of the merely descriptive matter can be omitted, and the shorter explanations suffice.

SUMMARY

To return to our thesis: the college can reconstitute itself an indispensable and successful factor in American life if it will devote itself, *and confine itself,* to pre-professional work—specific work in preparation for the learned professions and for business—and if it will devote itself, *and confine itself,* to turning out men and women able to solve problems. I think we must be ready to admit that, to do these things, the college requires, and should have, a more definite source for skilled teachers, and that the college must vastly improve the methods of instruction in many of its subjects. If we as chemists can devise a method for training teachers of chemistry and can improve the methods of teaching the science themselves, we shall not only have done a service to the science, but we shall have contributed our share towards the rehabilitation of the American college. Perhaps we can do more than our share, if we are right in feeling that chemistry, appropriately taught, can furnish quite exceptional training in the art of problem-solving. We can make our contribution doubly welcome and doubly valuable if we are willing to tackle the problem at once and resolutely by scientific methods, and to put our solution quickly into practise.

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COLLEGE CHEMISTRY BEYOND THE ELEMENTARY COURSE[1]

SINCE the character of college chemistry beyond the elementary course is determined to a great extent by the nature of the introductory work, one is compelled in a discussion of this kind to make certain suppositions concerning the nature of an elementary course, and to proceed upon the basis of these assumptions.

Toward the close of the first year, by imperceptible gradations, the course in general inorganic chemistry is often allowed to flow into routine analysis. I can not help feeling that this is especially undesirable. The practise materially shortens the course in general chemistry, and takes for its own uses time which might be spent with greater profit in the study of many properties of the metals which are more varied in character than the limited number usually chosen by the analyst for the purposes of testing and identifying these same elements.

If the elementary course has given the student a somewhat thorough preparation in general inorganic chemistry—a full year with the usual number of hours of recitation, lecture and laboratory work—the college student comes to his second year with the following customary divisions of chemistry before him: Qualitative analysis, quantitative analysis, organic chemistry, physical chemistry.

It would lead me too far afield to consider all of the courses which follow the student's elementary training; so I have chosen to limit my remarks to those courses only which lie in these divisions immediately beyond the course in general chemistry.

Among these divisions, qualitative analysis in the majority of cases is the one which may most profitably be made the successor of the first year of chemistry, provided, of course, this subject is approached from the proper standpoint. I fear, however, that many of our colleges, even to-day, have not emancipated themselves from the old method of teaching this subject, but are

[1] A paper read before the Section of Education of the American Chemical Society at Detroit, July, 1909.

still employing a plan which, although almost universal not many years ago, is now obsolescent. I refer to the purely mechanical process in which great emphasis was placed upon the art of making tests and separations, while the teaching of sound chemistry was a matter of minor consideration.

Under this régime, instruction in the laboratory usually fell into a routine and complacent following of some outline of analysis carefully arranged with side margins and pages with indented leaves for ready reference. The group separations were accomplished by unswerving adherence to certain tabulated schemes which demanded a minimum of mental exertion, and afforded a striking example of a "principle of least work." It was no uncommon thing to require a student to analyze one hundred "liquid unknowns," one hundred "solid unknowns" and forty minerals arranged in a row. The desired end was reached if the student, at the request of an instructor, could make a correct report of the "acids" and "bases" which he had found in each unknown.

The text-book frequently contained page after page of those incomplete equations in which the right-hand member was to be supplied by the student. This was often done in a successful way by the precarious process of analogy; but in many cases there were several guesses equally plausible, and the student generally made his choice without any effort to find out the facts in the case. When I think of the vagueness of these equations, I am reminded of a question which, I have heard, was once proposed to a class in history at an examination. It read, "Who chased whom how many times around the walls of what?" The answer to this question was probably more certain to be correct than the answers to be expected in the case of the fragmentary equations of the kind I mention.

If by chance any recitations were attempted in connection with this ineffective course, they usually degenerated into mere droning of equations, sometimes in unison, like a chant. In other words, the essential rôle of the course consisted in an endeavor to master the details of the manipulative art, with the result that the science underlying it was sadly neglected to the great detriment of the student who usually knew less chemistry at the end of his course in qualitative analysis than he did at the beginning of it.

