THE FIRST COURSE IN CHEMISTRY.¹

M. D. SOHON, PH.D.,
Morris High School, N. Y.

In school work, the teaching of any branch is not an end in itself, but one of the means employed in an extended system of education. We do not drill our pupils in drawing, music or Latin with any idea of cultivating artists or linguists, but because these subjects serve certain purposes in the general educational scheme. As applied to our subject, especially in the introductory course, the object of the work should not be to teach chemistry so much as to teach boys and girls such facts and principles concerning chemical phenomena, as, with the time and material at our disposal, will best meet their needs. Any technical or mercenary advantage which might be derived from the study of chemistry has but little consideration in the educational scheme, but our present social development depends so largely on applied science, no one can understand it unless he knows something of the general principles of chemistry and physics.

It is customary to discuss the educational process from three points of view: the ethical, the disciplinary and the informational. Yet, when we come to consider them practically, we find that we must take them in the reverse order; acquire knowledge concerning the world, be able to use our common sense and bring our knowledge to bear in working out the tasks in hand, to place a proper value on what we know or experience and to apply such conscientiously and honestly in life.

How far chemistry will or can contribute to this will depend on the teacher, the pupil and the content of the course. So that the question arises: when, how and what chemistry should be taught in our secondary schools?

Inquiry among chemistry teachers shows practical unanimity; everybody ought to study chemistry. This would necessitate chemistry being placed early in the course. On the other hand, most teachers want it after the pupil has studied physics, when the pupil is more mature; this would bring it at the end of the course and confine it to the few. There must be something about chemistry of fundamental importance if everybody *ought* to study it, and there must be something abstruse and difficult if it *can* be taught only to the elect.

¹Read at the Boston, 1909, meeting of the American Chemical Society.

The superabundance of chemical phenomena and products daily thrust upon our attention, testifies to its importance and a study of matter might easily compete with nature study of the lower grades. The difficulties of the subject are largely artificial, due to the acceptance of traditional methods of presentation especially of illustrative material. Why, in so many books is the law of multiple proportions introduced in connection with the oxids of nitrogen? Why is the law itself so expatiated on? If the atomic hypothesis is accepted, this law is a necessary conclusion and of no more importance than many others that receive scant attention. It has played an important part in the history of chemistry, but the historic order is not necessarily the best and we are not fair to the pupil if we refuse to use modern facilities merely to preserve historic form. Many of the beacons set up years ago are now outside the main channel; it is possible we may map out a new course and so plainly mark it that school children may follow it.

Our course on the disciplinary side must tend to develop an appreciation and an interest in current developments, compel telling the truth, lend ability to handle such problems as naturally arise, to weigh evidence impartially and intelligently interpret it in good English; this last is not least important. To accomplish this we must have a strong foundation of facts and a good teacher. We must build our own foundation. For one fact we may prove we must accept hundreds beyond our skill or means. We must learn what others have done, learned or thought. The first lesson of the child in school is to obey, to respect authority. It is impressed upon us in life we cannot act or think independently. The vast majority of our pupils will not be leaders in life, they will not be called upon to plan, but to carry out the plans of others. To succeed in life they must know the leaders and yield obedience to constituted authority, whether it be in the political or scientific world. It is this which is most liable to be slighted in our so-called inductive courses. A course that claims to be disciplinary and fails to impress this is worse than useless. It is injurious in that it develops a type of skeptical egoists whose cry is, "Show me." They contribute nothing to the social good and decry honest effort.

While the study of systematic method and the development of systematic habits and personal honesty are most desirable their usual concomitants, technical measurement and manipulation are of very minor importance and are of value only so far as they

contribute to the creation and fixing of honest habits. The so-called scientific spirit as displayed in our greatest scientists was not instilled by formal instruction but developed by habits of neatness, orderliness, attention to details, and especially by concise, honest, and accurate expression of ideas in language. Scientific method is based on the experience of the race, but it is not the way the individual works; life is too short to learn much at first hand so we must accept the experiences of others. The successful man, the genius, is the one who combines and brings to a practical result the work of his predecessors.

