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FIELD TESTS FOR THE COMMON METALS

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By

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PREFACE

This pamphlet has been compiled as a text to be used in the Arizona Bureau of Mines' extension lectures on "Field Tests for Metals." Many of the people attending these programs, 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 for beginners 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.

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FIELD TESTS FOR THE COMMON METALS

By George R. Fansett

TESTING EQUIPMENT

Ultraviolet ray (black light) lamp
Blowpipe (8 or 10 inches long)
Heating apparatus (candle or alcohol, lard oil, or some other lamp)
Charcoal sticks (4 inches by 1 inch by ¾ inch)
Hand lens
Streak plate
2 or 3 inch magnet or magnetized knife blade
Jackknife
Forceps (platinum-tipped are the best)
3 pieces (No. 26 B. & S. wire gauge) platinum wire and holder for the wire
Iron wire (baling wire), a few pieces 4 inches long
Pyrex test tubes (4 inches by ½ inch or 6 inches by ¾ inch)
Porcelain (china) cup
Porcelain crucibles
Soft glass tubing, 7 mm. (for closed and open tubes). Some prefer to buy these tubes already manufactured rather than to make them.
Book of litmus paper
Window glass (few pieces for fluorine test)

DRY REAGENTS

¼ ounce powdered borax. Borax glass is more satisfactory than ordinary borax.
1 ounce powdered sodium carbonate (baking soda)
¼ ounce powdered salt of phosphorus (sodium metaphosphate)
4 ounces zinc metal (mossy or granulated, 20 mesh or finer)
2 ounces tin (shavings or filings)
1 ounce powdered manganese dioxide
¼ ounce sodium acid phosphate (for magnesium test)
¼ ounce diphenylamine crystals (for nitrate test)
1 ounce sodium bismuthate (for manganese test)
2 ounces sodium or potassium ethyl xanthate (for molybdenum test)
2 ounces potassium or sodium hydroxide (pellets) (for molybdenum test)

WET REAGENTS

4 ounces concentrated hydrochloric (muriatic) acid
4 ounces concentrated nitric acid
2 ounces concentrated sulfuric acid (oil of vitriol)
8 ounces concentrated ammonia
3 ounces denatured alcohol

TESTS FOR METALS AND MINERALS

ANTIMONY

The most important antimony mineral of commerce is stibnite (antimonite, antimony glance, gray antimony, or antimony sulfide).

1. Antimony can usually be detected by the dense, white fumes given off and the heavy, white sublimate formed near the mineral when it is 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 the 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[1] (coating) on the charcoal near the mineral, the outer edges, where the coating is thin, appearing bluish white.

Beginners practicing this test should use antimony sulfide.

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 ½ 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) on the walls of the tube. This coating is black when hot, but on cooling changes to reddish brown.

Beginners practicing this test should use antimony sulfide.

ARSENIC

Nearly all of the arsenic that is marketed in this country is obtained as a by-product from the fumes given off when smelting other ores.

1. When struck a glancing blow with a hammer, many arsenic minerals give off sparks and a garliclike odor.

Beginners practicing this test should use arsenopyrite.

2. Arsenides, sulfides of arsenic, and native arsenic give off a garliclike 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.

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[1]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.

To make this test: Transfer to a flat stick of charcoal a little of the mineral to be tested for arsenic. Use about the 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, when thus treated, give off fumes that have a garliclike odor. These arsenical fumes form a white coating on the charcoal, at a distance from the mineral.

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.

To make this test: Mix thoroughly a little of the finely powdered mineral with three volumes of powdered sodium carbonate (baking soda). Place in a closed tube about ½ inch of this mixture. Heat the lower end of the tube at a red heat for some time. Arsenic and some arsenides when given this treatment yield a black, mirrorlike sublimate (coating) on the walls of the tube (arsenical mirror).

Beginners practicing this test should use arsenic.

4. Some orpiments (arsenic trisulfide) fluoresce (glow) green when exposed to strong ultravoilet rays (black light). Always check fluorescent substances by chemical and blowpipe tests.

ASBESTOS

Asbestos is a term applied to several minerals that have flexible, fibrous structures and are more or less acid- and fireproof. Among such minerals are fibrous serpentine (chrysotile) and various amphibole minerals (fibrous tremolite, fibrous actinolite, fibrous anthophyllite, fibrous crocidolite, and fibrous amosite). Chrysotile is the most important asbestos mineral produced in this country.

Asbestos can usually be recognized by its incombustibility, flexible structure, and slow conductivity of heat.

1. To make this test: Twist a few fibers of the material into a string or yarn. Hold one end of the string or yarn in a flame. If the material is asbestos it will not burn.

Beginners practicing this test should compare the combustibility (taking fire and burning) of cotton, wool, and asbestos.

2. The quality of asbestos and its suitability for most uses may be determined by a few simple tests. Length, color, silkiness, flexibility, and, to some extent, fineness of fiber and tensile strength may be determined by inspection. A sample of asbestos should be fiberized by rubbing or crushing between the fingers. Single fibers may then be tested for flexibility and tensile strength by bending and breaking. Several fibers may be twisted into a strand or yarn and again tested for flexibility and strength. Asbestos of good quality should be easily fiberized, soft, silky, strong, flexible, and easily twisted into a strong yarn. Fibers one-fourth inch or more in length and otherwise of a good grade are of commercial interest.[2]

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[2]R. B. Ladoo, *Non-Metallic Minerals* (New York: McGraw-Hill Book Co., Inc., 1925), pp. 62, 63.

BARIUM

The most important barium minerals are barite (barytes, heavy spar, or barium sulfate) and witherite (barium carbonate).

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

To make this test: Use a piece of iron wire (baling wire) about 4 inches long. 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 satisfactorily 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.

Beginners practicing this test should use witherite.

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 the amount of the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 4 teaspoonfuls of dilute (equal parts of acid and water) hydrochloric (muriatic) acid. Heat to boiling and then add about 10 teaspoonsfuls of cold water. To this solution add a few drops of dilute (one part acid added to four parts of water) sulfuric acid[3] (oil of vitriol). Upon the addition of the dilute sulfuric acid to the dilute acid solution, any barium in solution will be thrown down as a white precipitate.

Beginners practicing these tests should use witherite.

CALCIUM

Commercially, the most important calcium minerals are calcite (limestone, marble, chalk, or calcium carbonate), dolomite (brown spar or calcium-magnesium carbonate), gypsum (selenite, satin spar, rock gypsum, land plaster, or hydrous calcium sulfate), and fluorite (fluor spar or calcium fluoride).

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 mineral to be tested. Use about

[3]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.

the amount of powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 1 teaspoonful of concentrated (strong) hydrochloric (muriatic) acid[4] or about twice this amount of dilute (about equal parts of acid and water) hydrochloric acid.

This mixture either cold or on being heated (if the mineral contains calcium carbonate) will effervesce (boil; bubble) 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 5 teaspoonfuls of cold water. To this solution add ammonia[5] until a white precipitate begins to form or until the solution smells of ammonia. Then add a few crystals of ammonium oxalate or about ½ teaspoonful of concentrated aammonium oxalate solution (ammonium oxalate crystals dissolved in water). On the addition of the ammonium oxalate to this solution, a white precipitate will be thrown down providing the mineral used in the test contains an appreciable amount of calcium.

Beginners practicing this test should use limestone, 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 1 teaspoonful of concentrated hydrochloric acid. After all effervescence 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 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 limestone, marble, chalk, or some other easily soluble calcium mineral.

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

To make this test: Wet one end of a piece of iron wire (baling wire) about 4 inches long 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

[4]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.

[5]Ammonia when mixed with an acid generates heat which 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* concentrated acid solution.

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 limestone, 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 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.

