THE RELATION OF HIGH SCHOOL CHEMISTRY TO GENERAL CHEMISTRY IN COLLEGES.¹

By C. L. FLEECE,

Princeton University, Princeton, N. J.

In teaching general chemistry in colleges we cannot ignore the fact that a considerable portion of our students have studied chemistry in high school or preparatory school and that this elementary training will have an influence on their advancement. There is no doubt that we can teach these students more chemistry than beginners. But it is a problem to determine the exact advantage they may have and what credit may be given to their previous study of the subject.

This problem affects the colleges more seriously than the high schools, since a very small percentage of the high school graduates enter college and less than half of these have offered chemistry as an entrance subject. In an indirect way, however, it does have an important bearing on high school chemistry. If we cannot take high school graduates and use their knowledge of chemistry as a basis of a more advanced course, there is something radically wrong with their elementary training. And when I say this I would not have you think that high school chemistry should be *taught* as a preparatory course to future chemistry in college. In fact our elementary science courses in colleges, as well as in secondary schools, are frequently to be criticized because we look upon our pupils as future scientists and may teach them little that is of general educational value.

Those who teach elementary science in college are naturally inclined to consider that the ideal methods of teaching high school science are those that are miniatures of their own pet schemes. But we should expect high school students to come to us with a training meant to fit them for after life. It is the duty of the high schools to supply this and, if we put them in an advanced course in general chemistry, it should be one based on this idea. It is the only logical basis for such a course and probably the best that the high schools could possibly give us.

Very few colleges give two distinct courses in general chemistry, one for beginners and one for men who have already had an elementary training in the subject. Columbia has such an arrangement. At Harvard I believe the laboratory work is different. At Princeton we have different quiz groups, the lab-

¹Part of an address before the Chemistry Section of the New Jersey Science Teachers' Association at Newark, December 9, 1916.

oratory work is varied somewhat, and the courses will be entirely separate when the new laboratory is completed. But a number of colleges insist that the entrance requirements in chemistry must be on a par with those in other subjects, and after a student has passed those requirements and entered college his knowledge of the subject must be disregarded and he must elect a beginners' course. The colleges, as a rule, are not to be criticized for this state of affairs because two courses in general chemistry naturally mean a greater teaching force than one and a more complete physical equipment. These are often impossible to obtain.

Now comes up the question of the advisability of such a division, when possible, some of the obstacles, and the assistance the high schools may give to the plan. The statistics of the College Entrance Examination Board show that the percentage of students passing chemistry of late years is slightly below that of all subjects. And we may judge from this (assuming that the students get as good instruction in chemistry as in other subjects, and I believe they do) that the requirements are high enough to insure that a student will have considerable knowledge of the subject when he enters college. As to the part of that knowledge that may be the basis of a more advanced course, I shall speak later.

Let us now suppose that these students are put into a beginners course in general chemistry, and see what happens to them. They may be divided into three groups. First, those who are really interested and desire a further knowledge of the subject. Their work in high school was usually of such a high grade that they are prepared for rapid advancement and expect it. But they begin the course by hearing lectures that are too familiar to them to be very instructive or spectacular and by doing laboratory work that is too near a repetition of former trials to stimulate wonder or ingenuity. The idea of work of any variety is distasteful to some college students, but the repetition of work, once carefully performed, seems little short of criminal. And to be required to assemble a hydrogen generator for the second time and be exposed to the same dangers of an explosion seems much more of a waste of time to these students than if their mathematics course in college should begin with the multiplication table. Is it surprising that many in this group of students lose interest, become discouraged and do mediocre work, and finally forget their inclination toward chemistry?

The second group will include those students who think

their knowledge of chemistry will make a beginners' course a "cinch;" and a third group will be made up of those who go into the course for no special reason other than because it is required, or makes a convenient schedule, or because their parents requested it. To both of these groups the results are often more disastrous than they might have been if they had had no elementary knowledge of the subject. It will require little study for them to do passable work for weeks or possibly a whole term; but before the year is nearly over they will find that they have neglected new ideas and new principles to such an extent that they cannot keep up with the class or pass their final examinations.

In a more general way we may say that any course which requires a widely different amount of mental exertion from two groups of students is defective from the standpoint of mental development and efficiency. And as these considerations outweigh all others in any elementary course, it is evident that such results as I have mentioned are not based on sound pedagogic principles.

