THE IMAGE OF CHEMISTRY

By Dr. Anthony M. Trozzolo
Charles L. Huisking Professor
of Chemistry
November 7, 1975

THE IMAGE OF CHEMISTRY

The following is an address given by Dr. Anthony M. Trozzolo on the occasion of his inauguration as Charles L. Huisking Professor of Chemistry at the University of Notre Dame on November 7, 1975.

Dr. Trozzolo joined the Notre Dame faculty from the technical staff of Bell Laboratories where he was involved in significant work developing practical applications of organic photochemistry. He is associate editor of the Journal of the American Chemical Society *and an elected fellow of the American Institute of Chemists, American Association for the Advancement of Science and the New York Academy of Sciences. Dr. Trozzolo has been Reilly Lecturer at Notre Dame as well as Phillips Lecturer at the University of Oklahoma and Brown Lecturer at Rutgers. He received his Ph.D. from the University of Chicago in 1960.*

The Huisking Chair was named for the founder of Chas. L. Huisking & Co., Inc., the parent company of Glyco Chemicals, Inc., and was given to Notre Dame by the Huisking Foundation.

Father Hesburgh, Father Burtchaell, and other officials of the University; members of the Huisking family, especially Bill and Claire; trustees of the University; members of the advisory councils of science and engineering; Dean Waldman, Dr. Freeman and other colleagues in the College of Science; colleagues from Bell Laboratories; students, relatives and friends. Today we are here to acknowledge the merging of two names on one individual. It is a distinct honor for me to take on the title of the Charles L. Huisking Professor of Chemistry because I am aware of the contributions which Charles L. Huisking made to the University of Notre Dame and the aspirations which he had for its future. In a larger sense, it is he whom we honor on this occasion.

Charles L. Huisking was born in Brooklyn on February 2, 1885, was graduated from the public schools, and went to St. John's High School for a few months before ambition led him to a job as office boy at the age of 13 for Thomas M. Curtius, a drug broker in Manhattan. Charles quickly learned the business in the drug brokerage field and within 12 years left his first job and began his own business setting up Charles L. Huisking & Co., Inc., with which he was affiliated until his death.

The story of his colorful life in the drug and chemical fields from his days with Thomas Curtius to 1968 is recorded in a book which he wrote entitled: *Herbs to Hormones — The Evolution of Drugs and Chemicals Which Revolutionized Medicine.*

He married Catherine Frances Perridge on August 29, 1911, and from this marriage were born eight children, seven of whom are still living. All of the five Huisking sons, as well as four grandsons, are Notre Dame alumni, and one grandson is currently enrolled. Four of their granddaughters, including one Holy Cross sister, are alumnae of Saint Mary's College, and one granddaughter is currently enrolled.

A son, William, who is here today, is a member of Notre Dame's Advisory Council on Science, and a vice president of the Huisking Foundation, established in 1946 to honor the memory of a brother killed in World War II. The Foundation has supported a scholarship fund at Notre Dame since 1947. In addition, Charles L. Huisking served 17 years on Notre Dame's Advisory Council for the Colleges of Science and Engineering. He clearly made a magnificent contribution to this University.

Our presence here represents the intersection and interaction of the lives of many people. First, there is the Huisking family, for it is through their generosity that this particular position, which I now hold, came into existence. The Huisking Chair of Chemistry is one of two endowed faculty chairs given to the University by the Frank R. Huisking Foundation of Greenwich, Connecticut. The other is a chair in theology, named for Charles' wife, Catherine Huisking.

Secondly in this interaction of people, there is the University administration, with Father Hesburgh, Father Burtchaell, Dr. Frick and others, who appreciated the continuing needs of the University for sustained excellence in scholarship and teaching. In addition to the administration there are many colleagues in the College of Science, and in particular the Department of Chemistry, who have already provided me and my family with a warm welcome to the University. It is my fondest hope that the confluence of my life with theirs will be a continually rewarding experience for both us and the University.

Thirdly, there is the path which has brought me here. This path includes my parents, Pasquale and Francesca Trozzolo, who left the sunny skies of southern Italy in order to seek a more prosperous life and greater opportunities for their children. Their sacrifice on behalf of me and my brothers can never be compensated adequately. My brothers, Ralph and Mario, set a high standard of scholarship which greatly influenced my horizons and expectations. Then there are my teachers and professors who encouraged and sustained my interest in chemistry, and in particular my research advisor at the University of Chicago, Prof. Wilbert H. Urry. I would be remiss if I did not mention the great influence which my former colleagues at the Bell Laboratories have had on my research interests and the tremendous degree of interaction which we enjoyed during my 16 years in that organization.

