Essentials of Nuclear Chemistry: Critique of a review

P. S. Goel's comments on my book (*Curr. Sci.*, 1996, 71, 155–156) can be grouped under six heads: (1) Quoting unupdated values of some constants, (2) Conceptual errors, (3) Irrelevant references, (4) Mathematical errors (only two), (5) Use of outdated cosmological models, and (6) Language problems.

While the values of fundamental constants have been determined with high precision and are universally accepted, there are some of limited applicability whose values are known with less accuracy. Under this category come the proton decay constant, the ^{14}C content of living matter, the ages of the oldest rocks and of the earth. In fact, proton decay as a distinct form of radioactivity is yet to be accorded international recognition. This value, quoted in a footnote in my book, was taken from a popular lecture by an eminent scientist in the Indian Science Congress session of 1982. Since then there has been no new information on the subject. The approximate value quoted by me, viz. one proton out of 10^{30} per month was only to indicate the great rarity of proton decay. Similarly, all the workers on dating by ^{14}C are not agreed on the exact content of this isotope in living organic matter. Values cited vary from 13.6 to 16 c min^{-1} g^{-1}. I have only stated this fact in my book. Similar remarks apply to the assessment by different workers of the age of the oldest rocks of the world and of the age of the earth based on $^{40}Ar/^{40}K$ ratio. Stating these facts cannot imply lack of updating.

If I have referred to Urey's work in this context, it is because the famous geologist K. Rankama too had referred to Urey, not once, but some 30 times, in his classic work, *Isotope Geology* (McGraw-Hill, 1954). It is not clear how my referring to the Nobel laureate's work can be considered 'blatant misinformation'. My description of the term 'nuclide' as a given combination of Z protons and *N* neutrons in the nucleus, without referring to Z electrons in the outer sphere, and of 'isobars' as nuclides with a constant nucleon number A ($\equiv Z + N$), are succinct and error-free. Yet these are cited as examples of conceptional errors without pointing the error. Similarly, the numbers of stable odd *A* nuclides, 50 with Z-odd and 55 with *N*-odd being nearly the same, show *the charge-independent nature of the stability of odd-A nuclides.* This statement is also considered as a conceptual error. Similarly, the review includes other statements of mine as involving conceptual errors, without the errors being pointed out.

Goel has rightly pointed out two grave mathematical errors, (i) p. 134, last line, the expression $e^{(\lambda_1-\lambda_2)}$ should read $e^{(\lambda_1-\lambda_2)t}$. The correct expression is used in the table on p. 135 and elsewhere. (ii) The second error refers to the calculation of the surface area of 1 g of barium sulphate precipitate (p. 383, line 13), the formula weight of $BaSO_4$ is 233.4 and not 223 as given. This leads to a value of 19.51×10^{-16} cm^2 g^{-1} instead of 4.11 cm^2 g^{-1} as pointed. I am grateful to Goel for pointing out these two errors. These will be rectified at the time of the next reprint.

It is unfortunate that Goel did not see a single positive point in the 500-page fourth edition. The book has been reviewed by some others as well and it is widely used in the country and outside and has been translated into the Serbo-Croatian by the Faculty of the University of Belgrade and into Iranian by the Iranian Atomic Energy Organization.

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OPINION

Science policy in neo-liberal India: Corporate culture, basic science and scientific credibility*

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In the present neo-liberal era, there is great pressure to introduce corporate culture in managing Indian science and scientists and to de-emphasize basic science in favour of developing immediately useful technologies. This is ironic because the performance of our better universities and R&D institutions has been much closer to international standards than that of our corporate sector. With very few exceptions, the latter has been almost inimical to indigenous R&D. Nearly all serious scientists have worked in public-funded institutions. The demands of corporate culture are likely to accelerate the flight of bright youngsters from scientific careers and even reduce the credibility of science.

