THE INTER-RELATION OF THE SCIENCES

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The study of the sciences as unified and related subjects has an interesting analogy in the field of physical chemistry. Research in radio-activity and in atomic disintegration has led to a conception of the elements which points out a fundamental unity between them. Recent theories on atomic structure seem to indicate that atoms of helium are the most important components of the positive neucleus of every atom, and that differences in elements are not due to differences in matter but merely to differences in numbers and arrangements of these atoms of helium and the electrons which revolve about them. Now it is important to note that although the conception of elements was originally based on the assumption that there were different kinds of matter, this classification of simple substances is still justified not only by their obvious differences but also by their practical value to the chemist.

In the same way the sciences may be shown to be as closely related without detracting from the importance of the classification into departments. This classification is necessary because the general situations presented by nature are too complex to be studied as units. Nature presents an apparently simple phenomenon such as a rainfall, but history tells us that those who attempt to solve its mysteries without classifying its various aspects completely fail to arrive at valid conclusions. Mythical gods such as Thor, the God of Thunder, were invented to explain a situation too complex for their method of research.

Instead of drawing conclusions directly from nature's phenomena, the modern scientist idealizes certain aspects and studies them separately in the various departments. It was in accordance with this scheme that Mr. John Aitken discovered the importance of dust in precipitating a rainfall by passing steam into two large receivers, one filled with ordinary air and other with filtered air. The first was filled instantly with condensed vapor in the usual cloudy form while the other remained quite transparent. In the same way Schönben explained the fresh penetrating odor noticeable after an electric storm, by passing an electric spark through oxygen and identifying the same odor.

Although our classification is entirely justifiable we must remember that nature has no such scheme in mind when she provides her phenomena, and consequently most of them do not fit conveniently into our water tight compartments. We have a good example of this in osmosis. Its character and explanation is physical, but its importance comes in chemistry, as a proof of ionization, and in biology where it explains the rise of liquids in the roots of plants and trees.

It is because our classification is more artificial than natural that we are constantly finding relations between the sciences. Each science depends upon the others, and examples of this interdependence are numerous.

The fundamental conceptions of chemistry are physical in character as well as in the method of arriving at them. The atomic theory is undeniably physical, but, at the same time it is true that its proof is based on contributions from both sciences. Historically, the chemical law of combining weights was a strong factor influencing its adoption, but recently the objective reality of the atom has been established by calculation of its mass and dimensions from data obtained from radium emanation. The close approximation between results obtained in this way and those from more indirect methods is the physicist's proof of the atomic theory.

Other chemical conceptions are greatly enriched by considering them in the light of sub-atomic physics. Oxidation in chemistry originally was a narrow and restricted term which included only the addition of oxygen to metals. If oxidation is kept entirely within the field of chemistry, there is little possibility of broadening its meaning. It is true that it may be defined as the increase of positive valence, but where these valences come from is a problem of the physical chemist. We now define oxidation as the loss of electrons with the result that not only has the scope of the term been enlarged but the very nature of its mechanism has been determined. Now oxidation is based on the ability to lose electrons so that whether it will take place in a given case can be predetermined by referring to the electromotive series which lists metals in the order of their ability to lose electrons.

Helium is an element which forms no compounds. The chemist would say that this is because it is inactive, but the physical chemist has gone much farther when he explains it as due to the inability of helium to lose electrons and thus gain a positive valence, while the phenomenon is entirely accounted for by the sub-atomic physicist who says that the helium atom is composed of a positive neucleus and negative electrons which swing in an orbit which is in perfect equilibrium, so that there is no tendency for an electron to leave it.

Probably the most obvious contribution of physics to chemistry is in apparatus embodying physical principles. Whenever chemical changes or properties are not directly observable by the senses, the physical instrument is a necessary medium. When the hands cannot detect heat we use a thermometer; when the eyes cannot perceive the arrangement of the atoms within a crystal, we use X-ray diffractions to interpret this arrangement.

The spectroscope is a true product of the inter-relation of physics and chemistry, first because it was the outcome of joint research by a physicist, Kirchoff, and a chemist, Bunsen, working together in the same laboratory, and second because it has found application in both fields. To illustrate, Bunsen applied it to the analysis of water of certain springs and thereby discovered two new elements, caesium and rubidium. In the hands of Kirchoff it explained the dark lines in the sun's spectrum as being due to absorption, and as a result it became the means of determining the composition of other planets.