And finally, there are the most important people in my life, namely my wife, Dolly, whose patience and encouragement have constantly bolstered me during the course of my career, from the sacrifices in graduate school down to the present time, and our children, who have been a source of consolation to both of us. I am particularly pleased that all of the groups that I have mentioned are here today.

The title of this lecture, "The Image of Chemistry," came about because I wanted to emphasize two areas of my own experience in the field of chemistry. Much of my recent research has involved studies of photochemical systems, that is, systems which undergo transformations in the presence of light. A specific example of these is in the reaction which results in a change in color, and this phenomenon, when the color change is reversible, is called photochromism. This type of photosensitive system can be used to generate "instant" images.

The second activity in which I have been involved is in the area of chemistry and public affairs. At the present time I serve on the Joint-Board-Council Committee of the American Chemical Society, which is concerned with chemistry and public affairs. This, therefore, is a particularly appropriate time to share with you some thoughts regarding the public image of chemistry, how it affects those of us who are chemists, how accurate it is, and what might be done to improve its luster.

The word "image" means a likeness or perceived form of another object or entity. The image and object are never one and the same. A mirror image, for example, is clearly not the same as the object it represents. So our images are perceived, but clearly do not coincide with the object of reality. So it is with chemistry. While a substantial proportion of the image of chemistry is perceived directly as smog, automobile exhaust, billowing smokestacks and eutrophicated lakes, a sizeable contribution to the general public's image of chemistry is perceived indirectly in much the same way as the realities of Plato's "Den of Shadows" in *The Republic* were perceived as shadows on a wall.

The major producers of these shadows, or images, of chemistry are the mass media, whose purpose oftentimes seems better attuned toward sensationalism rather than providing a balanced point of view. What is particularly distressing to a chemist is that, frequently, deleterious ecological or environmental processes are stated clearly as being caused by chemistry, whereas beneficial effects, such as the synthesis of a new and potent drug or the elucidation of a molecular mechanism for a specific disease, are classified as advances in medicine and molecular biology, respectively. Chemistry is easily indicted but sparingly praised. Perhaps part of the reason for the inadequate recognition lies in the central position of chemistry in the material and life sciences; its borders pervade those of its neighbors so much so that a chemical contribution can be easily masked.

Now the consequences of this contemporary image of chemistry can be seen in the changes in the number of graduate students in chemistry throughout the country. Although the number of undergraduate majors in chemistry has actually increased, it appears that many of those students prefer to transfer to medical and biosciences rather than continue in graduate school in chemistry. One should not underestimate, however, the economic factors involved in those changes, for it is also clear that the number of positions available to Ph.D. chemists has been severely affected in recent years.

However, I cannot help but feel that we are losing some of our best-qualified chemical minds at the undergraduate-graduate interface because of the image that chemistry connotes.

But here is the challenge for those of us who have known the profession of chemistry intimately and are responsible for the training and education of future generations of chemists. The great problems of our times invariably involve unfulfilled human needs. Almost all, if not all, of these problems contain a materials- or life-sciences aspect in which chemistry plays a major role, and this includes those problems of ecology, environment, food, population and energy, which are often used by the mass media to implicate some aspect of chemistry as being causative. It does not require much imagination to realize that the solutions to many of the problems are going to require a fairly substantial amount of chemical input by well-qualified chemists with a broad spectrum of interests. It is our responsibility as educators to point out the tremendous challenges and opportunities which chemistry offers as a career to those persons who are well qualified and eager to help in the solution of the myriad of problems affecting our environments and ourselves. *For the problem is not that we have known too much, it is that we know too little.*

The technological backlash with its effect on the image of chemistry has resulted from our failure to understand the complexities of chemical and biological systems both on a large scale and at the molecular level. By learning more about the chemistry of these systems, it is usually possible to make the appropriate adjustments in the systems. But does this mean that in order to improve the image of chemistry we must do only applied research and solve practical problems that are presented to us in our environment? There seems to be a paradox in our choice of type of research. For on the one hand, we would like to be able to delve into the secrets of nature, but at the same time there are the existing problems crying out for solution. This paradox has been treated as far back as 1959 in an excellent talk by Dr. William O. Baker of the Bell Laboratories. At a symposium on basic research he pointed out that it was necessary to maintain a balance of basic and applied research in a given area.