Introduction

The Science Policy Resolution adopted by the Parliament on 4 March 1958 stated that the aims of the scientific policy of the Government of India would be:

(i) to foster, promote and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects – pure, applied and educational;

(ii) to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation;

(iii) to encourage and initiate, with all possible speed, programmes for the training of scientific and technical personnel

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on a scale adequate to fulfil the country's needs in science and education, in agriculture and industry, and defence;
(iv) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;
(v) to encourage individual initiative for the acquisition and dissemination of knowledge and for the discovery of new knowledge, in an atmosphere of academic freedom;
(vi) and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The SPR further stated that: 'the Government of India has decided to pursue and accomplish these aims by offering them an *honoured position*, by associating scientists with the formulation of policies and by taking such other measures as may be deemed necessary from time to time'.

The preamble to the resolution recognized that 'it (science) has not only altered man's material environment, but, what is of still deeper significance, it has provided a new tool to thoughts and has expanded man's mental horizon'.

The major moving thought behind this resolution was the realization that of the three main factors, namely technology, raw materials and capital that hold the key to national prosperity, technology was the most important. However, it also asserted that 'it is an inherent obligation of a great country like India, with its tradition of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably *mankind's greatest enterprise today*'.

It is now nearly four decades since the adoption of the above resolution. India is in the 50th year of its independence and the world is on the threshold of the 21st century. Indian science is in turmoil, and its public image is not very bright. Serious scientists are under great pressure to accept the culture of the corporate sector which in the Indian context has contributed little to R&D and produced hardly any goods or services of international standard. And most, including those who ought to know better, are succumbing to these pressures. Even the best scientific institutions are increasingly becoming unpleasant places to work, with a crude authoritarianism creeping in and academic freedom and scientific values not receiving the importance they deserve. Scientifically tainted individuals can today receive both protection and power merely by promising relevance (often the last resort of the mediocre) or ECF (external cash flow). Managers of science enjoy great power within their institutions but little credibility outside. Bright youngsters increasingly consider a career in basic science an unattractive proposition. Though many still flock to engineering, their final destination is mostly marketing and management and rarely ever development of advanced technology.

It is certainly an apt time for stocktaking. What has gone wrong? Has the performance of Indian science been really as bad as its reputation in certain quarters in this country would indicate? Were the dreams of the Indian architects of the SPR (Nehru and Homi Bhabha) unrealistic or unjustified? Have the policies enunciated in SPR become irrelevant now? If not, then why are scientists being forced to act against these policy directives? Has Indian science been wrongly maligned by the sustained campaign of anti-science ideologues and vested interests? Is it suffering because of the sins of its own managers and/or due to intellectual laziness and timidity of its foot soldiers? Or is the corporate sector, which has shown little inclination to invest in R&D, trying to hijack the S&T infrastructure and competence diligently created in the public sector by an enlightened government? How do the public investments in science compare with material returns that society has received from this investment? What is the nexus between developing S&T infrastructure and scientific temper? How much of the current pressures on Indian science are due to Indian people's disenchantment with science and how much of these are merely due to internal contradictions between basic scientists and technologists, and between power hungry careerists and serious scientists? How much of these are due to international trends and fashions? How much has our official scientific enterprise contributed to the development of scientific temper among our people? What role have the NGOs played in this regard? What more can the latter do? Is it desirable, or even safe, to leave the making and implementation of science policy totally in the hands of scientists and technologists who may not have had the time or inclination to educate themselves in the related sociological, philosophical, historical and intellectual issues? Is there a need for writing a critical history of the development of Indian science in recent decades? If yes, who should write it? Should it be scientists who have watched the working of our R&D institutions and science departments as insiders? Or should it be professionally trained historians with science education? Those who have enjoyed enormous power in Indian science must be subjected to historical accountability. But how are we going to do that?

