LABORATORY WORK BY THE STUDENT OF CHEMISTRY SHOULD BE SUBORDINATE AND AUXILIARY TO THE DEVELOPMENT OF FACTS, PRINCIPLES AND THEORIES BY THE TEACHER.[1]

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THOSE of us who are engaged in teaching chemistry recognize the fact that it is a difficult subject to teach scientifically; it is ofttimes hard to make its lessons clear to the mind of the student; difficult to employ it with its due power as a means of intellectual discipline and an element of general, liberal education; and yet it has a place, an accorded place, in every properly arranged scheme of education: no such scheme is complete without it, and no one can be said to be liberally educated who has not learned the elements of this science; for without the knowledge of these elements, at least, it is impossible to read understandingly the literature of our day and to appreciate a thousand things of common occurrence in respect to health, well-being and progress. The practical utility of chemistry is unquestioned; but some question its disciplinary value as an element of general education. In my opinion, the skillful teacher makes its value in this regard equal to the languages and mathematics, and gives to the mind exercise and truth which in character are peculiar and in quality most valuable.

The great value of the study of general chemistry turns solely on the adoption of good, sound methods of instruction.

The nature of the subject, the inquiry into strange forces, into marvellous activities and changes, give to it, in the eyes of beginners, the appearance of the mysterious, making it seem, as it did to the Egyptians, a "Black or Secret Art." The puzzling vastness of the number of facts, the important and interesting relations between them, the comprehensive laws, the profound theories, tax the powers of the capable and patient student. The teachers and the writers of text-books often find it difficult to decide what to use and what to omit of this profusion of material. The subjects can be so selected, the matter so arranged with due regard to the time at our disposal and such methods of instruction employed that no other subject could be profitably substituted for the study of chemistry.

The methods of teaching general chemistry have varied greatly at different times and now vary more or less in different schools. Of course, each teacher carries his personality into his class room: this is right and inevitable; there are differences of method which are broader, proceeding from difference of standpoint and difference of view both of the object to be accomplished and the way of reaching it.

We cannot emphasize too strongly the general disciplinary value of the study of chemistry and its essentiality to culture; and it devolves upon us to maintain the correctness of our estimate by the intellectual and industrial results of our teaching. The first object is to use chemistry in a scheme of education to make intellectual men, and the second is to prepare skilled chemists.

After noting these differences of method, I am sure we may all agree that the feature which specially characterizes the teaching of chemistry at present and which distinguishes it from the method of past years is experimentation by the student.

And yet in many high schools and *colleges*, even in this day, the effort is made to teach chemistry without experiments either by the instructor or by the pupil. Many of these schools and colleges have no apparatus. Such teaching of chemistry and of science generally is illusory. Chemistry is justly and highly valued in its general study as an element of disciplinary power and as a foundation for special attainments; but its most earnest and intelligent advocates in a course for a well-rounded education would admit that it would be far better to omit it altogether than to teach it in that irrational manner without experiments, and to devote the time thus saved to the study of some subject which can be scientifically taught without apparatus.

As teachers, we must insist that an experimental science, such as chemistry is, cannot be taught without experiments.

In my judgment, the best method of teaching general chemistry, in the earlier part of the course, the best way of laying a substantial basis of knowledge that is reliable and definite, on which the student can subsequently build most surely and rapidly, is for the professor to give in didactic style oral lectures, adapted to the comprehension of his class, setting forth in order the most important portions of the great body of established facts, connecting them by threads of scientific relation, that bring them into a simple unity, illustrating them by experiments, on the lecture table, which cover all essential points and help the minds of students to apprehend them as real.

A really good text-book is very valuable, and the instructor ought either to follow the order of subjects in the text-book or be careful in assigning the readings so that the lectures and text-book will each day cover the same ground substantially. Otherwise confusion of thought will arise in the student's mind.

To indicate something of the scope of instruction I would say that there should be a clear presentation of the nature of chemical science, its relation to other sciences, and the ways of doing the work: there should be a discussion of the elements and their most important, best known compounds: as the teacher's knowledge covers his whole course he is able to call attention to that which is essential and that which may be at the time incidental, to note the connection between facts, the relation between substances, and thus to systematize and organize knowledge and build up the science in the minds of students: this prepares the way for the proper presentation and discussion of laws and theories, for calling into vigorous exercise the faculties of comparison and judgment. He can exhibit the method of properly guarded generalizations and formulations of his teachings; his duty and plan are to guard the student against the presumptuous thought that one man can make experiments to cover all the facts and phenomena and demonstrate all the laws of chemistry, and to impress on the mind respect for the work that has been patiently done by others and thus give a just regard for authority, through which so much of our knowledge comes in every department of inquiry: the pupil learns that for a satisfactory demonstration of chemical truths he needs a large complement of facts and processes.

At each meeting the class should be questioned upon the matter of previous lectures and readings; skillful repetition is needed to make distinct and abiding impress of the truths, to wear off the strangeness of the subjects and to get a lodgement of the facts and principles.