To my mind, a course in qualitative analysis first of all should be designed to teach advanced general chemistry; in the second place it should aim to teach the necessary manipulative skill, a knowledge of which, I confess, is of the utmost importance for success in chemistry. The golden threads of physical chemistry have so intertwined themselves in every fiber of the warp and woof of general inorganic chemistry, and have so illumined the problems of analytical chemistry at every turn that there is no longer any excuse for making the subject matter of qualitative analysis profitable to the student mainly in the direction of acquiring laboratory technique. Such a course should furnish the teacher a most fortunate opportunity for presenting to the student certain views of general chemistry in a manner more advanced and more forceful than the latter has ever met them before; and should serve at the same time as a means of relating and fixing facts which, up to that time, may have been unrelated and vague.

I have in mind a course of recitations with lectures, so arranged that points taken up in the class-room shall be illustrated again and again in the laboratory practise

through the solution of definite problems suggested by the analytical operations themselves. The lectures should be very largely experimental, and might consider, among other things, the logical sequence of the most essential facts which led to the proposal of the theory of solution; the experimental basis for the hypothesis of ions and the theory of electrolytic dissociation; the significance and application of the laws of chemical equilibrium (homogeneous and heterogeneous) with illustrations chosen from the wealth of material furnished by analytical processes.

As an outcome of the discussion of the nature of chemical equilibrium, the student will be in a position to consider certain topics—the methods of deriving dissociation constants may be presented briefly, and the value to the analyst of a knowledge of these constants may be dwelt upon at some length; the problem of the solubility product may properly take some time, since there will be little difficulty in making its value and application plain by selected experiments, many of which the student himself may perform in the laboratory; the study of complex ions and their stability constants will furnish abundance of material for experiment and discussion. These few main points may serve to suggest the changes so greatly to be desired in the teaching of this division of chemistry in the colleges.

It is here that the subject matter of elementary physical chemistry and analytical chemistry overlap, and the one takes from the other certain chapters which may be of practical service to it in the successful elucidation of its particular problems. By this overlapping, qualitative analysis has ceased to be governed largely by rule of thumb, and has passed into an organized and orderly subject with that real "scientific foundation" prophetically announced by Ostwald a number of years ago.

What I have said concerning qualitative analysis applies with equal force to quantitative analysis. It must be admitted that the laboratory art is exceedingly intricate and varied, and should be thoroughly learned. When, however, the student is permitted to devote his entire time to it, except for interruption by a single weekly recitation on problems, the loss to him is irreparable.

As regards elementary physical chemistry there is little to say, since there are very few colleges which give any definite course in this subject, unless a course in theoretical chemistry is made to serve this purpose also; but it is doubtful whether the courses given under this title deserve to be classed as physical chemistry in the present sense of the term. There can be no question as to the desirability of such a course as a part of the college curriculum; its appearance in certain college announcements gives us hope that others may follow.

The recent changes which I have mentioned in connection with the teaching of analytical chemistry have gradually found an entrance into the methods employed in some institutions, and may be looked upon as fairly established in many quarters. With the teaching of organic chemistry the case is different. I believe that this division of chemistry is in a transition stage with respect to the content and character of the subject matter presented in the elementary course.

It is generally conceded that qualitative analysis ought to be the course which should follow logically upon the heels of the elementary course. In fact, this practise has been in vogue for so many years, and has been advocated by so many famous teachers that it has come to be looked upon as a matter of necessity, rather than choice. This, however, is by no means the case. For many years, organic chemistry has formed rather a mature part of a stu-

dent's course, and, in its advanced phases, must do so still. But there has come to be an increasing need on the part of students for this division of chemistry as a prerequisite for certain professional and scientific courses to follow; this has made it almost a necessity to insert organic chemistry immediately after the elementary course.

This juxtaposition has made the teaching of elementary organic chemistry a more difficult problem than it was, and has placed the teacher of this subject in a somewhat unfortunate and unenviable position. Those of you who have taught this subject are very well aware that the student is in the habit of approaching the course in organic chemistry with misgivings; it is proverbially a hard task, and is tabooed as "no snap." It seems to me that organic chemists have themselves to blame for this attitude. Let me cite one or two instances which may serve to justify this claim.

