CREATIVITY IN INORGANIC CHEMISTRY BASED ON THE LITERATURE*

JOHN R. VAN WAZER
Monsanto Chemical Company, St. Louis, Missouri
Received November 8, 1961

The word "creativity" is as much abused today in the midst of the Scientific Revolution as was the word "chastity" in the Middle Ages. As is the case with chastity, creativity is something to be practiced in appropriate circumstances but not to be talked about. However, since the subject matter of this symposium is "The Chemical Literature as the Basis of Creativity," the word cannot be avoided. For the purpose of the following discussion, I shall define "creativity" as making worthwhile contributions to the fundamental scientific literature—in this particular instance, to the literature concerned with inorganic chemistry.

About a hundred years ago, chemists found it desirable to divide the descriptive part[1] of their discipline into two sections: organic chemistry, which deals with the compounds of carbon, and inorganic chemistry, which deals with all of the elements and the compounds of the hundred odd elements other than carbon. Since that time, organic chemistry has become the main branch of descriptive chemistry, with inorganic chemistry being a more or less hodgepodge collection of miscellaneous data.

From the early days of chemistry up until around 1890, inorganic studies were a major concern of chemistry. However, descriptive inorganic chemistry practically died out in the first quarter of this century. Now, however, there is a renaissance under way—a renaissance which is due, in great part, to the fact that good inorganic chemical research requires a degree of theoretical and experimental sophistication which only recently is becoming available.

Ideas from the Current Literature.—Throughout most of organic chemistry, it is necessary for the scientific investigator to read the current literature in order to make sure that he is not working on a problem recently investigated by someone else and also to tie together pieces of information closely related to his own studies. This is usually not the problem in present-day inorganic chemistry, where it is quite easy to stake out an area that has received little or no attention for many years. When there are other investigators in the same field, they are generally relatively few and their names and works can be followed more easily than in the more crowded areas of science such as, say, biochemistry or nuclear physics.

It has been noted previously that good inorganic research requires considerable sophistication in both the theoretical and experimental approach. This means that the practicing inorganic chemist must be greatly concerned with the literature on new physical methods and improved or simplified ways of interpreting physical data. Simultaneously, he should also keep his eyes open for technical or trade literature describing newly introduced or significantly improved apparatus. Chromatographic procedures, both in the liquid and gas phases, and nuclear magnetic resonance for boron, phosphorus, fluorine, and hydrogen are examples of physical tools capable of elucidating questions which, until recently, could not be answered.

Large, previously unexplored areas of inorganic chemistry deal with rather labile substances, the molecules of which readily reorganize into other structures by exchange of parts. Another area of broad interest is the determination of molecular structures in amorphous solids for which there are no nondestructive solvents. Any information, ranging from pure theory to practical laboratory operations, on these subjects should be of prime value to the majority of practicing inorganic chemists.

Ideas from the Early Inorganic Literature.—In many areas of science, the literature of 50 to 100 years ago is of historical interest only. This is not true of inorganic chemistry. As stated previously, inorganic chemistry was a very lively subject a century ago, but practically everything the investigators of that time discovered was a puzzle. This early literature is a tremendous fountainhead of ideas for present-day study. Furthermore, it is occasionally possible to take some of these early papers and reinterpret them in light of modern theory. I have found that Mellor's Treatise[2] is a very valuable key to the early literature, although the interpretation and conclusions given in Mellor are usually hazy and often simply incorrect.

In reading this early literature, attention should be paid to fine details, such as casual descriptions of properties which the original investigators did not feel were significant. Thus, a "simple salt" exhibiting slimy viscous solutions at low concentrations probably is not simple at all but a complicated macromolecule. Because of the need for close attention to details (often ignoring the principal conclusions given by the author), it is necessary to read the early literature in its original form. Abstracts, except for some of the more recent review publications, are of little value in themselves.

The Future of Inorganic Chemical Research.—From the present-day literature in inorganic chemistry, it is possible to make some predictions concerning the future of this science. First of all, it seems that separate descriptive chemistries will be developed for many of the elements toward the top center of the Periodic Table. Thus, it is expected that the chemistry of boron, aluminum, silicon,

(1) Broadly speaking, descriptive chemistry deals with the way atoms are assembled into molecules and molecule-ions, as well as the physical properties, methods of synthesis, and chemical reactions of the elements and their compounds. A chemical compound may be defined as a collection of like uncharged molecules or small whole-number proportions of only a few different ions or molecules. An ion is a charged atom or molecule.

(2) J. W. Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Longmans, Green and Company, New York, N. Y., 1922.

* Presented before the Division of Chemical Literature, Americal Chemical Society Meeting, Chicago, Illinois, September 4, 1961.

phosphorus, sulfur, germanium, and arsenic, among others, can be developed into disciplines covering about as much ground as organic chemistry. However, each one of these subjects will have somewhat different rules of the game.