In my own experience, I have seen many examples supporting this particular thesis, and I'd like to illustrate this point with a couple of examples. The first example has to do with a problem which started out as one in purely basic research and turned out to have fairly interesting practical implications. We were interested in studying the low temperature photochemistry of a three-membered ring system containing two carbon atoms and an oxygen atom, a system of compounds known as oxiranes. It turned out that in studying the reaction of these systems at low temperature, we found that the three-membered ring fragmented to give some rather interesting chemical intermediates, and we were able to actually study these by certain spectroscopic methods. However, we also found that there was a colored species which was being formed for which we could not, at that time, identify a structure. Subsequent work with Thap Do Minh led to the formulation of a suitable structure, and we found that the coloration actually reversed itself in the dark, forming the original colorless system. It then became of interest to us to see if we could stabilize that colored system, and this ultimately led to a series of papers on the photochemistry of a three-membered ring system in which the oxygen of the previously mentioned system had been replaced by nitrogen. These systems are called aziridines. Now, in addition to the colorations, we began looking at the crystals of the compounds that formed the systems and were very much surprised to find that, when observed in polarized light, the crystals, even though they all appeared to be blue in color, were in fact of different colorations. And the interesting point was that in one polarization they would appear colored, and in the perpendicular polarization they would appear colorless. This particular property is the same property which Edwin Land was able to use to produce Polaroid for the first time. So here we have an example of a situation in which a study which began as basic research ultimately yielded useful results and devices.

The second example deals with a problem which started out initially as a practical problem, yielded some fundamental information, and this fundamental information was then used later in establishing a mechanism for a second practical problem. Here the process is the photodegradation of polymers, that is, the deleterious effect that light and oxygen of the air have on various polymers over a period of time. Some years ago, we became interested in the mechanism by which this particular process occurs and, in these studies, we concluded that one of the important intermediates in this degradation was an excited state of molecular oxygen; and in 1968, Field Winslow and I published a paper detailing this mechanism. In fact, the singlet excited state of molecular oxygen seems to have been implicated in a large variety of different chemical reactions and is one of the more extensively studied species at the present time.

Some years later, Dr. Angelo Lamola, who was interested in photobiology and had come to Bell Labs from the University of Notre Dame faculty, described a skin disorder which involved extreme photosensitivity. This particular disorder is known as erythropoietic protoporphyria, and the symptoms are the extreme sensitivity to light which leads to hemolysis, or breaking up of the red blood cells, with ultimate lesions both on the exposed parts of the face and, often, in the extremities.

Beta-carotene, which is related to vitamin A, had been shown to be a fairly good remedial compound to reduce the symptoms. And since it was known that beta-carotene is a good quencher of singlet molecular oxygen, it appeared that these excited states of oxygen might be playing a role in this particular disorder as well. We knew, for example, that there was an excess amount of a substance, protoporphyrin, in the red blood cells of patients exhibiting the disorder, which could conceivably be acting as a photosensitizer. The question was, where might the singlet oxygen be attacking the red blood cell? We looked at the composition of the lipid (fatty) fraction of the red blood cell, and picked out cholesterol as a fairly probable substrate, or position of attack, for the singlet molecular oxygen. We subsequently obtained evidence consistent with this view, and so we put forth a mechanism. In work that Dr. Lamola and I did in collaboration with Susan Fahrenholtz and Frank Doleiden, we later found that, indeed, cholesterol and the unsaturated fatty acids are attacked quite readily by the excited singlet state of oxygen. We also found, somewhat surprisingly, that vitamin E, alpha-tocopherol, which had been earlier shown to be a natural anti-oxidant, was in fact capable of quenching, or stopping, these excited states of oxygen. Also, it had been shown that alpha-tocopherol was effective in diminishing the symptoms of the disorder, and in fact had been used for treating the disorder.

Armed with that information we were now able to go back and design new kinds of photostabilizers for the polymeric system; for obviously chemistry doesn't really know if it is part of a biological system or whether it is part of a nonbiological system. This indeed was the case, for we, as well as others, were able to show that certain stabilizers which were effective singlet oxygen quenchers were also quite effective in stabilizing polymers such as polyethylene from the effect of degradation in the presence of light.