If we examine the content of our science, it is appalling, fact after fact come forward claiming attention. It is evident that at best we can but scratch the surface in the year of perhaps 150 hours allotted to chemistry. Where shall we begin? What shall we leave out? Roughly, we may divide the work in two parts; the descriptive side which deals with facts, sequences, and values as perceived by our senses; and the theoretical side which deals with the translation of these into the terms of those mental forms we have constructed. If we leave out the descriptive part we have no basis for the theoretical except from a mathematical standpoint. If we leave out the theory, apparently we make the work disjointed, empirical and not scientific.

Although we always teach with a view to culture, our ideas of the relative value of the content have been subject to change and it is coming to be more generally accepted that culture is best obtained through the study of such things as bear most directly and naturally on the pupil. Such material we find on the descriptive side of the subject. Theory is not fundamental in the progress of science, it comes and goes as the science develops. It is the polish which fills out and hides the gaps in the line of facts. It is attractive to our cultivated tastes. We like it because we made it. We saw it grow. To the beginner this is not so. Deprived of its personal application to the pupil, chemistry deals with mathematics and abstractions. To comprehend many of the most simple conceptions of chemistry, requires a more vivid imagination than is called for by any other branch of science. It is utterly beyond the average high school pupil and indeed of many college men. Our familiarity with the subject hides from us its difficulties to the pupil. John Dalton would not accept literal symbols instead of his own ideograms. As late as 1837 he wrote, "Berzelius' symbols are horrifying. A young student might as well learn Hebrew as make himself acquainted with

them. They appear to equally perplex the adepts of science, to discourage the learner as well as to cloud the beauty and simplicity of the atomic theory." The history of chemistry is full of instances where masters of the science have been unable to grasp theoretical conceptions we lay before our pupils as matter of fact.

Suppose we admit the possibility of teaching such theoretical ideas, is it worth while in a first course? If it is learned, it is as a matter of memory and useless. To derive the atomic theory from the laws of Dalton requires subtle argument, it is not for the child. Our best text-book authors use Avogadro's hypothesis as a big stick, yet they often sneak it into the text in a most unscientific manner. Our ordinary courses and texts, like Topsy, just growed. Usually elements or groups of elements are taken up first, as to occurrence and preparation then properties, compounds, and use. Almost all chemistry text-books follow this arrangement; where we find it, how we get it, what it is like and what it will do. It sounds well, what is the matter with it? I presume I shall be taking the bull by the horns when I say it is not pedagogical and not scientific. Apply it to sodium and see the result. Suppose we change the order of presentation; sodium has certain characteristics, it reacts thus and so, furnishing products with certain peculiarities. Having studied the compounds we can teach *why* salt occurs in nature, perhaps that it might be expected to occur. *Now* the pupil can undertake to learn how it is isolated and the reason for such procedure. This is logical and scientific, but, is it practical? In the case of sodium as I have outlined it, it is not, for this reason, I have brought no connecting link between the pupil and the subject and until I can furnish such a connection I would not make the element sodium a chapter in the course.

At the Baltimore meeting of the American Association for the Advancement of Science there was a rather pessimistic paper on the Problems in Science Teaching with especial reference to chemistry. Now, I do not think it is a condition to be despaired of. I believe we can put a large amount of chemistry, far more than we have time for, within the reach of far more pupils than at present, if we but step aside from the traditional position and look upon the content as the child will. Words, definitions and laws contribute nothing. The training that contributes to culture and efficiency comes from the content and this must be intelligent to the pupil. We know the pupil will not voluntarily respond to

the task unless the problem appeals to him as worth the effort. The question ever on the lips of the student is, "What's the use?" If we anticipate and find connecting links between the pupil and study we will secure his coöperation in the beginning and before he knows it he will be so hard at work he can't back out.

Education must be conservative, it must not react to fads and fancies however attractive, but in view of the criticisms of science teaching in general, and above all the social needs of our pupils demand such change in our methods as will make elementary chemistry teaching more efficient and general. There is a demand for what some call practical instruction. If we examine it we find that so far as chemistry is concerned it is not practical at all, in that it is a demand to teach technology. It is in the power of this society, it is its duty, to pay attention to the way chemistry is taught to the masses and not leave it to self-constituted authorities.

