SOME SUGGESTIONS FOR THE IMPROVEMENT OF INSTRUCTION IN TECHNICAL CHEMISTRY.*

IN attempting to discuss so broad a subject as the methods of teaching technical chemistry employed in this country, one is met at the outset by numerous difficulties of interpretation. No two of the thirty-odd institutions claiming to prepare students for the practice of technical chemistry seem to agree on the topics necessary for study, the order in which these should be taken up, the extent to which any one should be cultivated, or the actual subject-matter of courses given under the same name; to say nothing of the non-chemical subjects in the curriculum, such as mathematics, literature, analytic mechanics and other 'strains and stresses.' In some colleges, chemical engineering seems to mean a mixture of less chemistry and less engineering than is required of either chemists or engineers; whereas in others 'analytical chemists' are turned out after one or two years' experience on 'unknowns and complex ores.' It is plain therefore that in order to arrive at any comprehensive view of actual and of desirable conditions, it will be necessary to define, in a manner somewhat more precise than is usually customary, the fundamental aims of technical education with reference to chemistry.

THE UNITY OF CHEMICAL PRACTICE.

Stated in its baldest terms, the aim of such technical education must necessarily be adequate preparation for professional practice. To be sure, this definition merely restates the problem itself; we must immediately ask, what do we mean by adequate preparation, and what by professional practice? Let us consider the latter question first. At first sight, the professional practice of the chemist appears as an exceedingly complex affair, incapable of closer statement; a chemist may be a mineral analyst, a food analyst, a metallurgist, a manufacturer of heavy or of fine chemicals, a gas-chemist, an electro-chemist, a pharmaceutical chemist, a dyer, a manufacturer of coal-tar products, a fermentation chemist, to leave out further subdivisions, and last but not least, a teacher of chemistry, perhaps the most technical of all. It will be said that this is far too broad a picture of the chemist's activity, and that the whole of technical practice may be summed up under three distinct heads: Analysis, manufacture, instruction. Indeed, it may be safely said that this represents the opinion of the majority of American and English chemists. And yet, the analyst, the manufacturer, the teacher are merely chemists, thinking by the same mental processes, applying the same general laws, attacking very similar problems, differing only in the accidental circumstances of the materials they work with. The analyst sacrifices time and money to the cause of accuracy; the manufacturer gives up accuracy for the sake of time and money; the teacher wears himself out in the effort to be accurate without wasting either time or money.

The fundamental unity of chemical practice is not a new discovery. It was 'made in Germany' some forty years ago; and although not patented, the Germans enjoy an exclusive monopoly of its use. The analyst, the manufacturer and the teacher are continually exchanging their experiences through a sort of chemical clearing-house. Young docents frequently spend two or three years in a factory for the purpose of broadening their knowledge; a factory sends its problems to the university

* Read at the Denver meeting of the American Chemical Society, August, 1901. This paper was written before the publication of Dr. McMurtrie's recent address to the American Chemical Society. It is gratifying to note the substantial agreement of both articles as to the problem set before our teachers.

laboratory to be solved. An investigator in need of expensive substances, or of mechanical appliances to handle large bulks of materials, need only apply to the nearest factory to have its machinery placed at his disposal, or its wares furnished at little or no cost. The largest factories have their own research laboratories, in which a hundred and more university graduates and professors spend months and years on single investigations, and are paid liberal salaries even if their results are technically worthless. One factory recently purchased the entire scientific library of Kekulé. The manufacture of nearly all the numerous coal-tar products consists merely of laboratory methods on a large scale; and the scientific problems solved in this connection have been of the utmost importance and benefit to 'pure' science. Certain large establishments prefer their chemists to have had training in pure science only, and then give them from three to six months of technical training in their own works *and at their own expense.* The specifications of chemical patents constitute an important section of scientific literature, and the German Chemical Society spends large sums of money for the purpose of abstracting and indexing them. If we also take into consideration the unquestioned preeminence of Germany in all branches of chemical practice, what better demonstration can we give of the fundamental unity of the profession?

PRESENT STATUS OF INSTRUCTION.

We are now in a better position to return to the former question: What do we mean by 'adequate preparation'? For no matter what may ultimately be agreed upon, it will be identical in its first two or three years for all classes of students. It is a great comfort to have this important point definitely settled in advance; for one of the main difficulties in arranging our college curricula has been the supposed necessity of providing two or more coordinate sets of courses in chemical instruction. This has been a great strain on the teaching staff as well as upon the financial resources of the laboratory.

