

Prof. C.N.R. Rao: A Life Dedicated to Science

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Abstract: *Life of a chemical hero, Prof. C.N.R. Rao has been explored who laid the foundation of solid state and material chemistry in India. By his glorious achievements in the field of material science and his dedication to upliftment of science, he set a shining example for generations of scientists.*

1. INTRODUCTION



In the realm of chemical science Prof. C.N.R. Rao (Chintamani Nagesa Ramchandra Rao) adorns a brilliant position and shines like a pole-star. His passionate love and attraction for chemistry made him a keen worshiper of the subject. He is one of the famous pioneers and architects of chemical science who worked in India and internationally with full devotion and dedication. On 16th November 2013, Govt. of India made announcement of the award of the *Bharat Ratna* to Prof. C.N.R. Rao for his outstanding contributions in the field of solid state and material chemistry. In a special ceremony in Durbar Hall of Rashtrapati

Bhawan, he was conferred the award on 4th February 2014 making him the fourth scientist after Nobel Laureate and physicist Sir C.V. Raman (1954), Civil Engineer Sir M. Visvesvarayya (1955) and Aeronautical Engineer former president Dr. A.P.J. Abdul Kalam (1997) to have this honour. At present Prof. C.N.R. Rao is the National Research Professor, Linus Pauling Research Professor at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) and honorary professor at the Indian Institute of Science (IISC). He is also the chairman of the Science Advisory Council to the Prime Minister of India.

In addition to his deep involvement in research, teaching and writing work, Prof. Rao is a true patriot having serious concern for the progress of India. He firmly believes that proper attention towards the progress of science and technology is essential for the development of a nation and its citizens. He is the first scientist in the country who expressed frankly and boldly his concern on the decline of scientific research and education in India. He pleaded emphatically that Government should invest more on science in order to redress the existing malady. He candidly remarked in an interview given to *Science Reporter* in August 2007, *about 10-15 years ago, India was way ahead of China in basic science and other areas. But today China has overtaken us. China has more institutions working on science and a large number of people working in science. They have invested more in science.*

Chinese contribution to world scientific research is nearly 15% while India's contribution is less than 3% [1]. His intense love for the development of science is evident by the fact that while addressing a press conference just a day after the announcement of *Bharat Ratna* to him, he stressed the need for providing more resources for scientific research. He appreciated the fact that Indian Scientists are doing much more than the money being spent on science.

2. EARLY LIFE AND EDUCATION [2]

Prof. C.N.R. Rao is a distinguished son of mother India who left permanent impression on the head and heart of his countrymen and fellow scientists by his lofty ideals, high aspirations, path finding work and great achievements. He was born on 30th June 1934, in Bangalore in a highly cultured and educated *Kannada* family as a only child of Shrimati Nagamma Nagesa Rao and Shri Hanumantha Nagesa Rao. He got his primary education at home itself under the guidance of his mother who was a

pious and noble woman, and had a good knowledge of arithmetic and hindi literature. She used to narrate him mythological stories from *Ramayana* and *Mahabharata*. He was admitted in middle school in 1940, at the age of six, and completed the lower secondary examination (Class VII) in 1944 with a first class. In 1947, he passed secondary school leaving certificate examination (High School) with a first class. His father was of the opinion that mother-tongue is the best medium for learning, so he opted for *Kannada* medium for his high school course instead of English medium. But at home he was encouraged to learn english also and develop a proficiency in it. His father himself was a highly educated person employed in education department of Mysore state, having M.A. degrees in history, economics, political science and a degree in education also. Prof. Rao passed B.Sc. in first class, in 1951 at the age of 17 from Central College, Bangalore. After graduation, initially he was thinking to join Indian Institute of Science, Bangalore for a diploma or a post-graduate degree in chemical engineering. But destiny willed it otherwise. On persuasion of a teacher, he took admission in Banaras Hindu University for M.Sc. degree in Chemistry and obtained it in first division two years later in 1953. Those days Prof. S.S. Joshi was Head of the Chemistry department of B.H.U. who gave him inspiration for taking up research work. Just after obtaining M.Sc. degree he was granted a research scholarship in IIT, Kharagpur. But at the same time four foreign Universities, MIT, Penstate, Columbia and Purdue also offered research scholarship to him. Prof. Rao joined Purdue University for his research work. In two years and nine months, he completed his Ph.D. work. It was also at Purdue that he got the opportunity of meeting his boyhood hero, Linus Pauling. He was highly influenced by Linus Pauling and considered him as his *academic grandfather*. Pauling's book titled *Nature of Chemical Bond* inspired and motivated young Rao towards the study of structures of molecules and materials. He realized that understanding of structure and bonding provides a basis to understand chemistry and to do new chemistry.

