and can give the equation for the reaction between potassium permanganate and hydrogen peroxide—if he ever reaches such a period—but which leaves him ignorant of the real significance of the formula and the purpose of the equation. Symbols, formulæ, and equations are the tools of the trade and are not to be elevated into the place of objects of study. I also urge a fervent protest against the teaching of the laws of science as mandatory upon nature's facts instead of as expressions of our knowledge of the facts.

Finally I would also register objection to the too prevalent presentation of formulative hypotheses as established facts. For example, it is neither desirable nor correct to present the hypotheses of Dalton or of Arrhenius as established, not so much because we may or may not have doubts as to their correct expression of our knowledge of the facts as because such presentations of these hypotheses is a misapplication of the scientific method and gives the student a distorted view of the relative importance of fact and theory.

MAKING A CHEMICAL COLLECTION.

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(Continued from April issue.)

ELEMENTS.

Each common metal should be shown so far as possible in all the different forms, such as sheet, wire, powder, ribbon, mossy, granular, dust, bar, foil, ingot, and native. Mossy lead may be made by melting old lead pipe in a blast lamp flame and allowing the melted metal to fall into water. The mossy lead thus made should be rinsed with hot water and allowed to dry quickly of its own accord to prevent oxidation. Tin bullets may be made in a similar manner. Silver buttons and precipitated silver may be worked up from the silver residues that collect in many laboratories. Precipitated metals may generally be made by immersing strips of zinc in solutions of their salts. Gold leaf and foil should be passe-partouted between glass plates for convenience in handling and to bring out the green color by transmitted light. The common forms of iron should be accompanied by native iron, by meteorites, and by etched slabs

of meteoric iron, showing the Widmanstätten figures. Sodium and potassium may be shown under kerosene; they should also be sealed in glass tubes in an atmosphere of hydrogen, so as to retain their color and luster.

OXIDES.

More specimens can be obtained for this group than for any other of the groups of compounds. Oxide of silicon should be shown in chemically pure state as made from silicic acid; ordinary sand should be added; the number of varieties of quartz obtainable will probably depend upon the funds at hand. The following varieties should be shown both massive and polished: agate, opal, jasperized wood, tiger's eye, pudding stone, and rose quartz. The more characteristic iron ores should be included, even though part three of the collection may contain iron ores in connection with the extraction of iron therefrom.

HYDROXIDES.

Bauxite and brucite are the commoner mineral forms of hydroxides. The hydroxides of the heavy metals may easily be made from solutions of their salts, by precipitation with sodium hydrate or ammonia, the latter being preferable on account of the ease with which any excess thereof can be gotten rid of.

HYDRIDES.

Only two hydrides, phosphine and ammonia gas, are worthy of a place in the collection.

CHLORIDES.

Sodium chloride should be represented by as many different varieties as possible. Other chlorides may be represented by only one variety each. The common chlorides should be exhibited in twelve-ounce bottles, the less common chlorides in four-ounce bottles. Arsenic chloride and phosphorous penta-chloride should be kept in sealed glass tubes. The chlorides of silver, potassium, and sodium should be shown native.

BROMIDES.

Only eight or ten bromides need be shown. The common ones will suggest themselves. Since potassium bromide crystallizes exceedingly well, the large crystals showing cubical habit should be picked out and shown by themselves.

IODIDES.

Four or five iodides should be sufficient—those of Na, Ag, K, and Pb; the last should be shown in recrystallized as well as amorphous form.

FLUORIDES.

Cryolite, barium fluoride, sodium fluoride, and calcium fluoride are sufficient. The last named should be illustrated by several specimens, because of its beautiful crystalline form.

CYANOGEN COMPOUNDS.

Cyandies of K and Ag, sulphocyanides of K and NH_4 , and ferricyanides of K and Fe should be shown. Ferrocyanides of the more common metals may be made in the laboratory by precipitation.

SULPHIDES.

Sulphides of the metals usually obtained in qualitative analysis may be precipitated from the salt solutions and kept under the same solutions in tall stoppered foot test-tubes to prevent oxidation. The more common commercial sulphides should be shown, particularly antimony sulphide, zinc sulphide, and iron sulphide; also calcium sulphide, both the common and the phosphorescent varieties. Ammonium sulphide with its three colors may be made in the laboratory. The sulphides and allied compounds occurring as minerals are so varied and numerous that a judicious selection must be made. The following should be shown: galena, sphalerite, stibnite, cinnabar, and the sulphides of copper and of iron. The last named might well be shown massive, crystalline, radiated, and, if possible, as separate cubes.

