an ordinary Bunsen gas-burner † (Fig. 571), provided with a tube, *b*, which when inserted cuts off the air-supply at *a*; the gas then burns at the top with the usual yellow flame. This flame should be one to one and a half inches high. The tip of the blowpipe is held near (or just within the flame, see beyond), and the air blown through it causes the flame to take the shape shown in Figs. 573, 574.

571.



It is necessary to learn to blow *continuously*, that is, to keep up a blast of air from the compressed reservoir in the mouth-cavity while respiration is maintained through the nose. To accomplish this successfully and at the same time to produce a clear flame without unnecessary fatiguing effort calls for some practice.

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* The subject of the blowpipe and its use is treated very briefly in this place. The student who wishes to be fully informed not only in regard to the use of the various instruments, but also as to all the valuable reactions practically useful in the identification of minerals, should consult a manual on the subject. The Manual of Determinative Mineralogy, with an introduction on Blowpipe Analysis, by George J. Brush; revised and enlarged by Samuel L. Penfield (New York, 1896), is particularly to be recommended. Another recent work is the Manual of Qualitative Blowpipe Analysis and Determinative Mineralogy by F. M. Endlich (New York, 1892).

† Instead of this, a good stearin candle will answer, or an oil flame with flat wick.

When the tube, *b*, is removed, the gas burns with a colorless flame and is used for heating glass tubes, test-tubes, etc. An alcohol lamp will serve the same purpose.

468. Forceps. Wire.—The *forceps* (Fig. 572) are made of steel, nickel-plated, and should have a spring strong enough to support firmly the small fragment of mineral between the platinum points at *d*. The steel points at the other end are used to pick up small pieces of minerals, but must not be inserted in the flame. Care must be taken not to injure the platinum by allowing it to come in contact with the fused mineral, especially if this contains antimony, arsenic, lead, etc.

The *platinum wire* required should be of the size designated No. 27. A piece of platinum-foil is often useful; also a small platinum spoon.

469. Charcoal.—The *charcoal* employed should not snap and should yield but little ash; the kinds made from basswood, pine or willow are best. It is most conveniently employed in rectangular pieces, say four inches long, an inch wide, and three-quarters of an inch in thickness. The surface must always be perfectly clean before each trial.

572.

Instead of charcoal a support of the metal aluminium, as suggested by Ross, is used by some workers with good results.

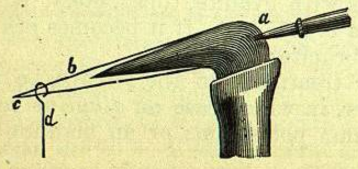
470. Glass Tubes.—The glass tubes should be of rather hard glass and say one-sixth to one-quarter of an inch in interior diameter. The smaller size is suitable for the *closed tubes;* these are simply made by heating a piece six inches long in the middle and then drawing the ends apart, the long ends being fused and pinched off. The larger size serves for *open tubes,* which may be five inches or so in length.

471. Blowpipe Flame.—The blowpipe flame, shown in Figs. 573, 574, consists of two cones: an inner of a blue color, and an outer cone which is nearly invisible. The heat is most intense just beyond the extremity of the blue flame, and the mineral is held at this point when its *fusibility* is to be tested.

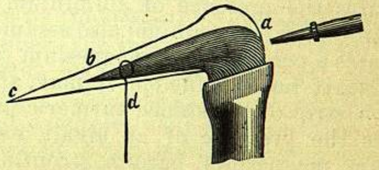
The outer cone is called the OXIDIZING FLAME (O.F.); it is characterized by the excess of the oxygen of the air over the carbon of the gas to be combined with it, and has hence an *oxidizing* effect upon the assay. This flame is best produced when the jet of the blowpipe is inserted a very little in the gas flame (see Fig. 573); it should be entirely non-luminous. The mineral is to be held at *d*.