Our third example is one which again involves a practical problem in which one was able to generate new fundamental information, put that information to use in solving the practical problem, and also go back and get additional fundamental information regarding the system itself. This system has to do with the development of a tunable dye laser, and it is work which I did in collaboration with two physicists, Chuck Shank and Andrew Dienes, who were interested in constructing a dye laser system which could be tuned over a very wide wavelength range, so that one could presumably have laser light at almost any wavelength in the visible range.

(The reason for desiring this tunability is that, eventually, one will be able to use laser light to transmit information over optical fibers.)

The search involved some rather fundamental principles of photochemistry, and the idea was to develop a system which would have a fairly wide wavelength range for the laser action. The principle which involves the formation of several species in their excited states (exciplexes), each of which is capable of producing this laser light, was realized in a system which involves a material that very often is used in the optical brighteners that we see added to textiles—it's a compound called 4-methyl umbelliferone, and that particular compound has the somewhat unusual ability of becoming both a stronger acid and a stronger base when it absorbs light. Because of these changes, it is able to form both its anion and its tautomer in excited state reactions, which then means that, instead of having one species which emits light, we actually can have the possibility of three; and since each of these has its own fluorescence spectrum, it is, at least in principle, possible to have a laser which can be tuned over those three emission ranges. This was indeed the case, and this device, as far as I know, still has the widest tunable range of any single dye laser made from one solution.

With these three examples, I think that one can see that it is possible to solve practical problems while at the same time gathering fundamental information. Invariably, there is a lack of fundamental information in solving practical problems, and the only way to find it is to do basic research. At a university, basic research has a double function. While it is stretching the borders of our knowledge, it is also serving to educate our future generations of scientists. At the same time, when one is doing basic research, it is important to have an awareness that one's basic research may be useful in other areas, whether in practical problems or in related studies, perhaps even within the same discipline. For example, there is nothing that should hinder an organic chemist from being able to use his systems or measure his systems with the tools of the physical chemist, or to interact with physical chemists in taking on a problem which is of biological interest; because it is through this kind of interaction that one's own spectrum of interests begins to broaden. And it seems to me that it is one of the areas where the universities, because they have communities of qualified scholars, can make a great contribution by encouraging the interaction between scholars not only of the same discipline, but of neighboring disciplines.

This brings me to the next topic, which is the image of chemistry at Notre Dame. Historically, chemistry has been a strong area at the University, certainly since the time of Father Nieuwland, who discovered some of the basic reactions for making synthetic rubber. So there has been a strong tradition in organic chemistry since that time. Later, the department was strengthened in physical and in inorganic chemistry; and with the advent of the Radiation Laboratory, the department increased its visibility and reputation. Within the last 10 years there has also arisen a young and already accomplished group of biochemists who have added to the strength of the department. In the most recent evaluation of graduate departments, namely, the Roose-Anderson Report, the chemistry department was considered to be in the "strong" category. However, it should be pointed out that if we are to maintain this position and be able to prepare our students so that they can compare favorably with their counterparts from other universities, it is necessary to continually reassess the extent and up-to-dateness of our laboratory facilities since they are so important in any experimental science.

There is no reason why we should not continue to grow in reputation if we are willing to interact with ourselves, if we realize that it is not just the students who need our skills and our backgrounds but it is our colleagues who can learn from us, and perhaps even more important, we can learn from them. And from these interactions, each of us individually, whether professor, postdoctoral or student, will become stronger, not only in our basic discipline, but in developing an increasing awareness of the kinds of problems that our particular background may be able to pervade. And then, although the image of chemistry may not achieve the luster of the Golden Dome, if we give of ourselves to our colleagues and to the tremendous problems that envelop us today which require chemical input, then I think that the image of chemistry within ourselves will be sufficient reward for the effort, and it will, perhaps, bring to mind the words which Kingman Brewster wrote in his preface to Father Hesburgh's book, *The Humane Imperative:* ". . . Notre Dame is one of the few universities I know that reminds the visitor, as well as those who work and study there, that learning at heart is a morally motivated act."

It is this special character of the University that has attracted many of us to Notre Dame. The image of chemistry very much needs that special quality, too.