Another physical instrument of value to the chemist is the polarimeter. This apparatus is used for measuring the degree which an optically active substance will rotate the plane of polarized light. Its importance to chemistry came when it was found that some substances with the same formula, which had hitherto been considered identical, differed in their effect on polarized light.

For example, lactic acid from beef extract rotated the plane to the right, being dextro-rotatory; lactic acid from the fermentation of milk sugar, with a certain ferment, was levo-rotatory, while the synthesized product was inactive. The chemist usually explains such isomers by a difference in arrangement of the atoms, but in the case of lactic acid only one structure could be conceived, unless, as Van't Hoff suggested, spatial relations were considered. So the immediate importance of the polarimeter was the incentive to study organic structure.

The inactive lactic acid referred to was found to be a mixture of the dextro and levo forms, so that the problem arose of separating them. In most cases the chemical and physical properties of two optically active isomers are the same except in their effect on polarized light, and so the usual method of separation based on differences of properties was difficult to apply. But here biology made an important contribution in the form of certain bacteria, which, when introduced into the mixture, would destroy one and leave the other. These living cells secrete complex proteins called enzymes which catalyze organic decomposition in order to use the energy liberated. Now in accordance with laws of evolution each organism will be provided with the enzyme which can attack the substances it finds in its environment, and consequently one which will be indifferent to most other substances. The mould penicillum glaucum is thus capable of destroying levo-lactic acid but is indifferent to the dextro-form, so that when it is introduced into the mixture, it will leave only the latter acid.

Aside from this practical value the study of enzyme catalysis is of the greatest importance in biological chemistry. The value of a compound as a food is largely dependent upon its ability to undergo decomposition, and since these decompositions are brought about in many cases only through the agency of certain enzymes, the question of food value becomes largely one of whether the necessary enzyme is present. The enzyme's selection of compounds has been shown to be according to the stereochemical structure of the molecule, and so one of nature's most fundamental processes, that of digestion and metabolism, may be quite as much chemical as biological.

Other complex problems of biology can often be simplified by resolving them into their physical and chemical components. Professor Lillie has shown that nerve currents, the biological basis of psychology, are essentially electrical and chemical in nature. Also, Sir Wm. Bateson, an eminent authority on evolution, believes that all its theories must be in accordance with facts of physics and chemistry. It is from this point of view that mutation, the act of differing from parent to offspring, has been resolved into problems of these two departments. Crystallization, diffusion, electric or magnetic lines of force, and harmonic vibration are factors which make for similarity between organisms from the same source; so that to find conditions which would modify these factors is to form a basis for the explanation of mutation. The contribution of physics has been such conditions as temperature and pressure, while the chemist has been studying the effect of colloids on crystallization, all of which show that mutation is not as obscure a process as it appears on the surface.

The biological discovery of insulin as a cure for diabetes had little practical value until the chemist had worked out a method of preparing it in quantity. The biological method was to extract it from the pancreas of a dog, by first destroying the pancreatic juices in order that they would not digest the insulin. Since this process required six months it was impractical, and the problem was turned over to chemists. After a year of research they were able to prepare it from the sweetbreads of cattle so that now the industry is able to supply the 18,000 people in the U. S. who take insulin daily. The function of insulin is to destroy the excess sugar in the blood, and the amount administered must be exactly in proportion to this excess, for an overdose of insulin is harmful to the patient. The difficulty is that in a given dose the amount of pure insulin is not known, so that its strength has to be determined by injecting it into a rabbit and measuring the amount of sugar destroyed. The present problem of the chemist is to prepare a compound of such purity that its strength will be known directly, thus eliminating the trial and error method.

We have thus shown how each science is dependent upon the others. It may have become evident that whenever one science has contributed to another, the contribution comes back much more useful to its original department. The chemist borrowed the electron theory from the physicist, developed it as an explanation of oxidation, then returned it to the physicist much more valuable because now he could use it in explaining the Voltaic cell and the storage battery. In the same way the spectrum came back to the physicist in the form of the spectroscope which he could use in explaining the dark line spectrum of the sun and in determining the composition of other stars. The biologist's knowledge of enzymes was greatly increased by loaning them out to the chemist for use in stereochemistry. Biological methods could never have found that the ferment's choice of foods depends upon so insignificant a thing as the interchange of a few hydrogen and hydroxyl groups.

It is such illustrations as these which show that if the inter-relation of the sciences is put to practical use, as is being done in the border-line sciences, it will lead to a greater exhaustiveness and accuracy in scientific research.