The inner flame is called the REDUCING FLAME (R.F.); it is characterized by the excess of the carbon or hydrocarbons of the gas, which at the high temperature present tend to combine with the oxygen of the mineral brought into it (at *d*), or, in other words, *to reduce* it. The best reducing flame is produced when the blowpipe is held a little distance from the gas flame; it should retain the yellow color of the latter on its upper edge (see Fig. 574).

573.



574.



472. Methods of Examination.—The blowpipe investigation of minerals includes their examination, (1) in the platinum-pointed forceps, (2) in the closed and the open tubes, (3) on charcoal or other support, and (4) with the fluxes on the platinum wire.

1. EXAMINATION IN THE FORCEPS.

473. Use of the Forceps.—Platinum-pointed forceps are employed to hold the fragment of the mineral while a test is made as to its fusibility; also when the presence of a volatile ingredient which may give the flame a characteristic color is tested for, etc.

The following practical points must be regarded : (1) Metallic minerals, especially those containing arsenic or antimony, which when fused might injure the platinum, should first be examined on charcoal *; (2) the fragment taken should be thin, and as small as can conveniently be held, with its edge projecting well beyond the points ; (3) when decrepitation takes place, the heat must be applied slowly, or, if this does not prevent it, the mineral may be powdered and a paste made with water, thick enough to be held in the forceps or on the platinum wire ; or the paste may, with the same end in view, be heated on charcoal ; (4) the fragment whose fusibility is to be tested must be held in the hottest part of the flame, just beyond the extremity of the blue cone.

474. Fusibility.—All grades of fusibility exist among minerals, from those which fuse in large fragments in the flame of the candle (stibnite, see below) to those which fuse only on the thinnest edges in the hottest blowpipe flame (bronzite); and still again there are a considerable number which are entirely infusible (*e.g.*, corundum).

The exact determination of the temperature of fusion is not easily accomplished (cf. Art. **413**, p. 232), and for purposes of determination of species it is unnecessary. The approximate *relative* degree of fusibility is readily fixed by referring the mineral to the following scale, suggested by von Kobell:

1. Stibnite.
2. Natrolite.
3. Almandite Garnet.
4. Actinolite.
5. Orthoclase.
6. Bronzite.

475. In connection with the trial of fusibility, the following phenomena may be observed: (*a*) *coloration* of the flame (see Art. **476**); (*b*) *swelling up* (stilbite), or *exfoliation* of the mineral (vermiculite); or (*c*) *glowing* without fusion (calcite); and (*d*) *intumescence*, or a spirting out of the mass as it fuses (scapolite).

The color of the mineral after ignition is to be noted; and the nature of the fused mass is also to be observed, whether a clear or blebby glass is obtained, or a black slag; also whether the bead or residue is magnetic or not (due to iron, less often nickel, cobalt), etc.

The ignited fragment, if nearly or quite infusible, may be moistened with the cobalt solution and again ignited, in which case, if it turns *blue*, this indicates the presence of aluminium (as with cyanite, topaz, etc.); but note that zinc silicate (calamine) also assumes a blue color. If it becomes *pink*, this indicates a compound of magnesium (as brucite).

Also, if not too fusible, it may, after treatment in the forceps, be placed upon a strip of moistened turmeric paper, in which case an *alkaline* reaction proves the presence of an alkali, sodium, potassium; or an alkaline earth, calcium, magnesium, barium, strontium.

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* Arsenic, antimony, and easily reducible metals like lead, also copper, form more or less fusible alloys with platinum.

476. Flame Coloration.—The color often imparted to the outer blowpipe flame, while the mineral held in the forceps is being heated, makes possible the identification of a number of the elements.

The colors which may be produced, and the substances to whose presence they are due, are as follows:

Color.	Substance.
Carmine-red	Lithium.
Purple-red	Strontium.
Orange-red	Calcium.
Yellow	Sodium.
Yellowish green	Barium.
Siskine-green	Boron.
Emerald-green	Oxide of copper.
Bluish green	Phosphoric acid (phosphates).
Greenish blue	Antimony.
Whitish blue	Arsenic.
Azure-blue	Chloride of copper; also selenium.
Violet	Potassium.