CARBONATES.

Calcium carbonate should be shown in as many distinctly different forms as possible, crystalline forms being included. Of other mineral carbonates those of Ba, Sr, Mg, Cu, and Pb are most interesting. Commercial forms of the carbonates of the alkali metals and alkaline earth metals should be included.

SULPHATES.

Of the mineral sulphates those of Ba, Sr, Pb, and Ca are most interesting. The last named should be illustrated by numerous specimens, for instance, anhydrite, satin spar, gypsum, and separate perfect crystals of selenite. Commercial sulphates of all the common metals are easily obtainable. Double sulphates such as alum, chrome alum, iron alum, and nickel-ammonium sulphate should be added. Several sulphates recrystallize easily and well, notably copper sulphate, alum, and chrome alum. These recrystallization experiments appeal strongly to the student mind. If strings are hung in the solutions the crystals form

easily, sometimes forming twins. Alum forms regular octahedra when the crystals are small; larger crystals of alum are often so modified as to appear hexagonal. Recrystallized efflorescent sulphates must be kept in stoppered bottles. The writer has succeeded in making a separate chrome alum crystal an inch and a half in longest diameter by repeated nursing of an octahedral chrome alum crystal from fresh solutions; it was necessary after each nursing to sandpaper off the secondary octahedra that persisted in growing out from the sides of the larger crystal. Anhydrous sulphates of the commoner heavy metals may be made quite easily by exposing thin layers of the crystallized salts to the air in a warm place.

SILICATES.

Next to the oxides this forms the largest group and consists almost entirely of mineral specimens. Judicious selecting must therefore be practiced. The following should be selected first: varieties of mica, of felspar, of beryl, of tourmaline, of garnet; also talc, soapstone, and serpentine. Others may be added as desired. Black and red varieties of tourmaline should be shown, the latter both polished and rough. Garnet should be shown massive, small crystals occurring in matrix, small, separate crystals, large, separate, native crystal, and single, polished crystal showing dodecahedron form.

Potassium silicate and sodium silicate, both solid, should be purchased; so should sodium silicate syrup. From this syrup and soluble salts of twenty or more common metals one may precipitate the metallic silicates; these may not have a constant or definite composition, but they are interesting as showing the separate silicates that go to make up the complex silicates which have been mentioned above and which are present in such enormous quantities in the earth's crust. The precipitated silicates are in many cases extremely gelatinous and it is therefore necessary to make an extremely dilute solution of the metallic salt, preferably in a crock holding several gallons, and adding thereto a very dilute solution of sodium silicate syrup. These must sometimes stand several days before the clear liquid can be decanted. Filtration should be resorted to only when the liquid has been reduced by decantation to the smallest possible amount.

OXALATES.

The oxalates of about two dozen metals may easily be made in the laboratory. Those of the alkali metals may be made

by neutralization of oxalic acid with the alkaline hydrates. The others may generally be made by precipitation from the metallic salt solution with ammonium oxalate. Oxalic acid may well be added. This may be made from starch and nitric acid. Both ferrous and ferric oxalates may be included, but the latter must be protected from the light, because the beautiful green crystals change extremely readily to the yellow ferrous oxalate.

CHROMATES.

The soluble chromates might well be purchased, though those of Na, K, and NH_4 may be made by neutralization. Other chromates may be made by precipitation. Lead chromate is the only interesting native chromate. Bichromates of Na and K may be included. A conspicuous specimen of the last named may be made by repeated nursing of a single crystal hung on the end of a stout string. The result is a spherical mass several inches in diameter covered with bright red, highly lustrous, tabular crystals. Such a mass of crystals should be supported on a small glass crystal pan to avoid breaking the crystals. Attempts to coat balls of various material with potassium bichromate crystals failed to give satisfactory results.

NITRATES.

Nitrates of all the common metals are easily procurable. Since potassium nitrate crystallizes exceedingly well, it should be possible to get hexagonal crystals an inch or so in diameter. What was said under chlorides in regard to bottles applies generally to each group but particularly to the nitrate group.

