

JNAN CHANDRA GHOSH

1893-1959

JNAN CHANDRA GHOSH will be remembered for his fundamental contributions to the theory of strong electrolytes which created a great impression on such leaders of science like Walter Nernst, Max Planck, Sir William Bragg, Prof. G. N. Lewis and others. He will also be remembered for his contributions to the promotion of education, science and technology; the foundation and development of (a) the Department of Chemistry in the then newly founded Dacca University and (b) the Indian Institute of Technology, Kharagpur and his services to the Indian Institute of Science, Bangalore. As Vice-Chancellor of the Calcutta University he made unique contributions to student welfare by providing facilities for study, rest and recreation to a large floating population of students of the colleges affiliated to the University of Calcutta. As a member of the Governing Body and the Board of the Council of Scientific & Industrial Research and of several of its Committees he materially contributed to the development of the Council and the National Laboratories under it. As the first scientist appointed as Director-General of Disposals and Supplies he helped the Government of India in plans of development of resources. Later as a member of the Planning Commission he helped the development of education, and of science and its applications under the Five Year Plans. He has also made notable contributions to the development of science as President/Member of a large number of learned scientific societies including the National Institute of Sciences of India.

Jnan Chandra was born at Purulia on September 4, 1893. His father Ram Chandra Ghosh owned a mica mine and was in an affluent condition when Jnan Chandra was born. He was the third son. Unfortunately his father suffered heavy financial losses and the family had to pass through some difficult days. He and his immediate elder brother studied in the Giridi High School from which he passed in 1909 the Entrance Examination of the Calcutta University and obtained a Divisional Scholarship (Chotanagpur Division). His eldest brother as also his sister died young. He had also a younger brother. He and his elder brother joined the Presidency College in 1909. Ghosh had a brilliant academic career. In 1911 he stood fourth in order of merit in the I.Sc. examination of the Calcutta University; in 1913 he passed the B.Sc. Degree examination with Honours in Chemistry and was placed First in the First Class. He obtained the M.Sc. Degree in Chemistry in 1915 and stood First in First Class at the Examination. He was awarded a number of medals by the





J. B. Ghosh



University. He was awarded the Degree of Doctor of Science of the Calcutta University for his work on some problems of electro-chemistry.

During his student life in the Presidency College he had friendly association with many fellow-students of whom mention should be made of such distinguished names in science as Satyendra Nath Bose, Meghnad Saha, Nikhil Ranjan Sen, Prankrishna Parija and Pulin Behari Sarker. The writer was also his fellow-student in the Presidency College. Five members of this batch of students of the Presidency College later became General Presidents of the Indian Science Congress Association; Bose, Saha, Ghosh, Mukherjee and Parija.

The atmosphere of the Calcutta University, the Presidency College and other colleges affiliated to the University of Calcutta during the period when he was a student and that following the establishment of the University College of Science and Technology in 1915 through the sole initiative and determination of the illustrious jurist, educationist and scholar, Sir Ashutosh Mookerjee, was unique for promoting the development of the talents of young men. This atmosphere was further strengthened when Sir Ashutosh Mookerjee brought within the fold of the University such illustrious men as Radhakrishnan and Raman, who have left their marks on the forward march of humanities and science and won for India a place in the forefront of the civilised world. At the time Ghosh joined the Presidency College, its staff included Sir Prafulla Chandra Ray as Professor of Chemistry and Sir Jagadish Chandra Bose as Professor of Physics and there were several other distinguished professors all eminent in their own subjects in science and humanities; and they individually and collectively had a great stimulating effect on the alumni of the College which heightened their inquisitiveness and created in them an earnestness for knowledge and progress. Those were the days of the 'Partition-Agitation' in Bengal led by Surendra Nath Banerjee and of the "Swadeshi" and revolutionary movements which created a deep impression on the minds of the entire student population of Bengal and inspired them with an intense feeling of patriotism and nationalism. Ghosh along with hundreds of other students naturally participated in some of these movements but he and some other fellow-students decided to devote themselves mainly to the cause of scientific progress. The mutual friendships created in their student days enabled this group of young scientists in their later life to work together for the development of the scientific institutions in India and the establishment of learned scientific societies including the National Institute of Sciences of India.