A yellowish-green flame is also given by the oxide or sulphide of molybdenum; a bluish-green flame (in streaks) by zinc; a pale greenish flame by tellurium; a blue flame by lead.

477. Notes.—The presence of soda, even in small quantities, produces a yellow flame, which (except in the spectroscope) more or less completely masks the coloration of the flame due to other substances, *e.g.*, potassium. The use of a wedge of blue glass then allows the characteristic violet color to be observed. Silicates are often so difficultly decomposed that no distinct color is obtained even when the substance is present; in such cases (*e.g.*, potash feldspar) the powdered mineral may be fused on the platinum wire with an equal volume of gypsum, when the flame can be seen (at least through blue glass). Again, a silicate like tourmaline fused with a mixture of fluorite and acid potassium sulphate yields the characteristic green flame of boron. Phosphates and borates give the green flame in general best when they have been pulverized and moistened with sulphuric acid. Moistening with hydrochloric acid makes the coloration in many cases (as with the carbonates of calcium, barium, strontium) more distinct.

2. HEATING IN THE CLOSED AND OPEN TUBES.

478. The tubes are useful chiefly for examining minerals containing volatile ingredients, given off at the temperature of the gas flame.

In the case of the *closed tube*, the heating goes on practically uninfluenced by the air present, since this is driven out of the tube in the early stages of the process. In the *open tube*, on the other hand, a continual stream of hot air, that is, of hot oxygen, passes over the assay, tending to produce oxidation and hence often materially changing the result.

479. Closed Tube.—A small fragment is inserted, or a small amount of the powdered mineral—in this case with care not to soil the sides of the tube—and heat is applied by means of the ordinary Bunsen flame. The presence of a volatile ingredient is ordinarily shown by the deposit, or *sublimate*, upon the tube at some distance above the assay where the tube is relatively cool.

Independent of this, other phenomena may be noted, namely: *decrepitation*, as shown by fluorite, calcite, etc.; *glowing*, as exhibited by gadolinite; *phosphorescence*, of which fluorite is an example; *change of color* (limonite), and here the color of the mineral should be noted both when hot, and again after cooling; *fusion*; giving off *oxygen*, as mercuric oxide; yielding *acid* or *alkaline vapors*, which should be tested by inserting a strip of moistened litmus or turmeric paper in the tube.

Of the *sublimates* which form in the tube, the following are those with which it is most important to be familiar:

Substance.	Sublimate in the Closed Tube.
Water (H_2O)	Colorless liquid drops.
Sulphur (S)	Red to deep yellow, liquid; pale yellow, solid.
Tellurium dioxide (TeO_2)	Pale yellow to colorless, liquid; colorless or white, solid.
Arsenic sulphide (As_2S_3)	Dark red, liquid; reddish yellow, solid.
Antimony oxysulphide (Sb_2S_2O)	Black to reddish brown on cooling, solid.
Arsenic (As)	Black, brilliant metallic to gray crystalline, solid.
Mercury sulphide (HgS)	Deep black, red when rubbed very fine.
Mercury (Hg)	Gray metallic globules.

In addition to the above: Tellurium gives black fusible globules; selenium the same, but in part dark red when very small; the chloride of lead and oxides of arsenic and antimony give white solid sublimates.

480. Open Tube.—The small fragment is placed in the tube about an inch from the lower end, the tube being slightly inclined (say 20°), but not enough to cause the mineral to slip out, and heat applied beneath. The current of air passing upward through the tube during the heating process has an oxidizing effect. The special phenomena to be observed are the formation of a *sublimate* and the *odor* of the escaping gases. The acid or alkaline character of the vapors is tested for in the same way as with the closed tube. Fluorides, when heated in the open tube with previously fused salt of phosphorus, yield hydrofluoric acid, which gives an acid reaction with test-paper, has a peculiar pungent odor, and corrodes the glass.