PHOSPHATES.

This group may be limited to twelve or fifteen specimens. Sodium phosphate, microcosmic salt, phosphoric acid, turquois, and calcium phosphate suggest themselves first. The last named should be shown in precipitated form, as phosphate rock, and as the beautifully crystallized apatite.

MISCELLANEOUS COMPOUNDS.

This group may contain all those compounds not included in preceding groups, such as acetates of Ca, Cr, Cu, Pb, and Na. Paris green, chlorates, bromates, and iodates of K and Na, borax, tartar emetic, cream of tartar, Rochelle salts, iron ammonium citrate, and one or two specimens of each of the following: permanganates, arsenites, arsenates, nitrites, tungstates, molybdates, carbides, sulphites, and thiosulphates.

ARTS AND MANUFACTURES.

This division of the collection was described briefly in the early part of this article, and under "classification" the general statement was made that this division should consist mainly of specimens illustrating those industries in which chemical reactions play an important part. Let it be added here simply that the different kinds of glass, porcelain, and crockery, together with their manufacture, should be illustrated. In almost every town it will be possible to get specimens illustrating the manufacture of illuminating gas. Metallic ores may be shown in considerable quantity and variety, and so far as possible the extraction of the metals from the ores should be illustrated. Electrolytic products and products of the alkali industries will bring the collection up to date. Specimens illustrating the manufacture of sulphuric acid are always of interest; so are specimens illustrating the various uses of carbon. Students coming from the coal regions are often ready to donate specimens showing the different stages in coal mining. A few organic substances should be included, such as a few alcohols, oils, organic acids, sugars, and starches. Petroleum compounds and aniline dyes would not be out of place. Organic compounds suggest a few food products, but here the teacher must choose for himself. Since the crystalline forms of technical chemicals and of minerals in the first two divisions of the collection are seldom geometrically perfect, but are rather modifications of the theoretically perfect crystals, it will be exceedingly helpful to the student if a set of about twenty models of the common forms of crystals are shown; they should preferably be made of solid crystal glass, highly polished and at least two inches in length. The more complicated models made of glass plates and showing the axes are too confusing for the elementary student. Though the collection is strictly chemical in its nature, the third division might properly include a limited amount of material illustrative of the other natural sciences, particularly if the school in question does not already own a museum containing such specimens. By extension, therefore, this division might include a few specimens to illustrate various earth movements and other formations studied in geology. A few samples of plant fibres would interest students of botany. An exhibition which never fails to attract attention is a set of American woods such as those published in section form by Romeyn Hough of Lowville, N. Y. These

are of particular interest at present on account of the widespread interest in forestry.

IN CONCLUSION.

A collection developed along the lines laid down above will be largely of exhibitiv value. Many of the specimens, however, should be taken into the lecture room and passed to the members of the class for personal examination, because it is a recognized fact in natural science work that a student becomes better acquainted with those substances that he can actually handle.

The curator should keep a careful record of all additions to the collection, preferably in card catalogue form. The time and funds ordinarily at the disposal of the secondary school teacher preclude the possibility of compiling and publishing a printed catalogue of the collection. About a year ago, the writer published such a descriptive catalogue of the collection that it has been his privilege to develop, and he has a limited number of these catalogues still on hand; he will be pleased to send a copy of this catalogue to any teacher who feels that it might aid him in building up a collection for his school.

One word of caution, please, as to a danger which has threatened the writer and which is pretty sure to threaten any teacher who starts a collection: *do not crowd specimens in the cases*. When shelf room is scarce and the specimens multiply, the teacher is strongly tempted to try to show all the specimens, and if this is done in insufficient cases the specimens themselves are impaired in value, the dignity of the collection is lost, and its effect upon the pupil and visitor is far from the desired object of the collection. Far better is it to keep newly acquired specimens packed away until suitable cases may be procured. Let it also be added that the arrangement of the specimens on the shelves is often of equal value with the specimens themselves; for that reason they should be arranged as artistically as their classification will allow and the harmonious appearance of the whole should constantly govern the arranging. By all means let not such a collection as here described parade before the visitor a cold, lifeless, strictly scientific classification, but rather let it stand as a monument to a happy combination in the teacher's mind of orderly arrangement and a human, artistic touch.