# HRIDAY BEHARI MATHUR

## (1928 - 1980)

## Elected Fellow 1974

### Childhood and Early Education

Hriday Behari Mathur was born on May 27, 1928 in Nasirabad, in Ajmer district of Rajasthan state. He had his schooling at the Government High School in Ajmer, affiliated to the Board of High School and Intermediate Education, Rajaputana, Central India and Gwalior. He always stood first at his school examinations and he passed his final school examination in 1942 with a distinction in science and mathematics. He was ranked twelveth in the order of merit in the whole Board. In recognition of his outstanding performance, he was awarded Haris Memorial Merit Scholarship in the year 1940-1942. Later he passed his intermediate examination from the same place scoring distinction in physics, chemistry and mathematics and standing fourth in the order of merit.

### University Education

Mathur obtained his Bachelor of Science degree in 1946 from the Agra University again obtaining a distinction in the examination. He was the recipient of the Kailashnath Shyamnath Memorial Merit Scholarship for the year 1944-46. He completed his Master of Science in 1948 from Delhi University standing first in the University. He also received the University of Delhi Science Exhibition Merit Award for the year 1947-48. Betwen 1948-50 he worked as an All India Research Fellow of Chemistry at the University of Delhi. Later he took up a teaching position as a lecturer in the Chemistry Department of the Delhi University. He was associated with the university during the period 1950-58. He was awarded the Government of India Overseas Central State Scholarship. He obtained lien from Delhi University in 1952 to take up a research position at the Lawrence Radiation Laboratory, University of California in USA. He obtained the Doctor of Philosophy in Chemistry in the year 1954. Between 1954-56, he served as a research associate in the famous Enrico Fermi Institute for Nuclear Studies in Chicago, USA. He returned to India in 1956 and continued his teaching at the Delhi University. In the year 1958, he joined the Physical Chemistry Group of the National Chemical Laboratory, at Pune as a Senior Scientific Officer, Grade I and later become the Head of the Physical Chemistry Division. In 1976 he was appointed as the Director of Defence Materials and Stores Research and Development Establishment at Kanpur.

## Scientific Activity

Dr Mathur had a keen interest in different scientific disciplines, which is evident from his scientific achievements. He started his research activity in the field of Nuclear Chemistry at the Lawrence Radiation Laboratory under guidance of Professor Hyde. His work on Neutron Deficient Isotopes in the closed shell region of 50 Protons and 50 Neutrons and the $\beta$ and $\gamma$ ray spectroscopic studies of the isotopes was started soon after the publication of Maria Mayer's theoretical paper and resulted in the discovery of hitherto unknown radioactive isotopes Iodine-121, Iodine-123, Xenon-121, Xenon-123, Cesium-121, Cesium-125, Niobium-89, Zinconium-90m and Molybdenum-90. It provided one of the earliest experimental confirmation of the shell model of the nuclear studies for which Maria Mayer later shared with JHD Jensen, the 1963 Nobel Prize in Physics.

In 1958 Dr Mathur joined the Physical Chemistry Group at the National Chemical Laboratory, Pune. He was instrumental in establishing a Radiation and Nuclear Chemistry Division at this Laboratory. He organized at this Laboratory, the facilities for the use of radioactive isotopes and radiation sources in Physicochemical and Biochemical research. One of the peaceful use of the radioactive isotopes is in the field of medicine, where it can be used for the diagnosis of thyroid disorders and also in the diagnosis of the cause of megaloblastic anaemias. This work involved development of methods of tagging the red blood cells with radioactive isotopes, determination of the growth and decay of red blood cells and the assimilation of Vitamin $B_{12}$ in the normal and anaemic humans. Dr Mathur was one of the earliest to start such studies in India in collaboration with the Armed Forces Medical College, at Poona.

In the year 1961 Rudolf Mossbäuer won the Nobel Prize in Physics for his discovery that nucleus bound in solids could undergo recoil-free emission and resonant absorption of gamma rays. The extremely high resolution of this resonance allows the measurement of the separation of the nuclear energy levels to one part in $10^{14}$, an accuracy sufficient to reflect the weak interaction of the nucleus with the surrounding electronic environment. Thus through the Mössbauer effect, nuclear physics provides a powerful tool for the chemical analysis of the solids.

