APPLIED ELECTROCHEMISTRY

By M. DeKAY THOMPSON.

The instruction in Applied Electrochemistry has the object of making students familiar with the methods employed in the most important electrochemical industries. In order to show to what extent this is accomplished, a short survey of the field will be necessary.

Electrochemical industries may be classed under two general divisions, which are respectively the production or refining of metals and chemical compounds by means of electricity, and production of electricity from chemical change. The second division includes the subject of storage batteries and primary cells. As regards money invested and power required, the latter is relatively insignificant compared with the former.

On account of the large amount of power required for the first class of electrochemical industries, they are generally located where power is cheapest, as at large water falls. A large number of such industries are represented at Niagara Falls, where at present 300,000-horse power is developed. The principal products are carborundum, fused alumnia (called "alundum"), artificial graphite, alkali and chlorine, aluminum and calcium carbide. To indicate the magnitude of these industries the production in 1908 is given in the following table:

	Pounds.	Value.
Carborundum	4,907,000	$294,430
Alundum	3,160,000	189,600
Graphite	7,385,511	502,667
Aluminum	13,000,000	4,095,000
Calcium Carbide...	84,000,000	1,800,000

The increase in production per year is very large in all of these materials, and the number of such industries is steadily increasing. For instance, the carborundum company has recently begun to produce silicon on a commercial scale. In 1908 five hundred tons of 90 per cent. silicon were sold for the purpose of refining steel. Also, at the present time, a large plant is building for the production of calcium cyanamide. This is the starting point in the fixation of atmospheric nitrogen, and is made by the direct union of nitrogen and calcium carbide at about 1,000 deg. C. It seems that the electric furnace products are at present increasing with greater rapidity, both in quantity and number, than those made in aqueous solution.

An older, but a very important, electrochemical industry is the refining of copper. There are eight refineries in America, with a total output of 360,000 tons a year. The most recent metal to be refined commercially is lead. The refining of steel is also carried out now in electric furnaces, both of the Heroult and induction type.

One of the latest and important industries is the fixation of atmospheric nitrogen by direct combination with oxygen in an electric arc furnace. This was attempted unsuccessfully at Niagara Falls, but is now carried out by several European companies. The first plant was at Notodden, Norway; there is another at Vevey, Switzerland, and the "Badische Anilin und Soda Fabrik" has also taken it up in Germany.

There are also a large number of electrochemical industries which are carried out on a somewhat smaller scale than the ones above enumerated. In many instances factories manufacture some electrochemical product for their own use alone. Examples of these kinds are electroplating and the electrolytic production of copper tubes, wire, powder and parabolic mirrors; electrotyping; the production of bleaching solutions by paper factories for their own use by the electrolysis of chloride solutions; the production of hydrogen and oxygen by the electrolysis of water; electrolytic oxidation and reduction, such as the oxidation of potassium ferrocyanide to potassium ferricyanide, of chromium salts to chromates, iodoform from iodide, chlorates and perchlorates from chlorides. Examples of electrolytic reduction are the production of lead from lead sulphide, carried out at Niagara Falls for some time, but finally given up on account of the bad effect of hydrogen sulphide on the workmen, and the production of the lower salts of chromium, venadium, molybdenum and titanium. The production of ozone by the silent discharge of electricity is carried out where it is to be used. Finally, the large extent to which electricity is used in making quantitative chemical analyses should be mentioned.

This brief sketch will give an idea of the kind of work that is carried out by electrochemical means.

The instruction in electrochemistry begins in the first term of the fourth year, and continues through the whole year. Theoretical electrochemistry is taught in a course of thirty lectures in the first term, accompanied by a laboratory course of 105 hours. The laboratory work consists principally in potential and conductivity measurements.

In the second term, applied electrochemistry is given in a course of twenty lectures, taking up all of the principal electrochemical industries in detail, with the exception of electrometallurgy, which is treated in the special course. When possible, each process is discussed from a general or theoretical standpoint before describing the actual methods used in carrying it out.