5. Some calcium minerals (some calcites, limestones, aragonites, gypsums, and others) fluoresce (glow) when exposed to strong ultraviolet light (black light). Red, yellow, orange, and blue are among the colors emitted by these minerals when activated by this light—best seen in the dark.

Always check fluorescent substances by chemical and blowpipe tests.

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; bubbles) when moistened with hydrochloric (muriatic) acid. This effervescing 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 is not a conclusive test for the determination of calcium carbonate, 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.

CHLORINE

1. Chlorine can usually be detected by its precipitation as silver chloride.

To make this test: Place in a test tube or some other glass receptacle a little of the material to be tested. If the material is a mineral use about the same amount of the powdered mineral that can be held on the tip of a knife blade; if the material is a liquid use about 1 teaspoonful. Pour into the receptacle about 1 teaspoonful of dilute nitric acid. Heat this mixture to boiling and then cool it. On the addition of a small amount of silver nitrate to this cool solution a white precipitate will be thrown down providing the material used in the test contains an appreciable amount of chlorine. If only a small amount of chlorine is present in the material tested, the precipitate gives the solution a

milky appearance; if considerable chlorine is present, the precipitate looks curdy. If exposed to the sunlight for a time, this white precipitate turns dark (from a violet to brown color). This precipitate (silver chloride) is also soluble in ammonia. To make this part of the test, pour into the receptacle an excess of ammonia (until the solution smells strong of ammonia). The ammonia will dissolve the silver chloride.

2. Chlorine can usually be detected by the fumes that are given off when a chloride is heated with potassium bisulfate and manganese dioxide. These fumes have a bleaching action.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal volume of manganese dioxide (pyrolusite, psilomelane, or wad) and about four volumes of powdered potassium bisulfate (acid sulfate of potassium). Fill a small test tube to about ½ inch from the bottom with this mixture. Heat the lower end of the tube at a red heat for several minutes. This mixture when given this treatment will give off rusty-green fumes that have a strong pungent odor providing the material used in the test contains an appreciable amount of chlorine. These rusty-green fumes, if chlorine gas, have a bleaching action. This can be tested by holding a strip of moistened litmus paper inside the tube in the fumes given off.

Beginners practicing these tests should use halite (sodium chloride, or common table salt) or sylvite (potassium chloride).

CHROMIUM

The most important chromium mineral is chromite (chromic iron ore or ferrous metachromite).

1. 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 2 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 may be used for this purpose. Make a small loop about 1/16 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. Touch the bead while it is red hot to a little of the very finely powdered mineral. If the bead[6] made from the borax and a very little of a mineral

[6]The chromium bead tests must not be confused with those for vanadium, which give 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.

knife blade. Pour into the receptacle about 1 teaspoonful of acid. Use concentrated (strong) nitric acid or a mixture of nitric and hydrochloric (muriatic) acid. Heat until the copper has been dissolved[9] and then add about 3 teaspoonfuls of cold water. To this add an excess of ammonia[10] (until the solution smells strong 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, azurite, chalcopyrite, chalcocite, or some other high grade copper mineral or a small piece of metallic copper.

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

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

To make this test: Use a piece of iron wire (baling wire) about 4 inches long. Wet one end of the wire in water so that some of the pulverized mineral will adhere to it. Draw the went 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[11] is moistened with hydrochloric 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.

4. With a Merwin's Flame-Color Screen: Follow the directions outlined in "Copper" (3) but observe or look at the flame through the different sections of a Merwin's Flame-Color Screen. Through

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[9]If the mineral does not dissolve readily fuse it as directed in "Copper" (5) and use the fused mass in this test.

[10]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.

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.

[11]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 made 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.

The copper of volatile copper compounds alloys with the platinum when platinum wire is used for making flame tests, making the alloyed piece of wire worthless for further copper flame tests.

When iron wire is used, use a new piece of wire for each copper flame test.

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 mass of metallic copper.

To make this test: Mix thoroughly a little of the finely powdered mineral with about twice its volume of powdered flux (sodium carbonate [baking soda]—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 this mixture 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. Copper can usually be detected by the colors it imparts to the fluxes. Borax and salt of phosphorus beads are green when warm and blue when cold in the oxidizing (bluish) flame. Saturated beads are opaque red in the reducing flame of the blowpipe. In the presence of much iron, the oxidizing flame bead is green or bluish green. Bead test instructions can be found under "Chromium" or "Cobalt."

7. Some copper minerals (some azurites, chrysocollas, and malachites) fluoresce (glow) blue, gray, or white when exposed to strong ultraviolet rays (black light).

Always check fluorescent substances by chemical and blowpipe tests.

FLUORINE

The most important fluorine minerals are fluorite (fluor spar or calcium fluoride) and fluorapatite.

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 pencil point for this purpose. In about 10 minutes wash off the mixture of acid and mineral, remove the paraffin by heating the glass, and clean

these reagents to the nitrohydrochloric acid, the solution will turn a deep purple color providing the mineral used in the test contained an appreciable amount of gold. On exposure to the air the purple solution turns yellow. This test is known as the "Purple of Cassius Test for Gold."

5. In nitrohydrochloric acid solutions of gold, ferrous sulfate gives a brown precipitate.

To make this test follow the directions outlined in "Gold" (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

Important iron minerals of commerce are hematite (red ocher, red oxide of iron, specular iron, iron glance, ferric oxide, or iron sesquioxide), limonite (brown oxide of iron, brown ocher, brown hematite, or bog iron ore), and magnetite (black iron oxide, magnetic iron ore, or lodestone.

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 the 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 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 flame until it is thoroughly fused. The resulting fused mass will contain a dark-colored, more or less metallic button[14] 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.

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 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 1 teaspoonful of

[14]Cobalt and nickel buttons produced in this manner are also magnetic. For that reason the magnetic button should be further tested for iron by "Iron" (3) and for cobalt and nickel by the test given for those metals.

concentrated (strong) hydrochloric (muriatic) acid and a few drops of nitric acid. Heat this solution until the iron has been dissolved,[15] and then add about 2 teaspoonfuls of cold water. To this solution add an excess of ammonia[16] (until the solution smells strong of ammonia). Upon the addition of the ammonia to this acid solution, there will be thrown down a brownish-red precipitate if the mineral used in the test contains an appreciable amount of iron.

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

4. Iron can usually be detected by the colors it imparts to the fluxes. In the oxidizing (bluish) flame of the blowpipe, the borax bead of iron is amber-colored when warm and yellow to colorless when cold, while in the reducing flame the borax bead is bottle-green, providing the bead is saturated. Bead test instructions are given under "Chromium" and "Cobalt."

5. Some limonites (brown hematite or iron sesquioxide) and some siderites (iron protocarbonate) fluoresce (glow) green when exposed to strong ultraviolet rays (black light).

Always check fluorescent substances by chemical and blowpipe tests.

LEAD

The most important lead minerals of commerce are galena (galenite, steel galena, potter's ore, or lead sulfide), cerussite (lead carbonate or white lead ore), and anglesite (lead sulfate).

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 an equal volume of powdered charcoal and three volumes of powdered sodium carbonate (baking soda). Moisten this mixture with water and transfer about the 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 blowpipe 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 is whitish on the outer edges, and the white portion should not be confused with an antimony or zinc sublimate.

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[15]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.

[16]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.

MANGANESE

Important manganese minerals are pyrolusite (black oxide of manganese, or manganese dioxide), psilomelane (impure hydrous manganese dioxide), rhodochrosite (manganese protocarbonate), rhodonite (manganese metasilicate), and bementite (hydrous manganese silicate).

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 2 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 may be used for this purpose. Make a small loop about 1/16 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. Touch the bead while it is red hot to a little of the very finely powdered mineral. If the bead made from the borax and a *very little* manganese mineral[19] are 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 oxidized manganese mineral.