These and many more questions need to be asked by our science policy makers, those charged with implementation of these policies, the working scientists and concerned individuals in other fields of intellectual activity. Here I shall try to give my views on some of these questions. These are entirely personal views of someone who entered a scientific career just a few years after the SPR was adopted and who has been dismayed in recent years by steady attacks on the achievements of Indian science both from within and outside and the resultant decline in the attractiveness of science as a career. These are also the views of someone who is concerned that the recent emphasis on introducing corporate culture into Indian science is likely to further drive away bright youngsters from science leading to decline in its performance which is unlikely to help the country in the long run. Perhaps even more importantly, the introduction of corporate culture may reduce the credibility of scientists and science, built by a scientific culture which demands much higher levels of objectivity and integrity than found in any profit-oriented, pragmatic culture.

Performance of Indian science

There is a general belief in this country that Indian science has not done well in the post-Independence era. Usually, three facts are cited to support this view. First, in recent years we have not produced outstanding scientists of the eminence of Raman, Bose and Saha, as highlighted in a recent *Times of India* article by J. Narlikar. Second, Indian S&T has not made significant contributions towards developing technologies for our industry. And, third, in spite of investments in S&T, we have not been able to solve our problems of poverty and underdevelopment. On all the three counts the criticism is less justified than it appears at the first sight. This point needs to be explained and emphasized as the constant criticism, especially when it comes from quarters which have no anti-science bias, can reduce public support for S&T and make science less attractive as a career option for brighter students. The consequences of this can be serious for our national image and development in the long run.

Narlikar considers the neglect of our university system, the parochial political considerations in the running of our universities, and the failure of the research institutes to have teaching programmes and attract young students as some of the main causes of our failure to produce scientific stars. All these are valid criticisms and corrective action should help. However, there is another side to the story. The performance of our universities and national research institutes has not been really as poor as most of us seem to believe. It is true that both in terms of production of scientific stars and developing novel technologies, our record compares unfavourably with that of the more advanced countries, especially the USA, with which we seem all the time to compare ourselves. But this is not a fair comparison, given the relative levels of our investments in science and the general level of our economic, industrial and socio-political development. It is more realistic and revealing to compare the records of our science education and R&D sectors with those of other sectors of our national life. While almost nothing produced by our private sector (be it a cake of soap, a pair of shoes or trousers, a news magazine, or a radio set) could be sold in the supermarkets of advanced nations until recently, the best products of our universities and research institutes, (viz. the students, scientists and research papers) have been of international standards and have sold in the most competitive global markets. Is there any other field outside our higher education and R&D system (with probable exceptions in the areas of purely Indian culture, such as classical music) which can make such a claim?

It is not insignificant that in the present liberalization the one factor which most international investors find attractive about this country is the abundance of highly skilled technical manpower. If today many advanced countries are trying to stop the entry of Indian scientists and technologists into their countries because they successfully compete with their own citizens for the best paid jobs, surely for this state of affairs some credit has to be given to what Indian universities and scientific institutes have been doing. This is perhaps a better index of good performance of post-independence Indian science than even the few memberships of the International Academies and invitations to Plenary Lectures (as pointed out by Narlikar), though I have absolutely no intention of belittling the latter honours earned against heavy odds. Certainly, the achievements of India-trained scientists and technologists in the post-independent era have done more than did Ramans, Sahas and Boses in changing the image of the country from an abode of *sadhus* and snake charmers to that of a major reservoir of scientific and technological personnel. Today, one hardly hears of the Hindu (read irrational) mind, which was a common phrase in western discussion of India up to the fifties and sixties.

Ramans, Sahas and Boses remain important role models and sources of national pride to India. But it should be recognized that the world in which they operated was very different from the post war world available to the later Indian scientists. It should be remembered that during the last few decades even the more advanced nations of western Europe have lost large number of elite scientists and brightest students to the US which has provided a working environment and facilities not available elsewhere.

