THE RELATION OF PHILOSOPHY TO MODERN SCIENCE[1]

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In a day when so much emphasis is placed on the experimental side of scientific development it may be well to take some time to consider the theoretical side,—the philosophical aspects of modern science. The question may be raised, "Is speculative philosophy still playing a role in the growth of such sciences as chemistry and physics?"

It is not the purpose of this paper to touch any large number of the philosophical aspects of modern scientific development. Philosophy, in the sense of a complete analysis and understanding of life and reality is, perhaps, too large a field for any individual to grasp, let alone one whose major interest is in a particular science: certain branches of science are so highly developed that it is difficult to master one of these and be even a moderately good philosopher. Yet philosophy and the sciences are so intimately related that one can not study a science properly without a sound philosophic viewpoint. The sciences are a part of philosophy and they should use all the tools and the rules which are known to bring about philosophic progress. Since a complete science includes facts, laws, hypotheses and theories, philosophy may demand as a minimum, an appreciation of the meaning of each of these terms and their relations.

With an appreciation of the necessity of giving a student of science a clear understanding of such terms as facts, laws, hypotheses and theories and their relations, authors of general textbooks on chemistry (the subject with which I am most familiar) usually give space in the introductory chapters to a discussion of these terms. It would seem, however, that teachers and students, in their eagerness to get down to the study of chemistry, or whatever the science may be, treat these chapters like the preface of a book, hastening to get through them to get to the "science proper." These introductions are usually brief and unless elaborated upon by the teacher they may be inadequate, especially when one considers the fact that there are some who would consider nothing less than a thorough course in logic the proper basis for the study of a science.

Students of chemistry have, as a rule, sufficient appreciation of the value of scientific laws to make them master these thoroughly. But even here, there are some interesting exceptions. It is well recognized that the science of chemistry is based upon certain fundamental laws, including the laws of definite composition, combining proportions, and multiple proportions, and yet, it is my experience that a large per cent of chemistry students after having two, three, and four years of training in that subject find it difficult to state clearly and understandingly

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the law of combining proportions and, more especially, that of multiple proportions. This paradoxial condition, it seems to me, is largely due to a failure on the part of these students to have the historical viewpoint, i. e. the failure to re-live in their own minds the early days of the science when these laws were formulated.

Hypotheses and theories are defined for us in many ways. The usual idea is that a hypothesis is a satisfying explanation of some fact or law (not merely a guess, but the thought of an expert) and put forth with the hope that the hypothesis may be fruitful in suggesting new avenues of investigation. A well-established hypothesis is in turn considered a theory. To illustrate how, in a sense, a scientist's idea of a hypothesis may be perverted, it is interesting to read a quotation from Goethe suggested by Mellor in his introduction to "Modern Inorganic Chemistry," "Hypotheses are the cradle songs by which the teacher lulls his pupils to sleep." Perhaps Goethe, like others, spoke half-truths at times to emphasize some particular point. It is undoubtedly true that at times teachers do use hypotheses to lull pupils to sleep, and since it is one purpose of a hypothesis to satisfy the craving of curious man to know why and how a thing happens, and since this satisfaction may come only after prolonged study, sleep as a consequence may be justified. Hypotheses do more for the scientist than satisfy a curiosity; they are suggestive, creative, working tools.

Many of the hypotheses of the physical sciences have been graduated to the status of the theory and occasionally one ceases to be hypothetical, becoming so factually based as to be a law. Such evolutions, often occurring within the span of a lifetime, are among the marvels of modern science. As an example we may consider the Avagadro law. Certain authors of modern texts on chemistry refer to this concept as the Avagadro hypothesis and others as the Avagadro law. At the first glance one might wonder if one or the other of these groups of authors do not have the philosophic viewpoint which recognizes the difference between a hypothesis and a law, but a more careful study would show that these authors are simply viewing the concept from different historical standpoints. In the early days of the science when the facts known were fewer and less conclusive, the concept was hypothetical, but now, since scientists have discovered methods for counting molecules, the concept, "equal volumes of all gases under the same conditions of temperature and pressure contain the same number of molecules," is a law. This is one of several instances in the physical sciences in which a concept has advanced from hypothetical through the theoretical stage to become a demonstrable law.