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 "Manganese" (1) (a) are followed, the color of the bead which is formed when the oxidizing 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 flame is colorless. Sodium carbonate beads are opaque.

If the greenish-blue sodium carbonate bead of manganese is

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

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.

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

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.

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

2. Nitric acid solutions of manganese with sodium bismuthate give a wine-purple (permanganate) colored solution.

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 the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 2 teaspoonfuls of concentrated (strong) nitric acid and about 1 teaspoonful of water. Boil the mixture for 1 or 2 minutes and then let it stand for a time so that all residue settles.

In a second test tube place a pinch of sodium bismuthate powder. Pour onto the sodium bismuthate about 1 inch of the clear nitric acid solution from the first receptacle. Then add some cold water and let the mixture stand until all residue has settled. Manganese, if present in the mineral used in the test gives a wine-purple (permanganate) colored solution with sodium bismuthate, providing an excess of chlorides or other reducing substances is not present.

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

3. Red oxide of lead when added to nitric acid solutions of manganese usually gives a pink (permanganate) colored solution.

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 1 teaspoonful of concentrated nitric acid and about the same amount of water. Heat the mixture to boiling and boil for a minute or two and then let it stand for a time, so that all residue settles.

In a second test tube place a pinch of powdered red oxide of lead (red colored litharge can be use). Pour onto the red oxide of lead about 1 inch of the clear nitric acid solution from the first receptacle. Then add a little cold water and let the mixture stand until all residue has settled. Manganese, if present in the mineral used in the test, gives a pink (permanganate) colored solution with red oxide of lead, providing an excess of chlorides or other reducing substances is not present.

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

4. 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 mineral to be tested. Use about the amount of the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 1 teaspoonful of concentrated hydrochloric (muriatic) acid. Heat gently at first, then increase the temperature as much as possible, and

another 6 inch test tube about 1 inch of strong sodium or potassium ethyl xanthate solution (the salt dissolved in water). Pour some of the acidified filtrate into the xanthate[22] solution.

If molybdenum is present in the mineral used in the test, a pink to purple precipitate (sometimes fading out rapidly) is usually given when the acidified filtrate mixes with the sodium or potassium xanthate solution.

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

2. In nitric acid solutions of molybdenum potassium ferrocyanide throws down a reddish-brown precipitate.

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 3 teaspoonfuls of concentrated (strong) nitric acid. Boil for a few minutes and then add 4 or 5 teaspoonfuls of cold water. Upon the addition of ferrocyanide to the acid solution, a reddish-brown precipitate will be thrown down providing the mineral used in the test contains an appreciable amount of molybdenum.

Beginners practicing this test should use molybdenite or wulfenite.

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

a) In the oxidizing (bluish) flame of the blowpipe, borax beads[23] 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 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 acid and tin is added to the boiling solution, the solution turns brown.

4. Some wulfenites (lead molybdate) fluoresce (glow) a green color when exposed to strong ultraviolet rays (black light).

Always check fluorescent substances by chemical and blowpipe tests.

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

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[22]Some prefer to use xanthate crystals with a couple of drops of acid (hydrochloric or sulfuric) instead of the water solution of xanthate.

[23]Instructions for making the bead tests can be found under "Cobalt" or "Chromium."

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.

Tests for molybdenum sulfides

1. Powdered molybdenum sulfide (molybdenite), if heated strongly in an open tube, gives off sulfurous fumes and deposits 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 (molybdenite), if heated on charcoal for a long time in the oxidizing (bluish) flame of the blowpipe, deposits a sublimate on the charcoal a short distance from the assay. This sublimate 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 reducing (yellow) flame of the blowpipe, it assumes a beautiful, deep-blue color.

3. Molybdenite is soluble (dissolves) in nitric accid. If heated strongly to dryness in a porcelain receptacle, a beautiful blue coating forms on the bottom and sides of the receptacle.

Tests for molybdenum oxides

1. Finely powdered molybdenum oxides are partially soluble in hydrochloric acid. Tin added to this solution produces a green, blue, and finally a brown-colored solution.

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 2 teaspoonfuls of concentrated (strong) hydrochloric (muriatic) acid, heat to boiling and boil for a few minutes. Dilute this solution by adding about 4 teaspoonfuls of cold water. If some metallic tin is then added to this solution, the solution will turn green, then blue,[24] and finally brown providing the mineral used in the test contained an appreciable amount of molybdenum oxide.

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 the amount of powdered mineral that can be held on the tip of a knife blade. Pour onto this mineral a few drops of concentrated 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 oxide.

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[24]The blue color may be of such short duration that the solution seems to turn to brown without showing any blue coloration.

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 the 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. Add from three to five drops of concentrated sulfuric acid 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 providing the mineral used in the test contains an appreciable amount of molybdenum oxide.

Beginners practicing this test should use wulfenite.

NICKEL

Important nickel minerals are millerite (nickel pyrites, sulfuret of nickel, capillary pyrites or nickel sulfide) and niccolite (copper nickel, arsenical nickel or nickel arsenide). Nearly all of the nickel of commerce is obtained from nickel-bearing pyrrohtite and garnierite.

1. In an alkaline solution, dimethylglyoxime[25] solution throws nickel down as a red precipitate.

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 1 teaspoonful of concentrated (strong) nitric acid. Heat until the nickel has been dissolved and then add about 2 teaspoonfuls of cold water to the solution. To this dilute solution add an excess of ammonia (until the solution smells of ammonia). Filter[26] the solution through a good filter and catch the filtrate (the clear solution through the filter paper) in a glass receptacle. To this clear filtrate add a few drops of dimethylglyoxime solution. On the addition of the dimethylgyoxime solution to this filtrate there will be thrown down a light red precipitate providing the mineral used in the test contains an appreciable amount of nickel.

2. 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 the amount of powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 1 teaspoonful of concentrated nitric acid or a mixture of about 1 teaspoonful of nitric, 1 teaspoonful of hydrochloric (muriatic) acid, and 1 teaspoonful of water. Heat this mixture to boiling

[25]Dimethylglyoxime solution is made by dissolving one part of the powder in about ten parts of alcohol. It takes several hours to prepare the solution since the powder dissolves very slowly.

[26]The filtrate must be clear (free from all precipitate).

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 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, niccolite, or a piece of metallic nickel.

3. 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 (melted). The resulting fused mass will contain a dark-colored, more or less metallic button[27] 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.

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

a) In the oxidizing (bluish) flame of the blowpipe, borax beads[28] of nickel are violet when warm and brown when cold. In the reducing flame the borax beads are colorless unless saturated with nickel, then they are gray and opaque.

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

NITRATES

Important natural nitrate minerals are sodium nitrate (soda niter or Chile saltpeter), potassium nitrate (niter or saltpeter), and nitrocalcite (calcium nitrate).

1. Nitrates[29] can usually be detected by the dark blue precipitate in diphenylamine[30] solution.

To make this test: Place in a test tube about 1 teaspoonful of the material to be tested for nitrates. To dissolve the nitrates pour onto this material about 3 tablespoonfuls of water. Heat to boiling, then cool and allow the residue to settle.

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[27]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), (2), and (4) and for cobalt and iron by the tests given for those metals.

[28]Instructions for making the bead tests can be found under "Cobalt" and "Chromium."

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.

[29]A nitrate is a compound formed by the union of nitric acid with a base, as sodium, potassium, or calcium.

[30]Diphenylamine solution is made by dissolving ½ gram of diphenylamine in 100 cubic centimeters of concentrated sulfuric acid (oil of vitriol) and cautiously adding this to 25 cubic centimeters of water.

