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Whither physical organic chemistry, or to what degree does it really exist? A personal view

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Biography: George Olah was born (1927) and educated in Budapest, Hungary. He moved to North America in 1957. Since 1977 he is Director of the Loker Hydrocarbon Research Institute and Distinguished Professor of Organic Chemistry at the University of Southern California, Los Angeles, California. He is a member of the US National Academy of Sciences, a Foreign or Honorary Member of other Academies and received Honorary Doctoral degrees from several Universities, including the University of Durham (England), the University of Munich, the Technical University of Budapest, University of Crete, the Universities of Szeged and Veszprem (Hungary), The University of Southern California, and Case Western Reserve University. His contributions to superacid/carbocation chemistry and electophilic chemistry of saturated hydrocarbons were singularly recognized by the award of the 1994 Nobel prize in Chemistry. Apart from the Nobel Prize, Olah's work has been recognized by many honors and awards. He is the winner of the American Chemical Society's Award for Petroleum Chemistry, Creativity in Synthetic Organic Chemistry and Roger Adam's Medal, Michaelson-Morley Award, Chemical Pioneer Award, California Scientist of the Year, *etc.* He has published more than 1000 scientific papers, holds 100 patents, and authored or coauthored 15 books and monographs.

Having been invited to contribute to the Symposium in Print "Physical Organic Chemistry for the 21st Century" I would like to briefly express my personal views. I must first of all say that I never considered myself as someone to be categorized into any specific narrow branch of chemistry. Chemistry is the science that deals with the composition, structure, and properties of compounds of the elements, as well as their transformations. As such it encompasses the entire material universe and thus is central to the understanding of other sciences. Because of the broadness of chemistry it is usually subdivided into major branches, such as organic, inorganic, physical, analytical, and biological chemistry. This division, however, is very frequently artificial. To me chemistry is indeed a broad, central science without any artificial boundaries. I recently had the occasion to express my views on the generality of chemistry to a wider audience of science (1) discussing the many facets of chemistry. Mankind's drive to uncover the secrets of living processes and to use this knowledge led to spectacular advances in the biological and health sciences. Chemistry richly contributes to this by helping our understanding at the molecular level. At the same time biotechnology in no small degree is based on chemical methods and processes. However, this is only one end of the spectrum. Chemistry is not just an adjunct of biology or the health sciences.

Chemistry enables us to understand the structure of compounds, the bonding nature involved in them, their physical and chemical properties, *etc.* Chemists also make compounds and strive to understand their reactions including their mechanisms. Synthetic chemistry produces all the man-made materials essential to modern life, from pharmaceuticals to textiles, from polymers to fuels, from biomaterials to composites, and everything else. With all this diversity, however, all chemistry is governed by the same principles.

I always pursued chemistry by making compounds and developing new reactions and processes. At the same time I was also interested to find out how these reactions really work, *i.e.*, what their mechanisms are and in particular studied reaction intermediates. I never considered, however, that by also applying physical methods and concepts to my organic (or for this reason inorganic) research I was just a "physical organic" chemist. As an example, the knowledge of carbocation intermediates based on their direct observation was a long standing challenge. We finally mastered their preparation in superacidic solutions and carried out many physical (spectroscopic such as IR, NMR, UV, electron spectroscopy, *etc.*) studies on these systems. At the same time related synthetic chemical investigations opened up the whole new field of the electrophilic reactivity of single bonds, including C-H or C-C σ-bonds of saturated hydrocarbons. This turned out to be more interesting and significant than the mechanistic-structural studies themselves.

My idol in chemistry was and always will be Hans Meerwein. Meerwein was one of the pioneers of what became known as physical organic chemistry, because he was one of the first to apply reaction kinetics as a tool to establish mechanistic aspects of reactions he was interested in. He applied kinetics in 1922 (2) to the study of the Wagner rearrangement of camphene hydrochloride to isobornyl chloride, showing both the effect of solvents and Lewis acid catalysis. From his results he concluded that the reaction of a neutral compound proceeded through a cationic intermediate to the neutral product, a strikingly novel suggestion at the time. Meerwein, however, never considered himself belonging to any hyphenated sub-group of chemistry and was content just being a chemist.

What we now know as physical organic chemistry grew to its recognized role through much fundamental research such as that of Ingold and Hughes and many following in their footsteps. They used initially the tools of kinetic measurements and stereochemical studies to establish for example such pathways as those of the S_N1 and S_N2 reactions. Subsequent development of varied spectroscopic and analytical methods ranging from IR-Raman, to NMR and ESR spectroscopy, to mass spectrometry, to various chromatographic methods (GC, LC, *etc.*) including computerized and automated methods, to various even more efficient and sophisticated analytical methods, to the spectacular advances through computerized methods and computational chemistry all greatly helped organic chemists and they increasingly use all available physical methods in their studies.

P. D. Bartlett of Harvard used to say that physical organic chemistry is a wonderful field for training young scientists, but *per se* it is not a separate area of research. I share his view. We should apply the methods of physical organic chemistry to any appropriate problems of chemistry to be solved. The 21st Century, I am sure, will bring many further advances to chemistry. We should try to stay, however, as broad as possible in our approach to chemistry. Even if physical organic chemistry is maintained as a separate discipline, particularly for teaching and training, we should be always aware that it offers primarily a collection of wonderful tools and methods to be used in chemistry and biochemistry, but is not necessarily an isolated field on its own. It must also be recognized, that whereas there may not be many jobs for physical organic chemists as such, but there always will be a need for chemists who are trained in using the methods and concepts of physical organic chemistry. Let's emphasize after all that from molecular biology and biotechnology through revitalized inorganic chemistry to material science, *etc.*, in all areas where chemistry plays a role the methods and techniques developed by physical organic chemists are essential.

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