There are difficulties to be encountered in accepting high school chemistry or physics as a foundation for a more advanced course in the particular science. A student's fitness to take up the more advanced course can be determined to only a small extent by his ability to pass the college entrance requirements and, paradoxical as it may seem, the schools that do not expect to prepare their students for college usually give them a sounder foundation for college chemistry than preparatory schools whose reputation is based on their ability to get students by the entrance examinations.

Although the college entrance requirements in such subjects as Latin, mathematics, or history may give us a fair estimate of a student's training in those subjects, they produce little evidence on numerous intangible factors that make for his proficiency in chemistry. A school that will look upon chemistry merely as a part of a general education will emphasize *quality* more than *quantity*. It will teach a student to *generalize* rather than *memorize*. And the training and analytical reasoning that may be developed in the laboratory are not sacrificed for cold facts that may later be put on paper. The chemical training that will help a man or woman to solve the problems of later life may, at the same time, meet the requirements of the College Entrance Examination Board or any similar board, and be the best asset toward progress in his college career.

The so-called "requirements" of the Board are too broad to be covered completely by any secondary school (or college) and should rather be considered as a list of suggested topics, or not at all. And teachers sometimes fail to get their students through their entrance examinations because they pay too much attention to these requirements and not enough to thoroughness and the correct methods of making their courses interesting. An attempt to cover the requirements as far as possible often results in a "cramming" process that may be useful in getting students through their examinations, but leaves their knowledge in such a chaotic state that it is unsuited to any further purpose. It is quite possible for them to memorize a mass of facts relating to physical and chemical properties and uses of chemical substances, along with a number of definitions and laws, and squeeze through an entrance examination. They may not be able to write a formula or equation that had not been previously memorized; they may have no idea of nomenclature or the relations between elements or compounds; problems in chemical arithmetic may have been lightly passed over; and they may be barely acquainted with a chemical laboratory. Yet I can conceive of such students passing the entrance requirements in chemistry and believing that their knowledge should entitle them to an advanced course in general chemistry.

But the number of such exceptional cases is decreasing rapidly, and it does not take long to weed them out and drop them into their proper atmosphere. Better laboratories and equipment and higher standards among high schools are having their effect on the quality of work turned out.

Of course the most striking evidences of poor training are still to be found in a student's laboratory work, and this is the most difficult consideration to meet in giving credit to high school chemistry. This is due not only to the lack of laboratory facilities but to the fact that laboratory instruction for beginners is the most tiresome of the teaching of chemistry and is most likely to be neglected. This instruction is punctuated ("punctured" would be as good a word) by such daily happenings as illustrating the correct method of removing a stopper from a bottle, explaining that a rat-tail file really looks like a rat's tail and is not triangular, that hot glass should not be cooled under the tap, that the hydrochloric acid is within reach and not to be found on the sideshelf, and that the "bottle of glowing splints" has ceased glowing. In addition we may be

called upon for police duty such as locating lost apparatus, putting out fires, and caring for the injured.

On such a day as this it will require a bit of self-control not to see imaginary precipitates and not to accept an apparatus merely because it "works."

Another thing that affects the laboratory training in some schools is the limited periods for such work and the desire to cover a set number of exercises. This sometimes forces a teacher to accept results that would be repeated if a student could find a period to do so and not fall behind the rest of the class. And if a student is hurrying through an exercise which should be finished before a bell concludes the exercise, he will usually miss the conclusion that should be drawn and gain little from the experiment. Also such things as poor cork boring and glass working are likely to be overlooked.

I saw a good example of this attempt to save time only a few days ago. I intended giving some extra work to a student who was unusually well prepared in textbook chemistry, and asked him whether he had had any experience with balances. He replied that his school had balances of different kinds but they were not required to use them, and were allowed to take their chemicals to the druggist to be weighed. That they saved time by so doing is doubtful, and if accuracy was the reason for such a procedure, a scientist was evidently wasted in a corner drug store. And the boy would have been better prepared for the work I assigned him if he had used only crude laboratory scales and had learned to replace weights.

It is a difficult matter to get much information on a student's laboratory training by an inspection of his laboratory notebook. Frequently the poorest students will be able to prepare the best looking books, and important conclusions and original work will be concealed with copied lists of apparatus and materials or lengthy instructions for performing the experiments. And I have seen books containing long lists of chemical formulas and their names which the students were supposed to memorize.