The laboratory course of 45 hours accompanying this lecture course consists in experiments modelled on the chief industries. Special attention is paid to the measurement of the current, voltage power, as well as the temperature involved in each process. Most important among these are the electric furnace experiments, which consist in the production of carborundum, silicon, aluminum, calcium carbide and iron. Then follow electrolyses in aqueous solutions, consisting in a storage battery test and the production of bleaching solution, chlorate, white lead and other compounds.

A 10 kilowatt induction furnace has been added to the equipment this year, which will also be used in the regular laboratory work, as well as for research work.

THEORETICAL PHYSICS

By DANIEL F. COMSTOCK.

It is not my intention in this short article to make an outline of Course VIII, this has been ably done in other articles in this number. What I wish to do is to talk quite freely about the kind of thing that the different studies in this course are designed to teach.

There seems to be properly current a very curious idea respecting the meaning of the word "theoretical." A good many students seem to think that the so-called "theoretical" side of any subject is only a mental game which touches more or less intimately at certain points the really practical subject itself. The idea causes a good many to turn away, when they get a chance, from courses which bear the adjective "theoretical," and turn toward the so-called practical. It is needless to say that this idea represents what is far from the truth. The theoretical side of a subject, properly understood, is merely the side of it which requires the most thought. This side, therefore, is the one least obvious, least sensational, and one the advantages of which are not easily appreciated from the outside.

Speaking in a very general way, the value of the theoretical courses at the Institute may be described under three heads

First: Increase of Mental Power.

Second: Training for Original Research.

Third: Training for the Profession of Teaching in Higher Institutions of Learning.

Of these three the first two are not generally appreciated.

With regard to the "teaching to think," we have to consider the well-known distinction between knowledge and mental power. Knowledge is almost always over estimated by the student and mental power very greatly under estimated. For this reason a great many students cannot understnd why certain types of problems are given them for solution, problems which seem to be very far from being of a practical kind; the conditions stated in the problem, they see, could never actually be carried out in practice, and they therefore conclude that the problem is of very little value. The problem does not add much to their knowledge, but anyone who has had any experience at all with the world of effort and achievement knows that it is far more important to have a well-trained mind than to be stuffed up, so to speak, with knowledge. Of course knowledge is also necessary, but it would seem to some almost incredible if they were told how rapidly a well-trained mind can assimilate knowledge. One case in particular, which I am fond of relating, is that of a Tech. man who went West and took charge of the electric meter department in a small Western city. He had been a close student of electricity and he had a well-trained mind, but two weeks before he left for the West he had never seen the inside of an electrical meter. He went to the meter department of an Eastern city and spent a day looking over the whole repair department, where we can easily guess that he understood everything that he saw.

He told me, also, that for a week he put in most of his time studying modern meter practice, and a few days later he went West. He found, rather to his surprise, that he knew more about meters than anyone in the city, and he found himself an acknowledged meter expert. He did his work well. He transformed a very dilapidated meter system into a thoroughly efficient one, was highly praised for his work, and, when he left for another position, he considered his work there entirely satisfactory.

This, of course, is no exceptional case, it is only an example. Suppose that man had not appreciated the value of general scientific training, and had started in at the beginning by studying meters. It is very doubtful if he would have been nearly as efficient as he actually was, and, moreover, there would have been nothing else that he could handle. As it was, he was equally fitted at two weeks' notice to take up any one of countless different positions involving only a little easily attained special knowledge on top of his general training.

A man who does not understand what this example implies as to the working of the human mind and the nature of success in engineering careers has missed one of the profoundest truths which he could learn.

What I have said above with regard to the enormous value of mental power as distinguished from knowledge, applies to all scientific professions alike. Next, I wish to speak of the advantages of so-called theoretical training to the pure scientist. The life and ideals of the scientist seems to be almost absurdly misunderstood by people in general, and particularly by young students. The activities of the inventor are appreciated by all, but the function of the pure scientist ceems to be much harder for the average person to understand.

