

PHYSICAL CHEMISTRY—A BASIS FOR SECONDARY SCHOOL CHEMISTRY (?)¹

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Perhaps it would have been well to have put the topic in this wise, "Can physical chemistry and the principles of physical chemistry be used to advantage in a secondary school course?"

We are all pretty well of the opinion, I believe, that the trend of scientific education of the past has been almost entirely an education of listening, absorbing, and appropriating, not of seeing and getting by activities, or as Dewey has put it, taught "too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking"—an attitude of the mind after the pattern of which mental habits are transformed; and we are of the opinion that a new education in science is upon us, which has for its goal that broader object—the making of a well-trained man not an anemic encyclopædia of facts. Yet many a so-called teacher, I fear is to-day following along the beaten path in the field of chemistry believing that he must teach the same things, after the same manner, as he was taught.

Why not challenge the assumption that seems to have been made in so many cases, that we have to teach in a more or less parrot-like fashion the properties, behavior, etc., of all the elements and their compounds? Since we cannot hope to teach all of chemistry in secondary schools, how much shall be taught, and what? This is the old question which has confronted us in such meetings for years, and one which I shall not attempt to answer. But are we not looking at the subject from the wrong angle? Rather than how much, shall we not turn our attention to the "How"?—How shall chemistry be taught? This problem properly solved will in a large measure solve the first.

At the outset let me say that I have no sympathy for "fads" or "cheap" science of any kind—painless science administered by painless methods is worse than useless and already far too prevalent.

Much less sympathy have I for that course which is injected with theory for the purpose *only* of gratifying the whim of some specialist—neither have I toleration for that course in any subject which has only for its excuse the meeting of some requirement imposed by some higher institution of learning.

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I am of the opinion, too, that one kind of chemistry will not meet the needs or requirements of all types of mind with which we have to deal. But that chemistry of whatever kind it is, should aim, not at cramming the head with crude facts, but at developing personal initiative a desire for investigation—at making individual creators. This can be done only by teaching principles, and clinching those principles in such a way that they will be recognized and used wherever met. A high school student finishing his first course in chemistry should be grounded good and deep in the basic principles of the science. If he is worth much, he will get the details of the subject at the same time; if he is worth little, these details may be lost, but the mental process has been awakened and the principles will remain. We do not expect to find trained scientists in secondary pupils, but that course in science which does not in a measure develop the scientific habit, has in that measure at least been a failure.

Now to the application of the subject. Do physical chemistry and the principles of physical chemistry offer a possible aid in the accomplishment of this somewhat idealistic ideal? Surely we cannot get far away from a physical basis for chemical manipulation for "Physical phenomenon is the language of chemistry." Change the viewpoint of much of chemistry and we have but one place to go, and that to physical chemistry. Place the emphasis on the "*WHY*" and where must we turn for the answer? From my point of view it is of far more value to know *WHY* magnesium chloride is deliquescent and glauber's salt is efflorescent and why blue vitriol is ordinarily neither the one nor the other, than to know by rote all the substances belonging to one class or to the other. It is a question of only a few quantitative vapour pressure determinations and a few well directed questions to teach the individual not *which* deliquesce but *why* they deliquesce. I am aware that the time element plays an important part in deciding upon such a course of action, but a marked growth in the ability of the pupil more than compensates in the end for any apparent loss of time in the beginning.

A few principles well learned is better by far than an accumulation of many unrelated facts.

I hear you say there is already too much to be taught, why add more? My answer is that principles well understood diminish the quantity, to illustrate—Teach well the principles of oxidation and you have made a short job of the halogens. How much of the student's time is really necessary to learn the physical

properties of the halogens or of HNO_3 if the attention is directed to the "how" and "why" of the fact and not to the fact alone? Shall we for example let the mere statement that chlorine is a bleaching agent pass, or shall we investigate how and why chlorine acts when bleaching is accomplished? Shall we teach merely that MnO_2 and KMnO_4 with HCl give Cl_2 and HNO_3 with S . give H_2SO_4 ? Or shall we teach the principle of oxidation and require the student to explain *Why* these things come to pass?

