tion. Finally, they decolorize a solution by allowing it to stand in contact with activated charcoal for a stated length of time.

Now, I feel that these and other experiments are valuable in the Beginning Pharmacy course because: *first*, they assist in the development of the student's technique. It is a well-known fact that students cannot develop technique by merely watching demonstrations. If the students are allowed to use their hands and correlate that use with their thinking they will acquire efficiency in handling more intricate apparatus that will be necessary in later courses. The students should be urged to use minimum quantities of materials which, of course, is an attribute to perfect technique.

Second, the purpose of this beginning laboratory course is to familiarize the students with processes and apparatus which they will use in later courses and finally at the prescription counter. We have found that this course serves as an introduction to the students and is a time-saver for them later when these processes and apparatus are employed. They must have an intimate acquaintanceship with laboratory technique and the way to gain that acquaintance is by actual employment and use of both processes and apparatus. My contention is borne out by this illustration from a leading pharmaceutical journal. It was said of a young man that "an acquaintance with the courtship of Dante and Beatrice will do him good but it will be neither so illuminating nor so satisfying as an affair of his own."

Third, the laboratory work helps to create and hold the interest of the students in pharmacy. The answers of the students themselves to a direct questionnaire provide testimony as to the effectiveness of the course in this capacity. By necessity most of the curricula do not include more than the beginning course in pharmacy in the first year's work. Many of the students become discouraged in spending their time on what they consider unnecessary work.

The experiences gained by students in this laboratory course and their experiments with processes and apparatus more clearly illustrate to them the direct application of these subjects of the curriculum to pharmacy, and give them an insight to some of the things they may expect later.

The reasons for teaching laboratory with a beginning pharmacy course may be summed up in the words of the German poet, Christopher Martin Wieland—"However learned or eloquent, Man knows nothing truly that he has not learned from experience."

NEWER IDEAS IN TEACHING A FIRST COURSE.*

BY E. V. LYNN.

All of you will agree undoubtedly that there is much opportunity for improving the results of teaching a first-year course in chemistry. In order to gage accurately these results, naturally we must base our opinion on how well the *average* student is able to grasp the principles we are endeavoring to teach. On this basis, the writer is willing to admit that he is entirely dissatisfied with his own experience

---

and undoubtedly many of you are of the same mind in reference to your own work. In any event, no one can deny that any change in method for the better is desirable.

One point which stands out most emphatically in the writer's experience is the confusion which ensues when attempt is made to apply the theories of atomic structure. There is no doubt, whatever, that the ideas of electronic reaction represent a great step in advance and that they have brought science much nearer to the true explanation of what happens in chemical activity. Nevertheless, it is pertinent to inquire whether a detailed discussion of these should be brought into a first-year course. Is it necessary or even desirable to study the principles and practice of reactions in the light of atomic architecture?

After all is said, the crux of the question comes down to two points. The first would ask whether the fundamental chemistry has been altered by these newer ideas. To this there must undoubtedly be entire agreement that the reactions are exactly as they were before. Even the discussion of isotopes and of deuterium and heavy water need not involve any electronic explanation.

The second question, whether introduction of theories as to internal operation of reactions will assist the student to comprehend the points, is perhaps debatable. In the writer's opinion, however, the answer is not only negative, but also that such introduction gives just so much more for the student to understand and thus hinders instead of helping. From that point of view it would seem preferable, instead of basing the whole chemical edifice on known facts and hypothetical ideas concerning electrons and protons, as is done in many modern texts, rather to instil the facts and principles first and then note the theories of atomic structure at the end of such course.

Personally, the writer would rather teach from a book published in 1900 than try to adapt the modern ones which attempt to follow fashions, and he is convinced that any of you will have more success with the *average* student in this way. Again let me emphasize that we are not considering the best ones in our class.

