Pure Appl. Chem., Vol. 73, No. 8, pp. 1229–1230, 2001.

Chemistry in the 21st century. A central science or a "back office" technical activity?*

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Abstract: The science of chemistry underlies all of our work in the environmental area and in the new technologies exemplified by materials science and molecular physics. For these areas to progress, chemistry must continue to be a creative and innovative source of new ideas rather than just a handmaiden for currently identified problems in these closely allied areas of study.

The beginning of the 20th century saw the discipline of chemistry change from an observational science to one focused on the synthesis of new materials. The production of synthetic dyes and the conversion of coal tar into a variety of useful chemicals illustrated the versatility and utility of a science that could exploit the molecular structure of naturally occurring materials. In many cases, the technology moved ahead of the science, with the study of detailed molecular structure and specific chemical reactions following the demonstrated utility of certain chemical processes. At the end of the 20th century, as pointed out by Shenda Baker in a review of "The New Chemistry" in *Science* (April 13, 2001, p. 226), "Nearly everything we use has been created, influenced, enhanced, or preserved by chemistry". This ubiquitous utility of the chemical sciences is offset by the view that "chemicals" are at the heart of many of our environmental problems, both old and new. The fact is generally ignored that chemical principles, properly applied, are also our best hope for the remediation of existing environmental problems and the creation of "environmentally friendly" new processes to meet our needs for sustaining a high quality of life.

During the last 50 years, we have exploited our ability to use chemical principles to solve problems in a variety of areas. In so doing we have designated many sub fields of chemistry as new disciplines in their own right, and we have become handmaidens to progress in other fields. Examples of the first category include materials science and molecular physics. Molecular biology and environmental science are examples of the second category. In many of these activities, chemistry has become a tool and a skill and knowledge base to support work in physics, biology, and even computational science, in much the same way that businesses use accountants and information specialists to handle the "back office" support of their commercial activities. In the area of the environment, chemistry is used mainly to mitigate the effects of unwanted waste products either by remediation processes or in "end-of-process" containment procedures. These are all worthwhile and necessary activities where chemical knowledge and skills are necessary. However, the real value of chemistry to environmental problems comes from the invention, design, and development of new chemical processes that minimize waste and energy usage and rely on raw materials that can be obtained and transported in environmentally friendly ways. These are the processes that can fairly be called "green chemistry". The research and devel-

*Lecture presented at the IUPAC CHEMRAWN XIV Conference on Green Chemistry: Toward Environmentally Benign Processes and Products, Boulder, Colorado, USA, 9–13 June 2001. Other presentations are published in this issue, pp. 1229–1330.

opment needed to produce such processes should be one of the major foci of chemistry programs in both the fundamental research in universities, and the targeted longer-term research in government laboratories and industrial facilities. As the chemical infrastructure ages, chemical research should be challenged to have new, "green chemistry" processes ready for the design for new facilities, which will produce the needed chemical products for this century. Specific targets that are worthy of some new imaginative chemistry include the conversion of carbon dioxide and water to new, usable chemicals; the incorporation of biological catalysts in process chemistry that can be carried out at low temperatures, have high selectivity and high efficiency; catalytic processes that can "crack" large, naturally occurring molecules selectively in a one-step conversion; and the selective chemical conversion of methane into hydrogen-rich, useful chemicals. Projects with these objectives will require new and imaginative chemical thought and "out-of-the-box" experimental design methods. However, they will be real chemistry that will not be confused with other disciplines, and they will not be part of the chemical services relegated to "back office" obscurity. They will also return chemical processes and the production of chemicals to favorable activities in the public's view. That is not too much to be expected for a science that contributes in so many ways to our well-being and our quality of life.