The new device assures rapidity and certainty in manipulation with complete absence of danger to the funnels employed.

These new disks are manufactured by Kaehler and Martini, of Berlin, Germany.

QUANTITATIVE WORK FOR BEGINNERS IN CHEMISTRY.[1]

BY W. A. NOYES.

IN most of our chemical laboratories the work which is given to beginners is chiefly or altogether of a qualitative nature. In many schools and colleges the work begins with a study of the qualitative properties of a series of chemical elements and their compounds, chiefly of gases and metalloids. In other schools the students begin at once with the study of qualitative analysis. A large majority of our students never get beyond this first stage and it is safe to say that they acquire but a very slight knowledge of real chemical work. The work which is done in our scientific and technical laboratories and in chemical factories consists almost entirely of quantitative analyses or of the preparation of chemical substances carried out in an accurate quantitative manner. Indeed, we are accustomed to say that the science of chemistry began with the use of the balance and we all recognize the extreme importance of quantitative relations in most of our chemical work.

We must keep in view several objects in selecting the laboratory work for beginners. First they should become personally acquainted with the appearance and properties of a number of the chemical elements and their compounds. The acquisition of a large amount of knowledge of this kind is desirable but we may easily make the mistake of endeavoring to impart too much. A few topics exhaustively studied will prove of greater value than a superficial study of a great many. This is especially true of qualitative tests with solutions. A beginner can apply a great many such tests in a comparatively short time, but unless his powers of discrimination and of memory are very unusual he will retain only a confused recollection of his work. A second object is to secure a training in delicate and accurate manipulation and in the use of different forms of apparatus. A third

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object is to fix in the mind of the student knowledge which may have been imperfectly acquired by watching the demonstrations of a lecturer or by the study of a text-book. Some teachers carry this thought so far that they seem to imply that no knowledge of a topic can be really acquired by the student until he has demonstrated it by personal experiment. Indeed I have heard some teachers contend that they would not allow a text-book in the laboratory, but would have their students acquire all of their knowledge at first hand by their own experiments. Such a principle if logically carried out could never take the student beyond the stage of alchemy, for the student of to-day is no better able to develop a science of chemistry for himself than was the old alchemist. And if you direct his experiments in such a way as to develop and elucidate the science as it is now known, you have forsaken the principle just as much as though a text-book were used.

It seems to me that such views arise from a mistaken conception of the real nature and purpose of laboratory instruction. After all, the method of personal experiment is a very slow and laborious method of acquiring knowledge. Only a very small fraction of our knowledge of a science, if that knowledge is by any means adequate, has been acquired in that way. It is true that the method is absolutely essential for beginners, and I do not think that any of us get beyond the need of it. The man who never uses a balance or handles a test tube will not for very long be a strong factor in the advancement of chemical science. But the method of laboratory instruction is essential, not because knowledge can not be acquired in other ways, but because at the start the imagination of the student is deficient and it is only by means of personal experiments of his own that he can acquire the ability to understand and appreciate the experimental work of others. The memory is also deficient and the personal work on a subject may be of great value for that reason, as well. But the things which we should endeavor to secure in laboratory instruction are, first, such an acquaintance with experimental methods as shall enable the student to thoroughly grasp the solid experimental basis of the science and give him the mental habit of referring everything back to the rigid experimental test; and second, the ability to do accurate and independent experimental work himself. No student can demonstrate for himself more than an infinitesmal number of experimental facts in comparison with the vast array of such material which has been accumulated.

If the principles which I have suggested are correct we should endeavor to secure as thorough a knowledge as possible of experimental methods, and neatness and accuracy in laboratory technique rather than the illustration of as large a number of details as possible. These results can be secured more fully by a series of quantitative problems than by a large amount of merely qualitative work. I do not mean by this that qualitative work is not necessary and desirable as well, but for the beginners, especially, quantitative work is of more value. In order to make my meaning more clear I will give a few illustrations. One of the earliest problems that I give is the determination of the weight of a liter of hydrogen essentially by Regnault's method. A bulb containing about one-half a liter and bearing a three way cock is exhausted with a Bunsen pump and the residual pressure determined with a manometer. The bulb is then weighed, using a sealed counterpoise of nearly the same volume, then filled with hydrogen, temperature and pressure noted, and weighed again. The results obtained by careful work are usually one or two per cent. too high. A similar determination of the weight of oxygen gives results with a far smaller percentage error. The determination of the amount of oxygen in potassium chlorate by heating about a gram of the salt in a small porcelain crucible placed within a second gives a good illustration of the law of constant proportion. The preparation of potassium perchlorate can be made to furnish a considerable amount of valuable instruction. The capacity of a bottle holding about two liters is determined, a calculation of the amount of potassium chlorate required to give oxygen enough to fill it when only the first stage of the reaction is used, is made and the experiment performed. Then the potassium chlorate and potassium perchlorate are separated and the latter is purified by crystallization. A study of the qualitative reactions which distinguish potassium chloride, potassium chlorate and potassium perchlorate is made and the tests to establish the purity of the last are applied. Finally a determination of the amount of oxygen in potassium perchlorate gives, in connection with the last problem, an illustration of the law of multiple proportion. I will give but one further illustration—the determination of the relative atomic weights of hydrogen, chlorine, and silver. A known weight of pure silver is dissolved in nitric acid, precipitated with hydrochloric acid and the silver chloride weighed on a Gooch crucible. In a dilute hydrochloric acid the amount of hydrogen is determined by allowing ten cc. of it to act on an excess of zinc in an appropriate apparatus, the hydrogen being measured in a gas burette, accurate corrections being made for temperature, pressure, and aqueous pressure. In another known volume of the same acid the chlorine is determined by precipitation with silver nitrate.

By a careful selection of problems it is possible to give the student, within a reasonable time, practice in the careful use of the more common forms of chemical apparatus. In other words the student can make a beginning at working as a chemist works instead of doing scarcely more than play with bottles and test tubes. Among other advantages of this method of instruction is the fact that the results which are obtained are usually a fairly good criterion by which to judge of the care with which the student has worked, and the student soon finds that careless work will not give good quantitative results. Also the student dwells long enough on a problem so that many details become thoroughly fixed—a result that is rarely obtained in qualitative work, except by means of many repetitions. I am aware that there are some practical difficulties in the way of carrying out the methods which I propose, especially in the matter of apparatus, but these difficulties are not nearly so great as they appear at first sight and I am sure that they are not greater than those which have been overcome in many of our physical laboratories.