Impressed by its experience during the second World War when numerous expatriate scientists from Europe played key roles in the Manhattan project and elsewhere, the US, as a matter of policy, provided a hospitable and attractive environment to scientists, technologists and bright students from all parts of the globe. Government support for research expanded rapidly. Professors received funds to hire large teams of best available graduate students and post-doctoral fellows from anywhere in the world. In this they succeeded admirably because the research facilities, the liberal intellectual environment, and the salaries available in the US were too irresistible for most students and scientists elsewhere in the world. Many pieces of equipment, chemicals, etc., which were earlier made by scientists themselves, became available commercially which gave a big advantage to those with more money and proximity to the centres of production. Little wonder that suddenly most of the star scientists were to be found in the US. Not only did India's Chandrasekhar, Khorana, Inder Verma, and Ananda Chakravarty choose to emigrate to the US, so did some of the best scientists from most other major nations. If a young Raman or Saha in post-independence India had resisted the temptation to emigrate to the US and doggedly stayed on in India, he would be functioning under considerably greater relative handicaps than he faced in the earlier era. If he had continued to work on exciting contemporary problems, he would have had many more competitors working on the same problems and supported by better facilities, brighter students and better trained post-doctoral fellows. The chances of his being scooped would be quite high. In the first past-the-post system of scientific credit, Raman and Saha might have received no credit for the work done by them.

Under such circumstances, it is indeed remarkable that India has retained sufficiently large number of good scientists to keep the standards reasonably high. The important point here is that our failure to retain some of our best students and scientists is less due to the manner in which our universities and research institutes have functioned and more due to our socio-economic conditions and policies originating elsewhere, about which we could have done nothing.

As to the question of our record in developing technologies for our industry, I think the reason lies again in the state of our economic development. Our industrialists, with limited capital from international standards and a vast captive market, have behaved quite rationally in acquiring proven, even if dated, technologies from elsewhere and using them to manufacture goods for our needs which Indian consumers accepted readily. To expect our industrialists to compete with the multinationals in R&D, or to use only the (unproven) technologies developed in Indian research laboratories, would require them to be financially imprudent. It is, therefore, not surprising that even though during the last 50 years most of the CSIR laboratories have concentrated on applied research (it is a mistake to think, as some seem to do, that the stress on industrial research in CSIR laboratories is a new phenomenon), few of its technologies have been used by Indian industry. Even in the future only such technologies developed by the CSIR are likely to see the light of the day as are sold to the major (mostly multinational) companies with in-house R&D capabilities to develop them into marketable products. It is unrealistic to expect Indian scientists and technologists to compete with international industrial houses in generating marketable technologies of comparable standards, without even the benefit of interacting with the user industries.

In advanced countries, scientists and technologists in publicly funded R&D institutes only generate technology ideas which are then developed into technologies and products by industrial scientists. Under the best of circumstances, scientists in Indian government institutions could be expected to compete with their counterparts elsewhere, not with the researchers working in industry. The main point is that though Indian industry has its own reasons for not using the technologies developed in public funded Indian research laboratories, as well as for not investing in in-house R&D of its own when it could easily buy ready-made technologies of standards acceptable to the Indian consumers, these reasons were not good enough to hold Indian scientists exclusively responsible for not developing and transferring technologies to the Indian industry. Indian research laboratories could have succeeded in transferring technologies to Indian industry only if the latter had no access to the proven technologies in the international market. This, of course, would not happen in non-strategic areas. International industry would not like its potential competitors to grow, if all that was required to stop it was to offer its obsolete technologies, and may be a few foreign trips, to the Indian industrial managers.

It is noteworthy here that in strategic areas such as atomic energy, defense and space, where the advanced nations were not willing to part with their technologies, Indian scientists and engineers have a much better record of the utilization of their efforts, even though the unavoidable teething troubles may have made these developments relatively slow.

