

*Bulletin No. 121*

*Mineral Technology Series No. 28*



# University of Arizona

Bulletin

Arizona Bureau of Mines

G. M. BUTLER, *Director*

## FIELD TESTS FOR THE COMMON METALS

(Fourth Edition)

By GEORGE R. FANSETT

Entered as second class matter November 23, 1915, at the postoffice at Tucson, Arizona, under the Act of Aug. 24, 1912. Issued semi-quarterly.

PUBLISHED BY THE  
University of Arizona  
UNIVERSITY STATION  
TUCSON, ARIZONA  
JANUARY 15, 1926

## BULLETINS AVAILABLE

The Arizona Bureau of Mines still has the following bulletins available for free distribution to residents of Arizona. Bulletins not listed herein are out of stock and cannot be procured from the Bureau. Any five bulletins will be sent free of charge to non-residents of the State, and additional numbers may be purchased at the uniform rate of ten cents each.

2. The Arizona State Bureau of Mines.
11. Tungsten, by A. C. Rubel.
14. Magnesite, by Frank L. Culin, Jr.
16. Mica, by Frank L. Culin, Jr.
19. Gypsum, by Frank L. Culin, Jr.
23. Bibliography of Literature Regarding Arizona Mining and Geology, compiled under the direction of Estelle Lutrelle.
25. Cement, by Frank L. Culin, Jr.
26. Mine and Smelter Methods of Sampling, by H. J. Stander.
35. Celestite and Strontianite, by Frank L. Culin, Jr.
36. The Selling of Copper, by H. J. Stander.
37. Copper, by P. E. Joseph.
39. The Selling of Lead and Zinc, by H. J. Stander.
40. Building Stones, by Frank L. Culin, Jr.
41. Mineralogy of Arizona Minerals.
43. Iron, by P. E. Joseph.
44. Workmen's Compensation, by J. Preston Jones.
45. Lead, by P. E. Joseph.
46. Lime Rocks, by Frank L. Culin, Jr.
48. Gems, by Frank L. Culin, Jr.
49. Miscellaneous Minerals, by P. E. Joseph.
59. Yavapai, The Land of Opportunity, by Grace M. Sparkes.
62. Selling Prospects, by Chas. F. Willis.
63. Sampling of Dumps and Tailings, by G. R. Fansett.
68. What To Do With The Other Eight Hours, by S. C. Dickinson.
72. Roads For Mines, by G. R. Fansett.
78. Valuation of Prospects, by G. R. Fansett.
79. Drilling for Oil, by M. A. Allen.
81. How to Organize for Safety, by S. C. Dickinson.
82. Shafts and Tunnels, by G. R. Fansett.
86. Keeping Your Town Clean, by S. C. Dickinson.
91. Manganese, by M. A. Allen and G. M. Butler.
99. Barytes, by M. A. Allen and G. M. Butler.
104. List of U. S. G. S. Publications Relating to Arizona by Olaf P. Jenkins and Eldred D. Wilson.
106. A Geological Reconnaissance of the Tucson and Amole Mountains, by Olaf P. Jenkins and Eldred D. Wilson.
113. Asbestos, by M. A. Allen and G. M. Butler.
114. Fluorspar, by M. A. Allen and G. M. Butler.
115. Vanadium, by M. A. Allen and G. M. Butler.
116. Petroleum, by G. M. Butler and M. A. Allen.
117. Uranium and Radium, by G. M. Butler and M. A. Allen.
118. Arizona Gold Placers by M. A. Allen.

(The following voluminous, beautifully illustrated Bulletin is sold for \$1.00)

119. A Resume of the Geology of Arizona, by N. H. Darton.
120. Gold and Copper Deposits near Payson, Arizona, by C. Lausen and E. D. Wilson.

## CONTENTS

	Page
Preface .....	3
Prospector's Blowpipe Outfit .....	3
Dry Reagents.....	4
Wet Reagents.....	4
Other Useful Apparatus and Supplies.....	4
Tests for Metals, Etc.....	6
Antimony .....	6
Arsenic .....	7
Barium .....	7
Calcium .....	8
Calcium Carbonate (Limestone).....	10
Chromium .....	10
Cobalt .....	11
Copper .....	12
Fluorine .....	14
Gold .....	15
Iron .....	16
Lead .....	17
Magnesium .....	18
Manganese .....	19
Mercury (Quicksilver) .....	21
Molybdenum .....	21
Tests for Molybdenum Sulfides.....	22
Tests for Molybdenum Oxides.....	23
Nickel .....	24
Oil .....	25
Oil Shale .....	26
Organic Material .....	26
Potassium .....	27
Silver .....	27
Strontium .....	28
Tin .....	29
Tungsten .....	29
Vanadium .....	30
Zinc .....	32
Tables of Weights and Measures.....	34
Bibliography .....	37

# FIELD TESTS FOR THE COMMON METALS

BY GEORGE R. FANSETT

## PREFACE

This pamphlet has been compiled as a text to be used in the Arizona Bureau of Mines' extension lectures on "Prospector's Mineralogy." Many of the people attending these lectures, especially those most interested, have had very little, if any, technical training in mineralogy, chemistry, and allied sciences. For that reason this pamphlet has been written in as simple and non-technical language as the subject permits, yet the directions given are full enough so that anyone should be able to understand how to do the work.

The method of procedure suggested to beginners in this line of work is first to practice each specific test for each metal on a mineral that is positively known to contain that metal or to practice the tests on a piece of that metal. This practice should be continued until the beginner becomes thoroughly familiar with the various tests for that metal as well as those for other metals. These tests can then be applied to ores of unknown metallic contents if it is desired to determine whether a certain metal is present.

## PROSPECTOR'S BLOWPIPE OUTFIT

- Blowpipe (8" or 10" long)
- Fuel (candle, alcohol, lard oil, or some other lamp)
- Charcoal sticks (4" x 1" x 3/4")
- Hand lens
- Streak plate
- 2" or 3" magnet or magnetized knife blade
- Forceps (platinum tipped are the best)
- 3 pieces (No. 26 B. & S. wire gauge) platinum wire and a holder for the wire
- Iron wire, a few pieces 4" long.
- Test tubes (4" x 1/2")
- Soft glass tubing, 7 millimeter (for closed and open tubes)

### DRY REAGENTS

1 ounce borax (powdered). Borax glass is more satisfactory than ordinary borax.

2 ounces sodium carbonate (powdered) or baking soda

$\frac{1}{4}$  ounce salt of phosphorus (powdered)

2 ounces of zinc or tin (granulated or shavings)

### WET REAGENTS

2 ounces hydrochloric (muriatic) acid, concentrated

2 ounces nitric acid, concentrated

2 ounces sulfuric acid (oil of vitriol), concentrated

4 ounces ammonia, concentrated

4 ounces denatured alcohol (if an alcohol lamp is used)

1 ounce cobalt nitrate solution (10%)

### OTHER USEFUL APPARATUS AND SUPPLIES

$1\frac{1}{2}$ " agate mortar and pestle

Pan or horn for panning

File (4" triangular)

Hammer (blowpipe)

Anvil (block of steel  $1\frac{1}{2}$ " x  $1\frac{1}{2}$ " x  $\frac{1}{2}$ " )

Flame-color screen (Merwin's)

Small beakers (about 120 c.c.)

2" glass funnel

1 package 4" filter papers

1 ounce potassium bisulfate (acid sulfate of potash)

$\frac{1}{4}$  ounce ammonium oxalate

2 ounces mercury (quicksilver)

1 zinc stick

G. M. Butler's "Handbook of Blowpipe Analysis" gives the following explanations of the flames made with the aid of the blowpipe and the directions for producing them.

Blowpipe Operations: "The blowpipe is used for the purpose of concentrating the flame into a long, slender cone which can be readily directed against the substance to be heated. It is very important that the blast be continuous and uniform, although this operation may seem very difficult at first. The blast is not produced by the lungs, but results from a bellows-like action of the distended cheeks. During the operation, air is inhaled only through the nose, and is exhaled largely through the mouth and the blowpipe. Before trying to use that instru-

ment, distend the cheeks, and, keeping the mouth closed, breathe through the nose for a moment; then open the lips just enough to allow a little air to escape slowly, and admit air from the lungs by a kind of gulping action just fast enough to keep the cheeks fully distended. This may take some practice, but when it is possible to allow the air to escape continuously from the mouth in this way, no matter whether it is being exhaled or inhaled through the nostrils, it is time to begin to use the blowpipe.

*“Producing the Oxidizing Flame.* Place the oil lamp so that the longer dimension of the wick is from right to left, and set its right-hand edge upon a pencil or some other low support so that it will tip somewhat to the left. Insert the tip of the blowpipe about one-eighth of an inch within and just above the right-hand side of the wick, and blow steadily parallel to the wick, directing the flame to the left, and producing a clear, blue flame about an inch long. If all of the flame cannot be thus diverted to the left, or if there are yellow streaks in the flame, trim or lower the wick. If the whole flame is inclined to be yellow, move the tip of the blowpipe a trifle to the left. If it is impossible to produce a flame approaching the length mentioned above, the opening in the end of the blowpipe is too small, and this opening is too large when a very long, hissing flame is produced. In order to succeed in blowing a steady flame, the hand must rest upon some support, or the third and fourth fingers may be placed against the lamp.