The activities and ideals of the pure scientist are very closely similar to those of the explorer, with this important exception, that whereas the explorer knows that the earth is limited, and that, therefore, his field of exploration is limited, the pure scientist knows nothing of the kind, for our present knowledge , though great, is so extremely small compared with what can be known, that the domain in which new truth can be discovered is practicaly infinite. There is an amusing popular idea that there is very little new being discovered; that is, I mean, absolutely new knowledge. It would come as a surprise, I suppose, to those who hold this view, to know that "Science Abstracts," a periodical which abstracts all of the important original papers published in the domain of physics, dealt with 2,161 papers during the year 1909. Every one of these papers strictly speaking, represented a new discovery. Not all of them, of course, were of great importance, but it is very rash indeed to assume what new truths will be epoch making and what will be forever valueless. At the time of Faraday's electrical discoveries in the early 40's, the "Youth's Companion" stated, I am told, that although these experiments were extremely interesting as curiosities, the effects were so small that they could never be put to any practical use. As a matter of fact, our knowledge of all induction phenomena, without which we may almost say there would be no electric engineering, rests entirely on the cornerstone of these very experiments of Faraday.

Never was there a time when the field for discovery was greater than at the present day; but there are men of remarkable ability already in it, and the untrained explorer has very little chance to win new knowledge. His insight into the habits of nature,—for, after all, that is what we mean by "natural law,"—must be broad and profound, and the so-called theoretical side of his studies is, from one point of view, the most important part of the study which gives him this insight.

There is, perhaps, a little less need of touching on the teaching side of the subject, partly because this is the side usually emphasized, and partly because, although greatly misunderstood in some ways, the ideals of the teacher are better appreciated.

There is a great demand at present for able teachers, a demand which is greater than the supply, and although it is true at the present time that salaries for teachers are low, it is also true, and this point is often missed, that the teacher in a higher institution of learning has already many of the things that a man in another profession will use money to buy. Moreover, a man with any ability can nearly always supplement his salary by means of outside activity, for which, in general, he has sufficient time.

It is impossible to give much new insight into the theoretical physics courses at the Institute by simply naming them, or by quoting from the Catalogue. It is the peculiar property of courses which involve more or less profound thinking, that they cannot be described easily to one who has not taken them. This is a corrollary to a general axiom, which might be put in the paradoxical form that "Only the obvious is obvious."

The Course in Theoretical Physics commences where the general second year course leaves off, and takes up the divisions of physics in the following order

Dynamics.
Electricity.
Optics.
General Theory of Heat and Heat Phenomena.

It is proper to begin with dynamics, because dynamics is the science of motter, motion, and force, and it therefore touches most closely our common everyday experience. The general mathematical methods which are applicable in all fields of physics can therefore be best introduced in the subject where the phenomena themselves are in part already familiar to the student. In these courses a great deal of original work on the part of the student is required. It does not do a man much good to sit in a chair and watch somebody else swing Indian clubs, and in a somewhat similar way, it is not very beneficial mentally to simply hear about things; the important thing is to learn to do, learn to think productively, and this is accomplished by requiring the student to work out a large number of problems.

After the course in dynamics is finished, electricity, optics, etc., follow in a natural order; for as soon as we get below the surface in the study of physical phenomena, it becomes obvious that many of the distinctions which are necessary in elementary exposition are really of little importance in the profounder study of the subject. The various habits of nature are very similar.

GRADUATE LETTERS

The increasing demand for trained physicists should operate to the advantage of graduates of Course VIII. The large physical laboratories recently constructed or now being built for colleges, universities and technical schools afford improved facilities for research, and requires that important additions be made to the staffs of instructors. The Bureau of Standards, with its several buildings and remarkable instrumental equipement, has drawn many physicists from the schools, and will doubtless require more good men. Graduates of Course VIII are needed in astrophysical observatories, where an acquaintance with physical methods is the best agent in the advancement of reseach. The laboratories which are being established by manufacturing corporations also employ physicists, and furnish ecellent opportunities for investigation. Under existing conditions, therefore, it should not be difficult for a good man to obtain a satisfactory start after graduation from the Institute.

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