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Insight: Green chemistry: the key to our future

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Chemistry is not merely a science of making observations in order to better understand nature. Our science is creative and productive, generating substances and materials of very high value from almost nothing. In view of its significance, chemical synthesis demands the highest level of scientific/technological creativity and insight to explore its limitless possibilities.

Some years ago, the National Academy of Engineering in the United States characterized the 20th century as 'A Century of Innovation' (Constable, G.; Somerville, B. 'A Century of Innovation', 2003, Joseph Henry Press, Washington D.C.), and selected the 20 technologies that have most decisively transformed our lives. The first was electrification, followed by the automobile, the airplane, water supply and distribution, electronics, the radio and television, agricultural mechanization, the computer, telephony, air conditioning and refrigeration, the highway, spacecraft, the Internet, imaging, household appliances, health technologies, petroleum and petrochemical technologies, lasers and fiber optics, nuclear technologies, and high performance materials. Without these inventions, we could not have realized the affluent civilized society we live in today. Most of the items on this list are based on physical principles and were realized through the chemical supply of man-made substances/materials with the aid of engineering. Thus, the contribution of our science to the quality of life is enormous. We are rightly proud of being chemists.

Chemical synthesis must pursue the goal of 'practical elegance'; it must be logically elegant and at the same time technologically practical. We must manufacture useful compounds in an economical, energy-efficient, resource-preserving, and environmentally benign way. Thus 'Green chemistry' is not a mere catch phrase; it is the key for the survival of mankind.

Catalysis remains one of the most important technologies in this regard. In fact, over 80% of chemicals are now produced using catalysis. The world market for catalysts is about USD 15B, and chemical production through catalysis is estimated to be USD 7T. Thus, practical catalysis, either heterogeneous, homogeneous, or biological, must be rapid, capable of mass production, and selective. Currently, the industry is in need of thermally stable enzymes that are resistant to salts, acids, and/or bases.

Modern health care relies on development of efficient pharmaceutical drugs with a precise three-dimensional and functional structure. Although the organic syntheses used for this purpose have reached a high level of sophistication, they still proceed in a step-by-step fashion. Ideally, the target compounds would be produced with a 100% yield and 100% selectivity without unwanted waste. In this regard, the concepts of 'atom economy' and the 'E-factor' must be taken into account. The 3Rs (reduce, reuse, recycle) of resources in process management are also important. Furthermore, in order to enhance the power of chemical synthesis by removing current thermodynamic restrictions, I strongly recommend that our young generation develop (1) a 'photo-synthetic' catalyst that facilitates a thermally unachievable, energetically uphill reaction, and (2) a 'single-step cascade synthesis' using multiple components. The latter would require an 'artificial cell' consisting of a well-designed multi-catalytic system and suitable co-factors.

Our science is inextricably linked with the destiny of human society. Green chemistry must be promoted and supported not only by the scientific community but also by governments, industries, and all other sectors of society. Clearly, our efforts must be directed toward solving a range of serious issues associated with water, energy, health, agriculture, biodiversity, and poverty (or WEHAB+P, as abbreviated in the summary of the 2002 Earth Summit in Johannesburg by UN Secretary-General Kofi Annan). It is my hope that our successors in chemistry will create new, undreamt-of marvels for the 21st century.

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