In the first place, the methods which were in vogue at a time when organic chemistry formed a more advanced part of the college curriculum have not been modified sufficiently to adapt it to the student at an earlier stage in his career in chemistry. As an illustration of this kind of fault, let me mention the universal practise of prefacing the systematic study of the various classes of organic compounds by a very detailed description of the quantitative methods of organic analysis. Instead of this, a brief statement of the essential principles would suffice. Except in a general way, these longer directions, still in use, are rarely comprehended by a student who has not taken quantitative analysis, and at the very beginning, they tend to create discouragement and discontent which could be dispensed with by applying a little sound pedagogy. Such remnants of earlier times and methods have no more justification at this stage than a minute description of every precaution necessary in the quantitative estimation of manganese would have as an introduction to a discussion of the compounds of manganese in a course of general inorganic chemistry. Numerous instances of this atavism are to be found in the elementary text-books of organic chemistry; there is little reason to doubt that they occur in the lectures as well.

A second and graver difficulty lies in the fact that there has come to be a widening gap between the methods employed in approaching the subject matter of general inorganic chemistry and the methods which we must believe are still not far from universal in attacking the problems of organic chemistry in an elementary course. Thanks to the timely warning of physical chemistry, and the practical example furnished by a few text-books of general inorganic chemistry, we have made a grand stampede to return once more to the facts of our experience as a basis of procedure. We have endeavored here to strip off much of the speculative husk which has encased the subject with almost impenetrable firmness. In this desirable simplicity, we are content to call a stone, a stone, and to name a flower, a flower. In the teaching of inorganic chemistry, this movement has demanded the wholesale striking out of intricately constructed graphic formulæ which had no serious or certain justification in facts, and therefore explained nothing. As a result, the other extreme has now been reached, and scarcely any of the reactions and relations considered in an elementary course of inorganic chemistry are presented to the student in this symbolic garb.

On the other hand, the organic chemist, up to the present time, has had little or no success in presenting his subject from an

inductive standpoint. The old genius is too strong, and stands menacingly by while he writes. Several text-books have made a bold start with this object in view; but after a brief beginning of little promise, the argument rapidly assumes the old dogmatic form. Substances are said to be aldehydes "because they contain the aldehyde group"; or unsaturated, "because they possess double bonds." At every turn, the chemical and physical properties of compounds are attributed to them as a result of certain "constitutions" or "groupings of the atoms within the molecules." Rarely, if ever, is the veil lifted, and the student permitted to see that, as a matter of fact, precisely the reverse order is the one which should hold, and that it is the physical and chemical properties which determine the constitution. It is a matter of some surprise that we do not hear of compounds with good constitutions, and of others, in pathological conditions perhaps, with bad constitutions. After an explosion of nitroglycerin, it would seem to be quite in keeping to hear that the compound unfortunately had ruined its constitution.

Since this difference of method has grown up within these two divisions of chemistry, it has come to pass that students, thrust suddenly into the field of organic chemistry, find themselves lost in a maze of symbols, formulæ and nomenclature. Since the elementary inorganic course at present has abandoned the use of graphic formulæ almost altogether, the student does not receive any discipline of that part of his mind which, for want of a better name, may be called his formulæ-comprehending faculty, and, in consequence, is at a loss to find himself in this unexpected confusion. No assistance is furnished him by the elementary texts of organic chemistry, because these volumes still take it for granted that the student has practised atomic gymnastics of the kind in favor some thirty years ago.

It seems to me that the teaching of elementary organic chemistry must soon undergo a radical change, perhaps a revolution. I believe this advance is developing at the present time. Let us return to the basis of experimental facts and observations, and let us state our theoretical conclusions with these fully in the foreground of our thoughts. There is no difficulty in presenting to the student a set of facts determined by experiment; and there is no impossibility in bringing him to see how these facts may be expressed, in part at least, by properly chosen symbols in terms of certain hypotheses and theories. The modern text-book of organic chemistry remains to be written; it will view the subject from this point of vantage.

In his memorable address before the German Chemical Society on the occasion of the celebration in his honor, held in 1890, Kekulé gave the well-known account of the origin of the theory of the benzene ring, and at the close of this account said, "Let us learn to dream, and then perhaps we shall find the truth . . . but let us beware of publishing our dreams before they have been put to the proof of the waking understanding."

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How can the Bureau of Education help the City Superintendent of Schools?

Among the questions which the Country Life Commission asked in its hearings in the several parts of the United States which it visited was: "In what way can government help in the work of public education?" The question generally evoked two types of answer. The one,