An examination of a number of college catalogues brings out the fact that at present all students actually do follow essentially the same course for about two years. These courses usually consist of one or two terms of general inorganic chemistry and simple laboratory work, one or two terms of qualitative, one or two terms of quantitative, analysis; all these combined so as to occupy from two to three years at the rate of eight to fifteen hours per week. It would seem, then, that here we have the present American conception of 'adequate preparation'; for the subsequent courses are almost invariably special short ones in various branches of work. We may well ask: Is this preparation really adequate? I think not; but before considering it in detail as the main business of this paper, a few words must be said concerning these special addenda, the 'finishing courses.'

Even in some of our best institutions these final courses come perilously near the standard of the 'polite deportment' and 'philosophy' of young ladies' seminaries. There is an unfortunate lack of caution in the claims published in their catalogues. Lack of space prevents citation of many of the choice extracts I have found; two or three will suffice, however, for purposes of illustration. One college offers a course of *forty-four* lectures on the following topics: 'metallurgy, glass, ceramics, chemicals, illuminating gas, bleaching, photography, petroleum, brewing, wines and liquors, vinegar, fats and oils, essential oils and rosins, sugar, starch, glucose, milk, distillation of wood, paper tanning, etc.' One suspects that these lectures must be illustrated with a kinetoscope. Another institution claims to prepare its students for 'metallurgy and mining, chemical manufactures, dyeing, bleaching, tanning, sugar-refining, etc., and for work as analytical chemists, assayers, or teachers of chemistry.' The claim is based upon *three lectures per week* for two years, and two laboratory courses of twelve hours per week each, *which may be taken in one year*. A third college offers a course of *three hours per week for one semester* in 'qualitative and quantitative examination of air, water, food disinfectants, baking powders, flour, bread, tea, coffee, cocoa, spices, milk, butter, lard, beer *and other subjects*.'

It may be objected to the above that college catalogues are notoriously optimistic. The fact would seem to be demonstrated; none the less, such exaggeration is of very questionable value, and should be discouraged for the benefit of the 'raw graduate,' if for no better reason. It would appear, moreover, that the majority of colleges consider training in analytical methods equivalent to complete technical training; nearly all of them give several courses in water analysis, analysis of fuels, iron and steel, etc. The importance of such analytical training is undoubtedly over-estimated; a student who must continually neglect the factors of time and cost in his work receives too one-sided a training. The same objection is to be raised to many of the so-called courses in 'technical work.' If they do not consider time and cost as the essential factors, they have no better claim to a 'technical' nature than the ordinary beginner's preparation of hydrogen or chlorine. But more of this later.

Let us now examine more closely the nature of that preliminary preparation which we have found to be so nearly uniform throughout the United States. In the way of lectures, there is always a course on inorganic chemistry, occasionally a short one on organic, infrequently a very brief treatment of 'general' or theoretical chemistry incorporated with the above or as a separate course. Modern theories and the details of organic chemistry are usually left for advanced and optional courses. The time spent on these lectures varies greatly; but perhaps a fair estimate is three hours per week for two years (of about thirty-five weeks each). In many, in fact in most, colleges this average is not maintained. The laboratory training includes one, very infrequently two, terms of general introductory work, ranging from three to six hours each week. On the whole, this course may be described as satisfactory. Then follows a course in qualitative analysis, averaging twelve hours per week for one or two terms. Recitations accompany it in many instances, mainly for drill in writing equations, it would seem. In a few of the better institutions, but only in very few, the subject is made to serve as a practical demonstration of the theory of solutions. Finally, from one to three terms are spent in quantitative analysis, also averaging perhaps twelve hours a week. The subject-matter of this last course also varies greatly with the college; at the best, there is included training on a few alloys, sulphide ores, silicates, and a number of volumetric methods on technical products. The feeling cannot be repressed that in this course results call for a disproportionate expenditure of time. It is with the training afforded by the above that the student proceeds to follow his natural bent, and to acquire the special technical skill needed for his professional activity.

OUTLINES OF THE PROPOSED IMPROVEMENTS.

