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Chemistry and problems of sustainable development and protection of the environment

According to the initiative of the International Union of Pure and Applied Chemistry (IUPAC) supported by the UNESCO, the 63rd session of the United Nations General Assembly declared the year 2011 as the International Year of Chemistry.

The United Nations resolution concerning the International Year of Chemistry emphasizes that the progress in fundamental chemistry largely determines the modern level of understanding of the structure of material world and that chemical approaches and chemical engineering play a key role in the solution of global problems of sustainable development and protection of the environment, in the provision of Earth's population with clean water, food, efficient medicines, and energy. The slogan of the International Year of Chemistry proposed by the IUPAC — 'Chemistry — our life, our future' — is expected to promote the appreciation and understanding of the role of chemistry by different layers of society, increase in the demand in chemical knowledge and innovations, attract gifted young people to chemical science and industry, enhance the international cooperation of chemists and their organizations for preserving the Earth and solving global problems of the humankind.

Conducting the International Year of Chemistry in Russia should benefit the development and implementation of new environmentally friendly, energy- and resource-saving chemistry and chemical engineering processes, favour modernization of the national economy, overcoming the raw-material type of the economy, switching to a modern high-tech route of development and solving many environmental and nature conservation problems.

An important motive and uniting aspect in pursuing these goals comes from the so-called 'green' movements and 'green' processes. The green movement was initiated back in the 1960s when the public of North America and Western Europe concerned about the environment protection enforced more stringent environmental legislation and control over the use of toxic chemicals in various fields of economy and social sphere. Apart from the penal provisions and prohibition of the use of some especially hazardous chemicals, this drew attention to the search for less toxic replacing chemicals, alternative industrial processes, energy- and resource-conservation. Moreover, toxicological control of manufactured and applied chemicals and chemical materials was put in legislation.

The United Nations Conference on the Environment and Development held in 1992 in Rio de Janeiro and attended by leaders of states and governments of many countries, which adopted Agenda 21 (the principles for the 21st century), was highly important for the problems of environment and sustainable development. Such conferences considering various aspects of environmental protection and sustainable development, for example, ozone layer depletion and global climate change were also held in the subsequent years at high political levels (however, with different degrees of success). Under the influence of these conferences and documents they adopted, many international and national scientific organizations and associations of scientists enhanced their activity along the outlined directions.

The International Union of Pure and Applied Chemistry IUPAC and its leading National Adhering Organizations were among the pioneers of this trend. Vice-President of our Academy of Sciences V A Koptyug, who was heading the Siberian Branch of the Academy for 17 years and was also one of the most active IUPAC officers in 1986 – 1991, initiated the foundation of a number of international structures and programmes oriented to the environment and sustainable development problems and established the scientific journal 'Chemistry for Sustainable Development'.

In 1992 the VIII International Conference CHEMRAWN (Chemical Research Applied to World Needs) 'Chemistry and Sustainable Development: Clean Environment, non-Waste Technologies, Highest Energy Efficiency' (Co-Chairmen of the Organizing Committee academicians V A Koptyug and O M Nefedov) was held in Moscow being organized by the IUPAC Standing Committee CHEMRAWN. In 1993, the XV Mendeleev Congress on General and Applied Chemistry fully devoted to the chemical problems of the environmental was successfully held in Minsk.

In Russia and in many other countries, educational structures and programmes on the environmental subject matter are being established. For example, in 1983, the rector of D I Mendeleev Moscow Institute of Chemical Technology (now D Mendeleev University of Chemical Technology of Russia) corresponding member of the Academy of Sciences G A Yagodin initiated the foundation of the first in the USSR chair and, several years later, the first Faculty of Industrial Ecology. In 1996, the world's first Department for the Problems of Sustainable Development was organized at the same University, and in 2000, the Institute of Chemistry and the Problems of Sustainable Development was founded on the basis of this department.

More recently, Moscow Institute for Chemical Mechanical Engineering was transformed to Moscow State University for Engineering Ecology. The universities and scientific centres actively develop the fundamental and applied research and design works dealing with green chemistry and sustainable development.