“In analytical operations it is sometimes desirable to oxidize substances to be tested, and at other times the aim is to reduce them to the metallic condition; either result can be more or less readily obtained with the blowpipe.

“A flame produced in the manner above described is called an oxidizing flame, but the action of all portions of such a flame is not oxidizing. The blue cone contains considerable carbon monoxide and is feebly reducing in its action, but just outside of the blue cone at the tip of the flame is an extremely hot but nearly colorless zone which is strongly oxidizing because of the free oxygen there present, and anything held in this zone about an eighth of an inch from the tip of the blue flame will be in the most favorable position for oxidation.

“The oxidizing flame is hotter than the reducing, and the hottest part of this flame is just outside of the blue cone. In the absence of other instructions, substances should always be heated there.”

Note: One of the best kinds of lamps is one burning a mixture of one-third kerosene and two-thirds lard oil, but the flame from a candle, an alcoholic, or any other kind of lamp or from a Bunsen burner can be used instead of that from an oil lamp for this work.

*"Producing the Reducing Flame.* Hold the tip of the blowpipe about one-sixteenth of an inch above and to the right of the wick, and a long, yellow flame containing much unconsumed carbon will be produced. This is sometimes called the smoky, reducing flame. Where greater heat is required, the inner cone of the oxidizing flame should be used. The strongest reducing action will take place at the tip of, and within the yellow cone of the reducing flame."

## TESTS FOR METALS

### ANTIMONY

(1) Antimony can usually be detected by the dense, white fumes given off and the heavy, white sublimate formed near the mineral when heated on charcoal before the blowpipe.

To make this test: Transfer to a flat stick of charcoal a little of the mineral to be tested for antimony (use about that amount of powdered mineral that can be held on the tip of a knife blade or a piece of the mineral about as large as a kernel of wheat). Heat the mineral before the blowpipe in the oxidizing (bluish) flame until the material is thoroughly fused. By this treatment, most antimony minerals give off dense, white fumes which often continue to arise even after the heating has ceased. These fumes deposit as a dense, white sublimate (coating) on the charcoal near the mineral, the outer edges, where the coating is thin, appearing bluish-white.

Beginners practicing this test should use stibnite (antimony sulfide).

Note: This bluish-white coating of antimony must not be confused with those of lead or zinc which are very similar on the outer edges. These coatings can easily be identified since the coating deposited on the charcoal from lead is yellow near the assay when hot or cold, and the coating deposited on the charcoal near the assay from zinc is yellow when hot and white when cold. The coating from zinc can also be further tested by using cobalt nitrate solution as explained under (1) for zinc.

(2) Sulfides of antimony if heated in a closed tube yield a sublimate which is black when hot and reddish-brown when cold.

To make this test: Fill a closed tube to about one-half inch from the bottom end with the powdered mineral to be tested. Heat the lower portion of the tube at a red heat for some time. Antimony sulfides if present in the mineral tested will give a sublimate (coating) that is black when hot, but that on cooling changes to reddish-brown.

Beginners practicing this test should use stibnite (antimony sulfide).

## ARSENIC

(1) When struck a glancing blow with a hammer, many arsenic minerals give off sparks and a garlic-like odor.

Beginners practicing this test should use arsenopyrite.

(2) Arsenides, sulfides of arsenic, and native arsenic give off a garlic-like odor when heated on charcoal before the blowpipe. This treatment also gives a white coating on the charcoal that forms at a distance from the mineral.

To make this test: Transfer to a flat stick of charcoal a little of the mineral to be tested for arsenic (use about that amount of the powdered mineral that can be held on the tip of a knife blade or a piece of the mineral about as large as a kernel of wheat). Heat the mineral before the blowpipe in the reducing (yellow) flame. The above-mentioned substances that contain arsenic, when thus treated, give off fumes that have a garlic-like odor.

Beginners practicing this test should use arsenopyrite.

(3) Arsenic and some arsenides when heated in a closed tube with sodium carbonate yield a black sublimate on the walls of the tube.

To make this test: Fill a closed tube to about one-half inch from the bottom with some of the mineral to be tested and sodium carbonate (this mixture should be made up of about one part of the pulverized mineral to about three parts of sodium carbonate (baking soda) thoroughly mixed). Heat the lower end of the tube to a red heat for some time. Arsenic and some arsenides when given this treatment yield a black, mirror-like sublimate (coating) on the walls of the tube (arsenical mirror).

## BARIUM

(1) Volatile compounds of barium (carbonates) color a non-luminous flame yellowish-green if heated therein.

To make this test: Use a piece of iron wire about four inches long (bal- ing wire). Wet one end of the wire in dilute (four parts of water to one part of acid) hydrochloric (muriatic) acid so that some of the pulverized mineral will adhere to it. Draw the wet end of the wire through the powdered mineral. Heat the end of the wire with the mineral on it in a flame, (an alcohol lamp flame is very satisfactory for this purpose). As soon as the wire and mineral are red-hot the flame will be colored yellowish-green if the mineral contains an appreciable amount of a volatile compound of barium. This test can be applied only to barium carbonate (witherite).

(2) With a Merwin's Flame-Color Screen: Follow the directions

outlined in Barium (1) but observe or look at the flame through the different sections of a Merwin's Flame-Color Screen. Through section 1 the barium (or boron) flame is green; through sections 2 and 3 it is a fainter green.

(3) In dilute solutions, dilute sulfuric acid precipitates barium.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the mineral to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about four teaspoonfuls of dilute (equal parts of acid and water) hydrochloric (muriatic) acid. Heat to boiling and then add about ten teaspoonfuls of cold water. To this solution add a few drops of dilute (one part of acid added to four parts of water) sulfuric acid (oil of vitriol). Upon the addition of the dilute sulfuric acid (oil of vitriol) to the dilute acid solution, barium, if present, will be thrown down as a white precipitate.

Beginners practicing this test should use witherite.

Note: Sulfuric acid when mixed with water generates much heat. To make dilute sulfuric acid always add the acid to the water, a drop or so at a time. NEVER add the water to the acid, as the heat generated may cause an explosion.

## CALCIUM

(1) Calcium can usually be detected by its precipitation as an oxalate.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid or about twice this amount of dilute (about equal parts of acid and water) hydrochloric (muriatic) acid.

This mixture either cold or on being heated (if the mineral contains calcium carbonate) will effervesce (boil) and give off a colorless, odorless gas (carbon dioxide) which will not support combustion (a lighted match or other flame if held in this gas will go out). After the effervescence has ceased add to the liquid about five teaspoonfuls of water. To this solution add ammonia until a white precipitate begins to form or until the solution smells of ammonia.\* Then add a few crystals of

\*Note: If barium or strontium is present in the mineral which is being tested, add to the hydrochloric acid solution potassium sulfate or some other alkali sulfate and boil for a few minutes. Filter off the residue and any precipitate that has been formed and proceed with the test.

\*Note: Ammonia when mixed with an acid generates heat which may cause an explosion. Therefore be certain to always point the end of the receptacle in a direction where no harm can result.

Never add ammonia to a hot concentrated acid solution.

ammonium oxalate or about one-half a teaspoonful of concentrated ammonium oxalate solution (ammonium oxalate crystals dissolved in water). This chemical will throw down a white precipitate (calcium oxalate) if calcium is present.

Beginners practicing this test should use marble, chalk, or some other easily soluble calcium mineral.

(2) Sulfuric acid precipitates calcium as a sulfate in moderately concentrated solutions.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the mineral to be tested (use about the amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid. After all effervescence (boiling) has ceased add to this solution a few drops of dilute (one volume of acid added to about four volumes of water) sulfuric acid (oil of vitriol). This precipitates the calcium as colorless, white crystals of calcium sulfate (gypsum) which is distinguished from the sulfates of barium and strontium in that it will dissolve in a solution of ammonium sulfate. Calcium sulfate (gypsum) is also soluble in hot water. If the solution is diluted with water to about ten times its original volume and warmed, the calcium sulfate will dissolve.

Beginners practicing this test should use marble, chalk, or some other easily soluble calcium mineral.

(3) Volatile compounds of calcium, with hydrochloric (muriatic) acid color a non-luminous flame yellowish-red if heated therein.

To make this test: Wet one end of a piece of iron wire about four inches long (baling wire) in hydrochloric (muriatic) acid. Draw the wet end of the wire through some of the powdered mineral. Heat the end of the wire, with the mineral on it, in a flame (an alcohol lamp flame is very satisfactory for this purpose). As soon as the wire and mineral are red-hot the flame will be colored yellowish-red providing the mineral contains an appreciable amount of volatile compounds of calcium and also providing that no other element masks the calcium flame.

Beginners practicing this test should use marble, chalk, or some other volatile compound of calcium.

(4) With a Merwin's Flame-Color Screen: Follow the directions outlined in calcium (3) but observe or look at the flame through the different sections of a Merwin's Flame-Color Screen. Through section 1 calcium gives a flashy, greenish-yellow, through section 2 a green, and through section 3 a faint crimson flame.

