



NEW PATHWAYS IN CHEMISTRY

Dr D V Prabhu, FRSC (London)

Department of Chemistry, Wilson College, Mumbai, India

Email: dvprabhu48@gmail.com

History: Received on 24th May, Approved and Published on 27th May 2020

Editorial Article

Chemistry: The Subject

Chemistry is a science whose progress is exponential as it touches every aspect of our existence and provides all the things required for life to survive on this planet. Chemistry is rightly called the Science of Life.

Chemical processes provide food, clothing, shelter medicines, and energy to sustain life. Feeding the ever-increasing population is a big challenge calling for increased production of crops, minimizing losses during their harvesting and storage and use of new, improved varieties like Genetically modified (GM) food grains and pulses. The use of fertilizers has increased manifold over the years, leading to an increase in the production of food. Clothing is made from plant fibres like cotton and silk. New and better varieties of cotton have been developed. Nylon, produced by the polymer industry is also a critical clothing material in some parts of the world. New materials like composites, fly ash bricks, and polymeric wastes are being increasingly used for construction purposes, especially for housing and roads. Research for the synthesis of new drugs to combat diseases is a continuous activity, and the pharmaceutical industry has a considerable investment, especially in our country. Indigenous medicine systems like Ayurveda, Homoeopathy and Unani are also contributing to health welfare, especially in India. Of late, nanomedicines are emerging as an essential area of medicine. Non-conventional energy sources like solar, nuclear, hydro, biodiesel and wind energy are being increasingly tapped as possible substitutes for the fast depleting coal and oil reserves. The International Solar Alliance, initiated by India, aims at forging a strong partnership between all nations to tap and use solar energy.

Chemistry: The Provider of Novel Materials

In the last few decades, Chemistry had developed some novel materials which have influenced and enriched our lives

- 1) Nanomaterials- materials with nanometer size of 10^{-9} m which is responsible for their unique properties eg. gold is golden yellow, but nanogold is reddish. Nanocomposites, used as heterogeneous catalysts, offer a wide range of benefits like good yield, reusability, thermal stability, non-toxic nature and solid crystalline structure. These nanocatalysts promote excellent atom economy and thus adhere to the principles of Green Chemistry eg. bimetallic oxides. Heterocatalysts are the best choice for water purification and degradation of organic wastes.
- 2) Superconductors which offer almost zero resistance to the flow of electric current below a specific temperature called transition temperature T_c which is much below room temperature. E.g. the transition temperature for LiTiO_4 is 13K, i.e., 260°C . Efforts are on to increase the transition temperature to room temperature so that transmission of electricity can be done efficiently at room temperature without loss. Superconductors find applications in power transmission and high field electromagnets which are used in NMR for structure elucidation and MIR for medical diagnosis.
- 3) Fullerenes – carbon clusters like C_{60} which have extraordinary physical and chemical properties and extraordinary strength. A whole new chemistry called Fullerene Chemistry has developed just like Carbon Chemistry.

Chemistry: The Pivotal Science

Chemistry is a central science with strong links with all other Sciences, especially Physics and Biology. Chemistry provides structural and reactivity data and information about the reaction mechanism, making it indispensable to other sciences. Advances in synthetic methodology and computational methods and refinement in instrumentation have revolutionized Chemistry resulting in a host of interdisciplinary subjects like Chemical Biology, Biophysics, Bioinorganic Chemistry, Bioanalytical Chemistry etc. Environmental Science is the best example of an interdisciplinary science.

Thrust Areas of Research

Today the thrust areas of research for chemists are:

- 1) Materials Chemistry-preparation of new materials with fascinating properties such as catalysts, nanomaterials composites, superconductors.
- 2) Medicinal Chemistry-Synthesis of new drugs, testing their efficacy and deciphering their routes of administration and assimilation in the human body.
- 3) Synthesis of biodegradable plastics
- 4) Supramolecular Chemistry

- 5) Harnessing renewable sources of energy-solar, tidal, geothermal biodiesel etc
- 6) Greening of Chemistry by using environmentally-friendly (benign) chemical processes.
- 7) Fast reaction kinetics with reaction times of the order of femtoseconds(10^{-15} s) which will help in the elucidation of the reaction mechanism of biochemical reactions in biological systems.
- 8) Refinement in instrumentation to enable detection at picogram (10^{-12} g) and femtogram (10^{-15} g) levels to detect pesticide and insecticide residues in food products, narcotics, impurities in drugs etc.
- 9) Nuclear Fast Breeder reactors-The third-generation reactors in our country will be based on Uranium processed from the large deposits of thorium found in Kerala as Thorite (ThO_2). ^{233}U will be obtained from ^{232}Th by a ($n,2\beta$) reaction. Nuclear fusion, still in its early stages promises to be an almost unlimited source of energy.
- 10) Increase in food production by use of more efficient agricultural and post-harvesting techniques which will minimize food losses.
- 11) Waste to Technology(WtT)-2000 such plants are in operation all over the world, treating 250 million tons of municipal solid waste annually to produce energy in the form of electricity and biogas. In our country, the CSIR-National Environmental Engineering Research Institute (NEERI) is actively involved in this project.Reuse and Recycling of solid waste and e-waste will be the major challenges for environmental chemists.

