THE RELATION OF THE TECHNICAL WORLD TO SCHOOL CHEMISTRY.*

BY WILLIAM CONGER MORGAN,

Assistant Professor of Chemistry at the University of California

A glance at the history of education during the last decade or so may be of advantage at the beginning of the present consideration to show us the position from which we have progressed and the direction of present day tendencies.

Twenty years or more ago the university and the common school found themselves in diametrically opposite positions. The college course of that time consisted almost entirely of mathematics and the classics, subjects intended to give to the student a liberal education and to impart to him as much culture as possible during his four years' sojourn in the college walls. The education furnished by the common school was almost entirely practical, "the three R's—readin' 'ritin' and 'rithmetic"—being those subjects of which the average man makes almost continual use. The high school course, occupying an intermediate position, partook of the character of both, inclining rather to the side of the practical than the cultural.

To-day the positions of the university and the common school have become to a considerable extent interchanged. By the introduction of what has been termed "the fads and frills courses" into the grammar school the attempt has been made to stimulate the development of the younger students in the lines of culture and æsthetics while the development of schools of law, medicine, agriculture, and engineering of all kinds have tended to make the university course for many of its students a training for future life work to the entire exclusion of all cultural ideas. The high school of to-day, again following both leads, offers so many courses of such diverse character as to make classification difficult.

The fact that the university has found it necessary to modify its curriculum in order that it may meet the practical needs of its students, while the common school has found it advantageous to emphasize to a somewhat greater degree those things for which the college formerly stood, are significant facts, however, and seem to indicate that neither the practical man nor he that is cultured merely is to be considered as the ideal product of our

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educational system. The call of the world to-day is for men who can *do*—who can clearly see the need of any situation in which they may be put and, seeing, can successfully accomplish those things that are necessary. The aim of education should be to develop thinking, feeling, and willing beings—men who “wear out but do not rust out.” Along the line of the thinking being, the demand is for men of keen and accurate observation and sharp and logical reasoning, possessing the ability to use the knowledge gained in school, college, and later life to plan and work independently. The schooling period of such a man is to be regarded not so much as a collecting trip for the accumulation of facts as an apprenticeship during which the youth becomes acquainted with methods and knowledge to be used as tools in the everyday work of later life.

Important as is the development of the feeling and willing sides of man's nature, these points are not within the scope of the present treatment and will not be considered further.

After these considerations we may ask ourselves to what end shall industrial applications be introduced into a high school course in chemistry.

I shall answer first of all that it should never be with the idea of making the course practical in order that the student who shall not continue his education further may go out into the world and apply himself to the task of the metallurgist, the pigment maker, or the soap manufacturer. This end could never be accomplished in the high school course of the present day, and even were it possible, it is certainly far better for the student whose education ceases with the high school to be taught to see clearly and accurately what is happening about him and to reason logically from his observations to the results to be expected therefrom according to the principles of chemistry, physics, or any other of the natural sciences.

On the other hand the science of chemistry is so closely connected with modern industrial progress that it is well to impress upon the mind of the young student how splendidly certain of the thinking men have been able to apply the knowledge of method and of fact gained during school hours to the solution of practical problems and how glorious and far-reaching are the results of so doing. Illustrations of this character cannot fail to excite interest, and certainly the awakening of interest and enthusiasm is a legitimate reason for their introduction.

The speaker would maintain, however, that possibly the best reason for introducing experiments from the industrial world is to illustrate the general principles of chemistry. If these principles, usually developed from a consideration of reactions performed in a test-tube or small beaker, can be shown to control those processes upon which we are dependent for the comforts and necessities of life, they will not lose interest or significance thereby.

The experiments should be introduced in such a way as to suggest the industrial process, but not with the idea of duplicating or repeating it. The reactions which take place when the reagents are measured in tons instead of in fractions of a gram usually depend for their success on attention to minute details as to temperature, dilution, and proportion of reagents and it is often quite impossible to duplicate them on a small scale.

One general class of illustrations from the technical world may be suggested as particularly valuable and well adapted for introduction into a high school course in chemistry. It is the production of well known substances from naturally-occurring material and the utilization of the products so obtained in subsequent experiments. From work of this character practice in extraction, filtration, crystallization and other methods of manipulation is obtained. The idea of a continuity in his work and of the dependence of one experiment on another appeals to a good student and emphasizes the necessity that an experiment must be made to "come out right" or be repeated in order to obtain the material for subsequent work.