The more important sublimates are as follows:

Substance.	Sublimate in the Open Tube.
Arsenic trioxide (As_2O_3)	White, crystalline, volatile.
Antimony antimonate (Sb_2O_4)	Straw-yellow, hot; white, cold. Infusible, non-volatile, amorphous. Obtained from stibnite, also the sulph-antimonites (*e.g.*, bournonite) as dense white fumes. Usually accompanied by the following:
Antimony trioxide (Sb_2O_3)	White, crystalline, slowly volatile. From native antimony and compounds not containing sulphur.*
Tellurium dioxide (TeO_2)	White to pale yellow globules.
Selenium dioxide (SeO_2)	White, crystalline, volatile.
Molybdenum trioxide (MoO_3)	Pale yellow, hot; white, cold.
Mercury (Hg)	Gray metallic globules, easily united by rubbing.

It is also to be noted that if the heating process is too rapid for full oxidation, sublimates, like those of the closed tubes, may be formed, especially with sulphur (yellow), arsenic (black), arsenic sulphide (orange), mercury sulphide (black), antimony oxysulphide (black to reddish brown).

3. HEATING ON CHARCOAL.

481. The fragment (or powder) to be examined is placed near one end of the piece and this so held that the flame passes along its length; a slight ridge to prevent the mineral being blown off is sometimes useful. If the mineral decrepitates, it may be powdered, mixed with water, and then the material employed as a paste.

The reducing flame is employed if it is desired to *reduce* a metal (*e.g.*, silver, copper) from its ores: this is the common case. If, however, the mineral is to be *roasted*, that is, heated in contact with the air so as to oxidize and volatilize, for example, the sulphur, arsenic, antimony present, the oxidizing flame is needed and the mineral should be in powder and spread out.

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* The distinction here made is important; cf. Penfield, revised edition of Brush's Determinative Mineralogy, 1896.

The points to be noted are as follows:

(*a*) The *odor* given off after short heating. In this way the presence of *sulphur*, *arsenic* (garlic or alliaceous odor), and *selenium* (odor of decayed horseradish) may be recognized.

(*b*) *Fusion.*—In the case of the salts of the alkalies the fused mass is absorbed into the charcoal; this is also true, after long heating, of the carbonates and sulphates of barium and strontium. (Art. **484.**)

(*d*) *The Sublimate.*—By this means the presence of many of the metals may be determined. The color of the sublimate, both near the assay (N) and at a distance (D), as also when hot and when cold, is to be noted.

The important sublimates are the following:

Substance.	Sublimate on Charcoal.
Arsenic trioxide (As_2O_3)	White, very volatile, distant from the assay; also garlic fumes.
Antimony oxides (Sb_2O_3 and Sb_2O_4)	Dense white, volatile; forms near the assay.
Zinc oxide (ZnO)	Canary-yellow, hot; white, cold; moistened with cobalt nitrate and ignited (O.F.) becomes green.
Molybdenum trioxide (MoO_3)	Pale yellow, hot; yellow, cold; touched for a moment with the R.F. becomes azure-blue. Also a copper-red sublimate (MoO_2) near the assay.
Lead oxide (PbO)	Dark yellow, hot; pale yellow, cold. Also (from sulphides) dense white (resembling antimony), a mixture of oxide, sulphite, and sulphate of lead.
Bismuth trioxide (Bi_2O_3)	Dark orange-yellow (N), paler on cooling; also bluish white (D). See further, p. 265.
Cadmium oxide (CdO)	Nearly black to reddish brown (N) and orange yellow (D); often iridescent.

To the above are also to be added the following:

Selenium dioxide, SeO_2, sublimate steel-gray (N) to white tinged with red (D); touched with R.F. gives an azure-blue flame; also an offensive selenium odor.