Another subject which should be introduced at this time is concerned with formulas and their relation to facts. One of the difficulties we meet is to impress the student with whys and wherefors for such substances as $Na_2B_4O_7.10H_2O$, Na_5IO_6, $NaPO_3$, Na_3PO_4 and $K_2Cr_2O_7$. We blithely proceed through nitric acid (HNO_3), sulfuric acid (H_2SO_4) and others like them and then hem and haw when we arrive at the salts noted above. The result is that the student must commit such formulas to memory and never really understands. Then, when we come to the silicates and silicic acids, we simply give up; the substances like sodium silicate, $(Na_2O)_x(SiO_2)_y$, are skipped over hurriedly or ignored entirely.

Actually the *average* student is much better able to understand common reactions if actual conditions are pointed out. Let me illustrate the contention by giving a few examples and by proposing some questions for you to contemplate.

When sulfuric anhydride is added to water, what takes place? We generally say that each molecule combines with one of water and write the equation

$$H_2O + SO_3 = H_2SO_4$$

We call the product sulfuric acid and, if asked to define sulfuric acid, say H_2SO_4. Yet we know that the hydration of SO_3 can lead to an indefinite number of sulfuric acids according to the equation

$$xH_2O + ySO_3 = H_{2x}S_yO_{x+3y}$$

in which practically the only limitation is that x is never over three times y. Actually, no one can say, except on theoretical grounds, what individual compounds are in a solution of sulfur trioxide and water and it is much better to presume a mixture of some of the many possible sulfuric acids in equilibrium. When a base is added to the solution we get salts of one of them, but that does not alter the original liquid. On that basis, therefore, sulfuric acid is a solution of SO_3 in water, not H_2SO_4.

The same remarks might be made about nitric acid or, indeed, of any hydrated, acidic oxide where the element concerned has a valance higher than one. Thus stannous acid, theoretically $SnO + H_2O$, might exist in solution as any one, or a mixture, of an indefinite number of compounds.
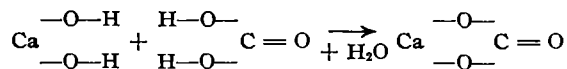
In view of these considerations, the student obtains a much better conception of acids, bases and salts if these ideas are taken up immediately after the subject of equilibrium and if both are introduced early in the course. It is very simple then, to show why neutralization of solutions of orthoboric or metaboric acids yields salts of pyroboric acid and why neutralization of meta-, pyro- or ortho-arsenic acid leads to derivatives of the last only. Many other apparent anomalies are thus easily brought before the student with a minimum of discussion. For example, the pharmacopœial formula for ammonium molybdate is readily understandable, as also are the salts $K_2Cr_2O_7$, Na_5IO_6, etc. Even the natural silicates in this way present no difficulties and one can easily see why commercial sodium silicate is not Na_2SiO_3 or Na_4SiO_4 but something more like $Na_2Si_4O_9$.

It is admitted that these considerations are not necessary with such salts as nitrates or many others. In the case of arsenates, arsenites, phosphates, silicates, etc., however, we must either ask the student to memorize the formulas without any discussion or else adopt the more logical method of explaining why. If this explanation is to be given, why not put it in early and let it apply throughout?
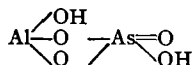
A great aid in impressing the reasons for such compounds on the average student is the use of structural formulas and the insistence that he also use them. Indeed, it would seem best to develop the structural idea right along with the molecular formula and for the teacher to employ generally nothing but structures in the discussion. Perhaps the student will in this way have greatly less difficulty with organic formulas when the time comes. The argument might be made here that we should not burden the beginner with more material, but it is contended by the writer that, if structural formulas are used in practically all cases, the student will not have more material and will have much less difficulty in understanding the whole.