Coming to the question of the contributions of Indian R&D to poverty removal and development, firstly it must be recognized that these contributions have not been insignificant. If we have not had a famine for the last 30 years and a war for the last 25 years and if our life expectancy has improved substantially, some credit for it does go to our S&T sector. Even if the contribution of agricultural scientists to the increased food grain production (approximately 140 million tonnes per year in the post-independent era) is calculated at Rs 1/kg (i.e. about 20% of the actual cost), this works out to a staggering Rs 1,400 crores per year, certainly much more than our total annual expenditure on R&D. Taken as a whole, Indian R&D is clearly more than paying its way. Our poverty and underdevelopment certainly remain. But to think that these problems will be solved faster by further reducing our already meagre investments in R&D, or by introducing corporate culture into our publicly funded R&D institutions is unrealistic. Such steps can only destroy what has been achieved, make scientific careers still more unattractive, and further aggravate our problems in the future. Our real problems lie in lack of capital and an ineffective population policy, especially the latter, on which we are silent these days.

Useful technologies vs basic research

Our tendency to be over-critical of ourselves and failure to appreciate that we have been doing something right about our higher education and S&T, has created an environment in which there is a real danger that much of the past good work may be undone. I refer here to the excessive emphasis in the last few years on support of only immediately useful S&T. Not only are the national laboratories being pressurized to de-emphasize basic science, which is absolutely essential to maintain high standards, but even the universities are being exhorted to become handmaidens of industry which, understandably, would support only short-term projects with prospects of immediate profits.

It is pertinent to note that the emphasis on immediately useful science and reduced support for basic science is not an original Indian idea. This is an imitation of what has become a fashion in several advanced countries since the era of Reagan and Thatcher. This is also true of the exhortations to the scientists to establish linkages with industry. This development has disturbed several of the more thinking scientists and intellectuals in the West who have articulated the risks involved in this approach. For instance, in a recent letter to the *Science* (16 August 1996), Nobel Laureate Arthur Kornberg pointed out that the antibiotic penicillin, as well as the entire molecular biology leading to the Human Genome Project (HGP) and bio-technology, would not have been possible, but for the support to the relatively unplanned, curiosity-driven research. At the same time, according to him, the high level of planned support to anti-cancer research has yielded much poorer dividends, because the knowledge generated to solve the problem simply did not exist.

Several other points which have recently appeared in international literature are of relevance in the context. A study conducted by the Science Policy Research Unit at the University of Sussex in the UK, has concluded that the economic impact of basic research has to be measured not only in terms of the value of the knowledge that it generates, but also in terms of producing the trained manpower which can make use of such knowledge, even if it is generated elsewhere. This is extremely important in our case. To cite an example, benefits emanating from the HGP are not going to be finally utilized by the needy countries if there is no trained manpower contributing to the generation of this knowledge. Hence, India would be making full use of knowledge generated by the HGP only if it invests money in projects aimed at generating knowledge in this area, even if this knowledge may not bring us glory that the advanced nations with their much bigger investments will corner. India will at least generate manpower needed for using the internationally available knowledge in patient care, in reducing the genetic load in our population, and in utilizing the technologies spun off by this project in agriculture, animal husbandry and molecular anthropology. The architects of our SPR, much more realistic as they were than some of our present-day critics and managers, would have been satisfied with the above as our initial goal.

In a beautifully argued article (*Interdiscip. Sci. Rev.*, 1995, **20**, 281–288), reproduced in *Current Science* (1996, **71**, 148), Martin Rees points out that a panel set up by the National Academy of Sciences, USA, in 1937 to predict the technologies of the following few decades, did *not* include among its predictions the nuclear power, transistors, antibiotics, jet aircraft, rocketry, or computers. All these developments were possible because in the post-war era the US government invested heavily in supporting curiosity-driven, investigator-initiated research projects in areas of *no obvious* immediate benefits. In contrast, the USSR which greatly emphasized the utilitarian science over basic science, contributed relatively much less to the development of novel technologies which have changed the world today. (It is, perhaps, not irrelevant to refer here to T. D. Lysenko who emphasized the empirical agricultural technology like vernalization and used his friendship with Stalin to decimate the growth of genetics in the USSR; the consequent failure of the USSR agriculture to grow food crops at the required levels in the long run played a key role in the failure of the entire Soviet experiment.)

