Funding chemical sciences research in India

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Chemistry is generally regarded as a descriptive science with a strong experimental bias. It is mainly concerned with the structure, properties and synthesis of matter. With such a broad, all-encompassing domain, chemistry forges strong links and overlaps with many branches of modern science and has a claim to be recognized as a 'central science'. Indeed, chemistry not only offers opportunities for creative research in such diverse and emerging areas as molecular electronics, molecular recognition, superconductivity, insect communication, gene synthesis, biological and abiological catalysis, nano-technology, to name a few, but also addresses itself to the needs and concerns of society in vital areas like health, food, energy and environment. The present write-up is intended to draw attention to the emerging scenario in chemical sciences and to make a plea for strengthening basic research and funding in this important branch of science.

The emerging frontiers

The practice and perception of chemical sciences has undergone major changes in the past decade and it has evolved into a more vibrant and interactive discipline. New frontiers have emerged. Several parallel developments at conceptual and hardware levels have made this possible. Foremost among these is the spectacular advance and sophistication in chemical instrumentation. For example, events in the nano-, pico- and femtosecond range, like electron-transfer processes in photosynthesis and specially crafted chemical systems or transient species in fast reactions, can now be readily monitored; high-field, multi-nuclear NMR in 2-D and 3-D modes make it possible to map three-dimensional structures from biopolymers to zeolites; liquid chromatographs can routinely detect and separate the minutest amounts of natural products or environmental pollutants; and mass spectrometers can now determine molecular composition in five digits. X-ray crystallography has now become a routine structural tool and three-dimensional structures of many biopolymers (protein, nucleic acids) are readily accessible.

On the preparative side, there has been an explosive growth of new reactions, reagents and methodologies to design new materials, exotic organic molecules, drugs, catalysts, enzyme mimics and chemical sensors among others. Heat, light, sound, pressure, plasmas, microwaves and lasers are being employed, along with new chemical reagents, in synthesis. Also, CVD and related techniques are finding increasing use in the 'synthesis' of new materials. The role of ordered or constrained media, e.g. micelles, solid state, liquid crystals, cyclodextrins, zeolites, clays, etc., in modifying reactivity and selectivity of substrates is being increasingly recognized as an important control element in diverse reactions. Biotransformations in aqueous and/or organic media, employing whole cells, crude or pure enzymes and abzymes (catalytic antibodies) provide opportunities for high level of selectivity in assembling diverse molecules, particularly bioactive compounds in enantiomerically pure form. 'Atom economy' is emerging as an important consideration in preparative processes due to limited availability of raw materials and environmental concerns. New processes are aimed at 'atom conservation' in which all reactant atoms end up in products! Particularly in organic synthesis, processes that involve simple addition of chemical building-blocks in chemo- and enantioselective manner represent the highest 'atom economy'.

Organometallic compounds have come to occupy a pre-eminent position in contemporary chemistry. Besides their breathtaking structural diversity and novel bonding characteristics, they have proved to be unique reagents, catalysts and materials. As reagents, they have found use in the synthesis of a wide variety of compounds like advanced ceramics, natural products and polymers. Reagents and catalysts based on transition metals and boron have heralded the era of catalytic asymmetric synthesis. Noyori's BNAP-based catalysts for asymmetric hydrogenation, Sharpless' asymmetric epoxidation and Corey's oxaborazilidine reduction are discoveries that are going to have a major impact on the chemical industry—specifically on chiral drugs, agro-chemicals and polymers.

The interface between chemistry and biology, and in particular, chemists' quest to mimic the large-scale order and organization present in biological systems, and to understand the molecular and supramolecular interactions that create and sustain superstructures and functions of biomolecules, hold great promise for newer developments and discoveries. Several recent reports on the design of self-assembling, self-organizing and self-replicating systems to perform specific 'tasks' point to the shape of things to come. The underlying principles

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and concepts of molecular recognition in biological systems are finding expression in the development of new materials through the design of nanometre-scale supramolecular structures. The resulting 'intelligent' molecular assemblies are projected to find applications in diagnostics, imaging, nonlinear optics, harvesting of solar energy and storage of information among others. The availability of commercial, molecular-level machines and molecular-scale computers before the turn of the century is a distinct possibility.

Lastly, the advent of faster computers, newer computational techniques, molecular graphics and access to data bases have enabled accurate predictions of electronic and molecular structures and reactivity. Molecular dynamics has advanced to the level of predicting minute details of the entire reaction. Simulation studies dealing with drug, catalyst and polymer design have made a major impact.

The foregoing examples are only representative and delineate important lines of research for the current decade and beyond in chemical sciences. They are meant to indicate that *nouveau chimique* lies at the interfaces with other disciplines and its creative potential is strongly dependent on instrumentation support, bench-level logistics and informatics. Being a 'central science', chemistry must remain conscious of its societal obligations and chemists should not hesitate to gaze at the horizons beyond their own disciplines.

The Indian scene

How do we in India gear ourselves to cope with this emerging scenario in chemical sciences? Before considering this question, it will be appropriate to briefly discuss how we have been doing and where we stand today. Since the early part of this century, research in chemistry has been pursued at many centres in the country. In the pre-independence era, laboratories located at Lahore, Calcutta, Allahabad, Bangalore and Bombay, and led by chemists of distinction, made many useful contributions. Some of these contributions received recognition but many went unnoticed. For example, not many chemists, even in India, know that the first crown ether (trithia-9 crown-3) was prepared and characterized by Acharya Ray in 1920 (P. C. Ray, *J. Chem. Soc.*, 1920, 1020), a full half-century before Pedersen's discovery of its oxa-analogues that fetched him the Nobel Prize in 1987. Post-independent India saw rapid expansion of our research base through a network of national laboratories, new universities and institutes of technology. In the process, chemical sciences also received their share of attention. Many new centres initiated research programmes and substantial number of Ph D students were enrolled. Among other areas, natural products research flourished in the country in this period (1950s and 1960s) and drew international attention. However, the momentum in this area began to slacken largely due to the lack of access to modern instrumentation facilities for purification and structure elucidation. It may be worth recalling that till 1970 we did not have more than half-a-dozen NMR spectrometers in the whole country!