The production of beautiful white crystals of alum from a shovel full of ordinary dirt is a very suggestive experiment to the average student. The chief source of aluminum compounds becomes firmly fixed in his mind and the typical reactions of the metal learned from a study of a product of his own making are considerably more interesting than when the material is obtained from the reagent shelf.

The extraction of "pearl ash" from wood ashes and the preparation from it of "potash lye" or of saleratus or soap is another series of experiments of the same kind.

The analogous manufacture of "soda" from salt according to the methods of the Le Blanc or Solvay processes at once suggests itself. The action of "washing soda" in "softening" water

may be emphasized by treating its solution with dilute solutions of calcium and magnesium salts and the use of "baking soda" in leavening breadstuffs may be fixed on the mind by the actual manufacture of samples of "baking powder," the virtues of which may be demonstrated by use in the home.

To Californians, also the preparation of borax or boric acid from colemanite or ulexite will occur to mind.

The industrial world presents so many different aspects that the choice of material becomes a question of some difficulty because of the superabundance offered for selection. The most commonplace processes are those about which we should know first of all. They will be found in general most interesting and the introduction of such of them as are practical under the conditions existing in any given laboratory should first be essayed.

The "burning of limestone," slacking of lime, making and "setting" of mortar may all be performed in the laboratory without difficulty. Similarly the "burning" of gypsum to make "plaster of Paris" and the heating together of limestone and clay for the manufacture of Portland cement will furnish products with which the phenomenon of "setting" may be easily observed.

All the reactions of photography from the making of the plate and the printing paper to the "toning" of the print may be repeated in the laboratory. The chemistry of the main reactions may be explained on the basis of simple general principles and the processes prove exceedingly fascinating.

Many of the metallurgical processes may be illustrated. Mercury is readily obtainable from cinnabar, and lead from galena by simple experiments arranged along the lines of the metallurgy of these metals given in every text-book. Finely powdered chalcocite or chalcopyrite "weathers" readily in a moist atmosphere and from the resulting sulfate solution electrolytic copper is readily deposited. In regions particularly interested in mining the amalgamation, chlorination or cyanide processes for the extraction of gold may be easily illustrated by treating small amounts of "concentrate" according to the well known methods.

Sulfur dioxide obtained by the "roasting" of pyrites or the sulfids of other metals may be converted into sulfuric acid without difficulty. Platinized asbestos (made by soaking asbestos fibre in platinum chloride and then igniting it) serves to catalyze the mixture of sulfur dioxide and air and leads to the formation of dense white clouds of sulfuric anhydride, thus illustrating

the newer "contact process." By bringing together in a large flask sulfur dioxide, air, steam and nitrogen dioxide, the reactions of the "chamber process" may be suggested. A little skill in glass blowing will be sufficient to produce a working model which will show the pyrite burner, Glover and Gay-Lussac towers as well as the main chamber in which the reaction takes place.

The distillation of Chile saltpeter or crude calcium acetate with sulfuric acid shows the industrial methods for the production of nitric and acetic acids respectively. In the latter case, if it be thought desirable, the production of the calcium acetate may be suggested by the distillation of a retort full of sawdust and by passing the vapors over lime which is maintained at a temperature above that of boiling water. The large amounts of water and combustible gas liberated in this process should be emphasized by the condensation of the former and the combustion of the latter.

These experiments call to mind the distillation of coal with the production of coke, coal gas, ammonia, and coal-tar. The derivation of the perfumes, flavoring extracts, aniline dyes and drugs from this last material should not fail to be set forth. By passing steam over red-hot coke the manufacture of "water-gas" may be shown.

Among other high-temperature reactions may be mentioned the making of glass by fusing sand and limestone together with a salt of lead, sodium or potassium and the product may be variously colored by the addition of iron, cobalt, manganese, chromium and the like. In connection with "water-glass" the fireproofing of wood and the preserving of eggs may be tried.

If the electric current be available, calcium carbide may be made in small amounts by forming an arc between carbon electrodes inside of an ordinary sand crucible into which a mixture of charcoal and lime is thrown in small amounts from time to time after the establishment of the arc.