### CALCIUM CARBONATE (LIMESTONE)

Many mining men and prospectors think that a conclusive test for the determination of calcium carbonate (limestone) is that it effervesces (boils) when moistened with hydrochloric (muriatic) acid. This effervescing (boiling) merely indicates that the mineral is a carbonate, providing a colorless, odorless gas which does not support combustion is given off (a lighted match if held in this gas will go out).

Various metals occur as carbonates, a few of the commonest being lead, zinc, copper, and iron. From this statement it is evident that this effervescence (boiling) is not a conclusive test for the determination of calcium carbonate (limestone), since the sample may contain a carbonate of some other metal. This fallacy has been responsible for failure to appreciate the importance of many valuable mineral deposits.

### CHROMIUM

Chromium can usually be detected by the colors it imparts to the fluxes.

To make this test: Use a piece of No. 26 platinum wire about two inches long. Fasten one end in a holder so that when the wire is heated it will not burn the fingers (special holders can be purchased, but a cork or a piece of soft wood into which one end of the wire is inserted can be used for this purpose). Make a small loop, about one-sixteenth of an inch in diameter, at the unattached end of the wire (this loop is easily made by winding the end of the wire around the point of a lead pencil). Heat this looped end in a flame until it is red-hot (an alcohol lamp flame is very satisfactory for this work). Dip the red-hot loop into some powdered borax or salt of phosphorus, a little of which will adhere to the wire loop. Fuse the borax or salt of phosphorus adhering to the wire by holding it in the flame. Continue these operations until a clear, glassy bead that fills the loop in the wire is secured. Add to this bead the mineral that is to be tested (touch the bead while it is red-hot to a little of the very finely powdered mineral). If the bead made from borax and a very little of a mineral containing chromium is heated before the blowpipe in the oxidizing (bluish) flame, the bead will be decidedly yellow while it is warm, changing to a yellowish-green color when cold. When more of the mineral is added, the colors are deeper, changing through reddish or yellow when warm to a fine green when cold. If this bead is heated before the blowpipe in the reducing (yellow) flame, the bead assumes a fine, green color when cold, but shows none of the yellow or reddish tint which is so prominent in the warm bead after heating in the oxidizing (bluish) flame.

If salt of phosphorus is used instead of borax for making the bead, and the operations outlined above for the borax bead test are followed, the color of the bead formed when the oxidizing (bluish) flame of the blowpipe is employed is a dirty green when the bead is warm, which changes to a fine green when the bead is cold. If the reducing (yellow) blowpipe flame is used the colors are about the same as with the oxidizing flame.

Beginners practicing the chromium test should use chromite.

Note: The chromium tests must not be confused with those for vanadium, which gives in the reducing flame almost identical reactions with the fluxes, but vanadium in the oxidizing (bluish) flame differs from the salt of phosphorus bead test in that it yields a yellow bead, while this flux never yields other than a green bead with chromium.

### COBALT

(1) Cobalt can usually be detected by the color it imparts to the fluxes.

To make this test: Use a piece of No. 26 platinum wire about two inches long. Fasten one end in a holder so that when the wire is heated it will not burn the fingers (special holders can be purchased, but a cork or a piece of soft wood can be used for this purpose). Make a loop, about one-sixteenth of an inch in diameter, at the unattached end of the wire (this loop is easily made by winding the end of the wire around the point of a lead pencil). Heat this looped end in a flame until it is red-hot (an alcohol lamp is very satisfactory for this work). Dip the red-hot loop into some powdered borax or salt of phosphorus, a little of which will adhere to the wire loop. Fuse the borax or salt of phosphorus adhering to the wire by holding it in the flame. Continue these operations until a clear, glassy bead that fills the loop in the wire is secured. Add to this bead the mineral that is to be tested (touch the bead while it is red-hot to a very little of the finely powdered mineral). If the beads made from either borax or the salt of phosphorus and a cobalt mineral are heated before the blowpipe in either the reducing (yellow) flame or the oxidizing (bluish) flame the color of the beads formed will be deep blue.

Beginners practicing this cobalt test should use roasted smaltite or roasted cobaltite.

Note: A sulfide or arsenic ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat until sulfur or arsenic fumes are no longer noticeable) before using the cobalt mineral in the bead tests.

(2) Cobalt compounds become magnetic when heated on charcoal before the blowpipe in the reducing flame.

To make this test: Mix thoroughly a little finely powdered mineral with about twice its volume of powdered sodium carbonate (baking

soda). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until the mixture is thoroughly fused. The resulting fused mass will contain a dark colored, more or less metallic button enclosed in the slag, and this button will be magnetic when cold if the mineral used contains cobalt.

Beginners practicing this test should use smaltite or cobaltite.

Note: Metallic iron and nickel are also magnetic; therefore a magnetic button obtained from any mineral, the metallic contents of which are unknown, should be tested further by applying test (1) for cobalt.

## COPPER

(1) Ammonia added to an acid solution of copper produces a blue coloration.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of acid. (Use concentrated (strong) nitric acid or a mixture of nitric and hydrochloric (muriatic) acid). Heat until the copper has been dissolved and then add about three teaspoonfuls of water. To this add an excess of ammonia (until the solution smells strongly of ammonia). Upon the addition of the ammonia to the acid solution the color of the solution will turn blue if the mineral used in the test contains an appreciable amount of copper.

Beginners practicing this test should use malachite, chalcocite, or some other copper mineral or a small piece of metallic copper.

Note: If the mineral does not dissolve readily fuse it as directed in COPPER (5).

Note: In order not to crack glass receptacles, heat very gently at first, shaking the receptacle so that the solution washes around the bottom and sides.

Note: Ammonia when mixed with an acid generates heat. This heat may cause an explosion. Therefore be certain always to point the end of the receptacle in a direction where no harm can result. Never add ammonia to a HOT acid solution.

(2) Clean iron, steel, zinc, or aluminum, if immersed in a dilute acid solution of copper, will become coated with a film of copper.

(3) Volatile compounds of copper color a non-luminous flame green if heated therein. With hydrochloric acid the flame is colored azure blue.

To make this test: Use a piece of iron wire about four inches long (baling wire). Wet one end of the wire in water so that some of the pulverized mineral will adhere to it. Draw the wet end of the wire

through the powdered mineral. Heat the end of the wire, with the mineral on it, in a flame (an alcohol lamp flame is very satisfactory for this purpose). As soon as the wire and mineral are red-hot the flame will be colored greenish if the mineral contains an appreciable amount of a volatile compound of copper.

If the same end of the wire is moistened with hydrochloric (muriatic) acid, more of the mineral taken upon it, and it is again held in the flame, the flame will be colored azure blue if the mineral contains an appreciable amount of a volatile compound of copper.

Beginners practicing this test should use malachite (copper carbonate) or some other volatile copper mineral.

Note: (a) Use a new piece of wire for each copper test.

(b) Never dip a wire which has been used for this or other tests in the acid bottle, since any soluble mineral present will dissolve and the acid may be valueless for further flame tests. Pour a few drops of the acid into a glass or cup, and dip the end of the wire into it.

(c) The copper of volatile copper compounds alloys with the platinum when platinum wire is used for making the flame tests; thereby making the alloyed piece of wire worthless for further copper flame tests.

(4) With a Merwin's Flame-Color Screen: Follow the directions outlined in (3), but observe or look at the flame through the different sections of a Merwin's Flame-Color Screen. Through section 1, copper gives a bright-green, through section 3 a bright-blue flame fringed with green, and through section 2 the same tints, but paler.

(5) Copper compounds fused with soda in the reducing flame yield a metallic copper mass.

To make this test: Mix thoroughly a little of the finely powdered mineral with about twice its volume of powdered flux (sodium carbonate alone or mixed with a little borax). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until it is thoroughly fused. The resulting fused mass will contain an irregular, spongy mass of metallic copper if the mineral used in the test contains an appreciable amount of copper.

Beginners practicing this test should use chalcopyrite, cuprite, or some other easily fusible copper mineral.

(6) Borax and salt of phosphorus beads are green when warm and blue when cold in the oxidizing (bluish) flame, and saturated beads are opaque red in the reducing (yellow) flame of the blowpipe. In the presence of much iron the oxidizing (bluish) flame bead is green or bluish-green. Bead test instructions can be found under "CHROMIUM" or "COBALT."

## FLUORINE

(1) Fluorine etches hard glass.

(a) Some compounds of fluorine with sulfuric acid etch hard glass.

To make this test: Take a flat piece of window glass and coat a section of one side of the glass with a thin, even layer of paraffin wax (wax melted and dropped from a burning paraffin candle can be used for this purpose). Allow the wax to cool and when cold write or mark through the paraffin to the glass (use a pencil point, a sharpened piece of wood, or some other tool that will cut through the paraffin, but will not scratch the glass). Pour into the marks made in the paraffin some of the finely powdered mineral that is being tested for fluorine. Onto this powdered mineral pour a few drops of concentrated (strong) sulfuric acid (oil of vitriol), and mix the mineral and acid together to the consistency of a thick paste (use a pointed stick or a pencil point for this purpose). In about ten minutes wash off the mixture of acid and mineral, remove the paraffin by heating the glass, and clean the glass. Etching of the glass indicates that fluorine was present in the mineral used in making this test.