Dr Mathur was one of the pioneers in this field to recognize the manifold applications of the Mossbäuer effect in chemistry and actively persue a programme to develop this discovery as a tool in chemical spectroscopy. In many cases, e.g. in spinels containing several metal ions of the first transition series, the ionic distribution cannot be determined by x-ray studies with great accuracy because of the small differences of the scattering power. In such systems especially those containing cations of variable valancy and capable of occupying more than one possible site. Mössbauer spectra may be used to give the information on cation oxidation state and the site distribution. Dr Mathur's major achievement in the field of Mössbauer spectroscopy was the

characterization of several spinel compounds containing Fe and Sn, the chemical effects of electron capture in solids, the nature of chemical bonding in iron organo compounds, the mechanism of oxidation in Silver-Tin alloys. Many of his papers find reference in standard publications and books. (e.g.) '*The Chemical Application of Mossbauer Spectroscopy* by VI Goldenskii and RH Herber, Academic Press, 1968). It is because of Dr Mathur's sustained interest in the field of Mössbauer spectroscopy, that the National Chemical Laboratory has been recognised as one of the leading research centres in the field of chemical application of Mössbauer spectroscopy.

Dr Mathur's work on the confirmation in solids of the hypothesis of Wexler that a molecule can sometimes virtually explode as a result of the coulombic repulsion when one of the constituent atoms is radioactive and decays by the electron capture has a very important bearing on the mechanism of radiation damage.

Studies on diffusion in solids plays an important role in the development of high temperature technology since most of the high temperature reactions in solids viz. precepitation, oxidation, corrosion, phase transformation, sintering etc, are diffusion controlled. The work on the kinetics of high temperature oxidation of metals and alloys and intermetallic diffusion lies in an area of great importance as far as the industrial development is concerned. These studies finds direct application in the development of solid fuels, semiconductors, catalysis and in nuclear technology. Dr Mathur's keen interest in these fields resulted in several publications on diffusion in solids using Radio Tracer Technique and the elucidation of oxidation mechanism in various metals, notable among them are the diffusion of rare earth metals in copper, isotope effect in diffusion, oxidation kinetics in rare earth metals, copper and silver-tin alloys.

Dr Mathur initiated a study on thermodynamics of complex ion formation with a view to clarify the mechanism of radiation protection by chemical protective agents such as aminoacid like cysteine. This work has been internationally recognized as standard work on thermodynamics of complex ion formation and is quoted in numerous references in modern books and reviews (e.g. *Interaction of Electrolytic solutions*, GH Noncollas, Elsevier Publishing Co, Amsterdam 1966. *Thermochemistry of Transition Metal Complexes*, SJ Ashcroft and CT Mortimer, Academic Press, 1970).

Apart from his basic studies, Dr Mathur has also shown keen interest in carrying out applied research. At National Chemical Laboratory, he has handled number of applied and sponsored projects as an investigator incharge in different areas of investigation. Molecular sieves of the type 3A, 4A, 10X and 13X are used as an industrial dehydrants and in gas purification and separation plants. The bulk demand of these materials will continue to grow with the growth of the petrochemical industries and the indigenous manufacture of air separation unit for the cryogenic industry. Dr Mathur has developed a process for the synthesis of some of the molecular sieves comparable to union carbide Linde molecular sieves. His involvement in other areas of

applied research are the investigation of synthesis and properties of new types of glycol monoalkyl ethers for the control of water evaporation to extend the industrial utilization of the cotton seed oil (sponsored by the Department of Agriculture, Agriculture Research Service, USA). He was also actively engaged in a project sponsored by the Department of Atomic Energy, Government of India. Some of the rare earth metals have a high neutron absorption cross section which makes them promising materials for use as controls of neutron intensity in the nuclear reactor. The results obtained in this project provide basic data on the physical and chemical factors which affect the rate and the mechanism of corrosion of the rare earth metals at high temperatures. He was also involved in a project sponsord by the Department of Industries, Jammu and Kashmir on the fractionation of turpentine oil. Basically he was interested in the collection of thermodynamic data on vapour liquid equilibria in the binary mixtures of the various components of the turpentine oil with a view to design a distillation coloumn for the fractionation of the turpentine oil into its components.

