COLLEGE CHEMISTRY FOR THE GENERAL STUDENT.[1]

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The material for the paper which I am about to read was suggested to me incidentally during a study which I have been making in recent years concerning the mutual dependence and natural boundaries of the several physical and biological sciences.

This material is of two sorts: First, more or less desultory conversations with, and communications from, teachers of physics in universities and colleges concerning the kind and amount of chemistry needed by a college student of physics; and, second, from the examination, made for another purpose, of a large number of students' notebooks in college chemistry. Such back-stairs methods of investigation are open to all sorts of objections, and I would be the first to discredit them, except as furnishing suggestions for further study. Most of this material was collected at the east during my summer vacation; little came from my own state; though I have no reason to think that conditions east and west are very different. Partly owing to the desultory character of this material, and partly in the interest of brevity, I will not attempt to discuss this material in full, but will allow myself the always hazardous liberty of giving some impressions derived from it.

It has, then, been borne in upon me that the enormous expansion of chemical instruction in these latter days has, to the general student, brought some evils—especially a desultory habit of mind and some tolerance of shallowness and inaccuracy. In a word, this general student has endeavored to cover too much ground, and this ground almost entirely outside the boundaries of the old chemistry—*the chemistry of reactions*—where his main interest lies. He entered classes in chemistry to get that which is most distinctive of chemical science rather than in the outlying fields and along the rapidly extending boundaries of this great subject. Sooner or later he will take courses in physiology, physics, bacteriology, etc., where he will get at once more extended and more consecutive work than he can hope to get in a year's course, mainly devoted to applied chemistry. He needs chemical experience, and some exact knowledge of chemical fact and chemical law, and failing in this it is of little account that he has spent much time and found great interest in winding

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dynamos, testing galvanometers, determining physical and optical densities, making "the bacterial count," and working with calorimeters, radiometers, osmometers, and that sort of thing. Richards in his address before the chemical section of the A. A. A. S., in 1898, complained that important fields of study had been neglected by both physicists and chemists because they happened to lie on the borderland between physics and chemistry. And what is true of research is also true of instruction. These important subjects are not well taught although the chemist, the physicist, the bacteriologist, the physiologist and the astronomer all have a hit at them. But my point now is that the attempt to do a little work with them has resulted in a loss of that which is most vital in chemistry.

But is there such a character in our colleges and universities as a general, or non-technical, student? Most assuredly there is. I have no complete statistics, but what I have been able to learn about certain classes in certain colleges has given me a strong impression that more than one-half the students of chemistry in our colleges, and nearly one-half in our universities do not intend to follow any chemical industry for a livelihood. They take chemistry as a part of a general education. Nor does it seem to me that they are ill-advised in doing so. Where, indeed, can the non-technical student—the intending business man, artist, or professional man—come into sympathetic contact with the scientific methods and aspirations of the time and feel the pulse-beat of modern life more truly than in the chemical laboratory and lecture room? There is a chemistry—an entirely noble chemistry, I hasten to say—of dollars and cents. The chemical laboratory has always kept open a well-worn path to the patent office and the employment bureau. But there is also a chemistry of culture—a chemistry which is an essential part of civilization. Nor are these aims—the technical and the culture aim—necessarily so far apart as is often represented. Very clearly differentiated in the abstract, they yet often blend and interpenetrate in the individual man. But where these two aims conflict the technical aim should undoubtedly rule—especially in the university. If any one is to suffer from badly arranged courses of study it is the general student. But need he suffer? Are not the very conditions which at present render this splendid discipline of so little use to the general student equally unfortunate for the technical student? My point is this: The general student will have but two years in chemistry—possibly only one—following a high school course. Does not the student of applied chemistry need quite as much time as this upon systematic chemistry as a preparation for his special work? At present it is customary to hasten the work in the principles; give a brief course in qualitative analysis; add some work in titration and quantitative analysis and press forward to the special fields of applied chemistry. Often these special fields—physical, industrial, physiological, etc., chemistry (there are some ten or more divisions of applied chemistry) are brought in from the beginning and systematic chemistry made an incident to this instruction. In the hands of a master and for the special student this may be a safe procedure, and surely it leads quickly to the very heart of some special field of work. And yet for most students such rapid work breeds narrowness and confusion.

I am not pleading for a rectification of the boundaries of chemistry. A classification of the sciences on the basis of some abstract principle and a thorough delimitation of the field of each is always an interesting exercise in logic but can have but little interest for the practical chemist. For him chemistry is the chemistry of the journals—the chemistry of the laboratory and of literature. It is a commonplace of pedagogy that each of the historical subjects of study may be so defined and taught as to embrace all the others. The rather futile studies of a few years ago concerning concentration around some organizing center worked upon this basis. And for the technical student who sees a long road ahead of him in his special subject it is perhaps reasonable that he should get his English, his mathematics, his biology, his physics, etc., incidentally along with and as a part of his chemistry. This indeed is the tendency of the time. A university lecturer not long ago opened his second year's course with the words: "Gentlemen, our science is having a tremendous expansion in these latter days. Physics, Geology, Physiology, Biology and Engineering are only subdivisions of the broader science of Chemistry." The lecture notes of the students, referred to in the early part of this paper, all bore witness to this tendency. One set of books contained the expression, evidently quoted, under the head, Industrial Chemistry: "All industry is chemical industry," followed by notes of lectures upon the gas engine, the Diesel engine, dynamometers, speed and reversing gears, aeroplanes, and drilling and hoisting machinery. Another set of notes included lectures upon The Smoke Problem, Ventilation; The Automobile Traffic; Cement; City Parks, etc. Latterly in some institutions chemistry has taken over the entire department of The Household Arts. And this notwithstanding the fact that "The Servant in the House" is a physicist every day and all day long; and that she is never anything else. It is true that her physical activities bring into play many chemical and bacteriological reactions, and it is also true that many of these physical activities have little significance, while some of the bacteriological and chemical reactions are of mighty significance and deserve large attention. But to sweep all this material into one heap and to label it chemistry—to regard work with pumps, sewing machines, vacuum cleaners, washing machines, gas and electric meters and motors, and the myriad contrivances of the kitchen, laundry and sewing room as chemical operations, is to put a premium on intellectual confusion. The case is different with the technical or research chemist. He follows his prey wherever it leads him. The question of boundaries has no meaning for him. But for the general student who comes into the class to get the special mental reaction of this subject it is unwise to go so far afield.