Beginners practicing this test should use fluorite (fluorspar).

(b) With acid sulfate of potassium, some compounds of fluorine etch glass.

To make this test: Mix thoroughly a little of the finely powdered mineral with about three volumes of acid sulfate of potassium (potassium bisulfate). Fill a closed tube or a small test tube to about one-half inch from the bottom end with this mixture. Heat the lower end of the tube at a red heat for several minutes. Etching (roughening or clouding) of the sides of the tube, just above the charge, indicates that fluorine was present in the mineral tested. The etching may be detected by breaking the tube, washing a fragment thoroughly, and rubbing the surface with the sharp point of a knife blade. The glass will feel slightly rough if it has been etched.

Beginners practicing this test should use fluorine (fluorspar).

(2) (a) Some varieties of fluorite become phosphorescent when heated.

To make this test: Place in a test tube a few fragments of the mineral to be tested (fragments should be about one-quarter of an inch in size). Heat the lower portion of the tube at a red heat, for a very short time (if heated too long the glowing will disappear). Some varieties of fluorite (fluorspar) when thus treated and held in the dark become phosphorescent (emit light of various tints).

Beginners practicing this test should use violet-colored fluorite (fluorspar).

(b) The above test can also be applied to a splinter of the material held in a pair of forceps.

## GOLD

(1) The following characteristics serve for the ready detection of gold: Its yellow color; its high specific gravity (weight); its high fusibility (the high temperature required to melt it); its malleability (can be flattened out if hammered on an anvil; it can be indented by the point of a knife blade without crushing); and its insolubility, i. e. cannot be dissolved in either nitric, hydrochloric, or sulfuric acid alone; but gold is soluble in aqua regia (one volume of concentrated (strong) nitric acid mixed with three volumes of concentrated (strong) hydrochloric (muriatic) acid).

(2) *Amalgamation.* To amalgamate or collect gold with mercury (quicksilver), mercury is added to the concentrates and these are ground together in a mortar until the mercury amalgamates (collects) the gold. If this pasty amalgam is then heated on charcoal before the blowpipe, the mercury is distilled off leaving the gold as a residue. If this residue, mixed with a little borax, is then heated before the blowpipe on charcoal, there will be obtained a malleable, yellow button which can be tested as explained above in (1).

(3) *Panning.* Gold can usually be detected in free-milling ores, sands, and gravels by panning.

With many complex, refractory (rebellious) ores panning does not give satisfactory results. For such ores, a preliminary roasting of the ore often overcomes the difficulty.

When the above tests do not indicate the presence of gold but the operator still believes that the ore contains gold, the policy recommended for testing such an ore is to have it assayed for gold. If an assay does not reveal the presence of gold in an ore, it can be safely assumed that gold is not present in that ore in commercial quantity.

(4) In nitro-hydrochloric acid solutions of gold, stannous chloride gives a purple precipitate.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) nitric acid and one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid. Heat this solution to boiling and until any gold present has been dissolved. To this solution add a pinch of stannous chloride or a few teaspoonfuls of concentrated stannous chloride solution (stannous chloride dissolved in water). Upon

the addition of stannous chloride to this nitro-hydrochloric acid solution there will be thrown down a purple precipitate if the mineral used in the test contains an appreciable amount of gold. This test is known as the Purple of Cassius Test for Gold.

(5) In nitro-hydrochloric acid solutions of gold, ferrous sulfate gives a brown precipitate.

To make this test follow the directions outlined in (4), but use ferrous sulfate instead of stannous chloride.

Beginners practicing these tests should use a piece of metallic gold or concentrates from a gold ore.

## IRON

(1) Iron minerals roasted on charcoal yield a magnetic residue.

To make this test: Place on a stick of charcoal a little of the finely powdered mineral to be tested (use about that amount that can be held on the tip of a knife blade). Heat before the blowpipe in the reducing (yellow) flame. If the mineral thus heated without a flux does not fuse (melt), but becomes magnetic, it contains iron. If it fuses (melts) and becomes magnetic it may contain iron, cobalt, or nickel.

Beginners practicing this test should use hematite, pyrites, or some other iron mineral.

(2) Iron minerals fused with soda in the reducing flame yield a magnetic button.

To make this test: Mix thoroughly a little of the finely powdered mineral with about twice its volume of sodium carbonate (baking soda). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until it is thoroughly fused (melts). The resulting fused mass will contain a dark-colored, more or less metallic button which is magnetic when cold, providing the mineral used in the test contains an appreciable amount of iron.

Beginners practicing this test should use hematite, pyrites, or some other easily fusible iron mineral.

Note: Cobalt and nickel buttons produced in this manner are also magnetic. For that reason the magnetic button should be further tested for iron by (3) and for cobalt and nickel by the tests given for those metals.

(3) Ammonia added to an acid solution of iron throws down a brownish-red precipitate.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of con-

concentrated (strong) hydrochloric (muriatic) acid and a few drops of nitric acid. Heat this solution until the iron has been dissolved, and then add about two teaspoonfuls of water. To this solution add an excess of ammonia (until the solution smells strongly of ammonia). Upon the addition of the ammonia to this acid solution there will be thrown down a brownish-red precipitate if iron was present in the mineral used.

Beginners practicing this test should use hematite, limonite, or some other iron mineral or a small piece of metallic iron.

Note: Many iron minerals are practically insoluble in the acids just mentioned. These minerals if roasted or treated as described in "IRON" (2) become easily soluble.

Note: Ammonia when mixed with an acid generates heat. This heat may cause an explosion. Therefore be certain always to point the end of the receptacle in a direction where no harm will result. Never add ammonia to a HOT acid solution.

(4) In the oxidizing (bluish) flame the borax bead of iron is amber colored when warm and yellow to colorless when cold, while in the reducing (yellow) flame the borax bead is bottle green, providing the bead is saturated. Bead test instructions can be found under "CHROMIUM" or "COBALT."

## LEAD

(1) Lead can usually be detected by the yellow sublimate and the metallic lead button formed on charcoal.

To make this test: Mix thoroughly a little of the finely powdered mineral with about an equal volume of powdered charcoal and about three volumes of powdered sodium carbonate (baking soda). Moisten this mixture with water and transfer about that amount that can be held on the tip of a knife blade to a flat piece of charcoal or into a shallow cavity that has been made in the charcoal. Heat this before the blow-pipe in a moderately strong, reducing (yellow) flame. This treatment, if the mineral used in the test contains an appreciable amount of lead, will produce small globules or buttons of metallic lead, which are soft and malleable (can be flattened out if hammered on an anvil), and also a yellowish sublimate (coating) on the charcoal, close to the mineral. This sublimate (coating) is whitish on the outer edges, and the white portion should not be confused with an antimony sublimate.

Beginners practicing this test should use galena, cerussite, or some other high-grade, lead mineral or some small cuttings of metallic lead.

(2) Hydrochloric or sulfuric acid throws down a heavy, white precipitate in cold, nitric acid solutions of lead.

To make this test: Place in a test tube or some other glass or porce-

lain receptacle a little of the powdered mineral to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) nitric acid and about two teaspoonfuls of water. Boil this solution until the lead has been dissolved, and then cool to room temperature. When cold add a few drops of dilute sulfuric acid (oil of vitriol) or a few drops of hydrochloric (muriatic) acid. Upon the addition of either of these acids to the cold nitric acid solution there will appear a white, heavy precipitate of lead providing the mineral used in the test contains any appreciable amount of lead. This white precipitate should be further tested for lead by using test (1) "LEAD."

Beginners practicing this test should use cerussite, or some other easily soluble, high-grade lead mineral, the lead buttons produced in test (1) "LEAD," or some small cuttings of metallic lead.

The white precipitate (lead chloride) formed when hydrochloric (muriatic) acid is used can be tested further as follows:

(3) Lead chloride is quite soluble in hot water.

To make this test: Add from ten to fifteen volumes of water to the mixture obtained when hydrochloric (muriatic) acid is used in making test (2) "LEAD." Heat to boiling and boil for a minute or two. If the white precipitate from test (2) "LEAD" is lead chloride, it will dissolve.

Note: When hydrochloric acid is used in test (2), silver and mercury if present may also be thrown down as a white precipitate, but silver in this form (silver chloride) turns purple if exposed to sunlight and is also very soluble in ammonia. The white mercury precipitate thus obtained usually turns dark grayish on the addition of an excess of ammonia.

## MAGNESIUM

(1) Magnesium can usually be detected by its precipitation as ammonium-magnesium phosphate.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about three teaspoonfuls of hydrochloric (muriatic) acid, a drop of nitric acid, and about four teaspoonfuls of water. Heat to boiling, and then cool to room temperature. To the cold solution add an excess of ammonia (until the solution smells strongly of ammonia). If a precipitate is thrown down, filter the precipitate off and catch the clear, filtered solution in another glass receptacle. To this clear liquid add a little ammonium carbonate or ammonium oxalate solution. Again filter off any precipitate which may form, and catch the clear, filtered solution in another glass receptacle. To this last

clear solution add a few drops of sodium phosphate solution. This will cause the formation of a white, crystalline precipitate of ammonium-magnesium phosphate providing the mineral used in this test contains an appreciable amount of magnesium.