Dr Mathur was the author of more than fifty research publications. He has written a chapter on *Mössbauer Spectroscopy and its Application in Inorganic Chemistry* and a chapter on *Application of the Mössbauer Effect in the Study of Ferrites and Garnets*,

## Honours

In recognition of his scientific works, particularly for his achievement in the field of Mössbauer Spectroscopy he was awarded the Shanti Swaroop Bhatnagar Memorial Award in the year 1973. Soon after, he was made a fellow of the Indian National Science Academy in 1974. He was a recognized research guide for the PhD degree in Physics and Chemistry of the Universities of Agra, Banaras, Bombay, Pune and Madras and also the Indian Institute of Technology, Bombay.

## Membership of Scientific Societies and Advisory Committees

Dr Mathur was a member of several scientific societies. He was a member of the Indian Chemical Society, American Physical Society, American Association of Advancement of Science, Magnetic Resonance Spectroscopy Association (India) and tbe International Diffusion Research Association. He was a Fellow of the Society for Sigma Xi, USA.

Dr Mathur was a member of the Board of Editors, Indian Journal of Chemistry (1974-76), Member of the Catalyst Research Committee, CSIR, New Delhi (1974-76), Convener, Planning Group-II on 'Fertilizers and other plant nutrients', National Committee on Science and Technology, Panel 1-V on Chemical Industry, Member, Task

Force on the Development of Fertilizer Industry, Ministry of Petroleum and Chemicals, Government of India (1973), Member, Planning Group on Surface Water Resources, National Committee On Science and Technology, Panel on Natural Resources, Member, Variable Energy Cyclotron Users Committee, Department of Atomic Energy, Government of India, and CSIR Metals Research Committee. His biodata has appeared in the national and international directories such as the Times of India Directory and Year Book including Who's Who (1974). World Nuclear Directory, published by Vallancey Press, UK and Who's Who in Atoms.

## Personnal Quality

Dr Mathur was an able administrator. His punctuality and regularity was very well known. He was always courteous, degnified and soft spoken. At the same time never hesitated to be outspoken, knowing well such expression can affect his popularity or personnel career. Dr Mathur was a strict disciplinarian with keen apptitude for precission and perfection. He had very cordial relation with his collegaues and students. However he was never willing to compromise on any scientific discussion unless he was convinced. He was always ready to carry out experiments by himself if any of his students found it very difficult to implement his ideas. As a research guide he had very few equals. He always tried to develop self confidence in his students and prepared them to tackle original problems. He had an excellent memory power and could even provide necessary references from his memory.

## Last Days

January 11, 1980 was a fateful day. Dr Mathur was to attend a selection committee meeting at the National Chemical Laboratory, Poona. On his way to airport, he had a sudden massive heart attack. Though all the medical help was provided, he could not servive due to repeated attack. The end come on January 12, 1980. His passing away was deeply mourned by a very large number of his collegues and admirors. Dr Muthur has left behind his wife Mrs Santhi Mathur, a son and a daughter.

## Acknowledgement

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S Badrinarayanan

# BIBLIOGRAPHY


## (A) APPLICATIONS OF RESONANT ABSORPTION OF GAMMA RAYS (MÖSSBAUER SPECTROSCOPY) IN CHEMISTRY

1965. Mössbauer spectra of spinel oxides containing ferrous ion. *Solid State. Comm.*, **3**, 401.

1966. Mössbauer effect in oxidation reduction system : The catalytic effect of iron in the oxidation of crysteine. *Indian J. Chem.* **4(8)**, 337.

— Mössbauer spectra as a tool for studying cation distribution in cubic ferrites. *Nuclear Physics and Solid State Phys.* (India), **8B**, 36.

1967. A Mössbauer study of the nature of bonding in ferric (Acetylacetone) $Cl_2$ and ferric (Acetylactone) $Cl_2$. *Indian J. Chem.* **5**, 208.

— Mössbauer spectra of cubic ferrites with spinel structure. *Indian J. Pure and Appl. Phys.*, **5**, 155.

— The Mössbauer spectra of sulphospinels containing $Fe^{2+}$ ions. *Solid State Communications*, **5**, 841.

1968. Mössbauer spectra of oxidic spinels containing $Sn^{4+}$ ion. *J. Phys. and Chem. of Solids*, **29**, 1779.

— A Mössbauer and X-ray diffraction study on the cation distribution in $FeAl_2O_4$. *J. Phys. (C) : Solid State Phys.*, **1**, 469.

— Charge distribution in the mixed oxide system, $ZnMn_xFe_{2-x}O4$ and $CoMn_xFe_{2-x}O_4$ *Indian J. Pure and Appl. Phys.*, **6**, 211.

