THE COLLEGE REQUIREMENT IN CHEMISTRY FROM THE HIGH SCHOOL STANDPOINT.*

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At the present time, under the rapid extension of the elective system, chemistry has come into great favor, and laboratories and other facilities have multiplied to keep pace with the increase of students of the subject. In some cases this has been at the expense of other electives, notably physics. Indeed, this useful and fundamental branch of science has in some schools and colleges been almost deserted because of the crowding of the chemistry courses. Chemistry offers the best opportunity for individual laboratory study, with less necessary restraint than is required in the ordinary class room. But, above all, the chief excellence in chemistry lies in its power to give pupils practice in the very noble accomplishment of learning to think.

Chemistry should be learned by laboratory practice, expressed in a laboratory record. Both the work and the thinking should be done by the pupil. He should be led up to the proper point, his curiosity should be stimulated, and his efforts encouraged by instruction from the teacher, who must point out clearly what is to be sought, and give such hints as will be necessary for the successful performance of the experiment. After this encourage the pupil to stand on his own feet. Guide him and lead him but never push him. If you do so he will soon expect to be picked up and carried bodily, thereby losing that very exercise which is so essential. The cultivation of keen power of observation, and the ability to form wise judgments is the best preparation for life, as well as for higher courses in college. Such training will be sure to teach a great many of the facts of chemistry directly, and many more will come from the teacher indirectly. It is remarkable to find the large number of common substances with which a pupil becomes personally acquainted in a course of

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inductive laboratory work. It is the most thorough kind of chemistry study.

What are the practical points to be carried out? What material should be selected from the broad fields of chemical science? A real laboratory record kept by the pupil is the first necessity. In making this record it should be particularly emphasized that the essence of all laboratory work is honesty. For this reason it may be proper to overlook other defects until the pupil has become familiar with this true scientific spirit. The honest pursuit of laboratory study may often be aided by insisting upon having each period of work carefully dated, and by using note books with leaves which can be neither removed nor inserted. It is very important that all notes, even records of failures, be preserved and frankly exhibited. It is well for beginners to keep their note books in the laboratory, and to make all notes in the environment of their work. To prevent confusion between such laboratory records and memoranda made primarily for future reference, it is well to keep another note book for lecture notes and material such as a pupil may obtain from reference books or from the teacher. While this second book is valuable, yet it must always be held subordinate to the laboratory record, and the separate and distinct purposes of these two books should always be kept clearly in mind. To learn to take notes of lectures, or of reading, is useful, and may well be cultivated in the high school. It is not out of place even to give some instruction on this point, and occasionally to examine and to criticise such notes; but laboratory records should, for the most part, be examined in the laboratory in the presence of the pupil and his laboratory surroundings. A pile of books collected at intervals and laboriously examined, and then returned, yield but poor results, for the criticisms are in most cases either misunderstood or neglected.

Next to the laboratory record and the discussion in the class room the best method of stimulating thought is a written examination, or a laboratory examination. This valuable kind of review, often disguised under such euphemisms as "written exercise," "written recitation," and "test," is becoming seriously neglected. From its abuse we have come to overlook its value. Over-

worked teachers and indulgent parents have failed to recognize the advantages of even an occasional strenuous effort. That is the very best kind of training which teaches our boys and girls to meet and to overcome difficulties.

The text book plays no essential part in this scheme of instruction. It is to the authors of text books that we owe the planting of the study of chemistry in the secondary schools of this country. But former methods, which had to instruct the teacher, as well as the pupil, have now ceased to be effective. Authors of the best of text books have, with commendable generosity, admitted that their books do not express their own high ideals. Publishers demand books that sell. Teachers lean on text books instead of improving their own knowledge by study. Pupils learn to depend on the book to such an extent that it becomes unnecessary to pay attention to the personal instruction of the teacher. But, above all, at the beginning, the ordinary text book would be as inappropriate for this method of teaching chemistry as a key would be in algebra. Text books and drill books are useful for review and for practice in problems, but most of the drill work, as well as laboratory directions, can be printed on one of the very numerous and convenient duplicating machines now to be had at low cost. Most of the information in text books can be better impressed by using numerous wall charts made by the teacher or pupil, by excursions to such manufacturing plants as illustrate chemical processes, and particularly by instructively arranged and easily accessible collections of models and chemical products. These accessories accumulate rapidly in any laboratory, if a little attention is given to obtaining the necessary material. To profit by the peculiar value of chemistry as a high school subject we must realize that the actual study of chemistry must be done in the laboratory. If chemistry teachers continue to demand more time in school hours for laboratory work, and they ought to have it, they can not expect to require more than occasional home study.

During the first year or two it is hardly worth while to devote much time to the study of qualitative analysis. With the pupil's scanty knowledge of descriptive chemistry, and of those

laws which govern chemical reactions, the scheme of separation and identification is meaningless, and is performed mechanically. It is an exciting game, which keeps him industriously at work, but like much of the "busy work" in lower grades, it is of indifferent educational value. Qualitative analysis is a very long and insecure path on which to reach descriptive chemistry. It is not uncommon for pupils to pass through a score or two of "unknowns," with the impression that barium chloride and silver nitrate are both liquids.