The technical preparations of the teacher need not concern us further. Every college and university is practically a technical school for training teachers first of all, and for training technologists only secondarily. Not that the training of teachers of chemistry is incapable of great improvement; but on the whole it is so much more satisfactory, that the improvement of instruction in other technical branches is more imperative. Moreover, taking as our major premise the essential unity of chemical practice, be it that of analyst, manufacturer or teacher, it follows that the main deficiency in the present training of our teachers is exactly the lack of knowledge we are deploring, and endeavoring to remedy. Should it be possible therefore to generate within the college walls the mental atmosphere of the busy world where *things* must be mastered as well as ideas, we shall also have ministered to the wants of the budding preceptor.

Having thus wearied you by a circuitous return to our starting point, in order to eliminate possible objections based upon differences in the point of view, let us again take up the question. 'What do we mean by adequate preparation?' If, in the following discussion, the proposals I have to make shall appear a trifle too radical, I trust you will bear in mind that they spring from a conscious and deliberate idealism; and should the views here expressed really prove to have a basis of truth, any merely practical difficulties will yield as surely as the difficulties of manufacturing indigo yielded to the idealism of the German professor.

I take it then that an adequate preparation for the technical chemist has been secured when (1) a sufficiently broad general foundation of inorganic, organic and physical chemistry has been laid in the class room and in the laboratory; (2) when the 'chemical instinct,' *i. e.*, the ability to think in chemical terms, has been developed; (3) when sufficient analytical skill has been attained to ensure accuracy in following new methods; (4) when enough preparative skill has been acquired to make any compound with maximum purity in maximum yield, at the lowest possible expense under given conditions; (5) when speaking acquaintance with current chemical thought, both pure and applied, has been reached; and (6) when time has been found to accomplish all this.

THE BROAD FOUNDATION OF CHEMICAL KNOWLEDGE.

First, then, as to the general foundation of inorganic, organic and physical chemistry, in the lecture room and laboratory. I think there can be no serious objection to the statement that the present equipment of our students in this line is too meager. The plan seems to be to give very elementary courses in all three subjects, and then to assume that this information will multiply by cell division in the laboratory atmosphere. Another very prevalent view among teachers is that if you only give the student fundamental ideas, the facts will take care of themselves. My own experience is that for the amount of time spent in study, the outfit of actual information about chemical substances is unreasonably small. The unfortunate policy of feeding students only on peptonized and malted facts may avoid mental indigestion in college, but it predisposes them to colic afterwards. Certain very prominent text-books have had a bad influence in this direction, by seeking to eliminate all possible difficulties of comprehension and any reference to partially solved problems. It is not uncommon for students to ask if they 'have to remember the names of those substances' in their lessons, after a few weeks with those books; indeed, the question is not unreasonable, if we consider that the names constitute the sole remaining difficulty. Again, both text-books and teachers seem afraid that the students will know too much, and prune out all except matter of the first importance. To be sure, excess of detail must also be avoided if clearness of presentation is sought; but is not the present tendency somewhat too violent a reaction from the methods of our forefathers? One very prominent teacher told me some years ago that each year he takes up less material in his lecture courses; what will become of them in ten years more? It is the function of the teacher to guide his students *through* the maze of facts as through a crowded city, that later they may find their own way about; not to whisk them around in a closed trolley-car, on the globe-trotter principle.

One difficulty lies in the use of text-books which are really only elaborated outlines of a lecture course. The result of using such books is that the student's horizon is bounded by the cover-boards. A lecture must be straightforward and consistent, if it is to have any value at all; but the printed page can be read over and over again, and its details mastered gradually. The text-book alone can provide the large number of facts that must be assimilated; the lecturer's syllabus is properly a key to the text-book, and no more. The teacher thus has a perfect right to demand of his students a greater knowledge of detail than he himself presents in his lectures. Another obstacle to the absorption of the proper number of facts lies in the almost universal attempt to treat a subject once and for all. This does not seem rational; nor do the student's mental limitations make it feasible. To take up the metaphor of the crowded city, the first efforts of a good guide result in a general survey, pointing out the topography, main thoroughfares and most important activities. Then come historical landmarks, and those sights which distinguish this city from all others; finally a detailed study of each quarter, of special industries and of prominent people. We can follow no better plan in teaching a new science, giving a broad survey first, then repeat, filling in many new details, finally going over it a third and fourth time, if necessary. In this way the student's memory will be aided rather than over-tasked; the relationship of parts to the whole, one of the most difficult of problems to him, will certainly be clearer; and the relative importance of various topics will stand out prominently. Then we shall avoid the necessity of turning out 'chemists' whose sole acquaintance with chemistry as distinguished from analysis was formed in the freshman year, and discontinued immediately thereafter. Chemical facts ought to be systematically studied each year of the college course.