Several very beautiful experiments along the line of pyrotechnics may be arranged by mixing sugar and an oxidizing agent together with some substance to give color to the flame. The alkaline chlorates combine the last two functions, furnishing the oxygen and the color at the same time. Strontium chlorate and sugar is a mixture largely used in commercial "red-fire." Barium chlorate produces the green flame, potassium the lavender, and calcium the orange. The blue flame is more difficult to

obtain, and requires the previous preparation of ammonia-copper chloride by precipitation by means of alcohol of a strong solution of copper chloride previously treated with ammonium hydroxide in excess.

The fact that various substances with which the student becomes familiar in a general course in chemistry find technical application as pigments under the trade names of "white lead," "zinc white," "chrome yellow," "chrome orange," "cadmium yellow," "vermillion," "Indian red," "Prussian blue," etc., may help to maintain interest during the course.

As an illustration of the laws governing the formation of salts and the precipitation of insoluble substances from solution the methods in vogue in the dyeing establishments are worthy of note. Most organic dyes are either acid or basic in character and hence affix themselves to animal fabrics by forming insoluble salts with silk or wool which possess the properties of uniting with both acid and base. Vegetable fibre, on the other hand, seems to be a neutral body possessing neither acid nor basic properties. It does not form insoluble compounds with organic dyes generally and therefore the color may be readily removed from the fabric by washing. By the use of "mordants," however, the colors may be permanently fixed. A "mordant" is any substance which will form an insoluble colored compound with the dye. The hydroxides of the heavy metals serve as "mordants" for acid dyes while tannic and other weak acids act in the same capacity for dyes which are basic in character.

These insoluble precipitates are very generally used as water-color pigments under the name of "lakes," the aluminum salt of carminic acid (the essential principle of cochineal) being known as carmine lake and the aluminum salt of alizarin (the dye obtained from the madder plant) as madder lake.

If the vegetable fibre be thoroughly impregnated with the reagents necessary to produce these compounds the lake will be precipitated throughout the entire fabric and will give a color to the goods which, since the lake is insoluble, cannot be removed by washing. In this way cotton goods are dyed fast colors, the well-known "Turkey-red" being simply madder lake deposited in finely-divided condition throughout the entire fabric.

These processes may be readily illustrated by adding salts of aluminum, chromium, iron, lead and tin to boiling solutions of the dyes. If the "lake" is not precipitated immediately, the

addition of a few drops of ammonium carbonate will bring it down.

By saturating cotton goods with a boiling solution of the salts and the dye and dipping for a moment or two in a hot ammonium carbonate solution, the color may be affixed to the fabric.

Since the different metals produce different colors with the same dye, if cotton be stamped with pastes consisting of gum-arabic mixed with salts of the various metals, different colors may be produced by once dipping into the dyeing solution, thus illustrating the method of the "calico printer." By treating cotton with four different pastes containing respectively aluminum, ferric iron, chromium and tin salts four different colors, red, black, lavender and brown, may be produced by one immersion in boiling water to which alizarin and ammonium carbonate have been added. These experiments are not at all difficult to perform and they appeal strongly because of their novelty.

Following a somewhat different line, the process of fermentation by which sugar or starch is changed into carbon dioxide and alcohol and this latter oxidized to acetic acid or vinegar are worthy of consideration. Attention might be directed also to those experiments which demonstrate the necessity of proper nourishment for plants. Comparative experiments on the growth of seedlings planted in pure quartz sand and fed with solutions of nitrates, phosphates, potash, and lime, on the one hand, when these are all present in the proper proportions, and on the other when certain ones are lacking will teach the value of fertilizers and of rational soil treatment.

-In conclusion a word in regard to cooking and allied processes may not be out of place. There seems to be a strong desire on the part of some people to see this subject introduced into the high school course in chemistry, because of the belief that it would be particularly valuable and helpful. It is well to remember that the chemist would have difficulty in differentiating by chemical methods alone between a raw and a cooked potato, or between a live steer and a deliciously broiled porterhouse. What the effect of cooking is can hardly be expressed in chemical terms other than that the change consists mainly in the loss of more or less water. The physical changes are so much more evident that it would seem that such a topic might be introduced with much greater propriety into the course of physics.