Black holes and dinosaurs

Another interesting point made by Rees in his essay is that the common people have maximum interest in some of the areas of science with hardly any conceivable use. Cosmology and dinosaurs are much more likely to make front-page news than any of the more useful technological breakthroughs. This supports a feeling I have always had that most of the attacks on basic science really do not come from general public but are generated by the internal politics within the scientific community. Rees also points out that a football team in which each player has to score goals in order to retain his place is unlikely to be a functional outfit. This should be a sobering thought for those, including some very influential policy makers, who would like to support only such basic researchers the impact of whose research is visible to all. It is essential to maintain a broad science base and a web of connections between different disciplines.

Threat to credibility of science

John Ziman, Emeritus Professor of Physics at the University of Bristol, pointed out in his 1995 Medawar lecture that in the current emphasis everywhere on useful research what is at stake is the very 'objectivity' of science. Scientists who are employed to do useful science will clearly not be in a position to publish their findings if they go against the interests of their employers. The implication of this is that the credibility of science and scientists will take a serious beating. It was the objectivity of science and the relative, even though not absolute, disinterest of the scientists in the benefits of their work that gave science a unique prestige as a methodology of generating knowledge. Science as a cultural and intellectual activity will lose its credibility, and in the long run will also lose its ability to benefit society and generate knowledge and technology, if public funding and prestige is denied to those who are willing to work in intellectually challenging areas even if the potential applications of their work are not apparent in the beginning.

Lastly, it is important not to ignore the lessons of history. Two examples, one of a long-term and the other of short-term historical context should suffice to make my point. (i) During the centuries immediately preceding the British colonization, India was ruled by one of the most powerful empires – the Mogul empire – in history. During this period, India had acquired, developed and used a large number of useful technologies in diverse areas such as production of textiles, fancy gold and silver embroidery, metal work, architecture, traditional medicine, perfumes, sophisticated musical instruments, etc. The country was sufficiently wealthy to attract traders from far away lands. However, little attention was paid to keeping track of the advances in S&T taking place elsewhere and to making original contributions to the advancement of knowledge in these areas. The result was that European traders could extract large concessions from Indian emperors simply by holding out the threat of attacking the Haj ships on the high seas to which Indians had no answer. Perhaps, even more importantly, the achievements of the Europeans in S&T so dazzled the Indian intelligentsia that many readily supported their rule, which was certainly an important factor in the easy colonization of India by Britain. (ii) The Government of India had created two Research Councils (viz. ICAR and ICMR) in the area of applied biology. The two have made major contributions toward improving our food production and health standards respectively. However, they made the mistake of concentrating almost exclusively on immediately useful projects and paid little attention to developing expertise in basic biology on which their future performance would depend. The result was that when in the 1980s the conceptual framework earlier developed by molecular biology altered the technological basis of modern agriculture and medicine, the ICAR and the ICMR had insufficient competence to exploit the new technologies. Nearly all the funding for molecular agriculture and molecular medicine had to come from the newly created Department of Biotechnology, and most work in these areas had to be done in the Institutions outside the purview of ICAR and ICMR. One shudders to think as to what would have happened to basic as well as applied biology in this country if the Government of India had not either created the DBT or if this Department had not been lucky to have an enlightened leadership which recognized the importance of basic science in developing technology. One hopes that other agencies which are keen to deemphasize basic research would learn the lessons from our earlier experiences.

To summarize, a realistic assessment in the light of the SPR shows that the performance of the Indian S&T sector, especially the R&D institutions and universities, which cultivated all aspects of science (pure, applied and educational), and gave reasonable encouragement to creative talent and individual initiative in generation of new knowledge in an atmosphere of academic freedom, has not been as bad as is generally believed in this country. They have succeeded in producing research scientists of international standard and in training large numbers of scientific and technical personnel who are a major source of our strength as a nation today and who can help in rapid industrialization of the nation, given adequate capital and proper economic and industrial policies. These institutions and basic research need continuous support. Our emphasis on immediately useful research at the expense of basic science can kill the goose that lays the golden eggs.

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