Pour into a second test tube about 1 inch of diphenylamine solution. Inclining this test tube slightly, carefully pour about 1 teaspoonful of the liquid from the first receptacle down the inside of the test tube containing the diphenylamine solution. Nitrates if present in the material used in the test usually give a dark blue precipitate with the diphenylamine solution.

Beginners practicing this test should use sodium nitrate, potassium nitrate, or nitric acid.

2. Nitrates can usually be detected by the brown ring formed when a concentrated solution of ferrous sulfate is added to a solution of a nitrate in concentrated sulfuric acid.

To make this test: Place in a test tube or some other glass receptacle a little of the mineral to be tested. Use about ½ teaspoonful of the powdered mineral. Pour into the receptacle about 1 teaspoonful of sulfuric acid (oil of vitriol). Heat this solution to boiling and then cool. If fresh, concentrated ferrous sulfate solution [31] is slowly added to this acid solution a brown ring will form where the ferrous sulfate solution touches the acid solution providing the material used in the test contains an appreciable amount of nitrates. Pungent, brownish-red nitrous oxide fumes are usually given off.

3. Nitrates, when fused with potassium bisulfate, yield brownish-red nitrous oxide fumes.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal volume of powdered potassium bisulfate (acid sulfate of potassium). Place in a closed tube or test tube about ¼ inch of this mixture. Heat the lower end of the tube at a red heat for some time. Nitrates when given this treatment give off nitrous oxide fumes which are recognized by their reddish-brown color and pungent odor.

Beginners practicing these tests should use nitric acid or sodium nitrate (soda niter or Chile saltpeter).

4. Sodium nitrate (soda niter or Chile saltpeter), potassium nitrate (niter or saltpeter), and calcium nitrate are the nitrate minerals of most commercial interest. All of them are soluble in water and have a salty taste. Sodium nitrate and potassium nitrate give a cooling sensation to the tongue, while potassium nitrate is rather sharp. Nitrocalcite (hydrous calcium nitrate) has a sharp and bitter taste.

OIL SHALES DEFINED

Shales are fine, dense, more or less consolidated sediments that were originally composed principally of fine silt. Their color is usually light gray to black, but yellow, brown, and reddish shales are found in some places. Shales have a noticeably clay-like odor when they are moistened by breathing upon them through the mouth. They can be readily scratched with a knife. The color of powdered shales is much lighter than that of

[31] Concentrated ferrous sulfate solution is made by dissolving that salt in water. Enough of the salt is used so that some of it remains undissolved by the water. If the ferrous sulfate solution is not carefully added, the entire solution may be colored brown.

uncrushed material, and is often nearly white. Shales commonly have a noticeably laminated structure, that is, they appear to be made up of thin sheets or plates. Frequently surface exposures look like piles of cardboard or paper, and such masses can be readily separted into flakes or sheets. Shales are usually associated with sandstones and limestones.

Oil shales have the characteristics above mentioned, but are usually dark brownish-gray to black on freshly broken surfaces and various shades of brown where they have been exposed to the weather. They usually lack all feeling of grittiness between the teeth. Oil shales contain little or no oil as mined, but they do contain variable portions of the solid gum called KEROGEN. Contrary to general belief, oil shales rarely emit the odor of petroleum except sometimes when freshly broken, and even then the odor is faint. Oil shales may be of the decidedly laminated "paper shale" variety, or the material may be a massive, more or less hardened, and very tough clay. Even the latter variety is usually composed of layers of different tints, or in some other way shows its relationship to laminated shales.[32]

This Kerogen is the carbonaceous matter in oil shales from which petroleum (crude oil) is obtained by destructive distillation processes. It can usually be detected if a splinter of the shale is held over a match, candle, or other 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. As soon as the flame from the Kerogen goes out, white fumes having the odor of burning petroleum are given off for a short time.

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 very considerably the strength of the concrete made from it. Tests carried on at Lewis Institute gave the following results:

Concrete made from a clean sand gave a compressive strength at twenty-eight days of 1,900 pounds. Concrete made from this same sand, but with one-tenth of one per cent 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 25 per cent.[33]

We can detect these organic impurities (humus or vegetable matter), even if we cannot see them by ordinary inspection, by using the following colorimetric 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 sand a 3 per cent solution of sodium hydroxide

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[32]G. M. Butler and J. B. Tenney, *Petroleum* (Univ. of Ariz., Ariz. Bur. Mines Bull. 130, 1931).

[33]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.

(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 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.

PETROLEUM

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

2. Petroleum when heated at a high temperature gives off vapors with the characteristic petroleum odor.

To make this test: Fill a test tube or some other small-necked receptacle to about 1 inch from the bottom with the material to be tested for petroleum. If the material is rock, it should be crushed and the pieces used in making this test should pass through a ¼ inch screen. Heat strongly over a flame until gases and vapors are given off freely. Smell the vapors given off. If the material used in the test contains an appreciable amount of petroleum, the gases and vapors given off will have the characteristic odor of petroleum, and petroleum will deposit on the cool portions of the receptacle.

Beginners practicing this test should use a few drops of petroleum.

3. Petroleum can usually be detected by the use of sulfuric ether or chloroform.

To make this test: Fill a test tube or glass bottle to about 1 inch from the bottom with the material to be tested. If the material is rock, it should be crushed, and the pieces used in making the test should pass through a ¼ inch screen. Pour onto this material about 1 inch of sulfuric ether[34] or chloroform. Cork the receptacle tightly. Shake this mixture at intervals until any oil present has been dissolved. (This may take from 1 to 10 hours.) After the petroleum in the material has been dissolved by the sulfuric ether or chloroform, let the mixture stand until the liquid becomes clear. Then pour the clear liquid into a shallow, clean, white china or porcelain dish. The sulfuric ether or chloroform will evaporate quickly leaving a greenish-yellow or brownish ring around the edge of the dish providing the material used in the test contains an appreciable amount of petroleum. The ring, if

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[34]Sulfuric ether vapors *explode* when ignited. It is *very dangerous* to make this test in the presence of open lights, open flames, or fires. These vapors will anaesthetize (render insensible, put to sleep). The evaporation of these liquids should, therefore, *always* be done in the open, or where the fumes will escape without doing harm.

petroleum, will have an oily feel and the characteristic odor of crude oil.

Beginners practicing this test should use a few drops of petroleum.

PHOSPHORUS

1. Phosphorus can usually be detected by the yellow-colored precipitate formed when a nitric acid solution of phosphorus is added to ammonium molybdate solution.

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 the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 1 teaspoonful of concentrated (strong) nitric acid and about the same volume of water. Heat this mixture and then cool it. Into another test tube pour about 10 teaspoonfuls of ammonium molybdate solution, and then pour into it a few drops of the cool solution made from the mineral. Let this stand for a time.[35] On the addition of the liquid to the ammonium molybdate solution, a yellow precipitate will be thrown down providing the material used in the test contains an appreciable amount of phosphorus.

Beginners practicing this test should use apatite (phosphate rock or asparagus stone), guano, phosphorite, or some other easily soluble phosphate.[36]

POTASH DEFINED

Potash, properly speaking, is potassium oxide (K_2O), but potassium carbonate (K_2CO_3) is also sometimes (although incorrectly) called "potash." The "potash" salts of commerce do not necessarily contain potassium oxide—for example, potassium chloride (KCl)—and they should more properly be called potassium salts. The term "potash salts," however, is now generally accepted, and all the compounds of potassium are known commercially as potash salts.[37]

From this definition it is evident that the characteristic element of all potash salts is potassium.

POTASSIUM

1. Volatile compounds of potassium color a nonluminous flame violet if heated therein.

To make this test: Wet one end of a piece of platinum or iron wire (baling wire) about 4 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

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[35]Sometimes the cold solution must stand for several hours before the precipitate begins to appear.