Beginners practicing this test should use magnesite, dolomite, or some other easily soluble magnesium mineral.

Note: In order to allow sufficient time for the ammonium-magnesium phosphate precipitate to form it is sometimes necessary to let the solution stand up to twelve hours.

(2) Some of the white or colorless, magnesium compounds, such as magnesite, when moistened with cobalt nitrate and heated before the blowpipe, assume a light pink, or flesh color. The following method for making this test is given in G. M. Butler's Handbook of Blowpipe Analysis.

To make this test: "Hold a small splinter of the substance to be tested in the platinum forceps and heat it in the blowpipe flame to the highest possible temperature. Then examine it with a lens; if it shows any signs of fusion, this test cannot be applied. If non-fusible, moisten it with cobalt nitrate and ignite strongly in the hottest part of the blowpipe flame. It will first turn black but after prolonged heating may assume a characteristic tint. If a splinter of the substance cannot be obtained it should be powdered and the test conducted upon a flat cake of the powder upon charcoal. Longer heating is required by this method, however, and the results are not apt to be as satisfactory."

This test can be applied only to non-fusible, white or faintly tinted minerals, or those which become white or faintly tinted upon ignition.

A pinkish or flesh-tinted coloration indicates magnesium.

Beginners practicing this test should use magnesite.

## MANGANESE

(1) Manganese can usually be detected by the colors it imparts to the fluxes.

(a) To make this test: Use a piece of No. 26 platinum wire about two inches long. Fasten one end in a holder so that when the wire is heated it will not burn the fingers (special holders can be purchased, but a cork or piece of soft wood can be used for this purpose). Make a small loop, about one-sixteenth of an inch in diameter, at the unattached end of the wire (this loop is easily made by winding the end of the wire around the point of a lead pencil). Heat this looped end in a flame until it is red-hot (an alcohol lamp flame is very satisfactory for this work). Dip the red-hot loop into some powdered borax, a

little of which will adhere to the wire loop. Fuse the borax adhering to the wire by holding it in the flame. Continue these operations until a clear, glassy bead that fills the loop in the wire is secured. Add to this bead the mineral that is to be tested (touch the bead while it is red-hot to a little of the very finely powdered mineral). If the bead made from borax and a *very little* manganese mineral is heated before the blowpipe in the oxidizing (bluish) flame, there is produced a bead which is opaque while it is hot, but on cooling it becomes transparent and has a fine, reddish-violet or amethystine color. If this manganese borax bead is heated for a time in the reducing (yellow) flame of the blowpipe, it becomes colorless when cold. The bead test is a very delicate one for manganese.

Beginners practicing this test should use pyrolusite, psilomelane, or some other manganese mineral.

Note: Use only a very little of the mineral in this test because, if too much of the mineral is added to the bead, the color produced will be so intense that it will appear to be black, thus making the test valueless.

Note: A sulfide or arsenide ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat until sulfur or arsenic fumes are no longer noticeable) before using the mineral in the bead test.

Note: If much iron is present in the mineral tested, the borax bead will have a reddish-brown color.

(b) If sodium carbonate (baking soda) is used instead of borax for making the bead test, and the operations just described for conducting the borax bead test are followed, the color of the bead which is formed when the oxidizing (bluish) flame of the blowpipe is employed is green when the bead is warm and greenish-blue when it cools. The sodium carbonate bead made in the reducing (yellow) flame is colorless. Sodium carbonate beads are opaque.

If the greenish-blue, sodium carbonate bead of manganese is dissolved in a drop of water on a piece of glass, and to this solution is added a drop of nitric acid, the solution will become pink.

(2) Many manganese minerals dissolve in hydrochloric acid with the evolution of chlorine gas.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid. Heat gently at first, then increase the temperature as much as possible, and chlorine gas will be given off providing the mineral used in the test contains an appreciable amount of manganese oxides. This gas can be recognized by its yellowish-green color and by its pungent odor.

Beginners practicing this test should use pyrolusite, psilomelane, or some other oxide of manganese mineral.

(3) Some manganese minerals when heated yield oxygen.

To make this test: Pour into a closed tube a few fragments or a small amount of a powdered manganese dioxide mineral such as pyrolusite or psilomelane. Place a sliver of charcoal in the tube a little above the mineral. Heat the tube so that the charcoal alone is heated, and it will be noticed that although the charcoal gets red-hot it does not burn, owing to the limited supply of oxygen in the tube. Keeping the charcoal red-hot, apply the heat to the tube so that the manganese dioxide mineral and the charcoal are heated. As soon as oxygen commences to be given off from the mineral the charcoal will burn brightly.

### MERCURY (QUICKSILVER)

(1) Mercury when heated with soda in a closed tube condenses as metallic globules of mercury on the sides of the tube.

To make this test: Mix thoroughly a little of the finely powdered mineral with about three volumes of (DRY) sodium carbonate (baking soda). Place in a closed tube about one-half inch of this mixture and cover this with an additional layer of soda to a depth of about one-half inch. Heat carefully and mercury will distil off and condense as globules on the walls of the tube providing the mineral used in the test contains an appreciable amount of mercury (quicksilver). If only a little mercury is formed, it will appear as a gray sublimate (coating) composed of minute globules which may be made to unite by rubbing with a splinter of wood.

(2) Most compounds of mercury if moistened with hydrochloric (muriatic) acid when rubbed on a piece of bright copper will coat the copper, which will then appear as if it had been silver plated.

Beginners practicing these tests should use cinnabar or a little metallic mercury.

### MOLYBDENUM

(1) Molybdenum can usually be detected by its reduction to the blue or black oxides of molybdenum.

To make this test: Place in a small porcelain crucible or some other porcelain receptacle a little of the powdered mineral that is to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour onto the mineral about one-half a teaspoonful of concentrated (strong) nitric acid. Heat this mixture strongly to dryness (until all of the acid has been boiled off, and nothing but a dry, white, or grayish residue is left in the bottom of the receptacle). Cool to

room temperature, and then pour a few drops of concentrated (strong) sulfuric acid (oil of vitriol) onto the cold residue. Heat again until dense, white fumes of sulfuric acid are given off freely and until only a little of the sulfuric acid remains in the receptacle. Cool again by blowing strongly onto the residue. On cooling a beautiful, deep-blue color develops on the sides and in the bottom of the receptacle providing the mineral used in the test contains an appreciable amount of molybdenum.

Beginners practicing this test should use molybdenite, wulfenite, or some other molybdenum mineral.

(2) Molybdenum can usually be detected by the colors it imparts to the fluxes.

(a) In the oxidizing (bluish) flame, borax beads of molybdenum are yellow when warm and colorless when cold. In the reducing (yellow) flame the warm and cold borax beads are colorless. These beads made in the reducing (yellow) flame when saturated with molybdenum are brown when warm or cold.

(b) All salt of phosphorus beads of molybdenum are green except the unsaturated, cold bead formed in the oxidizing (bluish) flame which is colorless.

(c) If several of the green salt of phosphorus beads are dissolved in dilute hydrochloric (muriatic) acid, and tin is added to the boiling solution, the solution turns brown.

Note: Instructions for making the bead tests can be found under "COBALT" or "CHROMIUM."

Note: A sulfide ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat until sulfur fumes are no longer noticeable) before using the mineral in the bead tests.

Several tests for molybdenum depend on whether the molybdenum mineral occurs as an oxide or as a sulfide.

#### TESTS FOR MOLYBDENUM SULFIDES

(1) Powdered molybdenum sulfide minerals (molybdenite, etc.), if heated strongly in an open tube, give off sulfurous fumes and deposit a pale-yellow sublimate (coating) on the sides of the tube, and delicate, hairlike, white or yellow crystals on the mineral itself.

(2) Powdered molybdenum sulfide minerals (molybdenite, etc.), if heated on charcoal for a long time in the oxidizing (bluish) flame of the blowpipe, deposit a sublimate (coating) on the charcoal a short distance from the assay. This sublimate (coating) is pale yellow when hot and almost white when cold, and often consists of delicate crystals. If this sublimate is touched for an instant with the moderately hot reduc-

ing (yellow) flame of the blowpipe it assumes a beautiful, deep-blue color.

(3) Molybdenite is soluble (is dissolved) in nitric acid.

#### TESTS FOR MOLYBDENUM OXIDES

(1) Finely powdered molybdenum oxides are partially soluble in hydrochloric acid. Tin added to this solution produces a blue coloration.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about two teaspoonfuls of concentrated (strong) hydrochloric (muriatic) acid, and heat to boiling. Boil for a few minutes, and the solution will turn green. If a little metallic tin is added to this green solution which has been diluted with water to about twice its original volume, and the solution is heated in order to start the reaction, the solution will turn blue and, finally, brown.

Note: The blue color may be of such short duration in some cases that the solution seems to turn brown without showing any blue coloration.

Beginners practicing this test should use wulfenite or some other oxidized, molybdenum mineral.

(2) Molybdenum oxides can usually be detected by their reduction to the blue oxide of molybdenum.