3. TEACHING AND RESEARCH CAREER

In 1959, he returned back to Bangalore and joined the Indian Institute of Science, on a monthly salary of Rs. 500/-, and started his research work with six Ph.D. students. He received his D.Sc. degree in 1961 from Mysore University. In 1963, he was directly appointed as Head of the Chemistry Department at IIT, Kanpur by its Director, P.K. Kelkar at the young age of 29 years. After working at IIT, Kanpur from 1963 to 1976, he came back to IISc, Bangalore and started a new unit of solid state chemistry and structural chemistry. He served as the director of IISc, Bangalore from 1984 to 1994.

He has been a visiting Professor in a number of Universities of repute, *Viz.*, Purdue University, the University of Oxford, the University of Cambridge, and the University of California Santa Barbara. He was the Jawaharlal Nehru Professor at the University of Cambridge and Professorial Fellow at King's College, Cambridge during 1983-1984.

4. RESEARCH WORK

Professor Rao started research with his work on study of spectra and structures of the molecules. His two books on *Ultraviolet & Visible Spectroscopy*, and *Infrared Spectroscopy* earned him world-fame. Subsequently, in the early 1960s, he started work in solid state and material chemistry. This was a lesser known subject of research during those days, and very few chemists were working in this area. In connection with his choice for the research field that was not in vogue, it is appropriate to quote following lines from a poem of Robert Frost [2].

Two roads diverged in a yellow wood And sorry I could not travel both

I took the one less travelled by

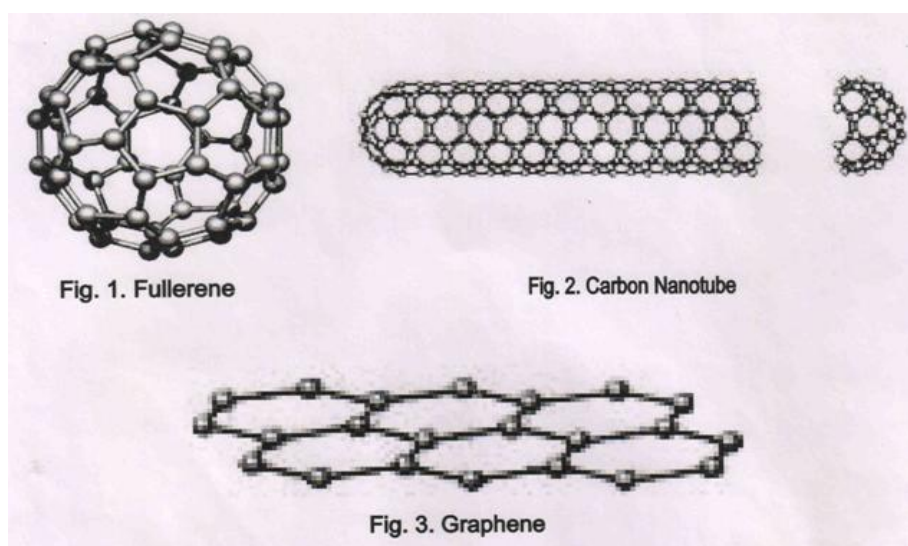
And that has made all the difference.

He made a remarkable contribution in the areas of solid state and material Chemistry [3, 4] and gave them a distinct identity. In appreciation of Prof. Rao's epoch-making work, Robert Cahn states in his book "*The Coming of Materials Science*", *Rao had been active in several of the major aspects which, together, begining to define material chemistry* [5]. Now material chemistry has emerged as a topical and valuable branch of chemistry that encompasses the study of synthesis and properties of various types of materials useful for human life. At present material chemistry aims at preparation of materials with the desired and controllable properties, which are being used extensively in electronics, computer, transportation and energy etc. Many biological materials, have been synthesized which find

use as substitutes for natural materials such as bone and spinal cord. Besides the synthesis of solid materials, chemists are actively engaged in the synthesis of gels, liquid crystals and other soft materials also.