But little need be said in addition to the above concerning the laboratory work to be correlated with this plan. I should merely wish to emphasize that substances should be studied from the preparative, analytical and physico-chemical sides simultaneously; the artificial division of the science for purposes of classification should influence the course of instruction little, if at all, during the first two years.

THE CHEMICAL INSTINCT.

Chemistry is a science which reasons about facts through a medium of abstractions. We observe colors, smells and precipitates, and we talk about atoms, molecules and space configurations. The thinking chemist must continually bridge the gulf that lies between fact and fancy; if he can do this freely, and avoid metaphysics, he possesses the chemical instinct. To develop this instinct in the student is the most important, and most difficult, problem of the teacher. Aside from intuitive, inherent teaching power, I know of but one plan for fostering this instinct: every topic should be presented in the form of a problem. Chemistry has advanced to its present proportions because of the problems presented to it; all research work is a series of correlated problems; the installation of every manufacturing plant, of every new process, the regular operation of every established factory, is a series of problems; every analysis for whatsoever purpose is a problem; teaching is one vast problem. The main preliminary to the solution of any problem is a clear and complete realization of its nature. What is aimed at, what are the difficulties, what means are available? These questions should be as definitely in the mind of the student at every point of his college work as they must necessarily be in his later professional activity.

ANALYTICAL SKILL.

Perhaps no portion of chemical instruction is better given than training in analytical work. Methods have been worked out with such precision, and mechanical aids are so perfect, that given time, patience and care, anybody may become a fairly skilled analyst. Moreover, teachers seem agreed that introductory work both in qualitative and in quantitative analysis should precede all special analytical courses. Perhaps it may seem superfluous to offer any suggestions for the improvement of this portion of chemical training; I shall discuss this later. At this point I wish to speak of these special courses. It has already been shown that they constitute the crux of the 'technical' training of this country. It seems to me that they tend to destroy the unity of analytical practice by inducing the student to specialize far too narrowly and far too soon. Students often spend the whole of their third and fourth years at college on these courses alone, and thus deliberately sacrifice the sole opportunity of their lives to acquire a broad and thorough training for all future emergencies. I have known students at one of the largest universities of the land to avoid all courses on theoretical and organic chemistry, on the ground that they would have no use for them at a blast-furnace—that college sending most of its graduates into the iron industry. Surely no college should thus encourage its students to neglect their opportunities. A little of the wise and far-sighted cooperation practiced by German employers would furnish immediate relief from this state of affairs. Experience has shown that the employer does not suffer by choosing broadly-trained chemists in place of stall-fed analysts.

Besides, most of the 'technical methods of analysis' taught in our colleges have a way of getting antiquated. Each year witnesses some new committee of technical societies for the purpose of improving analytical methods. By the time these methods get into the text-books (copper plates being valuable), another committee is under way. If such analytical instruction is reserved until the last term at college, and then based upon the reports of these committees, the student will be more likely to acquire really useful knowledge, and have more time for broader study.

PREPARATIVE SKILL.

Until quite recently the only training in the preparation of chemical substances was afforded by organic chemistry; latterly, a number of colleges have introduced courses in inorganic preparations as well. These courses constitute excellent discipline, as far as they go; they do not go far enough. The actual preparation of chemical substances may serve three purposes. It may be intended to place the substance in the student's hands for study; if no more is sought, it is often cheaper and always quicker to furnish it out of laboratory stock. It may be intended to illustrate the reaction. In combination with the first purpose this end is eminently desirable for beginners; for advanced students it wastes too much time in proportion to the result—such illustrations would be met as well by the use of chalk and blackboard. And finally, it may be intended as a study of chemical technology. As such it must inevitably take cognizance of the aims of technology, which are to prepare a substance in given grade of purity from the *available* 'Ausgangsmaterialien' at the smallest cost of time and money. It involves a sufficiently complete knowledge of the materials employed, strictest economy of time, labor and reagents, the demonstration of the required purity, and a calculation of cost and value. If a substance be prepared along these lines, to the amount of one gram or of one ton, it constitutes an exact duplicate of technical methods. The factory may employ cast-iron vats in place of flasks, and filter presses in place of funnels; it is not the more 'technical' by virtue of its appliances.