During the sixties and seventies a new generation of chemists initiated several new lines of contemporary research in chemical sciences at the IITs and some leading universities, and many notable contributions were made in areas like spectroscopy, solid-state chemistry, photochemistry, coordination chemistry, quantum chemistry and synthetic and mechanistic organic chemistry. Attention was also paid to chemical education and new broad-based curricula were devised and introduced at many places. Most of the research efforts during this period were supported in-house, with a few exceptions like the CSIR-extramural funding.

In the late seventies and early eighties new funding mechanisms became available. Science and Engineering Research Council (SERC) of DST initiated several imaginative schemes like Thrust Area Programme, IRPHA, RSICs, etc., and UGC launched COSIST programme in addition to its DSA and DRS schemes. Many other agencies too began to farm-out projects to individual researchers mainly in the academic sector. Several departments and centres involved in chemical research benefited immensely from these initiatives and could acquire sophisticated, state-of-the-art instruments like high-field NMR, ESR, GC-MS, X-ray diffractometers, GLC-HPLC units, nano- and picosecond spectrometers, laser flash photolysis set-ups, PES-ESCA and EELS and update their computing facilities. Many national facilities like 500 MHz NMR and high-resolution electron microscope, established by DST, also became accessible. These acquisitions and investments by funding agencies, though very modest by western standards, had a definite impact on the research output from within the country. Research efforts in areas like superconductivity, solid-state chemistry, coordination chemistry, photochemistry, laser spectroscopy, organic synthesis and theoretical chemistry among others recorded impressive progress. As a result, throughout the decade of eighties, contributions from India in the leading international journals of chemistry recorded a steady increase. For example, in *Chemical Communications*, a journal for preliminary communications in all branches of chemistry, published by the Royal Society of Chemistry, UK, contributions from India accounted for about 6–7% of the total papers published during the last few years. However, for a country of our size and with a large number of researchers in chemistry, our contributions on a per capita basis to the world's leading journals may not be very impressive, but then, this has to be judged in relation to the level of investment Chemical sciences-related projects receive only about 10% of the total extramural R&D support given by the various funding agencies. In money terms it means about $ 3–4 million per annum, which is roughly equivalent to the annual budget of a medium-sized chemistry department in a university in the US. There have been other pointers as well of our improved performance and capability during the eighties like more plenary and invited speakers in major international meetings and increase in citations from India.

A plea for funding

While the attainments of the eighties are satisfying, they are by no means enough or what they ought to be. However, one thing does appear to be clear and that is we do have researchers of calibre, competence and dedication in chemical sciences and that improved funding and infrastructure does lead to better outcome in basic research. Therefore, to cope with the emerging challenges in chemical sciences in the nineties the need for enhanced level of funding through new intiatives was imperative. New, state-of-the-art equipment needed to be made available. In addition, most of our universities with antiquated laboratories and obsolete equipment needed to be refurbished. But, in reality we have been witnessing not only stagnation but shrinking in budgetary support for basic research and education in the past couple of years. As a result, the already impoverished university system has been hit hard. In fact, university budgets now seem to be made only for disbursement of salaries and there is very little or negligible support available for maintaining infrastructure and academic needs like research, maintenance of laboratories and libraries. With unprecedented increases in the cost of chemicals, equipment and library journals, due to devaluation of the Rupee among other factors, the situation has so deteriorated that even the survival of research and teaching programmes at an acceptable level is at stake. We can now find chemistry departments with no journals, no chemicals and, in some cases, not even assured of running water supply! Universities are being mentioned here specifically because that is where most of our chemists work and PhD students are trained. Chemists, in particular, for whom bench-level logistic support is absolutely essential, are in deep trouble. There is an air of resignation and demoralization among the research community, in general, and the universities in particular. Something needs to be done on an urgent footing to rectify the situation and prevent further damage to our research capabilities. The university system, learning and research are too precious to be left to the mercy of market forces. No matter what the economic compulsions of the day may be, the intellectual wealth and the creativity of our scientists has to be nurtured and protected through pragmatic investments. It is bound to repay in the long run. Therefore, there is no alternative to massive funding, with appropriate structural changes, to sustain our research capabilities. It is to be hoped that the political leadership and those charged with promoting and protecting our scientific base will recognize the seriousness of the situation.

Summary

In summary, chemical sciences research is in the midst of major changes globally and new interdisciplinary frontiers are emerging. In our country, chemical sciences research made steady progress in the eighties due to improved funding and healthy support for science. However, the nineties have started on a depressing note and unless major funding is made available we may not be able to measure up to the challenges that lie ahead in this important branch of science. Chemical sciences research in the university system needs special attention, without which it may not survive for long.

Earth sciences in India: the concerns ahead

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THE past decade witnessed a qualitative shift in Indian endeavours in earth sciences—a shift from description to dynamics, that is enquiry into the nature and progression of critical earth processes in space-time, which whilst continually refashioning the earth, helpfully leave behind distinctive signatures in the fine structure of natural systems such as variations in their isotopic compositions and fabric. More importantly, the shift was in the approach to these studies led by the new conceptual advances which would need to be sharpened by incisive analytical tools. True, that this new culture was only cultivated by a few, but even as the majority continued to regard data

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