I do not advocate bread and butter chemistry, teaching chemistry as a trade or to ape the methods of schools of technology, neither would I have it purely informational—many of our text-books are merely information. In dealing with students many of whom will receive no farther science teaching, I would so far depart from the old methods as to teach *topics* rather than elements. Discuss phenomena and problems such as naturally arise in connection with subjects in which we are interested. Not catering to curiosity yet confining the content to matters which the pupil might be expected to comprehend. If the pupil does not understand the material before him it is the wrong material or wrongly presented. The content should be chosen from the side of the pupil regarding his capacity and wants, to develop him rather than to develop the subject. The metallurgist does not think in atoms, but in tons. The engineer measures pounds, not molecular bombardments. Empirical application has nearly always preceded pure science. We must teach pupils to think in masses before we attempt abstractions; to attempt both inevitably leads to confusion.

Aside from some sporadic skirmishing nearly all text-books get started at the same point, a chemical change and a chemical compound. The chemical compound is a substance that has definite composition by weight (they always put in the *by weight*). For the chemical change, they are less definite, they do not seem to be able to put their meaning in words, they expect the student to absorb it from illustrations. For this the sulphur-iron stunt is

the most popular. The ordinary pupil knows nothing of sulphur, little more than the name of iron, as for the product—the less said the better. So far as the experiment is concerned the pupil might as well have used glue or sealing wax as sulphur.

If we want to begin here why not do it sensibly, using things and language the pupil can understand? Teach this idea truthfully *as you understand* it and not rehearse an old formula. If this idea of a chemical compound is to be the starting point it is better that it be taught in connection with something worth knowing. Take water from the tap, freeze it, you can see segregation and changing temperature. separate and refreeze until segregation stops and we have constant freezing temperature. Distill in same manner. Get pure water. Study its properties. Here is the practical isolation of a chemical compound. A chemical compound is a substance having *definite properties*. Its composition, by weight or otherwise, is but one of its many properties. You recognize substances preferably by their physical properties, appearance, form, density, melting or boiling points, since these are definite. You consider yourself in hard luck if you have to determine the composition by weight, in order to identify a material. Since *you* do not use the definition why insist that the pupil start with it? He will never use it.

In the practical recognition of water, many facts will be brought out which will aid later work. Distillation, solidification, boiling and freezing temperatures and their variation have been touched upon, not made subject of theoretical study or explanation, but *introduced* in such a way that when they come up again the pupil will have some facts to bear on the new matter. Instead of being disjointed the topical method will find its connections in the pupil. It will furnish abundant opportunity for that repetition so lacking in our teaching. The same substances and the same processes will come up again and again, slightly changed in aspect as seen from a different point of view, but recognizable and ever widening the view, contributing to efficiency.

For many years hydrogen was the first element taken up in the texts. Of late years oxygen has moved up to first place. It is convenient that the student should know something of oxygen early in his course. It is important that what he learns should be the truth, and in the beginning confined to what is worth knowing. Practically all that an elementary student need know about oxygen will come out in its proper place and at its proper value if we study, not oxygen, but *burning*. Oxygen is important

not for any properties it possesses as an element but in its reactions with other substances. It is but one of the factors in combustion. Study the process of burning of common fuels, solid, liquid, and gas, as we meet them in our stoves, lamps, and burners. Find the conditions controlling the temperature or light, the products of combustion, their character and disposal.

Of course this is not a complete study of oxygen; it does not pretend to be. It is a study of the principles involved in reactions in which oxygen is a factor. When new properties of oxygen are needed they will easily fall into their proper place among these. So we might extend the topics, studying not the elements but their applications. Silver, as a metal, should not come in the same chapter as photography, but with gold and copper. Teach the metals as metals and their compounds where they belong. The uses of lead should not be confined to a small paragraph at the end of the chapter, but we may start with them and ascertain what properties lead possesses that it may be so applied.

In conclusion: The first course in chemistry should be adapted so as to be within the capacity of any child in the high school.

It should be designed for the many rather than the few.

It should be broad rather than deep.

Its content should be such as to give a comprehensive view of the general principles involved in ordinary chemical phenomena and some knowledge of the sources, preparation and utilization of commercial products.

Its method should exercise the pupil in careful habits of work, accuracy of observation and truthful expression.

Its aim should be to promote personal honesty in thought and deed, and furnish a workable knowledge of the world.

For the pupil who will continue in school such a course will serve as a foundation for more intensive work. The pupil who does not continue will have had his interests aroused to increased efficiency. He will not think that his time was wasted; a nite will have been contributed to his happiness.