1969. Chemical effects of electron capture in $^{57}Co$ (III) (1-10 phenanthroline)$_3$. $(C10_4)_3$. $2H_2O$. *Inorganic and Nuclear Chem. Lett.* **5**, 89.

— A Mössbauer spectroscopic study of the effects of electron capture in $K^{57}CoF_3$. *Indian J. Chem.*, **7(4)**, 353.

1969. A Mössbauer spectroscopic study of the nature of bonding in bisdithioacetylacetone tetrachloroferrate (II) *Chem. Phys. Letters.*, **3(4)**, 191.

— Mössbauer spectroscopic determination of the valency states of iron formed in the decay of $^{57}Co^{2+}$ in $CoCr_2O_4$ and $CoCr_25_4$. *J. Inorg. and Nucl. Chem.*, **31**, 3363.

— Electric field gradients in normal spinels. *Molecular Phys.*, **16**, 625.

1971. The nature of precipatated tin oxide in the internally oxidized Sn-Ag alloy. *Indian J. Chem.* **9**, 864.

— A Mossbauer study on the nature of *Fe* (II) bonding in bis-dithioacetylacetone tetrabromoferrate (II) and bis-dithiobenzoylacetone tetrachloroferrate (II). *ibid*, **9**, 1348.

— A Mössbauer and X-ray diffraction of the cation distribution in the ferrite $FeV_2O_4$. *J. Phys. (C) : Solid State Phys.*, **7**.

## (B) THERMODYNAMICS OF COMPLEX IONS IN SOLUTION AND THEIR RELATED STRUCTURES

1961. A relation between N-H stretching frequency and the stability of metal complexes of β—alanine. *Spectrochimica Acta.*, **7**. 895.

1964. John-Teller distortion and entropy changes accompanying the formation of metal-amine acid complexes. *J Inor. and Nucl. Chem.*, **26**, 382.

— Nature of metal-donor bonds : studies on infrared spectra. *Indian. J Chem* **2(7)** 257.

— Structure of Ni (ii) ion amino acid complexes : Studies on absorption. *ibid*, **2(1)**, 5.

1965. Thermodynamic properties of co-ordination complexes of transition metal ions with aminoacids. *ibid.*, **3(11)**, 475.

— The N-H stretching frequency and the Living-Williams order of stability of transition metal complexes of α-alanine, β-alanine and α-amino butyric acid. *Bull nat. Inst. Sci. (India)*, **29**, 152.

1965. Stability of transition metal amino-acid complexes. *ibid*, 7, 146.
1968. The effect of inner orbital splitting on the thermodynamic properties of the transition metal complexes of serine and threonin. *J. Inorg. & Nucl. Chem.* **30, 2181.**
1969. Thermochemical studies : The heats and entropies of reactions of transition metal ions with histidine. *ibid*, **3**, 425.
— Thermochemical studies : The effect of substituents on the heat of ionization of β-diketones. *Indian J. Chem.* **7(12)**, 1234.
1971. Thermodynamics of interaction of transition metal ions with histamine. *J. Inorg. & Nucl. Chem.*, **33**, 809.
— Thermodynamics of interaction of Cu (II) and Ni (II) ions with diketones in aqueous dioxane medium. *ibid*, **33, 2919.**
1973. Thermodynamics of the interaction of Ni (II) with cysteine. *ibid*, **35**, 253.
— Thermodynamics of linked metal chelate systems. I. Enthalpies and entropies of reaction of transition metal ions with N. (2-aminoethyl) 1, 3-propanediamines. *Indian J. Chem.*, **11,** 936.
— Thermodynamics of linked metal chelate systems. II. Enthalpies and entropies of reaction of transition metal ions with N, N'-Bis-(2-aminoethyl), 1, 3-propanadiamine. *ibid*, **11,** 1293.
1974. Thermodynamics of interaction of Ni (II) ion with monothiodibenzoyl methane. *ibid*, **12,** 736.
– Thermodynamics of linked metal chelate rings. III. Enthalpies and entropies of reaction of *Cu* (II) and *Ni* (II) ions with N,N'—Bis—(3-aminopropy), 1, 2-ethanediamine, *ibid*, **12**,