A large part of this memory work can be eliminated by a greater emphasis on the rules of nomenclature and valence. These are topics that will add little to a student's general knowledge but they will help clear up the confusion that results from this new language of chemistry. Previous study of grammar and languages has taught him that different endings are used merely to give different shades of meaning to words, and it is

hard for him to grasp the idea that such compounds as sulphides, sulphites, and sulphates can be quite different substances. Nomenclature is usually not explained until a systematic study of acids, bases, and salts has been made, but I believe that the main ideas may be combined with valence earlier in the course. If you explain that there is a relation between the name and radical of a salt and the name and radical of some acid the writing of formulas and naming of compounds will at once assume a logical basis. The topic may be taught in an interesting way that will result in a spirit of rivalry in the class and the dread of meeting unfamiliar chemical substances will disappear. And the variety need not be limited to the compounds that have been studied in detail. One of the questions on the Board paper last June asked for the *name* of the *potassium salt of chlorplatinic acid* and the *name* of the compound that *magnesium* forms with *silicon*. The answers frequently included the statement that they had never used or studied the substances.

Another cause of a one-sided knowledge of chemistry is occasionally met in students who have had a detailed drill on some comparatively unimportant topic. This is usually in the teacher's own special field of interest, and a thing that he is most competent to teach. A student's notebook sometimes shows the influence of an organic chemist in the large number of organic equations and processes, of an industrial chemist in the emphasis that is put upon such things as soaps, dyes, explosives, etc. I even remember one student who could write practically no chemical formulas, and yet he had studied osmotic pressure until he attempted to apply it to all doubtful points, and another who considered alloys the most important subject in elementary chemistry. Any teacher of chemistry must have some particular hobby to keep alive his interest in the science, but this can be persistently inflicted on an entire class of beginners only at the sacrifice of more fundamental topics. But there are sure to be some bright students in the class who can be assigned outside reading or special laboratory work in some particular field and the results will be very encouraging to them and to the teacher.

Apart from these more or less exceptional deficiencies noticed in the chemical training of some students is the universal difficulty with chemical arithmetic which we must all face. It is a new application of arithmetic that requires constant repetition

and individual instruction before a student can recognize that it is not a new branch of mathematics. And, after a student has gotten to the point where he can apply mathematical reasoning to chemical problems, we are never sure that his arithmetic will enable him to carry out operations involving such simple things as decimal fractions, percentages, or proportions.

Summing up these and other defects in a student's knowledge of chemistry is an easy matter. As often as not they are due to his dislike of the subject or a mental inability to grasp the ideas of a science that demands clear reasoning and careful observation. And there is no remedy that any high school or college can use to correct this. But the outlook for chemistry is brighter than ever before, and it is becoming more and more popular over the country. This popularity is due, to some extent, to the remarkable advertisement given to chemical products and chemists at the outbreak of the war. Fathers, formerly unfamiliar with college curricula, are reading of chemistry in their daily papers and advising their sons to take it throughout their college course. Aside from any possible effect on our advanced courses, this popularity will certainly have its influence on elementary chemistry in high schools and colleges; it will gradually result in a readjustment of courses, the addition of new equipment, and the raising of standards. And it is to be hoped that more colleges will be in a position to give credit to high school chemistry and that the quality of work done by the high schools will continue to improve.

EXTENSION AGRICULTURAL WORK EXPANDED.

Full development of the plans for further wartime expansion of the extension service of the United States Department of Agriculture will mean at least one demonstration agent—possibly two, a man and a woman—in nearly every agricultural county in the nation and a woman in each of the large cities to give advice on production, conservation, and utilization of food products. This is a statement in the annual report of the Secretary of Agriculture, David F. Houston.

Through provisions in the food production act for development of the extension service more than 1,600 emergency demonstration agents had been appointed by the end of October, making a total of approximately 5,000 cooperative extension workers. Nearly 750 additional counties are cooperating with the department under the food production act in employing county agents. Men county agents total now about 2,000, many district agents are supervising their activities, and about 1,300 women home demonstration agents are at work. These agents not only are performing the normal and emergency demonstration and educational work but also are assisting in other special Governmental activities, such as the Liberty Loan and food conservation campaigns.