The trend of modern chemical pedagogy seems to be toward an abbreviated treatment of the chemical laws and elimination of so-called chemical theory. It may sound like heresy to say it, but I firmly believe that from the point of view of interest and development of "chemical sense" on the part of the student more of theory, illustrated by concrete examples, is desirable rather than less of it. With Le Châtelier's theorem in view the study of a very few solutions with respect to thermal and volume changes and a liberal use of solubility graphs the *why* of increased solubility with increased temperature in some cases and vice versa is easily disposed of. Is this not of more value than merely knowing that some substances belong to one category and some to another? Or even knowing in a perfunctory way which belong to which. The kinetic molecular hypothesis, solution pressure, vapor pressure, osmotic pressure, yes, even the phase rule all lend themselves to a complete understanding of questions of saturation, freezing mixtures, boiling point and kindred questions, and give the student a sane view of the unity of things.

Nor would I eliminate from a laboratory course the determination of some equivalent weights—three at least, with method so selected that the meaning of "equivalent weight" as correctly defined will be amply illustrated; nor eliminate exercises in determining molecular volumes for by such exercises is an easy insight into atomic weight attained. Define an atomic weight as the smallest weight of an element that occurs in a molar volume of all of the volatile compounds of the element and little difficulty presents itself.

The law of mass action may have no place in elementary chemistry, but what better basis for reversible reactions, chemical equilibria and displacement of equilibria? Shall this very important concept of chemical actions be omitted from a secondary course? It may be omitted, I grant, but the loss of that concept is

fatal to an understanding of hydrolization, dissociation, and ionization—Omit these and you are forced to omit a large and vital part of chemistry.

Is it not better that a pupil possess the ability to write the scheme of equilibrium for a solution of such a salt as Na HCO_3 or $\text{Na}_2 \text{HPO}_4$ in water, and arrive at a complete and positive decision as to its acidimetry or alkalimetry, than by a memory process to have this information of all the salts in the kingdom? Is it not of fundamental importance to know why $\text{Ca C}_2 \text{O}_4$ dissolves in HCl and not in $\text{HC}_2 \text{H}_3 \text{O}_2$, and why certain sulphides will precipitate in acid solution and others not? It is unquestionably desirable that a student know that $\text{NH}_4 \text{Cl}$ prevents precipitation of Mg (OH)_2 from magnesium salt solutions by $\text{NH}_4 \text{OH}$; but that student who has such a grasp on the subject that he can explain *why* no precipitate is formed is decidedly better equipped than one who knows the fact only. Is ionic product constant out of place in secondary chemistry? It may be from a theoretical point of view, but from actual experience I am of the opinion that it has a place and a fundamental place in such a course. Osmometer, boiling point and freezing point determinations with solutions of ionogens and non-ionic materials of various concentrations give clear ideas of the evidences of dissociation and lead naturally to questions of ionization. A voltmeter and solutions of various concentrations make per cent of ionization a reality. The principles of ionization once illustrated, proper perspective gained, problems such as before mentioned become as nothing and are a source of constant delight to the normal pupil.

Nor have I spoken of things that are beyond the ability of the normal mind of the age and development at which they belong in chemistry. The conclusions I have reached in my own case are not ideas hatched from theory, but come from actual trial and observation for a period of three years during which time I have had ample opportunity to test its advisability and practicality. Of course the development and ability of the pupil must be constantly kept in mind, exhaustive treatment of physical chemical material cannot be attempted, nor is it desirable, only so much as is of service in making clearer some fundamental has a place. A keen balance must be kept between the theoretical and the practical by a skillful teacher who knows the subject and who is endowed with a fair degree of what might be termed "pedagogical sense."