Tellurium dioxide, TeO_2, sublimate dense white (N) to gray (D); in R.F. volatilizes with green flame.

Tin dioxide, SnO_2, sublimate faint yellow hot to white cold; becomes bluish green when moistened with cobalt solution and ignited.

Silver (with lead and antimony), sublimate reddish.

(*e*) *The Infusible Residue.*—This may (1) glow brightly in the O.F., indicating the presence of calcium, strontium, magnesium, zirconium, zinc, or tin. (2) It may give an alkaline reaction after ignition: alkaline earths. (3) It may be magnetic, showing the presence of iron (or nickel). (4) It may yield a globule or mass of a metal (Art. **482**).

482. Reduction on Charcoal.—In many cases the reducing flame alone suffices on charcoal to separate the metal from the volatile element present, with the result of giving a globule or metallic mass. Thus silver is obtained from argentite (Ag_2S) and cerargyrite (AgCl); copper from chalcocite (Cu_2S) and cuprite (Cu_2O), etc. The process of reduction is always facilitated by the use of soda as a flux, and this is in many cases (sulpharsenites, etc.) essential.

The finely pulverized mineral is intimately mixed with soda, and a drop of water added to form a paste. This is placed in a cavity in the charcoal, and subjected to a strong reducing flame. More soda is added as that present sinks into the coal, and, after the process has been continued some time, a metallic globule is often visible, or a number of them, which can be removed and separately examined. If not distinct, the remainder of the flux, the assay, and the surrounding coal are cut out with a knife, and the whole ground up in a mortar, with the addition of a little water. The charcoal is carefully washed away and the metallic globules, flattened out by the process, remain behind. Some metallic oxides are very readily reduced, as lead, while others, as copper and tin, require considerable skill and care.

The metals obtained (in globules or as a metallic mass) may be: *iron*, *nickel*, or *cobalt*, recognized by their being attracted by the magnet; *copper*, color red; *bismuth*, lead-gray, brittle; *gold*, yellow, not soluble in nitric acid; *silver*, white, soluble in nitric acid, the solution giving a silver chloride precipitate (p. 255); *tin*, white, harder than silver, soluble in nitric acid with separation of white powder (SnO_2); *lead*, lead-gray (oxidizing), soft and fusible. The coatings (see the list of sublimates above) often serve to identify the metal present.

The metals obtained may be also tested with borax on the platinum wire.

483. Detection of Sulphur in Sulphates.—By means of soda on charcoal the presence of sulphur in the sulphates may be shown, though they do not yield it upon simple heating. When soda is fused on charcoal with a compound of sulphur (sulphide or sulphate), sodium sulphide is formed, and if much sulphur is present the mass will have the *hepar* (liver-brown) color. In any case the presence of the sulphur is shown by placing the fused mass on a clean surface of silver, and adding a drop of water; a black or yellow stain of silver sulphide will be formed. Illuminating gas often contains sulphur, and hence, when it is used, the soda should be first tried alone on charcoal, and if a sulphur reaction is obtained (due to the gas), a candle or lamp must be employed in the place of the gas.

484. It is also useful in the case of many minerals to test their fusibility or infusibility with soda, generally on the platinum wire. Silica forms if not in excess a clear glass with soda, so also titanic acid. Salts of barium and strontium are fusible with soda, but the mass is absorbed by the coal. Many silicates, though alone difficultly fusible, dissolve in a little soda to a clear glass, but with more soda they form an infusible mass. Manganese, when present even in minute quantities, gives a bluish-green color to the soda bead.

4. TREATMENT ON THE PLATINUM WIRE.

485. Use of the Fluxes.—The three common fluxes are borax, salt of phosphorus, and carbonate of soda (p. 254). They are generally used with the platinum wire, less often on charcoal (see p. 260). If the wire is employed it must have a small loop at the end; this is heated to redness and dipped into the powdered flux, and the adhering particles fused to a bead; this operation is repeated until the loop is filled. Sometimes in the use of soda the wire may at first be moistened a little to cause it to adhere.