It will be objected that no university can make soda-ash or sulphuric acid on technical lines. To be sure; but it need not attempt to. The first condition of success in any undertaking is a clear understanding of one's limitations. The college cannot do much more than teach the factory spirit; if it does that much well, enough will be accomplished at present. Moreover, chemical industry is not limited to the production of heavy chemicals at the rate of fifty tons a day. Innumerable substances are manufactured in relatively small quantities, and by methods which do not differ widely from standard laboratory manipulations. These are wholly within the power of the college. I would propose that each college inaugurate as a part of its curriculum, required of all its graduates in chemistry, a full year's course in the actual economical preparation of laboratory supplies. It can manufacture most of its own C. P. reagents, ammonia and its salts, the products of the rarer minerals, ether much more cheaply than it can be bought or imported under existing revenue laws, and practically all its organic preparations, from a few technical products. Even if it should cost a little more to make these substances than to buy them, the gain in actual experience to instructor as well as to students is worth the extra cost. The equipment for this work need not be expensive. For the C. P. reagents, for example, the same outfit of large evaporators ana crystallizing dishes, solution tanks and filter-presses can be used. The need of great care in cleaning these out for use on different materials would be an excellent feature of the work, to be controlled by analysis. By systematic planning, the laboratory could manufacture from thirty to sixty substances a year, in quantities to last five years; at the end of that period it would have supplied all its wants and could begin the cycle over again. In one year of such work the student would gather more experience than a factory would yield in ten; for no factory can undertake to slow down its procedure for the benefit of a novice.

In connection with this laboratory instruction, the usual lectures on chemical technology will certainly be more fruitful of results. Such lectures should not be omitted, nor anything else likely to broaden the student's acquaintance with facts. Indeed, these lectures are able to supply information not obtainable in the factory, viz., the *comparison* of factory methods, and the deeper principles that underlie all technical work and are taken for granted—the business world drives them home with a club. Finally, it need hardly be said that *frequent* visits to every establishment within reach should be a constant feature of technological training. In my own college course the 'frequent visits' materialized just *once,* when three large factories were visited in the course of two hours—another illustration of the optimism of college catalogues.

ACQUAINTANCE WITH CURRENT CHEMICAL THOUGHT.

The necessity of familiarizing students with new facts at first hand is self-evident, and realized by all conscientious teachers. The main difficulty would appear to be the accomplishment of the task. I know of only one method—to weary not of well-doing, and to keep everlastingly at it. Frequent meetings of students and instructors on an informal basis, be it a seminar or a 'chemical society,' where new facts are discussed without reference to their classification, comprehensive lectures on recent progress, essays by the students themselves, the current numbers of journals laid out in a cozy reading room *in the laboratory* (the librarian must be overcome by fair means or foul)—all of these methods persisted in for two or three years will solve many a 'complex unknown' cerebral obstruction. *Ad astra per aspera.*

WHERE TO FIND THE TIME.

The ambitious program I have outlined now calls for the consideration of a purely practical problem: How can we find the time to accomplish all this? Even as our courses stand, there is barely time within the four years at college to complete the minimum of chemical work; where is there room for all the extra lectures and laboratory exercises that a really thorough technical preparation would seem to call for? I am afraid that my suggestions will contain many heresies.

For one thing, our college authorities must be made to realize that the main essential of training in technical chemistry is a knowledge of chemistry. This somewhat axiomatic doctrine is by no means universally accepted. Thus, the chemical engineers in two prominent institutions (Columbia and Pennsylvania) take considerably less chemistry than other students in chemical branches. Now while other topics are certainly necessary and valuable assets for chemical engineers, there must be a limit somewhere. The main problems before even the chemical engineer are chemical; those of the teacher and analyst almost wholly so. I will not presume to outline just how much or how little of these extraneous courses should be incorporated in the curriculum for technical chemists; but I should like to venture upon the principles which may fitly guide those more directly concerned with the task. I should say, then, that the question should be considered upon its own merits; no inherited prejudices, no educational theories, should stand in the way of the prime fact that in studying chemistry a knowledge of chemistry comes first. The problem of general education and culture must not be allowed to interfere in any way; where cultural education is also sought, the time needed for it must be debited to its own account, and not written off the technical calendar. The two problems are absolutely distinct, and have no business with each other. This must be insisted upon, since college faculties are only too prone to ignore it altogether. Better for a college not to give any technical courses at all, than to play at make-believe and ruin the careers of its graduates. If four years at college are not enough for both general and technical education, take six, eight or ten—but take enough to do the work thoroughly. I would say also that the non-chemical subjects should be reduced to the lowest possible figures, and chemistry be given the benefit of every doubt. Wherever feasible, these subjects should be a part of the general education, and thus serve both ends; such would be, *e. g.*, German and French, physics, first-year chemistry, mathematics, etc. The cardinal rule should always be kept in mind, that it is better to know one thing well than to have a smattering of many and command of none. We must not expect to see in each of our students a Helmholtz or a Ludwig Mond; if any of them are destined for such versatility, they will have little need of our poor instruction.