(a) To make this test: Place in a small porcelain crucible or some other porcelain receptacle a little of the powdered mineral to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour onto this mineral a few drops of concentrated (strong) sulfuric acid (oil of vitriol), and heat strongly until dense, white fumes of sulfuric acid are given off for a minute or two. Cool the receptacle by blowing strongly onto the mineral. On cooling, a beautiful, blue color develops around the sides and in the bottom of the receptacle providing the mineral used in the test contains an appreciable amount of molybdenum oxides.

Beginners practicing this test should use wulfenite or some other oxidized molybdenum mineral.

(b) This test can also be made in the following manner: Place in a test tube a little of the powdered mineral to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Drop onto the mineral a small piece of paper. Pour onto this from three to five drops of concentrated (strong) sulfuric acid (oil of vitriol) and about an equal amount of water. Heat strongly until dense, white fumes of sulfuric acid are given off freely, and then cool. The

liquid on cooling turns a beautiful, deep-blue color that disappears if the liquid is again heated to boiling, and reappears on cooling.

Beginners practicing this test should use wulfenite.

### NICKEL

(1) Ammonia added to an acid solution of nickel produces a pale-blue coloration.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral that is to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) nitric acid or a mixture of about one teaspoonful of nitric, one teaspoonful of hydrochloric (muriatic) acid, and one teaspoonful of water. Heat this mixture to boiling until the mineral has been dissolved. If the mineral used in the test contains an appreciable amount of nickel, the solution will turn a greenish color, and if an excess of ammonia is added to the solution (until the solution smells strongly of ammonia), the solution will turn to a pale-blue color that is considerably lighter than that produced by copper.

Beginners practicing this test should use millerite or niccolite.

(2) Nickel minerals fused with soda in the reducing flame yield a magnetic button.

To make this test: Mix thoroughly a little of the finely powdered mineral with about twice its volume of sodium carbonate (baking soda). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until it is thoroughly fused (melts). The resulting fused mass will contain a dark-colored, more or less metallic button which is magnetic when cold providing the mineral used in this test contains an appreciable amount of nickel.

Beginners practicing this test should use niccolite or millerite.

Note: Cobalt and iron buttons produced in this manner are also magnetic. For that reason the magnetic button should be further tested for nickel by (1) and (3), and for cobalt and iron by the tests given for those metals.

(3) Nickel can usually be detected by the colors it imparts to the fluxes.

(a) In the oxidizing (bluish) flame of the blowpipe borax beads of nickel are violet when warm and brown when cold. In the reducing (yellow) flame the borax beads are colorless unless saturated with nickel when they are gray and opaque.

(b) The salt of phosphorus beads made in the oxidizing (bluish) flame are yellow when cold and reddish when warm.

Note: Instructions for making the bead tests can be found under "COBALT" and "CHROMIUM."

Note: A sulfide or arsenide ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat, until sulfur or arsenic fumes are no longer noticeable) before using the mineral in the bead tests.

## OIL

(1) Crude oil or petroleum in rocks can usually be detected by the odor of petroleum given off when the rocks are vigorously scratched or struck together.

(2) Crude oil and petroleum can usually be detected by using ether or chloroform.

To make this test: Place in a test tube or some other receptacle, such as a bottle, about one-half inch of the broken-up material that is to be tested. Pour onto this material about one inch of sulfuric ether or chloroform, and cork the receptacle tightly. Shake this mixture well and repeat the shaking at intervals of about ten minutes until any oil present has been dissolved (this process may take from ten minutes to six hours). After the oil has been dissolved let the mixture stand until the liquid has become clear and then pour the clear liquid into a shallow, clean, white porcelain dish (plate). The ether or chloroform will evaporate quickly, and leave the oil as a greenish-yellow or brownish ring on the dish. This ring, if it consists of oil, will have the characteristic odor and oily feel of petroleum.

Beginners practicing this test should use sand which carries petroleum or a few drops of crude oil.

NOTE: SULFURIC ETHER AND CHLOROFORM VAPORS EXPLODE WHEN IGNITED. IT IS VERY DANGEROUS TO MAKE THIS TEST IN THE PRESENCE OF OPEN LIGHTS AND FIRES.

NOTE: SULFURIC ETHER AND CHLOROFORM WILL ANAESTHETIZE (PUTS A PERSON TO SLEEP), THEREFORE THE EVAPORATION OF THESE LIQUIDS SHOULD ALWAYS TAKE PLACE IN THE OPEN OR WHERE THE FUMES CAN ESCAPE WITHOUT DOING HARM.

(3) Crude oil or petroleum when heated at a high temperature gives off vapors with a petroleum odor.

To make this test: Use one or both of the following methods:

(a) Heat some of the material until gases or vapors are given off freely. If the material contains crude oil or petroleum the gases given off have the characteristic odor of petroleum.

(b) Pour into a test tube or some other small-necked receptacle (a bottle) about one-half inch of the broken-up material that is being tested. Heat over a flame or fire until gases and vapors are given off freely. If the material contains any appreciable amount of crude oil or petroleum the gases given off will have a distinct odor of petroleum and petroleum will deposit on the cooler portions of the receptacle.

### OIL SHALE

The carbonaceous matter in oil shale, from which crude oil is sometimes produced, by destructive distillation processes, is called KEROGEN. This material is doubtless the original source of much of the crude oil produced, and the distillation has been accomplished by the high temperatures generated by the tremendous pressures operating when beds of this material are overlain by thousands of feet of earth.

Kerogen, or oil shale, gives off vapors or gases with the characteristic odor of petroleum when heated at a high temperature. To make this test, follow instructions (3) "OIL."

Kerogen in shale can often be detected if a splinter of the shale is heated over a match flame. If the proportion of kerogen in the shale is fairly high, the splinter will burn for several seconds after it is removed from the flame.

### ORGANIC MATERIAL\*

Laboratory studies have brought out important facts regarding sand and other materials that are used for concrete. One of these discoveries is the great importance of being sure that the material is clean, not only in appearance but in fact. Very often sand which appears to the eye to be clean contains enough humus or vegetable matter to reduce the strength of the concrete made from it very considerably. Tests carried on at Lewis Institute gave the following results:

Concrete made from a clean sand gave a compressive strength at 28 days of 1,900 pounds. Concrete made from this same sand, but with one-tenth of one percent of tannic acid added, gave a strength of only 1,400 pounds; in other words, one thousandth part of organic impurities, in terms of the weight of the sand, reduced the strength of the resulting concrete nearly 25 percent.

We can detect these organic impurities (humus or vegetable matter) even if we cannot see them by ordinary inspection, by using the following calorimetric test for organic impurities, which was devised at the laboratory of the Lewis Institute, Chicago:

To make this test: Take a 12-ounce, graduated prescription bottle and fill to the 4½-ounce mark with the sand to be tested. Pour onto this a 3-percent solution of sodium hydroxide, made by dissolving 1 ounce of sodium hydroxide (caustic soda) in enough water to make 32 ounces (1 quart), until the volume of the sand and solution, after shaking, amounts to 7 ounces. Shake thoroughly and let it stand for 24

---

\*Extracted from Lieut. Col. H. C. Boyden's "Notes on Recent Developments in Concrete." For full information on concrete, address Prof. D. A. Abrams of Lewis Institute, Chicago, or The Portland Cement Association, Chicago.

hours. Observe the color of the clear liquid above the sand. If the solution resulting from this treatment is colorless or has a light-yellowish color, the sand may be considered satisfactory insofar as organic impurities are concerned. If the liquid is a brown color, especially dark brown, reject the sand or wash it thoroughly before using it for concrete.

### POTASSIUM

(1) Volatile compounds of potassium color a non-luminous flame violet if heated therein.

To make this test: Wet one end of a piece of platinum or iron wire (baling wire) about four inches long with hydrochloric (muriatic) acid so that some of the finely powdered mineral will adhere to it. Draw the wet end of the wire through the powdered mineral. Heat the end of the wire, with the mineral on it, in a flame (an alcohol lamp flame is very satisfactory for this purpose). As soon as the wire and mineral are red-hot the flame will be colored violet if the mineral contains an appreciable amount of volatile compounds of potassium and provided, further, that the potassium flame is not masked or obscured by the flame of some other element.

Beginners practicing this test should use kainite, carnallite, or sylvite.

Note: The yellow flame of sodium and the red flame of lithium obscure the violet flame of potassium. To intercept and cut off these flames of sodium and lithium, look at the flame through a thick, blue glass.

(2) With a Merwin's Flame-Color Screen: Follow the directions outlined in (1), but observe the flame through the different sections of a Merwin's Flame-Color Screen. Through section 1 potassium gives a blue-violet flame, but it appears violet grading into reddish through section 3 and the same tints, but fainter, are seen through section 2.

### SILVER

(1) Silver can usually be detected by its reduction to metallic silver.

To make this test: Mix thoroughly a little of the finely powdered mineral with about three times its volume of sodium carbonate (baking soda). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until it is thoroughly fused (melted) and a metallic, silver globule or button results providing the ore used in the test contains an appreciable amount of silver. This button is bright when hot or cold and is malleable (can be flattened out if hammered on an anvil), but it is both harder and less easily cut than a lead button. It should be further tested for silver as explained in the following test.

Beginners practicing this test should use argentite, pyrargyrite, or some other high-grade, silver mineral.