One outcome of such instruction is to show the actual chemical identity of acids and bases, except in the matter of degree. The bases are usually written $M(OH)_x$ which is exactly the same as completely hydrated acids, usually H_xMO_x, while the common acids are H_yMO_z, or dehydrated products of the above. In other words, the theoretical addition of water to an oxide, one molecule at each oxygen atom to yield two OH groups, gives a compound which may act as an acid or as a base or as either. Thus, As_2O_3 gives $AsO(OH)$ or $HAsO_2$ and $As(OH)_3$ or H_3AsO_3, as well as many other hydration products. We generally refer to them as arsenous acids but they are typically amphoteric and act as bases if placed in contact with strong acids.
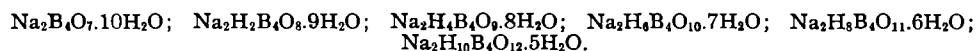
Another natural result of using the method outlined is to explain partial and complete hydrolysis of salts. The salt is obtained by dehydration between two apparently similar substances which we call acid and base, respectively. Thus calcium carbonate is formed by the reaction

$$Ca\begin{matrix}\text{—O—H}\\\text{—O—H}\end{matrix} + \begin{matrix}\text{H—O—}\\\text{H—O—}\end{matrix}C=O \xrightarrow{+ H_2O} Ca\begin{matrix}\text{—O—}\\\text{—O—}\end{matrix}C=O$$

The complete hydrolysis gives back these substances, or reverses the reaction. On the other hand, incomplete hydrolysis splits off either some acid or some base, depending on whether the basic element or the acidic element has the higher valence. The products are then basic salt or acid salt. If the valence is the same, no partial decomposition is probable. Thus, tertiary sodium orthoarsenate, Na_3AsO_4, might give NaOH and Na_2HAsO_4 (an acid salt) while aluminum metanitrate, $Al(NO_3)_3$, might yield HNO_3 and $Al(NO_3)_2OH$ (a basic salt), and aluminum ortho-arsenate, $AlAsO_4$, would be hydrolyzed completely or else produce the improbable product

$$Al\begin{matrix}\diagup\text{OH}\\\text{—O}\\\diagdown\text{O}\end{matrix}\diagdown\text{—As}\diagup\begin{matrix}=O\\\diagdown\text{OH}\end{matrix}$$

There is just one more point to be raised, having to do with formulas of salts as written. We give $NaBO_2$, Na_3BO_3 and $Na_2B_4O_7$ for sodium metaborate, sodium orthoborate and sodium pyro (bi di tetra) borate, respectively. Since the last contains ten molecules of water of crystallization, why could it not be any one of the following:

$Na_2B_4O_7.10H_2O$; $Na_2H_2B_4O_8.9H_2O$; $Na_2H_4B_4O_9.8H_2O$; $Na_2H_6B_4O_{10}.7H_2O$; $Na_2H_8B_4O_{11}.6H_2O$; $Na_2H_{10}B_4O_{12}.5H_2O$.

Of course, any further incorporation of the water is incompatible with a valence of three for boron. On the other hand, $NaH_2PO_4.H_2O$ is the formula given for sodium biphosphate U. S. P. Why is it not $NaPO_3.2H_2O$ or even NaH_4PO_5? A still more striking illustration is given by $(NH_4)_6Mo_7O_{24}.4H_2O$, the formula accepted for ammonium molybdate. According to this it is a salt of $H_6Mo_7O_{24}$, one of the possible myriads of molybdic acids, but it might just as well be a salt of $H_8Mo_7O_{25}$ or $H_{10}Mo_7O_{26}$. From analytical figures on the composition of salts which contain alleged water of crystallization, it is impossible to say just what is the formula. Even those which contain no water of crystallization are not necessarily fixed; for example, $KClO_3$ or $K-O-ClO_2$ could just as logically be $K_2Cl_2O_6$ which can be written structurally in several ways. Only determinations of molecular weight would tell and this is often impossible or impracticable and certainly is not frequently done.

In the short space of time which can be assigned to this presentation, it is almost impossible to give an adequate idea of the points I am endeavoring to make. Nevertheless, it is to be hoped that sufficient has been noted so that you will have gained the chief ideas and so that considerable free discussion will follow. The principal object in presenting this paper is to elicit such discussion.