Early work of Prof. Rao was related with chemistry of solids which included structural transformation in oxides & halides etc., decomposition & oxidation of solids, and properties of solids such as electrical conductivity as a function of structure. He worked extensively on synthesis and properties of metal oxides which constitute a significant area of material chemistry. Metal oxides have been found to exhibit a vast array of useful properties such as conductivity, superconductivity etc. They have been found as excellent insulators or dielectrics. Another area of his interest is synthesis of open framework structures and hybrid materials which contain both inorganic and organic components. Due to their porous nature, some of these solid compounds are capable of absorbing hydrogen and consequently, they can be utilized in the field of energy.

In 1980s, Prof. Rao developed a keen interest in the synthesis and properties of small clusters or nano particles of the metals. He worked with full devotion and zeal on nanoparticles, nanowires, nanotubes and a variety of nanostructures. His work on inorganic nanotubes and different types of carbon nanotube structures is regarded as an excellent contribution in nanochemistry which made him a great exponent of nanoscience. Some of the contributions of Prof. Rao which are related with fullerene and graphene are of very high quality. Fullerene is a form of carbon having large spherical molecule consisting of a hollow cage of 60 or more carbon atoms joined together as hexagons and pentagons like a soccer ball. Fullerenes are also known as buckyballs or Buckminsterfullerene because their structure (Fig.1) resembled the geodesic dome invented by famous architect Richard Buckminster Fuller [3]. Carbon nanotubes are also members of family of fullerenes. They are extended fullerenes having cylindrical shape [4] (Fig. 2). In recent years graphene consisted a popular area of research. It is a single sheet (0.34 nm thick) made of six membered rings of carbon atoms (Fig. 3) and exhibit some unexpected properties and phenomena [4]. Graphite is composed of layers of graphene.



Nanomaterials are extremely tiny substances derived from their own bulk form and measured in nanometers. They are very useful to human life due to their some special properties. The word „nano“ is a Greek word meaning dwarf and is used to denote one billionth of something [3]. One billionth part of a meter (10^{-9}) is known as a nanometer. The diameter of a hydrogen atom is 0.1 nm. The width of a DNA molecule is 2.5nm. Size of the glucose molecule ($C_6H_{12}O_6$) is less than 1nm. The diameter of a human hair is 20,000nm. Nanomaterials are almost close to the size of atoms and molecules, and it is not possible to see them with naked eyes and touch and manipulate them with hands. We know that in case of normal or usual materials, there is not a significant change in their properties with the change in size. But contrary to this, the nanomaterials on change in size exhibit a remarkable variation in their properties due to interplay of quantum effects. If iron is converted into particles of very small size, it loses magnetism. Gold is very shining metal and is not chemically reactive. But small particles of gold (1 nm diameter) are non-metallic, without shine and chemically reactive.

5. PUBLICATIONS AND OTHER ACHIEVEMENTS

In the world of research and academia Prof. C.N.R. Rao is an internationally acclaimed personality. He has published around 1550 research articles and 46 books on spectroscopy, solid state and material chemistry, superconductivity, nanochemistry and various other subjects. He has published his autobiography with the title *Climbing the limitless ladders a life in chemistry*. He is the recipient of 61 Honorary Doctorate degrees from Indian and foreign Universities. A large number of Post-graduate Research Students and Postdoctoral Associates have the privilege of working under his supervision. More than 140 research students completed their Ph.D. work under the supervision of Prof. C.N.R. Rao. He is member of the editorial boards of large number of prestigious International journals dealing with chemical physics, spectroscopy, solid state and material chemistry. Prof. C.N.R. Rao has received large number of awards which include Marlow Medal of Faraday Society (1967), *Bhatnagar Prize* (1968), *Padma Shri* (1974), *Padma Vibhushan* (1985), Hevrosky Gold Medal of the Czechoslovak Academy (1989), Einstein Gold Medal of UNESCO (1996), Hughes Medal (2000), the Centenary Medal of the Royal Society of Chemistry, London (2000), first recipient of Indian Science Award of the Government of India (2005), Dan David Prize for science in future dimension (2005), Nikkei Prize (2008), The Royal Medal (The Queen's Medal) of the Royal Society of Chemistry (2009), The August-Wilhelm-von-Hoffmann Medal of the German Chemical Society (2010), and Ernesto-Illy Trieste Science Prize from Third World Academy of Science (2012).