One solution of the time problem, then, is to insist that enough time must be granted, and all extraneous matter reduced to a minimum. By the same token, however, it behooves us as conscientious chemists to do our best to shorten the time required for our own subject—for the benefit of the student, it might be observed, not for the benefit of the college faculty. By the aid of one further heresy, I feel able to indicate where an important saving of valuable time may be accomplished. I would abolish from the curriculum the study of qualitative analysis, the arch-type of anachronisms. We owe a tender feeling to the kindly nurse who brought us up carefully, and taught us the dark ways and vain tricks of the phosphates; but our nurse is old and decrepit, and no longer able to guide the toddling steps of the beginner. It will not be difficult to prove this. The study of qualitative analysis is intended to give knowledge of a useful art, and specific exercise in chemical thinking. It achieves neither purpose.

SYSTEMATIC QUALITATIVE ANALYSIS AS A USELESS ART.

The problem of systematic qualitative analysis as taught in our schools is to recognize all the ingredients of a given mixture. As a matter of fact, however, how much of this art have we achieved? We are able to recognize a limited number of inorganic acids and bases under special circumstances; and the instructor must exercise great self-restraint not to make his unknowns 'too hard.' As for the rarer acids and earths, to say nothing of the vast bulk of organic compounds, as well as for the commoner acids and bases in the presence of these latter substances, we must admit our inability to follow any comprehensive 'scheme' of analysis. The analysis of such mixtures resolves itself into a series of special tests, and our only check upon the correctness of the analysis comes through the quantitative necessity of finding one hundred per cent. of the ingredients. This limitation is clearly recognized by the professional analyst. Thus the chemists of the U. S. Geological Survey never carry out qualitative analyses of the rocks they investigate; they assume that all of some twenty or thirty ions are or may be present, and check the absence of any one during the progress of the quantitative analysis. Nor do they undertake to analyze one single sample for all of these thirty ingredients; two or more possible ones constitute a group that is examined by itself, without reference to the other contents. Again, the analyst is seldom, if ever, called upon to make a complete analysis of an absolutely unknown brew; on the contrary, he is usually asked to estimate some two or three ingredients, whose presence is either known or whose absence is to be demonstrated. The assayer never makes other than a quantitative analysis of gold and silver ores. For the food analyst, all is grist that comes to his mill—moisture, fats, carbohydrates, proteids and ash.

Where then is our boasted art of qualitative analysis? And where the need of dragging every chemist through the wearisome unknowns, so fearfully and wonderfully made, the like of which man never saw before nor will again? Why spend from two hundred to four hundred valuable hours to teach an art which does not exist? At the same time, it will be objected, the numerous qualitative tests referred to must be learned, and as well this way as any other. Not so; the important qualitative reactions of all the important substances should be studied in the first instance, when the substances themselves are studied—not be kept on ice for a 'systematic' course. In the laboratory instruction in elementary chemistry time can be found for the methods of recognizing the acids and the metals the student works with, while he is working with them. We must counteract our mania for subdivisions and classifications, and teach chemistry as a unit. To be sure, the regular 'scheme' for the metals and acids is a useful thing *occasionally,* and students ought to be familiar with it; but it can be taught in one week to any student having a fair supply of analytical reactions among his mental baggage. I would teach these reactions by the side of a course in chemical preparations, rather than in a course by themselves.

QUALITATIVE ANALYSIS AS AN INFERIOR DISCIPLINE.