(2) Hydrochloric acid or salt precipitate silver from nitric acid solutions as a white, curdy residue.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral that is to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about one teaspoonful of concentrated (strong) nitric acid and about one teaspoonful of water. Heat this solution to boiling, and boil until the silver has been dissolved. Cool to room temperature, and then add a few drops of concentrated hydrochloric (muriatic) acid, a small pinch of common table salt, or a few drops of strong, salt water. Upon the addition of the hydrochloric (muriatic) acid or salt to the nitric acid solution there will be thrown down a white, curdy mass (silver chloride) if silver is present to an appreciable extent in the mineral used in the test. If it is silver chloride, this white, curdy mass turns purple when exposed to the sunlight for a time. It is also very soluble in ammonia. Therefore, if an excess of ammonia is added to the solution (until the solution smells strongly of ammonia), the white, curdy mass, if it is silver chloride, will be dissolved.

Beginners practicing this test should use argentite, pyrargyrite, or some other silver mineral, the globule resulting from test (1), a small amount of silver filings, or a small piece of metallic silver.

Note: In test (2) it is sometimes better to use concentrated (strong) nitric acid instead of the dilute acid for dissolving the silver.

Note: When hydrochloric acid is used in test (2), lead and mercury may also be thrown down as a white precipitate, but silver in this form (silver chloride) is very soluble in an excess of ammonia while the other two are practically insoluble. See note under "LEAD."

## STRONTIUM

(1) Volatile compounds of strontium color a flame crimson if heated therein.

To make this test: Wet with dilute (one part acid and four parts of water) hydrochloric (muriatic) acid one end of a piece of iron baling wire about four inches long. Draw the wet end of the wire through the powdered mineral. Heat the end of the wire with the mineral on it in a flame (an alcohol lamp flame is very satisfactory for this purpose). As soon as the wire and mineral are red-hot the flame will be colored crimson if the mineral contains an appreciable amount of a volatile compound of strontium.

Beginners practicing this test should use strontianite, which is the only mineral that yields the result described when the test is conducted in this way.

**Note:** The crimson flame of strontium must not be mistaken for the red flame of lithium.

(2) With Merwin's Flame-Color Screen: Follow the directions outlined in (1), but observe the flame through the different sections of a Merwin's Flame-Color Screen. Through section 3 strontium gives a crimson-colored flame which is absorbed by sections 1 and 2.

## TIN

(1) Tin can usually be detected by the sublimate formed on charcoal and its reduction to small, metallic globules. These globules if treated with nitric acid yield a white powder.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal volume of powdered charcoal and two volumes of sodium carbonate (baking soda). Transfer to a shallow cavity in a stick of charcoal about the amount of this mixture that can be held on the tip of a knife blade, and form a paste of the mixture with water. Heat before the blowpipe in a strong, reducing (yellow) flame. This treatment gives a sublimate (coating) on the charcoal which is yellowish when hot and white when cold.

If this sublimate is moistened with a drop or two of cobalt nitrate solution and if the assay is then heated strongly before the blowpipe in the reducing (yellow) flame, the sublimate will assume a dull, bluish-green color when cold.

This treatment also yields small metallic globules, which can only with difficulty be forced to run together into one single, larger globule. These globules on cooling become coated with a white film but if cut open show a white, metallic color. If these globules are treated with nitric acid, a white powder is produced which is insoluble in that acid.

## TUNGSTEN

(1) Tungsten forms in hydrochloric acid a lemon-yellow residue that is soluble in ammonia.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the mineral that is to be tested (use about that amount of the powdered mineral that can be held on the tip of a knife blade). Pour into the receptacle about two teaspoonfuls of concentrated (strong) hydrochloric (muriatic) acid, and heat to boiling. Boil strongly, replenishing the acid if necessary, until a lemon-yellow colored residue (tungstic acid) has formed in the bottom of the receptacle. If an excess of ammonia is added to this solution (until the solution smells strongly of ammonia), the lemon-yellow colored residue, if it is tungstic acid, will be dissolved.

Beginners practicing this test should use scheelite or some other easily soluble, tungsten mineral.

(2) Tungsten can usually be detected by the blue oxides of tungsten formed on the addition of tin or zinc to a hydrochloric acid solution.

To make this test: Follow the instruction as given in test (1) up to and including the formation of the lemon-yellow colored residue (tungstic acid) just before the ammonia is added, and then proceed as follows: To the solution containing the tungstic acid add a piece of metallic tin or zinc. (If no pure tin or zinc is available, use a piece of galvanized iron with the zinc on it, or a piece of a tin can with the tin on it). On the addition of the tin or zinc the solution turns deep blue and later changes to brown providing the mineral used in the test contains an appreciable amount of soluble tungsten.

Note: Tests (1) and (2) should only be used on very soluble tungsten minerals (such as scheelite), as the test will take too long if used directly on rather insoluble minerals (such as wolframite or hubnerite). The rather insoluble minerals should be given the preliminary fusing treatment as described in test (2) for iron. The fused mass resulting from the fusion should then be treated as just described in tests (1) and (2) for tungsten.

(3) Tungsten can usually be detected by the colors it imparts to the fluxes.

(a) All of the borax beads of tungsten are colorless except the warm, saturated beads which are yellow.

(b) All of the salt of phosphorus beads of tungsten are colorless except the warm, saturated bead which is yellow and the cold, saturated bead, made in the reducing flame, which is greenish-blue.

Note: Instructions for making the bead tests can be found under "COBALT" and "CHROMIUM."

## VANADIUM

(1) Vanadium can usually be detected by the deep, cherry-red color imparted to concentrated hydrochloric acid, the greenish tint given the dilute acid, and the evolution of chlorine gas.

To make this test: Place in a bone-dry test tube or some other glass or porcelain receptacle a little of the powdered mineral that is to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour onto the mineral in the receptacle about one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid. Almost immediately chlorine gas will be given off, and the solution will turn to a deep, cherry-red color providing the mineral used in the test contains an appreciable amount of vanadium. This chlorine gas is easily recognized by its rusty, green color and its pungent odor. If a few drops of water are added to this cherry-red solution, it changes

to a light-greenish tint. If too much water is added, the solution becomes almost colorless.

Beginners practicing this test should use vanadinite, descloizite, or some other easily soluble vanadium mineral.

(2) Vanadium can usually be detected by the greenish color given sulfuric acid.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral that is to be tested (use about that amount of powdered mineral that can be held on the tip of a knife blade). Pour onto the mineral about one teaspoonful of concentrated (strong) sulfuric acid (oil of vitriol). Heat the solution to boiling, and boil until dense, white fumes of sulfuric acid are given off. Cool to room temperature, and when cold add very carefully from one to two teaspoonfuls of cold water to the solution. Almost immediately upon the addition of the water the color of the solution will change to a light green providing the mineral used in the test contains an appreciable amount of vanadium.

Beginners practicing this test should use vanadinite, descloizite, or some other easily-soluble, vanadium mineral.

(3) Vanadates with potassium acid sulfate in a closed tube give a yellow mass.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal amount of potassium acid sulfate (potassium bisulfate). Place about that amount of this mixture that can be held on the tip of a knife blade in a closed tube, and heat strongly over a hot flame. This will produce a yellow mass, providing the mineral used in the test contains an appreciable amount of vanadium.

Beginners practicing this test should use vanadinite or descloizite.

(4) Vanadium can usually be detected by the colors it imparts to the fluxes.

(a) In the oxidizing (bluish) flame borax beads of vanadium are all yellow except the unsaturated, cold bead, which is colorless. In the reducing (yellow) flame all borax beads of vanadium are green.

(b) All salt of phosphorus beads of vanadium made in the oxidizing (bluish) flame are yellow, and all those beads made in the reducing (yellow) flame are green.

Note: Instructions for making the bead tests can be found under "COBALT" and "CHROMIUM."

Note: A sulfide or arsenide ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat until sulfur or arsenic fumes are no longer noticeable) before using the mineral in the bead test.

## ZINC

(1) Zinc can usually be detected by the sublimate formed on charcoal when heated with soda before the blowpipe. This sublimate is yellow when hot and white when cold. If moistened with cobalt nitrate solution and heated, it assumes a green color.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal volume of sodium carbonate (baking soda). Transfer to a shallow cavity in a stick of charcoal about the amount of this mixture that can be held on the tip of a knife blade, and form a paste of the mixture by moistening with water. Heat before the blowpipe in a strong, reducing (yellow) flame. This treatment gives a scanty sublimate (coating) on the charcoal, which is canary-yellow colored when hot, and white when cold, providing the mineral used in the test contains an appreciable amount of zinc.

If the sublimate made in the test just described is moistened with a drop or two of cobalt nitrate solution and if the assay is then heated strongly before the blowpipe in the reducing (yellow) flame, the sublimate will assume a bright-green color that is best seen when it is cold.

Beginners practicing this test should use sphalerite, smithsonite, or a small piece of metallic zinc.

Note: A few zinc compounds such as sphalerite (zinc blende or black jack) give the above results without mixing the mineral with a flux.

(2) Zinc is thrown down as a white precipitate by ammonium sulfide from an alkaline solution, this being the only white sulfide that is insoluble in such a solution.