In these days when not only milk, kerosene oil, and hay are either measured or weighed, but also heat, power, gas, water, electricity and almost the very air we breathe, and when anthropometry is an established practice, it is natural to follow this exact spirit of our time. It is certainly not worth while for pupils to waste days over wearisome determinations depending upon accuracy as their chief end. Yet every student of elementary chemistry ought to be able to handle a "horn" balance, and weigh a mass of a few grams to the second place of decimals. He should be taught the significance of the zero in such a quantity as twenty-hundredths (0.20) of a gram. Moreover, he should come to learn that the balance can answer many questions concerning those laws which govern the formation of chemical substances. Above all, let him learn to respect the balance as a useful and reliable scientific instrument.

The theories and the experiments relating to physical chemistry may seem difficult for a beginner. Nevertheless, the underlying Principles of the Dissociation Hypothesis and of the Mass Law are very fundamental. They are certainly as essential to a course in elementary as is the Law of Definite Proportions or Avogadro's Rule. The whole organism of the science is so affected by these theories, that without them the subject loses its significance. Teach theory as a means of stimulating the pupil to explain to himself the constantly occurring enigmas of nature.

In order to teach chemistry as a coherent subject it is necessary to avoid rambling in other fields. The applications of chemistry to cookery, biology, sanitary science, or geology and mineralogy, should be carefully subordinated to the general plan,

and used only so far as they illustrate chemistry. These other subjects should all be taught in the high school, but usually as separate courses. Except in very small schools, where it is necessary to combine subjects, chemistry teachers would do well to exert as much influence as possible toward the introduction of separate courses in industrial and sanitary science. Have them in addition to chemistry, but do not rob chemistry to make room for them. The teacher's skill should always be directed toward framing a well organized course of instruction, well defined in every detail, with each part well proportioned and intimately related.

But where shall we find material for such a course of instruction? Text books and college requirements suggest the main topics. We should teach the chemistry of familiar substances and their related compounds, about half a dozen elements, and the important compounds of a dozen more, including carbon. There should be some quantitative experiments, and the main principles of theoretical and physical chemistry should be introduced. The Boston chemistry teachers, meeting in the laboratory of Miss Laura B. White of the Girls' High School, prepared two years ago a course based largely on the Harvard requirement. Several Boston teachers have since been using this with satisfaction, either in whole or in part, although the text has never been put into print. The Harvard Requirement, published by the University, is sent on application, free, to teachers only. The circular of the College Entrance Examination Board is also an excellent guide. Printed notes like Miss White's *Chemical Theory*, a modest but useful pamphlet, may furnish excellent material for fastening principles which have previously been worked out in the laboratory.

The advocates of inductive teaching have frequently been told that it is absurd to try to make children do research. This is a misunderstanding of the situation. If Archimedes had been furnished with a "J" tube and a bottle of mercury, not to mention the instructions of a patient teacher at his elbow, the familiar law governing the relation of the volume and pressure of gases would not have had to wait for Robert Boyle. The exploration of new fields is of quite a different order of difficulty.

The crying demand of the intelligent critic is for specific education. We are just now burdened with much pseudo-education. No person can learn the chemistry of silicon by washing windows, any more than he can learn the chemistry of alcohol by drinking it. Does your experiment teach anything? If so, is it really worth teaching? Are you training pupils toward self-reliance? Are you cultivating mainly the imitative or are you cultivating the constructive and inventive faculties? How does your pupil act when he encounters obstacles? Do you ever bring to light a genius? It is a hopeful sign that each year the new education is sending out into the world not a few persons capable of original work in some field.

Above all a teacher of chemistry should be definite in his aims. Having decided on a policy pursue it without hesitation, and long enough to gain familiarity and efficiency in teaching the course. Remember that a poor method and a good teacher is far superior to a good method in the hands of a poor teacher. But seek to attain the supreme result in both good teaching and a good method. Insist on the spirit of scientific integrity. Give the same instruction to all the members of the class. It is a most pernicious practice to put a few choice souls into a separate division, just because they are going to college. Give your best instruction to every pupil. If he has done his work successfully in school, he will be able to pass any reasonable examination for college.

A wise prophet as well as a distinguished American statesman has recently told us that the test of all education's worth is that "it induces the will to adhere to its general, permanent and deliberately conceived purpose, in spite of the motives which appeal to it with special strength at the time of choice of action."

We may also apply Dr. Sargent's test of physical efficiency to our chemistry teaching, and ask of ourselves concerning each pupil, What can he do? How well can he do it? How long can he keep at it?

We must not forget that we are training boys and girls for the responsibilities of democracy, where intelligence, discriminating judgment, deliberate action, continuous labor, and sturdy integrity mean enduring liberty.