Prof. Rao has the honour of being a member of several scientific academies including the Indian National Science Academy, The Royal Society, London, The Royal Society of Chemistry, London, U.S. National Academy of Sciences, The Royal Society of Canada, Japan Academy, Russian Academy of Sciences, French Academy of Sciences. He has been President of International Union of Pure and Applied Chemistry and President of the Third World Academy of Sciences (TWAS) In the year 1988, he was elected as the President of the Indian Science Congress Association. Due to his efforts, Chemical Research Society of India was established in the year 1999, and he was elected its Founder President.

Prof. C.N.R. Rao is not a so called *Ivory Tower Scientist* who works with in the solitary confinement of the four walls of his laboratory only with a limited thinking. In addition to his glorious research activity, he takes time to think and do something for the bright future of young students, young scientists and for the bright future of the country as a whole. He is quite keen to see India emerge as a scientifically developed nation, and become a global leader in science in the next 20 years or so. He strongly advocated the better educational facilities to young children in villages and foundation of good residential schools in the rural areas. He emphasizes the need of better undergraduate education in science, better funding in research, creation of better laboratories, and rectifying the present university education.

Prof. Rao and his wife Mrs. Indumati Rao are working with a missionary zeal to excite the young students all over the India and infuse a true spirit of science in them through direct contact programmes. They travel throughout the country and benefit the students by their learned and thought provoking lectures. The couple organizes science camps in different parts of India to make science an interesting subject. As a part of this programme they have prepared books and CDs. For promotion of science education, at the suggestion of his wife, Prof. Rao has created C.N.R. Rao Education Foundation from a part of the million-dollar Dan David award from Tel Aviv University, Israel. Mrs. Rao is managing this trust efficiently with the help of other family members. The foundation gives awards to outstanding teachers of science in the country and good students in IISER. It also provides prizes to best researchers at BHU and IIT, Kanpur. There is also provision for an award to a bright scientist from a least developed country administered by TWAS.

6. CONCLUDING REMARKS

Today, even at the ripe age of eighty years, Prof. C.N.R. Rao is deeply involved in research and teaching. His present research interests are focused on graphene, the new wonder material, and artificial photosynthesis. He is continuing his daily schedule of work enthusiastically with full interest and devotion, and serving the nation by his vast knowledge. Commenting on the multidimensional scientific achievements of this great Indian scientist, Dr. R. A. Mashelkar, former Director General of Council of Scientific and Industrial Research, has rightly said, *the future generations will find it hard to believe that all this could be achieved by a single individual*. Around 50 years ago he had started a

new era in chemical science by lighting a lamp of new knowledge. It is hoped that light of this lamp will continue to guide and inspire many generations of students, teachers, and scientists in India as well as abroad. His motivating message to younger generation is being quoted below which will help them as tip for success.

- *Pursue your dreams with passion, hard work and dedication.*
- *Never stop learning. The thirst to gain more knowledge should never come to an end.*
- *Always gain fresh insights, don't hesitate to ask right questions.*
- *Observe leaders closely; learn as much as you can from their leadership styles.*
- *Build a strong base. The journey to peaks of excellence requires a strong base camp.*
- *Keep a balance between professional and personal life. Find time for your family and things which interest you.*

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Membership/Fellowship of Learned Societies:

- Fellow of Royal Society of Chemistry (London).
- Fellow of Indian Chemical Society.
- Life Fellow of Institution of Chemists (India).
- Life Fellow of Indian Council of Chemists.
- Life Member Indian Science Congress Association.
- Life Member Chemical Research Society of India (Indian Institute of Science, Bangalore).
- Life Member, International Society of Teachers and Researchers in Chemistry.