

THE CASE AGAINST QUALITATIVE LABORATORY EXPERIMENTS IN GENERAL CHEMISTRY.¹

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The introduction to a well-known and excellent scientific treatise in general chemistry bears this statement: "The great importance to the student of himself performing experiments illustrating the preparation and properties of many of the substances treated of in his text-book, cannot well be overestimated. If he be in attendance upon a course of chemical lectures, opportunity should be given him of repeating the simpler experiments he may see performed upon the lecture table; if he be not attending lectures the necessity for such practical work on his part is greater still." The author has in mind the usual qualitative experiments, which do not require definite measurement of any kind. With both alternatives in his statement I take issue. If the student is not attending a course of lectures in general chemistry he cannot perform experiments in the laboratory with any large chance of success; if he is attending such a course, the case against that kind of laboratory practice is as follows:

1. It is a waste of the student's time to merely repeat in the laboratory what has been done in the lecture room, not because he is an awkward workman or uses cruder apparatus, but because he learns nothing new or makes wrong inferences. If he gets accurate results nothing has been added to his knowledge; if he fails to do so, he thinks he has learned that sometimes matter acts as the book states and sometimes it does not. The student is thus cheated of his right to get something new or additional in every hour of the course, and of his right to receive such a presentation of the science that his early impressions will not need later revision, and that correct inferences will be inevitable.

The time element in no course of study is more worthy of consideration than in the course in general chemistry. Students must be given more in these days than twenty years ago, because there is more to be given. Thermal and electrical relations must be dealt with, as well as the synthetic and analytic processes. Some physical chemistry must be taught, and more about the carbon compounds should be included than is the usual practice. Hence not only should more time be given to chemistry than has hitherto been allotted the subject in the ordinary curriculum, but every hour of that time should be very carefully planned.

¹Read before the section on Chemical Education of the American Chemical Society at Boston, December, 1909.

2. The student is likely to get wrong impressions of the science from his qualitative experiments, or to miss entirely some impressions he should receive. This results from the facts that no great care is required for their performance, because the experiments are not exact, and that, even if performed with great care according to the student's standard, he may not get the results he has been led to expect. No great care is required to get *some* oxygen and even when it is impure its properties may be studied in a kind of way. The careless student may take more or less of the ingredients he is directed to take, may not even weigh them at all, may mix them imperfectly, apply heat roughly, use dirty apparatus, and yet secure a fraction of the correct amount of product. Such a bungler will miss entirely the impression of exactness in the weight relations of the elements to each other in their compounds.

Or, in some instances, the apparent product of the reaction does not show the properties expected. Antimony will not flash fire in the chlorine gas the student generates. His alleged hydrogen is not lighter than air. Sometimes ammonium nitrate gives off a gas that will support combustion and sometimes it does not. Hence he makes the inference that reactions of matter are variable in results.

3. Qualitative experiments do not make for independence. This is especially the case in those laboratories where students work in groups, and it may be true in any case. It is always possible in this kind of laboratory practice for a student to write his notes or sketch his apparatus on the basis of what he has learned in the text or seen on the lecture table. This is to be expected, for he goes to the laboratory after the reaction has been emphasized and the apparatus shown. At best, notebook work of such descriptive character is of questionable value, and the time given to it far from most profitably spent.

4. Painstaking and critical observation is possible in qualitative experiments, but is difficult. Important phenomena may be overlooked or fail to occur, because of hurried work, careless use of materials, or faulty apparatus.

The case against qualitative experiments in general chemistry may be summed up thus: the weightiest pedagogical consideration is that the student learns nothing new from them, and may get wrong impressions, or miss impressions that he should get. The weightiest scientific consideration is that the student learns nothing of the four laws of chemical combination, nothing of

the exactness of the science, nothing of the fact that reactions result from definite conditions.

This is detrimental to the student and to his knowledge of chemistry. There are two classes of students in the beginning course, the one needing a descriptive knowledge of the science, the other a detailed knowledge. Both require the same foundation, the basal stones of which are the four laws of chemical combination. These laws are statements of quantitative relations. Correct and lasting impressions of their exactness must be given, as well as a knowledge of the general reactions of matter. Lectures and quizzes deal sufficiently with those theories of the science which do not readily lend themselves to experimental demonstration; the lecture table experiments, with the preparation and properties of the elements and their compounds; the text-book emphasizes what has been learned from these sources; therefore the time in the laboratory can most advantageously be used to "connect fact with theory and to emphasize by a large number of determinations the quantitative relations." It is self-evident that the qualitative experiments cannot accomplish this result. The quantitative experiments both do this and meet the objections already stated in the case against the former kind. They require exact measurement, definite results, independent work, a notebook that must of necessity be a record of what is done, care in construction of apparatus, critical and painstaking observation, exactness and definiteness of habit. To the knowledge gained from books, lectures, and quizzes is thus added knowledge of the exact quantitative relations set forth in the laws of chemical combination. The student both gets practice in manipulation of apparatus, and also must construct it well. He handles a chemical problem not as a matter of mathematics but as a matter of fact. The care necessary to secure the required result compels keen observation. The laboratory becomes the place of serious work and the laboratory period a period of study. The student's time is economized to the last degree, for his attention must be concentrated on the experiment, effort is directed at a precise result, and something valuable is acquired that cannot be learned from lecture or text-book.

I know what some of the objections are to an all-quantitative course of laboratory experiments. The experience of the last few years in the chemical laboratory of Union College has shown that the objections are not insurmountable. Quantitative experiments are not beyond the capacity of the beginner. They admit

of gradation, for the variation from theoretical result is easily adapted to the experience of the student.

A second objection has been raised, that the worker is so intent on the precise result that he loses sight of the chemistry of the experiment and may even lose his interest in his work. We have found the contrary to be the case. The addition of a quantitative requirement has, far from distracting the student's attention, made more emphatic the chemistry of the reaction, and has demanded more critical observation. I have seen students watching with intense interest the action of zinc on sulphuric acid, and the physical changes which potassium chlorate undergoes when heated, because they knew that every bubble of gas was essential to the accuracy of their result.

The cost of equipment is not prohibitive. Glassware for quantitative work costs no more than the ware that should be used for qualitative work. Excellent burettes and eudiometers are available at comparatively low cost. Accurate thermometers and barometers are within the means of any laboratory. A good balance, sensitive to a milligram, and enclosed in a glass case, can be imported, duty free, for about \$14. Even if equipment were more costly, I would still urge the quantitative course, with a smaller outlay for laboratory furniture. A good balance is more essential to correct teaching of chemistry than the best laboratory locker. A carefully graduated burette rests as well on a wooden top table as on white tile.

A fourth objection to quantitative work for beginners is that the experiments possible of performance are too limited in number and kind, and do not illustrate a sufficient variety of reactions. Prof. J. T. Stoddard's excellent book, "Quantitative Experiments in General Chemistry," is the answer.

The considerations here given do not constitute a contribution of something new to the discussion of the comparative value of qualitative and quantitative experiments in a course in general chemistry, but are the reason for, and results of, the introduction of an all-quantitative course in Union College. The results warrant our recommending the use of quantitative experiments to all teachers of chemistry, whether in secondary schools or colleges. By means of them the student not only receives correct impressions of the science, which need no later revision, and is better prepared for whatever subsequent courses he may pursue in chemistry, but also develops habits of accuracy and definiteness which are of inestimable value in all courses and in any career.