[36]A phosphate is a salt formed by the combination of phosphoric acid and a base. The determining element of phosphoric acid is phosphorus.

[37]R. B. Ladoo, work cited, p. 437.

be colored violet if the mineral used in the test contains an appreciable amount of volatile compounds of potassium and provided, further, that the potassium flame is not masked[38] or obscured by the flame of some other element.

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

3. With a Merwin's Flame-Color Screen: Follow the directions outlined in (1), but look at 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

Important silver minerals are native silver, argentite (silver glance, sulfuret of silver, vitreous silver, or silver sulfide), pyrargyite (dark ruby silver, dark red silver, or silver sulfantimonite), proustite (light ruby silver, light red silver, or silver sulfarsenite), and cerargyite (horn silver or silver chloride).

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). A metallic, silver globule or button results providing the material used in the test contains an appreciable amount of silver. This button is bright when hot or cold and is malleable (it 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 "Silver" (2).

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

2. Hydrochloric acid and soluble chlorides, when added to a nitric acid solution of silver, give a white precipitate (silver chloride). Silver chloride turns dark on exposure to light and 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 to be tested for silver. Use about the amount of the powdered mineral than can be held on the tip of a knife blade. Pour into the receptacle about 2 teaspoonfuls of dilute nitric acid[39] (1 teaspoonful of concentrated

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[38]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.

[39]In test "Silver" (2) it is sometimes better to use concentrated (strong) nitric acid (add no water) for dissolving the silver.

Some silver minerals are insoluble in nitric acid. These minerals if treated as described in "Silver" (1) become easily soluble in that acid.

[strong] nitric acid and about 1 teaspoonful of distilled or rain water). Heat this nitric acid solution to boiling and boil until any silver present has been dissolved. Then cool the solution to room temperature. Add to this cold dilute nitric acid solution a few drops of hydrochloric (muriatic) acid, a small pinch of common table salt, or a few drops of concentrated (strong) salt water. Upon the addition of the hydrochloric acid, the salt, or the salt water to the cold dilute nitric acid solution, a white precipitate[40] will be thrown down providing the material used in the test contains an appreciable amount of silver. If much silver is present, this white precipitate appears as a white curdy mass; if only a small amount of silver is present the precipitate gives the solution a milky appearance. This white precipitate should be tested further for silver by the following tests:

a) Expose some of the solution containing the white precipitate to the bright light for a time. If the white precipitate is silver chloride it will turn dark (violet to brown).

b) Add to the solution containing the white precipitate an excess of ammonia (until the solution smells strong of ammonia). If the white precipitate is silver chloride, the ammonia will dissolve it.

c) If the solution resulting from (b) is rendered acid with nitric acid, the silver will be reprecipitated.

STRONTIUM

The most important strontium minerals are celestite (strontium sulfate) and strontianite (strontium carbonate).

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

a) To make this test: Use a piece of iron wire (baling wire) about 4 inches long. Wet one end of the wire in dilute (one part acid and four parts of water) hydrochloric (muriatic) acid. Draw the wet end of the wire through the finely 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[41] providing the mineral used in the test contains an appreciable amount of a volatile compound of strontium.

b) Moisten one end of a fragment or chunk of the mineral in hydrochloric acid. Heat[42] the moistened end to red heat at the base of an alcohol lamp flame. As soon as the end of the mineral

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[40]When these reagents are used in test "Silver" (2), lead and mercury may also be thrown down as a white precipitate. Silver in this form is very soluble in ammonia, while the other two are practically insoluble. It also turns dark on exposure to light. See note under "Lead" (2).

[41]The crimson flame of strontium must not be mistaken for the red flame of lithium. The flame may be of such short duration that it appears as a crimson flash.

[42]If the fragment of mineral used in the test is small, use a clean pair of iron tweezers, pliers, or pincers for holding it in the flame.

is ignited (red hot) the flame will be colored crimson providing the mineral used in the test contains an appreciable amount of a volatile compound of strontium.

2. With Merwin's Flame-Color Screen: Follow the directions outlined in "Strontium" (1) but look at 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.

3. Some strontianites (strontium carbonate) fluoresce (glow) a white or green color when exposed to strong ultraviolet rays (black light)—best seen in the dark.

Always check fluorescent substances by chemical and blowpipe tests.

TIN

The only important tin mineral is cassiterite (tinstone or tin dioxide; when it is recovered from placers it is called stream tin). Cassiterite (tin dioxide) when boiled with metalliz zinc in hydrochloric or sulfuric acid usually becomes coated with a gray metallic deposit.

To make this test: Place in a test tube a ragged fragment of the mineral, somewhat larger than a bean. Around this fragment pour metallic zinc, allowing about one half of the fragment to project above the zinc. Granulated zinc, about 20 mesh, works satisfactorily in this test. Onto this pour about 3 teaspoonfuls of either concentrated (strong) hydrochloric (muriatic) acid or concentrated sulfuric (oil of vitriol) acid and about 2 teaspoonfuls of water. Heat this mixture to boiling and allow it to boil for a couple of minutes.

Cassiterite when given this treatment usually becomes coated with a dull gray metallic deposit. If the fragment is washed in water and the coating is then rubbed dry the metallic deposit becomes bright.

2. 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 than 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 scanty 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 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

Important tungsten minerals are wolframite[43] (wolfram, hübnerite, megabasite, or tungstate of iron and manganese), ferberite (iron tungstate), tungstite (sulfide), scheelite (calcium tungstate), and cuproscheelite (calcium copper tungstate).

1. In hydrochloric acid, tungsten gives 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 finely powdered mineral to be tested. Use about the amount of the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 2 teaspoonfuls of concentrated (strong) hydrochloric (muriatic) acid. Heat this mixture to boiling and boil for a time, replenishing the acid if necessary. This treatment will give a lemon-yellow residue (tungstic acid) in the bottom of the receptacle providing the mineral used in the test contains an appreciable amount of tungsten. This lemon-yellow residue, if it is tungstic acid, is soluble in ammonia. Therefore this test should be carried further for tungsten by testing the solubility of the yellow residue in ammonia. To do so, pour into the receptacle an excess of ammonia (until the solution smells strong of ammonia). Warm slightly if necessary. The lemon-yellow residue will dissolve in the ammonia if it is tungstic acid (tungsten).

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

2. In hydrochloric acid solutions of tungsten, tin or zinc give a blue color.

To make this test: Pour into a test tube or some other glass or porcelain receptacle a little of the finely powdered mineral to be tested. Use about the amount of the mineral that can be held on the tip of a knife blade. Pour into the receptacle about 2 teaspoonfuls of concentrated hydrochloric acid. Heat this mixture to boiling and boil strongly for a time, replenishing the acid if necessary. After a lemon-yellow colored residue begins to form in the bottom of the receptacle, add a little metallic tin or metallic zinc to the solution. If no other tin or zinc is available, use a piece of galvanized iron with zinc on it, a piece of a tin can with tin on it, soft solder with tin in it, or hard solder with zinc in it. On addition of the tin or zinc to this solution, the solution will turn

[43]Tests "Tungsten" (1) and (2) should be used only on very soluble tungsten minerals, as these tests take too long if used directly on rather insoluble minerals. The rather insoluble minerals should be given the preliminary fusing treatment as described in "Iron" (2). The fused mass resulting from the fusion should then be tested as described in tests "Tungsten" (1) and (2).

deep blue and, later, brown providing the material used in the test contains an appreciable amount of tungsten.

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

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

a) All of the borax beads[44] 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.

4. Some scheelites (calcium tungstate) fluoresce (glow) a blue or bluish-white color when exposed to strong ultraviolet rays (black light).