Another contribution to come from the renaissance in inorganic chemistry may well be a better understanding of the underlying principles of chemistry. I am firmly convinced that certain types of chemical behavior, which are not considered as general phenomena, are specific to the compounds of carbon. Likewise, there are probably a number of examples of chemical behavior which either are not found in the area of organic chemistry or are curiosities therein but which will prove to be of general applicability to a number of other elements. An example of this is the type of behavior which organic chemists call "redistribution reactions."

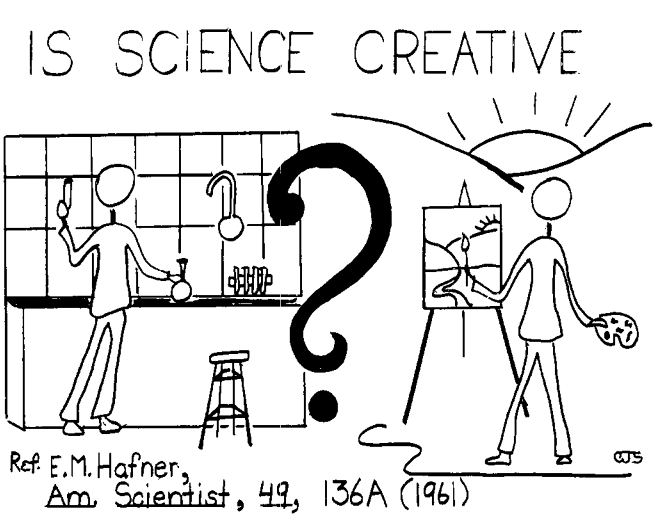
At present it seems that there are two broad and basic challenges facing chemists. One is biochemistry, which consists of the elucidation of the physical-chemical basis of life. The other is inorganic chemistry, the mission of which is to prepare and understand the behavior of a myriad of potential new compounds which are not found in nature. The title of a film concerned with organic plastics, shown by the Monsanto Chemical Company several years ago, is "The World that Nature Forgot."[3] The part of this world dealing with the compounds of carbon has been rather well studied by organic chemists. The challenge of inorganic chemistry is to explore the part of the world that nature forgot which deals with the hundred odd other elements!

(3) "The World That Nature Forgot," Modern Talking Picture Service, Inc., 45 Rockefeller Plaza, New York, N. Y., or any of the M.T.P.S. film—distributing centers in 28 principal cities; or from Monsanto Chemical Company, Public Relations Department, Film Library, St. Louis 4, Mo.

CREATIVITY IN PHYSICAL CHEMISTRY BASED ON THE LITERATURE*

By HILTON A. SMITH
University of Tennessee, Knoxville, Tennessee
Received November 8, 1961

In a recent article dealing with creativity in science, E. M. Hafner, Professor of Physics at the University of Rochester, suggested that, "It is easy to suspect that the observational sciences cannot be truly creative. The natural scientist discovers things by looking keenly at the world. He does not—or at least should not—invent his data. He may construct ingenious experiments, but he designs them in order to bring into the laboratory whatever small part of the world he wishes to observe more precisely."[1] Dr. Hafner goes on to say that "if we define an act as creative only if it brings something new into existence, scientific activity can be regarded as uncreative"



* Presented before the Division of Chemical Literature, American Chemical Society Meeting, Chicago, Illinois, September 4, 1961.

when compared with literary, graphic or musical arts. He does point out, however, that in any scientific system, "laws can be derived from abstract principles, but the truth of the principles themselves cannot be proved." Thus one can regard science as a framework for creative work of the highest calibre. The scientist is attempting to create a true picture within the framework of science itself.

Chemists may well challenge Professor Hafner on the basis of the fact that molecules which are not only unknown, but may never have existed, are created by both organic and inorganic chemists. These are, however, created not by chance, but in the light of hypotheses such as those referred to by Dr. Hafner and which in themselves are creations. If, then, one considers physical or theoretical chemistry in reference to creativity, he must recognize the fact that it is, to a large measure, a creative field in the sense used by Dr. Hafner; one must also recognize that it is virtually impossible to separate it from the other branches of chemistry or from physics.

No individual physical chemist can divorce himself from the literature which of course contains the experimental findings and theoretical deductions of his predecessors and colleagues, for science has become too complex to allow any worker to ignore the efforts of others. The subject of this article deals with the actual creative aspects of physical chemistry which are based on such literature. This has been rather arbitrarily divided into three phases:

1. The introduction of new instruments and continued improvement of those types already available make possible measurements of physical properties with ever greater precision, and often allows measurements of a type not hitherto possible.