In a brief way I have mentioned a few of the principles which

may be spoken of as physical chemical which have been found to be decidedly helpful in secondary chemistry. By their use one is enabled to teach more of elementary chemistry and better elementary chemistry than is possible without, and to send the pupil from the course equipped to meet a proposition squarely and to attack it in a logical sensible manner. The test of any course should be a certain power gained to do work, the ability to weigh evidence to discriminate between the probable and improbable—the real and the hypothetical.

I would not leave the impression that such a plan is in any way antagonistic to the report of your committee on fundamentals; I am in hearty accord with practically all of that report. But in the accomplishment of what is laid down as fundamental I have suggested some things which seem to me fundamental for these fundamentals. I am not advocating the view that chemistry should be studied and taught for its intellectual content rather than for its material content. I believe that both demands can be satisfied simultaneously if they both are given the proper setting.

In the school with which I am associated the situation is in some respects perhaps unique. Chemistry is offered as an elective. Physics is a prerequisite and is required of all juniors. The city might be termed a manufacturing center and a large per cent of the boys who elect chemistry have industrial chemistry in view after leaving high school. These, I might say, at the time they come to us have been found to be among the strongest and best pupils of the school. A match factory, a wire mill, and the Illinois Steel Company have been able to use all whom we can recommend for positions in their laboratories. To meet the needs of others not so well prepared or who have other objects in view, and those wishing a general view of the subject, a second course is offered termed Household Chemistry, less intensive and employing domestic problems and domestic tests rather than the broader principles of the first mentioned course. Of seventy-five electing chemistry this fall, sixty elected the former—eight being girls, the fifteen electing the latter course are all girls. It is with the more intensive course that I have conducted my experiments and made my deductions. In this course the tendency is naturally to emphasize industrial processes and reactions and the pupil is viewing the subject from the standpoint of its commercial value. Since perhaps less than one-tenth of those who pass from this class into this industrial work will have opportunity for

further chemical preparation it behooves the high school to give to those pupils the very best possible training for that work. I can imagine a condition no more deplorable than to send such a pupil into such a sphere of activity with a perfunctory knowledge of chemical reactions and manipulations and without a broad view of the principles underlying such reactions and manipulations. Without the latter he must become a mere automaton, with no hope for future development or growth—as superficial as was his training. It was Goethe who said, “Nothing in the world is so terrible as activity without insight.” In our zeal to “practicalize” and popularize chemistry I fear we are prone to allow the material content to eclipse all, and put a cheap value on the intellectual.

It is for the intellectual AND the material content, the theoretical AND the utilitarian that I plead, believing that the intellectual is the sane pathway to the material and that physical chemical principles is the fountain head of much of the intellectual. Does not Emerson's paradox apply to chemistry? Is not chemistry for the majority of high school students what remains to them after what they have learned in school is forgotten?

The recent electrical show held in Denver was one of the most successful exhibitions of its kind ever held in the West. The show was notable for its illumination not only within the auditorium, but outside as well. A novel feature of the outdoor illumination consisted of a representation of Franklin's kite soaring in the air. The kite was studded with electric lights and a string of small lamps led down to a large illuminated key. Within the auditorium a most unique spectacle was a sunrise picture. First the moon was shown sinking below the horizon, and as it faded from view the hills were lighted up by the rising sun, which was very realistically represented by 2,500 electric lamps. This illuminated picture occupied the whole of one side of the auditorium.

Large territories in Europe and Asia, under Turkish rule, abound in rivers that could be used to advantage to generate electricity. During the rule of Hamid II., such projects were out of the question; but now that the young Turks are in control of the government, electricity is gradually being introduced into the country, and plans are already on foot to utilize some of these resources that have heretofore been wasted. Our consul-general in Smyrna has recently called attention to a lake fifteen miles long, at an altitude of 2,500 feet above the surrounding plains, from which a stream of two thousand cubic feet per second flows during the winter season, while in summer time the flow is reduced to half this amount. It is estimated that three hundred thousand horse-power could be generated from this source. Not only could the power be used for generating electricity, but the water could be utilized to advantage for irrigating the arid plains.