The intrinsic value of qualitative analysis is thus seen to be small. Its pedagogic merit is not much greater. As a matter of fact, teachers know only too well that it requires herculean exertions on their part to prevent students from rushing through the course mechanically. The majority of text-books are the merest skeletons of outlines, omitting a vast bulk of details 'because they interfere with a clear grasp of the subject.' One is strongly reminded of the way Latin is—or used to be—taught: the object being to reproduce its literature and culture, the literature and culture are left out to have more time for the syntax. So with qualitative analysis: the object being to train analysts, the analytical facts are left out to have more time for the system. Nor are we alone in our troubles; permit me to quote from the recent vice-presidential address of Professor W. H. Perkin to the British Association:*

"It has always seemed to me that the long course in qualitative analysis which is usually considered necessary, and which generally precedes the quantitative work, is not the most satisfactory training for a student. There can be no doubt that to many students qualitative analysis is little more than a mechanical exercise; the tables of separation are learnt by heart, and every substance is treated in precisely the same manner; such a course is surely not calculated to develop any original faculty which the student may possess. * * * I question whether any really competent teacher will be found to recommend this system as one of educational value or calculated to bring out and train the faculty of original thought in students."

With this quotation I am content to rest my case.

WHAT SHALL WE SUBSTITUTE FOR IT?

One important question remains. The art of testing unknown substances must always be an integral portion of the chemist's outfit; if the present course, designed for that very end, fails to teach it, what alternative have we to offer? The plan I venture to suggest may be found worth a trial.

I propose, first of all, to annul the divorce of chemical analysis and chemical preparation. Many colleges now introduce quantitative experiments into their *beginner's* course, such as (I quote in part from a circular issued by a conference of teachers at Chicago in 1896): definite proportions by volumetric methods, multiple proportions from the oxygen evolved from potassium chlorate and perchlorate, equivalent weight of zinc, weight of a liter of air, water of crystallization in copper sulphate (both stages), neutralization of normal acids and bases, etc. If along with these quantitative experiments the student is also taught the descriptive features and

* *British Association Reports,* 1900. Cf. SCIENCE, Vol. XII., p. 641, 1900.

qualitative tests of the substances studied, as well as the fundamental facts of physical chemistry (also recommended and elaborated by the Chicago conference), I should say that there we had a course eminently satisfactory. If time permits, a year might be spent with great profit on this work. Then should come a course of the same general order, but more difficult. Starting with a metal, a mineral or some technical product, the student should prepare a series of salts or other compounds of some ten or more metals. He should study the problem of obtaining the desired compounds; submit his plans to the instructor for criticism; prepare his substances, and analyze them qualitatively and quantitatively. The analyses should not be complete, but merely for effective purity and undesirable impurity; for *economy of labor should be taught,* and no work done that is not of direct value under the given circumstances. By a proper selection of material, the teacher will be able to present to his pupils, during two or three terms, all of the important qualitative and quantitative methods of separation. Nor is it necessary for each student to do exactly the same work; indeed, I should call it undesirable. Students would then learn from each other as well as from the teacher, and a laboratory 'atmosphere' would then be created where students may learn by a process of cutaneous absorption —as they seem to do in Germany. The work, moreover, should be reported regularly in the accompanying seminar; current and older periodical literature should be searched for additional information bearing on each student's topics; innumerable little opportunities for research will present themselves, and the most ought to be made of them; a well-planned course of lectures should parallel the laboratory work and expand its horizon, for the whole field of chemistry cannot be reviewed in the laboratory; and then, I venture to believe, the instructor will have a class of interested, if not enthusiastic, students. Special schemes of separation, the 'systematic' analysis now so widely current, the examination of milk and honey, can then be taught as the special things they are, and made to take their proper places in the economy of chemistry.

CONCLUSION.

In conclusion, allow me to summarize the propositions I have tried to maintain:

1. The practicing chemist, be he teacher, analyst or manufacturer, is of one kin.

2. For that reason, the training for these professions ought to be identical for *several* years, at least.

3. At present this training is inadequate.

4. There is needed a much broader foundation in pure chemistry.

5. The 'chemical instinct' needs cultivation.

6. Analytical training should be general rather than special.

7. The college should establish *bona-fide* courses in preparations, on a working scale.

8. Acquaintance with current thought must be fostered.

9. Time must be made for this program by cutting off all but the most important non-chemical topics.

10. Time can also be saved by eliminating qualitative analysis, because it is useless as an art and inefficient as a discipline.

11. The place of qualitative analysis should be taken by properly organized laboratory courses.

Perhaps it will be best to leave the twelfth and last conclusion to the charity of my hearers.

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