In 1993, the University Consortium 'Chemistry for the Environment' INCA was founded in Italy. In 1994, a

symposium-based book *Benign by Design, Alternative Synthetic Design for Pollution Prevention (ACS Symp. Ser.)* Vol. 557 (Eds P T Anastas, C A Farris) (Washington, DC: American Chemical Society, 1994) was published. However, the terminology 'green chemistry' and 'sustainable chemistry' appeared in the literature only in 1996–1997 and their scope became the subject of long debates, despite the similarity of the meaning of both terms. The word 'green' appears clearly political for western public and the definition 'sustainable chemistry' is fairly vague from the chemical science standpoint.

In 1996, a working group for green chemistry problems was formed at the IUPAC, and in 2001 the green chemistry sub-Committee including representatives of practically all IUPAC divisions was formed. The sub-Committee manages the publication of books within the green chemistry series, organizes international conferences on green chemistry (the 2nd International Conference held in Russia in 2008 was a success) and coordinates the IUPAC projects in this field. In 2009, the IUPAC established a prize for young scientists of developing countries in the field of atmospheric chemistry and green chemistry. Since 2002, the Russian Academy of Sciences has awarded the Academician V A Koptyug Prize for outstanding achievements in chemistry for environmental protection and development.

The definition of 'green chemistry' adopted by the IUPAC [P Tundo, P Anastas, D StC Black, J Breen, T Collins, S Memoli, J Miyamoto, M Polyakoff, W Tumas *Pure Appl. Chem.* **72** 1207 (2000)] states 'Green chemistry is the invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances'. This definition directly points to the necessity of taking into account the possible adverse consequences as early as at the stage of development of new compounds, which was often neglected formerly by the researchers. Paul Anastas and John Warner formulated 12 principles of green chemistry, which have now become classical [P T Anastas, J C Warner, in *Green Chemistry: Theory and Practice* (New York: Oxford University Press, 1998) p. 30]. These principles disclosing the practical aspects of the IUPAC definition are given below.

Prevention (it is better to prevent waste than to treat or clean up waste after it has been created).

Atom Economy (synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product).

Less Hazardous Chemical Syntheses (wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment).

Designing Safer Chemicals (chemical products should be designed to effect their desired function while minimizing their toxicity).

Safer Solvents and Auxiliaries (the use of auxiliary substances (*e.g.*, solvents, separation agents, *etc.*) should be made unnecessary wherever possible and innocuous when used).

Design for Energy Efficiency (energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure).

Use of Renewable Feedstocks (a raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable).

Reduce Derivatives (unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste).

Catalysis (catalytic reagents (as selective as possible) are superior to stoichiometric reagents).

Design for Degradation (chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment).

Real-Time Analysis for Pollution Prevention (analytical methodologies need to be further developed to allow for real-time, inprocess monitoring and control prior to the formation of hazardous substances).

Inherently Safer Chemistry for Accident Prevention (substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires).

The reviews included in this issue of the *Russian Chemical Reviews* and the review by S G Zlotin and N N Makhova 'Reactions of CH acids and 1,3-dipoles in the presence of ionic liquids' (see issue 7, 2010) are devoted to various aspects of green chemistry: catalysis as an important tool of green chemistry (I P Beletskaya and L M Kustov), application of ionic liquids in nanochemistry (N P Tarasova, Yu V Smetannikov and A A Zanin) and in organic synthesis (S G Zlotin and N N Makhova), the use of dimethyl carbonate as a safe methylating and methoxycarbonylating reagent and solvent (F Ariko and P Tundo), production of biofuel from various types of biomass (S D Varfolomeev, E N Efremenko and L P Krylova), modern methods for detoxification of hazardous industrial wastes using polychlobiphenyls as examples (T I Gorbunova, V I Saloutin and O N Chupakhin), development and upgrading of high-precision methods for determination of organic compounds in air media (V A Krylov, P V Mosyagin, D A Mikhirev, S A Eremin, and A V Krylov).

Corresponding Member of the RAS **N P Tarasova**
Director of the Institute of Chemistry and the Problems of Sustainable Development at D I Mendeleev University of Chemical Technology of Russia, member of the IUPAC Bureau and Executive Committee
Academician **O M Nefedov**
Chair of the Higher Chemical College of the RAS, Chair of the National Committee of Russian Chemists
Academician **V V Lunin**
Dean of the Department of Chemistry of the M V Lomonosov Moscow State University, Head of the Science and Education Centre 'Chemistry for Sustainable Development – Green Chemistry'