(C) KINETICS OF HIGH TEMPERATURE OXIDATION OF METALS AND ALLOYS AND STUDIES ON SOLID STATE DIFFUSION IN METALS

1963. Oxidation of copper in oxygen in the temperature range 500-650°C. *Indian J. Tech.* **1(2), 77.**
1964. Oxidation of gadolinium metal in the temperature range 500°—700°C. *Indian J. Chem.*, **2(8), 307.**
1967. High temperature oxidation kinetics of lanthanum metal. *ibid*, **5(9)**, 427.
1968. Kinetics of oxidation of dysprosium metal in the temperature interval 500°C–800°C. *ibid*, **6, 156.**
– Transition from internal to external oxidation in indium-silver Alloys. *Canadian J. Chem.*, **46**, 1187.
— Impurity diffusion of antimony and silver in aluminium. *Intr. Jr. Appl. Radiation and Isotopes.* **19**, 353.
1969. Transition from internal to external oxidation in dilute *Sn/Ag* alloys. *Indian J. Chem.*, **7(4)**, 340.
1970. Impurity diffusion of rare-earth metals in copper. *Indian J. Pure and Appl. Phys.*, **8(6)**, 324.
1972. Isotope effect for diffusion of cobalt in copper. *ibid*, **10, 512.**
— The correlation factor and the mass dependence for the diffusion of cobalt in copper. *Nuclear Phys. and Solid State Physics* (India) **14C**, 197.
1973. On the diffusion of cobalt in Silver. *Indian J. Chem.*, **11,** 463.
1974. Mass dependence for the impurity diffusion of cobalt in silver. *ibid*, **12, 702.**

(D) NEW RADIOACTIVE ISOTOPES IN THE CLOSED SHELL REGION AND THEIR BETA AND GAMMA SPECTROSCOPIC STUDIES

1952. Titration curves of the clay minerals Attapulgite and Nontronite. *J. Phys. Chem.* 56, 633.
1954. Spectrometer studies of the neutron deficient isotopes of cesium and the E-3 isomers, xenon-127m and xenon-125m. *Phys. Rev.*, **95**, 708.

— Spectrometer studies on the neutron dificient isotopes of xenon and iodine. *ibid.* **96**, 126.

1955. Isomeric states in the chain $Mo^{90}$_____$Nb^{90}$_____$Zr^{90}$. *ibid.* **98**, 261.

— Studies on the isomeric pair $Nb^{89m}$ and $Nb^{89}$. *ibid.* **97**, 117.

— The radiations of 34-day $Xe^{127}$. *ibid.* **97**, 707.

— The radiations of Molybdenum$^{90}$ and the isomeric states of Niobium$^{90}$. *ibid.*, **98**, 79.

1965. Use of radioactive isotopes in '*A study of thirty two cases or megalo*-blastic anaemia' (In collaboration with the Armed Forces Medical College, Poona). *J. Tropical Medicine and Hygiene* (*UK*), **68**, 147.

1968. Streospecificity of the recombination reactions in the neutron irradiated cis-and trans-Cr (Ethylenediamine)$_2$—$Cl_2Cl$. *J. Inorg. and. Nucl. Chem.*, **30**, 1663.

1970. Thermal decomposition of the formates of the rare earth elements. *Indian J. Chem.*, **8**, 638.

(F) BOOKS AND REVIEW ARTICLES

1967. 'Mössbauer Spectroscopy and some of its Applications in Chemistry'. *Proc. Nuclear and Radiation Chemistry Symposium*, Department of Atomic Energy, Govt. of India, 159-173.

1970. 'Mössbauer Spectroscopy and its Application in Inorganic Chemistry'. In '*Spectroscopy in Inorganic Chemistry*' Vol. I, 347-381. Editors : Rao and Ferraro, Academic Press, New York.

1973. Applications of the Mössbauer Effect in the study of Ferrities and Garnets'. In '*Solid State Chemistry*'. Editor : CNR Rao, Marcel Dekker, Inc., New York.

(F) UNPUBLISHED TECHNICAL REPORTS

1969. Investigations of the syntheses and properties of new type of glycol monoalkyl ethers for the control of water evaporation to extend the industrial utilization of cottonseed oil. Final Technical Report for the PL-480 Project No. UR-A7 (40)-28, Grant No. FG-IN-158.

1972. Status Paper on Fertilizer Industry. Report prepared for the Planning Group-II on 'Fertilizers and other Plant Nutrients' of the National Committee on Science and Technology, Panel-V on 'Chemical Industry'. The report is based on the information provided by the Fertilizer Corporation of India and the Fertilizer Research Institute, New Delhi.