India's Success Stories

India brought about the Green Revolution (Dr M S Swaminathan)in the 1970s, which converted a food deficient nation into a self-sufficient nation.Subsequently, the White Revolution (Dr Varghese Kurien)made the nation self-sufficient in milk and the largest milk producer in the world. The drug revolution brought about to produce and market drugs which are 10-100 times less expensive than the drugs available anywhere else have greatly helped to combat diseases and improve the health of the people. Today, India is a major supplier of good quality drugs to many countries eg.in the COVID19 crisis.

Mention must be made of the DNA technology mission which made India the second country in the world to develop its probe for DNA fingerprinting (Dr Lalji Singh) which is widely used to solve criminal cases.

The other major biotechnological achievements are the production of the genetically engineered Hepatitis B vaccine and development of LISA kits for the diagnosis of infection by Japanese encephalitic virus, Hepatitis A and Dengue fever.

All these success stories are a tribute to the genius and self-confidence of our scientists and technologists.We should be proud of our scientists.

Chemistry Education and Research in India

In India, Chemistry is offered as a subject in most colleges and has a large enrolment.We have several world-class research institutions where front line research is carried out. Some of these National Centres of Excellence are, to name a few, Bhabha Atomic Research Centre, Mumbai, Indian Institute of Science, Bengaluru, CSIR National Chemical Laboratory, Pune, IITs and IISERs.

The important funding agencies are DST,CSIR,DAE,DBT,DOD,BRNS and the State Science Councils. Chemistry has plenty of career prospects in the industry, nuclear industry(atomic plants, fuel processing and heavy water production), teaching, research and entrepreneurship.

Paradigm Shift in Learning and Research

Of late, a perceptible paradigm shift is seen from the traditional classroom teaching to self-learning using multimedia, online courses, MOOCs etc. This technology-enabled learning is in participatory and interactive modes where the teacher is a guide and facilitator. Today, several educational institutions are offering online instructions. The concept of a Global Classroom is fast becoming a reality.Today the focus is on interdisciplinary research, and the emphasis is on the filing of patents along with publishing in high impact factor journals

The Path Ahead

The quality of higher education and research has to be enhanced by the inclusion of interdisciplinary and frontier areas of the subject in our curricula. More experimentation has to be included. We have to prepare a clear roadmap to convert our universities into active centres of research.

A vibrant academic-industry interaction will lead to cross-fertilization of ideas.Academic –industry collaboration is a win-win situation reaping benefits for both partners. Industry learns about cutting edge scientific and technological advances, gains insights in the direction of research and gets an early access to PhD students as future employees. In turn, universities get a ready set of hardcore industry problems that fuel their research and funding.Students gain access to potential employers, along with training and first-hand exposure to industrial research.



Courses offered should increase the employability of our students. Preparation of good quality textbooks and study material will play a vital role in enhancing the quality of teaching and instruction. Our courses should also include soft skills as required by industry, communication skills, knowledge of patent laws, environmental audit and IPR.

At present, a project in an industry is a part of the M Sc programme in most Indian universities. Some bold initiatives worth mentioning are the inclusion of Chemical Engineering subjects in the MSc Chemistry curriculum of Institute of Chemical Technology, Mumbai and National Initiative for Undergraduate Science (NIUS) programme at Homi Bhabha Centre for Science Education (TIFR), Mumbai wherein talented and motivated undergraduate students are nurtured for advanced studies and research

Mention must also be made of **The International Chemistry Olympiad (IChO)** which has proved to be a great motivator to students to pursue Chemistry as a life long passion and career. It is possibly the only competition which emphasizes experimentation. The Indian Chemistry Olympiad programme, organized by HBCSE(TIFR), Mumbai involves scientists from national-level research laboratories and academicians from prestigious Indian institutions. It is a matter of pride that India has been doing exceedingly well and winning laurels in the International Chemistry Olympiad as in all other Science Olympiads.

To sum up, INNOVATION should be the buzzword in today's Chemistry education and should light the pathway to the future.