Theories, although they are not the primary objective of a science, are its mightiest working tools. Since they have advanced beyond the state of the hypothetical, with all that that implies, they are valuable and worthy of respect. Unfortunately, in the popular mind the word "theory" is almost synonymous with the word "guess." In discussing this situation with Dr. Sanborn of the Department of Philosophy of Vanderbilt University some time ago, he suggested that it would be an interesting study to learn how the term theory had become so degraded in the popular mind. This conception has made inroads even upon the minds of the younger students of science, until to say that a thing is theoretical is to convey the idea to some that it is visionary or almost useless. Perhaps, an interesting symposium for a general group, such as the State Academy of Science, would be to consider the theories of each branch of science, to see how extensive they are in each field and to study their status and usefulness. Perhaps a study of that kind would convince scientists themselves of their dependence upon theories for progress and of the great extent to which theories are factually based in certain fields. This in turn might help to change the concept of the "theoretical" in the popular mind.

Very often persons who are not particularly interested in the sciences will volunteer the suggestion that the theories of the sciences are after all quite insecure. One of the theories often singled out is the molecular theory and one hears the suggestion that, "No one has ever seen a molecule" or that the molecule is but a figment of the imagination. Yet the molecular theory is one of the best established theories of the sciences: the molecule is as real as most things commonly considered real.

The kinetic theory of the structure of matter which holds that matter is made up of discrete particles called molecules and that these are perfectly elastic and in constant motion, was first formulated as the "atomic hypothesis" by the ancient Greek philosophers. At that time one group of philosophers held that matter is continuous and another group that it is discontinuous in structure or atomic. It is most interesting to see how the old atomic "theory," the child of speculative philosophy, though sterile for 2,200 years, when mated with the researches of Joule and Thompson on the nature of heat, became one of the most fruitful concepts of the physical sciences. It is well known how in the hands of the mathematical physicists the kinetic theory has been formulated into the "kinetic equation," and how this, in turn, suggests the effect of temperature and pressure on the volume of gases, the relative rates of diffusion of gases and suggests even the Avagadro law.

In its mathematical form the kinetic theory predicted the specific heat of a monatomic gas so accurately that, to quote Millard, "At the time that the equation was first formulated the only monatomic gas known was mercury vapor, and it was considered a triumph of the kinetic theory that the molal heat capacity of this gas is equal to that predicted by the equation. Since that time, five other monatomic gases, the so-called 'rare' gases of the atmosphere, have been discovered and subjected to experiment." These, too, have specific values predicted by the theory. "It is, indeed, a useful equation," says Millard, "from which one can predict the heat capacity of a substance before it has been discovered."

There have been other useful applications of the kinetic theory, but to hasten to its greatest triumph,—it was in 1908 that Perrin, at the suggestion of the mathematical physicist Einstein, found experimentally that particles of matter which are visible with the ultramicroscope and even with the microscope and which exhibit the Brownian movement are actually molecules in the sense of the kinetic theory. These relatively large molecules were found to move with velocities quantitatively predicted by the theory. The factual bases for the molecular theory were so thoroughly demonstrated by these and similar experiments by Millikan, that even the strongest opponents of the kinetic theory have relinquished their attacks. The scientist's belief in molecules is much more than an emotional belief. The record of the kinetic theory parallels the recent progress of the physical sciences.

Another hypothesis which has enjoyed a remarkable record is the ionic hypothesis of Arrhenius. This hypothesis was put forth less than fifty years ago and in spite of the fact that it took about twenty years after its enunciation for its general adoption by the scientists, it has revolutionized the teaching of Analytical Chemistry, has given a clearer insight to the chemistry of solutions and has virtually given birth to the subject of Electro-chemistry. It has so greatly influenced life in general that it affects us at every point. The medical profession is interested in "hydrogen ion concentration" in connection with their studies on the conditions of acidosis and alkalosis. The sanitary engineer in charge of water supplies is advised to measure the pH value of the water before adding purifying reagents, and we are told that in order for a bakery to produce uniformly good soda-crackers, the baker must control the hydrogen ion concentration of the dough. With even this very brief record for a theory before us, it is evident that theories do play a role in modern scientific progress.

At the present time there are new theories on the horizon. In the field of chemistry the concept of "free energy" and that of the "quantum" are becoming effective. The concept of free energy is the child of Thermodynamics. It promises a quantitative measure of "reaction tendency." This should be a valuable guide to the practical chemist in his attempt to bring about new reactions and processes, and it is significant that even the journals of applied chemistry, such as the "Journal of Industrial and Engineering Chemistry," are already carrying articles on free energy studies.

The quantum theory, the new corpuscular theory of energy, which is thought of primarily in connection with the science of physics, is invading the field of chemistry in connection with the mechanism of chemical reaction. The quantum theory throws light on the fact that certain reactions are accelerated by one type of radiation more than they are by others, and on the peculiar fact that a ten degree rise in temperature will increase the velocity of a wide variety of chemical reactions ten times. Should the quantum theory continue to give results along these lines it will be of interest to the biological sciences as well as to Chemistry.