Always check fluorescent substances by chemical and blowpipe tests.

VANADIUM

Important vanadium minerals are patronite (vanadium sulfide), vanadiferous asphaltite, vanadinite (chlorovanadate of lead) descloizite (hydrated basic vanadate of lead and zinc), roscoelite (vanadium mica), and carnotite (a mixture of vanadium and uranium compounds).

1. Vanadium colors concentrated hydrochloric acid a deep cherry red. This reaction takes place with the evolution of chlorine gas. A little water added to this red solution changes it to a light green color.

To make this test: Place in a bone-dry test tube or some other glass or porcelain receptacle a little of the mineral to be tested. Use about the amount of the powdered mineral that can be held on the tip of a knife. Pour onto the mineral about ½ teaspoonful of concentrated (strong) hydrochloric (muriatic) acid. Almost as soon as the hydrochloric acid comes in contact with the mineral, 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 vanadate.

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 mineral that is to be tested. Use about the amount of powdered mineral that can be held on

[44]Instructions for making the bead tests can be found under "Cobalt" and "Chromium."

the tip of a knife blade. Pour onto the mineral about 1 teaspoonful of concentrated 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 1 to 2 teaspoonfuls of cold water. 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 soluble vanadium.

Beginners practicing this test should use vanadinite, descloizite, or some other vanadate.

3. Vanadates with potassium bisulfate in a closed tube give a yellow mass.

To make this test: Mix thoroughly a little of the finely powdered mineral with an equal volume of potassium bisulfate (acid sulfate of potassium). Place in a closed tube about ½ inch of this mixture. Heat the lower end of the tube at a red heat for some time. This will produce a yellow mass providing the mineral used in the test contains vanadates.

Beginners practicing this test should use vanadinite, descloizite, or some other vanadate.

4. Hydrogen peroxide gives a brownish-red color to an acid solution of vanadium.

To make this test: Place in a porcelain receptacle a little of the mineral to be tested. Use about the amount of the powdered mineral that can be held on the tip of a knife blade. Pour into the receptacle about 1 teaspoonful of concentrated hydrochloric acid and boil the solution for a couple of minutes. Cool the receptacle and pour into it about 1 teaspoonful of concentrated nitric acid. Boil for a couple of minutes and cool. After it is cold add about 1 teaspoonful of concentrated sulfuric acid and boil this mixture over an open flame until dense white fumes are given off. Cool to room temperature and very carefully add about 3 teaspoonfuls of cold water. Boil for a couple of minutes and then filter. Catch the filtrate (the clear solution that passes through the filter paper) in a glass or porcelain receptacle. Pour about 1 teaspoonful of this filtrate into a test tube. To this add a drop or two of fresh hydrogen peroxide. On the addition of the hydrogen peroxide, the solution will become brownish red providing the mineral used in the test contained an appreciable amount of soluble vanadium.

Beginners practicing this test should use vanadinite or some other vanadate.

5. Vanadium[45] can usually be detected by the colors it imparts to the fluxes.

a) In the oxidizing (bluish) flame of the blowpipe, borax

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[45]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.

APPENDIX I

FEDERAL STATUTES GOVERNING SIZES OF MINING CLAIMS

LODE CLAIMS

Length of lode claim

Not to exceed 1,500 feet.—Revised Statutes Section 2320.—Mining claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits, heretofore located, shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location. A mining claim located after the tenth day of May, 1872, whether located by one or more persons, may equal, but shall not exceed, 1,500 feet in length along the vein or lode; but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located.—Section 2, Act of Congress, May 10, 1872.

Width of lode claim

Revised Statutes Section 2320.—No claim shall extend more than 300 feet on each side of the middle of the vein at the surface, nor shall any claim be limited by any mining regulation to less than 25 feet on each side of the middle of the vein at the surface except where adverse rights existing on the tenth day of May, 1872, render such limitation necessary. The end-lines of each claim shall be parallel to each other.—Section 2, Act of Congress, May 10, 1872.

The following interpretations are drawn from the above:

Lode claim.—It cannot exceed 1,500 feet in length, along the vein or lode. It cannot extend more than 300 feet nor less than 25 feet on each side of the middle of the vein or lode. The end lines must be parallel to each other. The maximum area of a lode claim is 20.6 acres.

PLACER CLAIMS

Open to location and patent

Revised Statute Section 2329.—Claims usually called "placers," including all forms of deposit, excepting veins of quartz, or other rock in place, shall be subject to entry and patent, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims; but where the lands have been previously surveyed by the United States, the entry in its exterior limits shall conform to the legal subdivisions of the public lands.—Section 12, Act of Congress, July 9, 1870.

Size of claim

Revised Statutes Section 2330.—Legal subdivisions of 40 acres may be subdivided into 10-acre tracts; and two or more persons,

or associations of persons, having contiguous claims of any size, although such claims may be less than 10 acres each, may make joint entry thereof; but no location of a placer-claim made after the ninth day of July, 1870, shall exceed 160 acres for any one person or association of persons, which location shall conform to the United States surveys; and nothing in this section contained shall defeat or impair any bona-fide pre-emption or homestead claim upon agricultural lands, or authorize the sale of the improvements of any bona-fide settler to any purchaser.

Twenty acres to one locator

Revised Statutes Section 2331.—Where placer claims are upon surveyed lands, and conform to legal subdivisions, no further survey or plat shall be required, and all placer-mining claims located after the tenth day of May, 1872, shall conform as near as practicable with the United States system of public-land surveys, and the rectangular subdivisions of such surveys, and no such location shall include more than 20 acres for each individual claimant; but where placer claims can not be conformed to legal subdivisions, survey and plat shall be made as on unsurveyed lands; and where by the segregation of mineral land in any legal subdivision a quantity of agricultural land less than 40 acres remains, such fractional portion of agricultural land may be entered by any party qualified by law, for homestead or pre-emption purposes.—Section 10, Act of Congress, May 10, 1872.

The following interpretations are drawn from the above:

Placer claim.—The maximum size of a placer claim for each claimant is 20 acres. Placer claim boundaries conform to public land surveys.

MILL SITES

Extent—how patented

Revised Statute Section 2337.—Where non-mineral land not contiguous to the vein or lode is used or occupied by the proprietor of such vein or lode for mining or milling purposes, such non-adjacent surface-ground may be embraced and included in an application for a patent for such vein or lode, and the same may be patented therewith, subject to the same preliminary requirements as to survey and notice as are applicable to veins or lodes; but no location hereafter made of such non-adjacent land shall exceed 5 acres, and payment for the same must be made at the same rate as fixed by this chapter for the superficies of the lode. The owner of a quartz-mill or reduction-works, not owning a mine in connection therewith, may also receive a patent for his millsite, as provided in this section.—Section 15, Act of Congress, May 10, 1872.

APPENDIX II

MINING STATUTES FROM THE REVISED CODE OF ARIZONA 1928

ARTICLE 1.—MINING LOCATION

2266.—Location upon discovery of mineral in place. On the discovery of mineral in place on the public domain of the United States the same may be located as a mining claim by the discoverer for himself, or for himself and others, or for others.

2267.—Location notice, contents; amendment. Such location shall be made by erecting at or contiguous to the point of discovery a conspicuous monument of stones, not less than 3 feet in height, or an upright post, securely fixed, projecting at least 4 feet above the ground, in or on which there shall be posted a location notice, signed by the name of the locator. The location notice must contain: The name of the claim located; the name of the locator; the date of the location; the length and width of the claim in feet, and the distance in feet from the point of discovery to each end of the claim; the general course of the claim; the locality of the claim with reference to some natural object or permanent monument whereby the claim can be identified; and until each of the same shall have been done no right to such location shall be acquired. The notices may be amended at any time and the monuments changed to correspond with the amended location; provided, that no change shall be made which will interfere with the rights of others.