The careful keeping of notes, subject to periodical inspection of the teacher, the writing of chemical reactions and the solution of problems constitute an important part of that instruction which is necessary to exactness in method and clearness of understanding. It goes without saying that the student must be taught to

[1] Read before the International Congress of Chemists, Chicago.

make experiments. But in order to carry out this plan, the experiments to be made by him should be connected with the course of instruction and should be definitely related to the experiments given on the instructor's table. Indeed, the relation should be so close that a knowledge given by the instructor's experiments would be in large measure a guide to the performance of the student's experiments and that without it the successful performance of the practical work by the student would be beyond his power. This insures the closest attention and care on the part of the student to get the professor's instructions; it trains the mind to correct observation, concentration of energies and carefulness in drawing conclusions.

In the beginning of a course in general chemistry and for two or three months, one hour of laboratory work by the student to four hours of such instruction by the professor, as I have outlined, will be a good division of time. As the student's knowledge of the subject increases and his manual dexterity in handling apparatus improves, his working hours should increase. This mode of instruction proceeds on the rational assumption that the pupil needs to be instructed; it will furnish him the largest amount of reliable, systematic, classified knowledge that is attainable in a given time and give him the best foundation for extended scientific study.

Other special advantages of this mode of study will appear by comparison.

Many excellent chemists make laboratory experiments by the student the starting point and the centre of all instruction. Their idea seems to be to make the student do his own work, draw his own conclusions and thus instruct himself: the instructor, according to this method, gives him the fewest practicable hints and directions. In furtherance of this plan of instruction many "laboratory manuals" have been written which contain a great profusion of experiments: in many cases these are poorly arranged. In the preface to one of these "manuals," now open before me, I find these words: "The teacher should be but the guide that points out the right path, calling attention to the bypaths of error." This plainly implies that if only the direction be pointed out, the student can make the trip. This plan puts the student forward to work for unknown truth; it holds out to him the idea that in some sort he is an investigator, when in reality at first his work should be to learn what others have brought to light and how they have done it.

The objections to making the laboratory work of the student in the beginning the leading and independent method of learning chemistry are numerous and strong: 1. It involves an unnecessary consumption of time. 2. It assumes that the student can do properly what, in the very nature of the case, is well-nigh impossible. A certain amount of knowledge is necessary to the acquisition of other knowledge under the best conditions: there is hardly any fact more palpably true than this.

A student of algebra could hardly be expected to solve problems of any degree until he had the preliminary operations and rules that had been established by the patient work of strong, industrious minds. A traveller, ignorant of the topography and history of Rome, her archæology, her classic and Christian art, would not be profited by a visit to the famous city: he would stand unmoved before the ruins, the historic arches and temples and the treasures of her splendid galleries. A man sees what he has eyes to see. This principle applies in the study of chemistry. An untaught youth knows not what to expect, what to look for in an experiment; he sees things and knows not what is essential and important and what incidental and accessory. Many things he fails to see because he knows not what to look for and how to look. This brings him into a hesitating, doubting state of mind which is very unfavorable to definite, strong impressions. He does not know the significance of those actions which he observes, and he is unable to give them scientific interpretation and impression.

Chemistry is a great science, difficult to master: it has risen upon stepping stones of errors and obstacles by the continued efforts of great men. For centuries minds of able and laborious investigators reached out after the truth and battled against error. The advance from the unknown to the known has been very slow.

Glauber's "Sal Mirabile," Shahl's "Phlogiston" and various other propositions and hypotheses, strenuously advocated and rejected, tell us of the intensity of the struggle and how the mists of uncertainty hung over their work. But when Lavoisier availed himself of the labors of others, patiently compared facts with facts and generalized scientifically, he saw a new light, and the birth of modern chemistry was announced; chaos gave place to order; principles became harmonious.

In view of all this, is it not erroneous to require a student in the very outset to make and interpret experiments as the means of getting knowledge and to proceed with the most meagre knowledge to classify phenomena? Students at first should be put in possession of that knowledge which is their just inheritance from the history of the past and should have the opportunity of learning the methods of experimentation adopted by the builders of the science, and from this study of facts and principles and modes of manipulation to acquire the power of orderly thinking and get the key to higher and greater treasures.

When one wishes to enter upon research he carefully inquires what has been done already; he gets the bibliography, and learns the methods of investigation in that line that have been most fruitful of results: not uutil he has come to this point is he ready to enter upon the work which he proposes.

The object of work in the laboratory by the student in the beginning is to learn to use apparatus: his instruction must come mainly from the skillful teacher: the teacher is not merely "a guide" but a positive power in instruction, an intellectual quickener. The work of a student left to himself in the laboratory profits but little.

ORIGIN OF THE HYDROCARBONS.

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A RECENT review of the paper of Dr. Engler on this subject in *Science* is an interesting one, as it is in the line with my own observations on that subject in Utah. The time-worn theory of the origin of our Utah hydrocarbons from coal has been repeated by several persons in *Science* during the past year, but unfortunately there is hardly a particle of evidence of such origin. I do not know of a single deposit near our coal beds in Utah, with perhaps the exception of one bed of impure asphalt, which seems to be close to the Dakota group, but may have come down from above, as it is not certainly interstratified with the Cretaceous beds. With this exception I do not know of any deposits of our hydrocarbons that are earlier than the Miocene Tertiary. There are some places where it is not possible to certainly tell whether some sandstones are Eocene or Miocene where asphalt has collected from adjacent beds of shale or clay. In using the word "near" it is used in a geological sense, i. e., stratigraphically near. There are some hydrocarbon beds which are within perhaps one-half a