My purpose is not reactionary. Instruction in chemistry has greatly improved in the past few years. I do not count my own work in the forties and fifties of the last century, though it extended through more than six years and was taken under some of the masters of that day—still honorable names—Youmans, Clark, Joy, Chandler—and in two of the best secondary and collegiate laboratories of the time, as worth more than four or five years of the chemistry of present day. Improved methods of analysis have been introduced; the course has been condensed and rendered far more interesting and practical by the introduction of examples from daily life; the ionic theory has been introduced to explain reactions, indeed the entire science has been rejuvenated. My complaint is that the science has lost the old unity and continuity, has gone far outside its old boundaries and become a sort of circle of the sciences, or a kind of advanced nature study.

Now what can be done? With much hesitation I suggest:

1. Follow a good manual—and we have many excellent ones—not slavishly but with reasonable rigor. I find, indeed, some manual in the hands of practically all students of chemistry, but it is not followed except in the most desultory way, the last half being often slurred over.

2. Insist more fully upon some sort of sequence of the

sciences. Systematists incline to place chemistry after physics. Personally, I make no point of this order but hold some consensus of opinion and practice desirable, together with a reasonable conformity to the prescribed order. At present, both in school and college, freshmen, sophomores, juniors, and seniors will be found side by side in the chemistry classes.

3. A considerable amount of physical chemistry, industrial chemistry, etc., is chemistry in the strict sense and may well be incorporated in the general course and taught in a consecutive instead of a desultory way.

4. The chemistry of particular substances, especially those of common occurrence and large use, deserves more attention than is usually given it. The general student has a right to some familiarity, both in lecture room and laboratory, with substances which he sees all about him and finds mentioned constantly in the public press. This is often decried. What the general student needs, it is often said, is a knowledge of principles. True; but he needs to come to chemical principle in the only real way through chemical fact. The man who knows little chemistry in particular is not likely to know much chemistry in general.

5. As a particular case of the above, it seems to me that the chemistry of the so-called rare metals deserves more attention than is usually given to this part of the work.

6. Most important of all, we need some commission to partition among the several sciences those outlying subjects that are now treated so hastily and in such an elementary manner by each science in turn.

To illustrate, the thorough treatment of the balance—its theory, care and use—at present very ill done, might be assigned to the chemist. The so-called gas laws, very ill taught at present, might also be given to chemistry. Physical density and optical density and all fundamental work with refractometers, hydrometers, etc., might be the special work of the physicist. The same might be done with the measurement of heat and all work with calorimeters for solids, liquids and gases, at present very ill done. Work with colloids and the general subject of osmosis might be given over to the biologist, and so on through these outlying subjects. This would do away with a double or triple equipment of very expensive apparatus in the same institution, would allow the purchase of better apparatus, and would provide for a more leisurely and fundamental treatment of many important topics.

Chemistry is in herself a science of radiant beauty and power, and least of all sciences needs the adornment of shreds and patches from other fields. We think of her always as resplendent and triumphant in her own right. There is in the British museum a Greek coin, of the best age of die-sinking, representing Alexander about to enter upon the conquest of the east. His head is raised, his hair is blowing back, and his eye is lifted as if it held the east in fee. This is our image of chemistry. We may well hope that our science will not also be like Alexander, bent upon foreign conquest while the homeland—poor little Macedonia—be left neglected and forgotten.

EXPERIMENTAL CHEMISTRY SIMPLIFIED.

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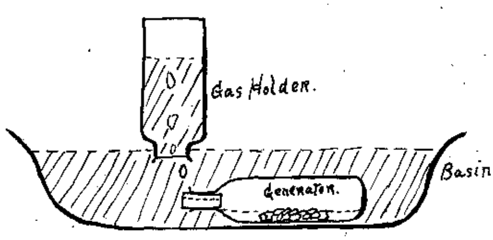
The following suggestions in experimental chemistry were selected for the purpose of aiding students who have no access to a chemical laboratory. However, present abnormal market conditions may render them of interest to the laboratory instructor



who finds his supply of glass-ware in a state of depletion. In fact, the writer has substituted these procedures for the conventional methods in his secondary school work with the result that there has been a lessened tendency toward obscuring the true object of the experiment. No expensive glass-ware or rubber tubing is needed. Although the experiments are of necessity very simple and qualitative in nature, much pleasure and intellectual stimulus may be derived from them.

Hydrogen: Hydrogen may be prepared by replacing the hydrogen of an acid, dilute hydrochloric or sulphuric, with some metal such as zinc. The apparatus, which the writer believes is new, is illustrated in the figure. The gas generator consists of a three or four ounce medicine bottle. A groove is cut in the side of the cork running the entire length, so as to allow means