To make this test: Place in a test tube or some other glass or porcelain receptacle a little of the powdered mineral that is to be tested (use about the amount of the powdered mineral that can be held on the tip of a knife blade). Pour onto the mineral in the receptacle about one teaspoonful of concentrated (strong) hydrochloric (muriatic) acid and a drop of nitric acid, and heat to boiling. After the zinc has been dissolved add about two teaspoonfuls of cold water and cool the solution to room temperature. To the cold solution add an excess of ammonia (until the solution smells strongly of ammonia). Any iron present will be thrown down as a brownish-red precipitate as mentioned in test (3) "IRON." Filter off the residue and precipitate, and catch the clear, filtered solution in another glass or porcelain receptacle. To the clear, filtered solution add a few drops of ammonium sulfide solution. This will throw down zinc as a white precipitate (zinc sulfide).

(3) Silicates of zinc when moistened with cobalt nitrate and heated before the blowpipe assume a blue color. The following method for

making this test is given in G. M. Butler's "Handbook of Blowpipe Analysis."

To make this test: "Hold a small splinter of the substance to be tested in the platinum forceps and heat it in the blowpipe flame to the highest possible temperature. Then examine it with a lens; if it shows any signs of fusion, this test cannot be applied. If non-fusible, moisten it with cobalt nitrate and ignite strongly in the hottest part of the blowpipe flame. It will first turn black, but after prolonged heating may assume a characteristic tint. If a splinter of the substance cannot be obtained, it should be powdered and the test conducted upon a flat cake of the powder upon charcoal. Longer heating is required by this method, however, and the results are not apt to be as satisfactory."

This test can be applied only to non-fusible, white or faintly tinted minerals, or those which become white or faintly tinted upon ignition.

A blue coloration best seen when cold indicates zinc, but infusible aluminum minerals will yield the same color when treated in this way.

Beginners practicing this test should use calamine or willemite (zinc silicates).

(4) The following method for the quick determination of the grade of zinc ore was given by G. M. Butler, Dean of the College of Mines and Engineering, University of Arizona, and Director of the Arizona Bureau of Mines, in the January, 1913, issue of *Economic Geology*:

"Probably the quickest method for quickly ascertaining the approximate grade of oxidized zinc ore is to place about a teaspoonful of the finely powdered material to be tested upon a piece of iron or steel barrel-hoop, one and a half to two inches in width. This charge should be introduced into the incandescent coals of a blacksmith forge which has been blown until little black smoke is evident. The iron should be sunk into a depression in the glowing coals so that they stand a half inch or so above the sample on all sides. Then the draught should be increased until the iron is heated white-hot. Oxidized zinc ore will take fire at this point, burning with a bluish flame and emitting white fumes of zinc oxide. The density of these fumes varies with the grade of the ore. Experience enables one to judge within five percent of the zinc content by this method which, although long known and practiced in some places, is unfamiliar to those in other localities. The scheme can be applied to ore of any grade as material assaying five percent zinc will yield visible fumes."



## WEIGHTS

## Avoirdupois

- 1 Dram=27.343 Grains
- 1 Ounce=16 Drams
- 1 Pound=16 Ounces
- 1 Short Ton=2,000 Pounds
- 1 Long Ton=2,240 Pounds

## Troy

(Used in weighing Gold or Silver)

- 1 Pennyweight=24 Grains
- 1 Ounce=20 Pennyweights
- 1 Pound=12 Ounces

## Apothecaries'

(Used in putting up Medical Prescriptions)

- 1 Scruple=20 Grains
- 1 Dram=3 Scruples
- 1 Ounce=8 Drams
- 1 Pound=12 Ounces

## Metric

- 1 Centigram=10 Milligrams
- 1 Decigram=10 Centigrams
- 1 Gram=10 Decigrams
- 1 Decagram=10 Grams
- 1 Hectogram=10 Decagrams
- 1 Kilogram=10 Hectograms
- 1 Tonneau (Metric Ton)=1,000 Kilograms

## Equivalents

- 1 Pound (Avoirdupois)=1.215 Pounds (Troy or Apothecaries')  
=14.58 Ounces (Troy or Apoth.)=7,000 Grains=0.4536 Kilogram
- 1 Pound (Troy or Apothecaries')=0.82286 Pound (Avoir.)=13.166  
Ounces (Avoir.)=5,760 Grains=0.3732 Kilogram
- 1 Gram=0.0353 Ounce (Avoir.)=0.03215 Ounce (Troy or Apoth.)
- 1 Kilogram=2.2046 Pounds (Avoir.)=2.679 Pounds (Troy or  
Apoth.)=35.274 Ounces (Avoir.)=32.151 Ounces (Troy or  
Apoth.)=1,000 Grams
- 1 Tonneau (Metric Ton)=1.1023 Short Tons

## MEASURES OF VOLUME

## Cubic

- 1 Cubic Foot=1,728 Cubic Inches
- 1 Cubic Yard=27 Cubic Feet=46,656 Cubic Inches
- 1 Cubic Meter=1,000 Cubic Decimeters (Liters)=1,000,000 Cubic Centimeters

## Dry Measure

- 1 Quart=2 Pints
- 1 Gallon=4 Quarts
- 1 Peck=2 Gallons
- 1 Bushel=4 Pecks
- 1 Cord of Wood=128 Cubic Feet (Cut 4 feet long, piled 4 feet high and 8 feet on the ground)

## Liquid Measure

- 1 Pint=4 Gills
- 1 Quart=2 Pints
- 1 U. S. Gallon=4 Quarts
- 1 Barrel=31.5 U. S. Gallons

## Fluid Measure

- 1 Fluid Dram=60 Minims
- 1 Fluid Ounce=8 Fluid Drams
- 1 Fluid Pint=16 Fluid Ounces=1 Pint (Liquid Measure)
- 8 Pints=1 Gallon

## Metric Liquid and Dry Measures

- 1 Centiliter=10 Milliliters
- 1 Deciliter=10 Centiliters
- 1 Liter=10 Deciliters=1 Cubic Decimeter=1,000 Cubic Centimeters
- 1 Decaliter=10 Liters
- 1 Hectoliter=10 Decaliters
- 1 Kiloliter=10 Hectoliters

## Equivalents

- 1 Quart (U. S. Dry Measure)=67.2 Cubic Inches=0.03889 Cubic Foot=0.001101 Cubic Meter=1.101 Liters
- 1 Quart (U. S. Liquid Measure)=57.75 Cubic Inches=0.0334 Cubic Foot=946 Cubic Centimeters=0.946 Liter
- 1 Liter=1.0567 U. S. Liquid Quarts=0.908 U. S. Dry Quart=0.0353 Cubic Foot=61.023 Cubic Inches=1,000 Cubic Centimeters
- 1 Cubic Meter=1.3079 Cubic Yards=35.31 Feet

## BIBLIOGRAPHY

- BOYDEN'S—Notes on Recent Developments in Concrete.  
BRUSH-PENFIELD—Determinative Mineralogy and Blowpipe Analysis.  
BUTLER—Handbook of Minerals.  
BUTLER—Handbook of Blowpipe Analysis.  
FORD—Dana's Manual of Mineralogy.  
PRESCOTT AND JOHNSON—Qualitative Chemical Analysis.  
ROGERS—Study of Minerals.

## MAPS OF ARIZONA

The Arizona Bureau of Mines now has available for distribution four different maps of the State, as follows:

1. Base map of Arizona in two sheets on a scale of about eight miles to the inch. This map is strictly geographic, with the positions of all towns, railroads, rivers, surveyed lands, national forests, national parks and monuments, etc., indicated in black, and the location of mountains and other topographic features shown in brown. It also indicates where the various mining districts are situated, and is accompanied by a complete index. It was issued in 1919 and is sold, unmounted, for 35c, or mounted on cloth with rollers at top and bottom for \$2.50.

2. A topographic map of Arizona in one sheet, on the same scale as the base map. It shows 100-meter contours, and there is a meter-foot conversion table on the map. It was issued in 1923, and is sold, unmounted, for 50c, or mounted on cloth with rollers at top and bottom for \$2.50.

3. A geologic map of Arizona on the same scale as the base map, printed in many colors. It was issued in 1925, and is sold both mounted and unmounted for the same prices as the topographic map.

4. A relief map of Arizona on the same scale as the base map, printed in various shades of brown, black, and blue. It was issued in 1925, and looks exactly like a photograph of a relief model of the State. This map was prepared by the U. S. Geological Survey, and is sold by the Survey for \$1.00. Unmounted copies may be obtained from the Arizona Bureau of Mines at the same price. The same map mounted on cloth with rollers at the top and bottom is sold by the Bureau for \$3.00.

POSTAGE IS PREPAID ON ALL MAPS.

### SERVICE OFFERED BY THE BUREAU

The Arizona Bureau of Mines will classify free of charge all rocks and minerals submitted to it, provided it can do so without making elaborate chemical tests. Assaying and analytical work is done at rates fixed by law, which may be secured on application.

The Bureau is always glad to answer to the best of its ability inquiries on mining, metallurgical, and geological subjects; and takes pride in the fact that its replies are always as complete and authoritative as it is possible to make them.

All communications should be addressed and remittances made payable to "The Arizona Bureau of Mines, University Station, Tucson, Arizona."