When the bead is ready it is, while hot, brought in contact with the powdered mineral, some of which will adhere to it, and then the heating process may be continued. Very little of the mineral is in general required, and the experiment should be commenced with a minute quantity and more added if necessary. The bead must be heated successively first in the oxidizing flame (O.F.) and then in the reducing flame (R.F.), and in each case the color noted when *hot* and when *cold*. The phenomena connected with fusion, if it takes place, must also be observed.

Minerals containing sulphur or arsenic, or both, must be first *roasted* (see p. 261) till these substances have been volatilized. If too much of the mineral has been added and the

bead is hence too opaque to show the color, it may, while hot, be flattened out with the hammer, or drawn out into a wire, or part of it may be removed and the remainder diluted with more of the flux.

With salt of phosphorus, the wire should be held above the flame so that the escaping gases may support the bead; this is continued till quiet fusion is attained.

It is to be noted that the colors vary much with the amount of material present; they are also modified by the presence of other metals.

486. Borax.—The following list enumerates the different colored beads obtained with borax, both in the oxidizing (O.F.) and reducing flames (R.F.), and also the metals to the presence of whose oxides the colors are due. Compare further the reactions given in the list of elements (Art. **488**).

Color in Borax Bead.	Substance.
	1. OXIDIZING FLAME.
Colorless, or opaque white...	Silica, calcium, aluminium; also silver, zinc, etc.
	Iron, cold—(pale yellow, hot, if in small amount).
Red, red-brown to brown....	Chromium (CrO_3), hot—(yellowish green, cold).
	Manganese (Mn_2O_3), amethystine-red—(violet, hot).
	Iron (Fe_2O_3), hot—(yellow, cold)—if saturated.
	Nickel (NiO), red-brown to brown, cold—(violet, hot).
	Uranium (UO_3), hot—(yellow, cold).
Green......................	Copper (CuO), hot—(blue, cold, or bluish green if highly saturated).
	Chromium (CrO_3), yellowish green, cold—(red, hot).
Yellow..............	Iron (Fe_2O_3), hot—(pale yellow to colorless, cold)—but red-brown and yellow if saturated.
	Uranium (UO_3), hot, if in small amount; paler on cooling.
	Chromium (CrO_3), hot and in small amount—(yellowish green, cold).
Blue......................	Cobalt (CoO), hot and cold.
	Copper (CuO), cold if highly saturated—(green, hot).
Violet......................	Nickel (NiO), hot—(red-brown, cold).
	Manganese (Mn_2O_3), hot—(amethystine-red, cold).
	2. REDUCING FLAME (R.F.).
Colorless..................	Manganese (MnO), or a faint rose color.
Red........................	Copper (Cu_2O, with Cu), opaque red.
Green......................	Iron (FeO), bottle-green.
	Chromium (Cr_2O_3), emerald-green.
	Uranium (U_2O_3), yellowish green if saturated.
Blue.......................	Cobalt (CoO), hot and cold.
Gray, turbid...............	Nickel (Ni).

487. Salt of Phosphorus.—This flux gives for the most part reactions similar to those obtained with borax. The only cases enumerated here are those which are distinct, and hence those where the flux is a good test.

With *silicates* this flux forms a glass in which the bases of the silicate are dissolved, but the silica itself is left insoluble. It appears as a skeleton readily seen floating about in the melted bead.

The colors of the beads, and the metals to whose oxides these are due, are:

Color.	Substance.
Red...........	Chromium in O.F., hot—(fine green when cold).
Green..........	Chromium in O.F. and R.F., when cold—(red in O.F., hot).
	Molybdenum in R.F., dirty green, hot; fine green, cold—(yellow-green in O.F.).
	Uranium in R.F., cold; yellow-green, hot.
	Vanadium, chrome-green in R.F., cold—(brownish red, hot). In O.F. dark yellow, hot, paler on cooling.