2268.—Completing location; additional facts; failure. From the time of the location, the locator shall be allowed ninety days within which to do the following: Cause to be recorded in the office of the county recorder a copy of the location notice; sink a discovery shaft in the claim to a depth of at least 8 feet from the lowest part of the rim of the shaft at the surface, and deeper, if necessary, until there is disclosed in said shaft mineral in place; and monument the claim on the ground so that its boundaries can be readily traced. Failure to do all such things in the time and place specified shall be an abandonment of the claim, and all right and claim thereto of the discoverer and locator shall be forfeited.

2269.—Monumenting. Such boundaries shall be monumented by six substantial posts projecting at least 4 feet above the surface of the ground, or by substantial stone monuments at least 3 feet high, one at each corner of the said claim and one at the center of each end line thereof; when, however, the point of a monument is at the same point and coincides with a monument of the survey of the United States, the monument of such government survey shall be deemed a mining claim monument.

2270.—Tunnel as location work. Any open cut, adit or tunnel, made as a part of the location of a lode mining claim, equal in amount of work to a shaft 8 feet deep and 4 feet wide by 6 feet long, and which shall cut a lode or mineral in place at a depth of 10 feet from the surface, shall be equivalent, as discovery work, to a shaft sunk from the surface.

2271.—Relocation. The location of an abandoned or forfeited claim shall be made in the same manner as other locations, except that the relocator may perform his location work by sinking the original location shaft 8 feet deeper than it was originally, or if the original location work consisted of a tunnel or open cut, he may perform his location work by extending said tunnel or open cut by removing therefrom 240 cubic feet of rock or vein material.

2272.—Locating and monumenting placer claims; recording notice. The locator of a placer mining claim shall locate his claim in the following manner: By posting a location notice thereon containing the name of the claim, the name of the locator, the date of location and the number of acres claimed; a description of the claim with reference to some natural object or permanent monument that will identify the claim and by marking the boundaries of his claim with a post or monument of stones at each angle of the claim located. When a post is used it must be at least 4 inches in diameter by 4 feet 6 inches in length, set one foot in the ground and surrounded by a mound of stone or earth. Where it is practically impossible on account of a bed of rock or precipitous ground to sink such posts, they may be placed in a pile of stones. If it is impossible to erect and maintain a post or monument of stone at any angle of such claim, a witness post or monument may be used, to be placed as near the true corner as the nature of the ground will permit. When a mound of stone is used, it must be at least 3 feet in height and 4 feet in diameter at the base. The locator shall, within sixty days after the date of location, record a copy of the location notice.

2273.—Affidavit of performance of annual work; prima facie evidence. Within three months after the expiration of the time fixed for the performance of annual labor or the making of improvements upon a mining claim, the person on whose behalf such work or improvement was made, or some person for him knowing the facts, may make and record an affidavit, in substance, as follows:

State of Arizona, county of.....ss: .....being duly sworn, deposes and says that he is a citizen of the United States and more than twenty-one years of age, resides at....., in.....county, Arizona, is personally acquainted with the mining claim known as.....mining claim, situated in .....mining district, Arizona, the location notice of which is recorded in the office of the county recorder of said county, in book.....of records of mines, at page..... That between the.....day of....., A.D....., and the.....day of ....., A.D....., at least.....dollars worth of work

and improvements were done and performed upon said claim, not including the location work of said claim. Such work and improvements were made by and at the expense of....., owners of said claim, for the purpose of complying with the laws of the United States pertaining to assessment or annual work, and (here name the miners or men who worked upon the claim in doing the work) were the men employed by said owner and who labored upon said claim, did said work and improvements, the same being as follows, to wit: (Here describe the work done, and add signature and verification).

Such affidavit when recorded, shall be prima facie evidence of the performance of such labor or improvements.

2274.—One affidavit for group. When two or more contiguous claims are owned by the same person, and constitute a group, and the annual work is done upon each of said claims or upon one of more of the same for the benefit of all, or wholly or partly outside of such claims for the benefit of all, all such claims may be included in a single affidavit.

2277.—Sufficiency of description of mining claims. In all actions, judgments, grants or conveyances it shall be sufficient description of a mining claim if the name of the claim, the district, county and state where it is situate, and the book and page where the location notice thereof is recorded can be intelligently learned therefrom.

APPENDIX III

TABLES OF WEIGHTS AND MEASURES
WEIGHTS

AVOIRDUPOIS WEIGHT

1 Dram = 27.343 Grains.
1 Ounce = 16 Drams = 437.5 Grains.
1 Pound = 16 Ounces = 7,000 Grains.
1 Short Ton = 2,000 Pounds = 32,000 Ounces = 0.8928 Long Ton.
1 Long Ton = 2,240 Pounds = 35,840 Ounces = 1.12 Short Tons.

TROY WEIGHT*

(Used in Weighing Gold or Silver)

1 Pennyweight = 24 Grains.
1 Ounce = 20 Pennyweights = 480 Grains.
1 Pound = 12 Ounces = 5,760 Grains.

APOTHECARIES' WEIGHT*

1 Scruple = 20 Grains.
1 Dram = 3 Scruples = 60 Grains.
1 Ounce = 8 Drams = 480 Grains.
1 Pound = 12 Ounces = 5,760 Grains.

METRIC MEASURE

1 Centigram = 10 Milligrams.
1 Decigram = 10 Centigrams.
1 Gram = 10 Decigrams = 0.001 Kilogram.
1 Decagram = 10 Grams = 0.01 Kilogram.
1 Hectogram = 10 Decagrams = 100 Grams = 0.1 Kilogram.
1 Kilogram = 10 Hectograms = 1,000 Grams.
1 Metric Ton = 1,000 Kilograms = 1,000,000 Grams.

EQUIVALENTS

1 Ounce (Avoir.) = 0.911 Ounce (Troy) = 28.35 Grams.
1 Ounce (Troy or Apoth.) = 1.097 Ounces (Avoir.) = 31.103 Grams.
1 Pound (Avoir.) = 1.215 Pounds (Troy or Apoth.) = 14.58 Ounces (Troy or Apoth.) = 0.4536 Kilogram = 453.6 Grams.
1 Pound (Troy or Apoth.) = 0.82286 Pound (Avoir.) = 13.166 Ounces (Avoir.) = 0.3732 Kilogram = 373.2 Grams.
1 Short Ton = 0.8928 Long Ton = 0.9072 Metric Ton = 907.2 Kilograms.
1 Long Ton = 1.12 Short Tons = 1.016 Metric Tons = 1,016 Kilograms.
1 Gram = 0.0353 Ounce (Avoir.) = 0.03215 Ounce (Troy or Apoth.) = 15.432 Grains.

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*The Troy grain, ounce, and pound weigh the same as the respective units of the Apothecaries' system.

METRIC CUBIC MEASURE

1 Cubic Centimeter = 1,000 Cubic Millimeters = 1 Milliliter.
1 Cubic Decimeter (Liter) = 1,000 Cubic Centimeters.
1 Cubic Meter (Stere) = 1,000 Cubic Decimeters (Liters) = 1,000,000 Cubic Centimeters.

EQUIVALENTS

1 Teaspoonful (Liquid) = Approximately 5 Cubic Centimeters.
1 Tablespoonful (Liquid) = Approximately 15 Cubic Centimeters.
1 Cubic Inch = 16.39 Cubic Centimeters.
1 Cubic Foot = 28,320 Cubic Centimeters = 0.028 Cubic Meter.
1 Cubic Yard = 0.764 Cubic Meter.
1 Cubic Centimeter = 0.061 Cubic Inch.
1 Cubic Meter = 1.307 Cubic Yards = 35.31 Cubic Feet = 61,020 Cubic Inches.
1 Cord of Wood = 128 Cubic Feet (cut 4 feet wide, piled 4 feet high and 8 feet long).

U.S.A. DRY MEASURE

1 Pint = 0.5 Quart = 0.125 Gallon = 0.0625 Peck = 0.0156 Bushel.
1 Quart = 2 Pints = 0.25 Gallon = 0.125 Peck = 0.0312 Bushel.
1 Gallon = 4 Quarts = 8 Pints = 0.5 Peck = 0.125 Bushel.
1 Peck = 2 Gallons = 8 Quarts = 16 Pints = 0.25 Bushel.
1 Bushel = 4 Pecks = 8 Gallons = 32 Quarts = 64 Pints.

LIQUID MEASURE

1 Gill = 0.25 Pint.
1 Pint = 4 Gills = 0.5 Quart = 0.125 U.S. Gallon.
1 Quart = 2 Pints = 8 Gills = 0.25 U.S. Gallon = 0.0079 Barrel.
1 U.S. Gallon = 4 Quarts = 8 Pints = 32 Gills = 0.0317 Barrel.
1 Barrel = 31.5 U.S. Gallons = 126 Quarts = 252 Pints = 1,008 Gills.

There is no standard liquid "Barrel." The one used in this table contains 35.31 cubic feet.

APOTHECARIES' FLUID MEASURE

1 Fluid Dram = 60 Minims.
1 Fluid Ounce = 8 Fluid Drams.
1 Fluid Pint = 16 Fluid Ounces = 1 Pint (Liquid Measure).
1 Gallon = 8 Pints = 128 Fluid Ounces.

METRIC LIQUID MEASURE

1 Centiliter = 10 Milliliters.
1 Deciliter = 10 Centiliters = 100 Milliliters.
1 Liter (Cubic Decimeter or Millistere) = 10 Deciliters = 100 Centiliters = 1,000 Milliliters (Cubic Centimeters) = 0.001 Cubic Meter.
1 Decaliter (Centistere) = 10 Liters = 1,000 Centiliters.
1 Hectoliter (Decistere) = 10 Decaliters = 100 Liters.
1 Kiloliter (Stere) = 10 Hectoliters = 1,000 Liters.

EQUIVALENTS

1 Quart (U.S. Dry) = 67.2 Cubic Inches = 0.0389 Cubic Foot = 0.0011 Cubic Meter = 1.1 Liters = 1,101 Cubic Centimeters.

1 Quart (U.S. Liquid) = 57.75 Cubic Inches = 0.033 Cubic Foot = 0.00094 Cubic Meter = 0.946 Liter = 946 Cubic Centimeters.

1 Gallon (U.S. Dry) = 268.8 Cubic Inches = 0.1556 Cubic Foot = 0.004 Cubic Meter = 4.405 Liters = 4,405 Cubic Centimeters.

1 Gallon (U.S. Liquid) = 231 Cubic Inches = 0.1337 Cubic Foot = 0.00378 Cubic Meter = 3.785 Liters = 3,785 Cubic Centimeters.

1 Liter = 1.0567 (U.S. Liquid) Quarts = 0.908 (U.S. Dry) Quart = 0.0353 Cubic Foot = 61.023 Cubic Inches = 33.81 Apoth. Fluid Ounces = 0.264 Gallon (U.S. Liquid) = 0.227 Gallon (U.S. Dry).

AVERAGE WEIGHTS OF VARIOUS SUBSTANCES

Name	Pounds per cubic foot	Cubic feet per short ton (2,000 lbs.)
Aluminum, cast	160	12.5
Amalgam	868	2.3
Andesite	181	11.0
Antimony, cast	418	4.8
Antimony sulfide (stibnite)	287	7.0
Arsenic	357	5.6
Arsenic sulfide (realgar)	218	9.2
Asbestos	175	11.4
Asphaltum	69 to 75	26.5 to 29.0
Barium	242	8.2
Barium sulfate (barite)	280	7.1
Basalt (traprock)	181	11.0
Borax	109	18.3
Brass (copper and zinc), cast	527	3.7
Brick, common	100 to 130	15.4 to 20.0
Bronze (aluminum)	480	4.1
Cadmium	539	3.7
Calcite	168	11.8
Calcium	99	21.0
Cement (Portland)	85 to 195	10.2 to 23.6
Chalk	146	13.7
Chromium	312	6.4
Clay, loose, dry	65	30.8
Coal, bituminous, broken loose	47 to 60	36.4 to 42.5
Cobalt, nickel arsenide (smaltite)	405	4.9
Concrete, stone	130 to 150	13.3 to 15.4
Copper, cast	550	3.6
Copper carbonate (malachite)	243	8.2
Copper pyrites (chalcopyrite)	262	7.6
Diabase or diorite	187	10.6

AVERAGE WEIGHTS OF VARIOUS SUBSTANCES—*Continued*

Name	Pounds per cubic foot	Cubic feet per short ton (2,000 lbs.)
Diatomaceous earth, pure dry blocks	28	71.5
Diatomaceous earth, pure dry powder, loose	10	200.0
Earth, loam, loose, dry	72 to 80	25.0 to 27.8
Feldspar	160	12.5
Flour spar (fluorite)	199	10.1
Gold, native	1,184 (1,215.9 pure)	1.8
Granite	170	11.7
Graphite	140	14.3
Gravel, dry	112	18.1
Gravel, wet	125	16.0
Gypsum	143	14.0
Iodine	308	6.5
Iridium	1,379	1.4
Iron, cast	450	4.4
Iron, wrought	480	4.2
Iron pyrites	318	6.3
Iron sesquioxide (hematite)	312	6.4
Lava	165	12.2
Lead	711	2.8
Lead carbonate (cerussite)	405	4.9
Lead sulfide (galena)	467	4.3
Limestone, average	162	12.4
Magnesium	107	18.7
Magnesium carbonate (magnesite)	187	10.7
Manganese	499	4.0
Manganese carbonate (rhodochrosite)	224	8.9
Manganese dioxide (pyrolusite)	299	6.7
Marble, domestic, average	165	12.2
Mercury (quicksilver), native	849 at 32° F.	2.3
Mercury sulfide (cinnabar)	505	3.9
Mica	183	10.9
Molybdenum	538	3.7
Mortar, lime	103	19.4
Mortar, cement	105	19.1
Nickel	517 to 550	3.6 to 3.9
Nickel sulfide (millerite)	349	5.7
Nickel arsenide (niccolite)	467	4.3
Palladium	736	2.7
Platinum, native, average	1,091	1.8
Porphyry	162	12.4
Potash	141	14.2
Pumice stone	57	35.1
Potassium	54	37.1
Quartz	162	12.4
Rhyolite	149	13.4
Salt, loose	45	44.5
Sand	90 to 130	15.4 to 22.2
Schist	168	11.8
Shale	162	12.4
Silver, native, average	655	3.1
Slate	175	11.4

AVERAGE WEIGHTS OF VARIOUS SUBSTANCES—*Continued*

Name	Pounds per cubic foot	Cubic feet per short ton (2,000 lbs.)
Sodium	61	32.8
Sulfur, native, average	131	15.2
Steel, cast	492	4.0
Steel, wrought	490	4.1
Talc	175	11.4
Tellurium	391	5.1
Tin, cast	455	4.4
Tin oxide (cassiterite)	424	4.7
Tungsten	1,193	1.7
Tungsten ore (scheelite)	374	5.3
Tungsten ore (wolframite)	455	4.4
Type metal, cast	652	3.0
Uranium	1,153	1.3
Water	62.4	32.0
Zinc	437	4.5
Zinc sulfide (sphalerite, blende)	249	8.0

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