Towards the end of 1915 he was appointed as an Assistant to the Palit Professor of Chemistry, University of Calcutta. He participated in the initial organisation of the Department of Chemistry of the University College of Science, then in the process of establishment. Sir Prafulla Chandra Ray joined as Palit Professor some time later after his retirement from the Presidency College. Ghosh was next appointed in 1917 a lecturer



in Chemistry in the newly opened Post-Graduate classes of the University of Calcutta. In 1919 he was awarded a Sir Tarak Nath Palit Scholarship and proceeded to London to work for a Doctorate Degree and joined the Chemistry Department of the University College, London, then under the charge of Prof. F. G. Donnan, C.B.E., F.R.S. At the instance of Sir William Bragg, Donnan arranged a meeting with Ghosh who gave an account of his theory before them.

In the University College Ghosh worked on some problems of Photochemistry of interest to the theory of photography. At this stage Sir Phillip Hartog, Vice-Chancellor-designate of the proposed University of Dacca persuaded him to join the Dacca University as Professor and Head of the Department of Chemistry; Ghosh accepted the offer. On his way back to India he paid a visit to Germany; there he met Professors Walter Nernst, Max Planck, and F. Haber at their request, they were keen to meet the person who placed the theory of strong electrolytes on a permanent footing. Mention may be made here of the criticisms made by Partington, reference to which has been made later. There were some aspects of these criticisms which were not very pleasant. Ghosh published a rejoinder to which also reference will be made later. But the fact remains that the criticisms of Partington had apparently no effect on men like Sir William Bragg, Profs. W. Nernst, M. Planck, F. Haber. Nernst in his reputed book 'Theoretische Chemie' published in 1921 wrote—"In ein ganz anderes Stadium ist die ganze Frage durch eine Reihe von Arbeiten gekommen, in denen J. Chandra Ghosh sowohl das Zurückbleiben des osmotischen Druckes wie das der Leitfähigkeit theoretisch berechnet und durch sorgfältige Diskussion des vorhandenen Beobachtungsmaterials die sehr genaue Bestätigung seiner Theorie nachweist; trotz gewisser Bedenken im einzelnen scheint im wesentlichen ein Problem gelöst, mit dem zahlreiche Forscher während der letzten drei Dezennien sich eingehend beschäftigt haben. Die hauptsächlichen Resultate sind folgende" (p. 613).

Later Prof. G. N. Lewis in his book on 'Thermodynamics' written in collaboration with Prof. Randall published in 1923 remarked as follows: "If then we agree that strong electrolyte is one which is completely polar and that the ions are held to one another by a simple electrostatic force which obeys Coulomb's law it becomes merely a matter of terminology to decide whether we shall say that a certain fraction of such an electrolyte is dissociated or with Ghosh that a certain fraction of the ions are free or outside the sphere of mutual attraction" (p. 325). Previous to Ghosh, Sutherland and Milner emphasised the role of electrostatic forces in determining the properties of strong electrolytes, but it is only after Ghosh's publication referred to above that the conception of strong electrolytes and the importance of electrostatic forces between the ions came to be universally accepted. It is no reflection on Ghosh that a mathematical physicist of the stature of Paul Debye in collaboration with W. Hückel



gave a more satisfying theory of the strong electrolytes which has been further modified by succeeding workers. The concept of ion atmosphere of Debye is essentially an extension of the postulates of Ghosh.

In 1921 he joined the Dacca University where he worked for 15 years and took an active part in an all-round development of the newly founded University. The reputation he built up at Dacca for his scientific work and his personal qualities attracted students from different parts of India to his laboratory. He founded at Dacca two schools of Research, the first of their kinds in India, namely, in Photochemistry and in Gas Reactions of industrial importance. The work on Photochemistry done in his laboratory covered a wide range of topics. Prof. Max Bodenstein of the University of Berlin in his report on a thesis submitted by a student of Ghosh paid a high tribute to the work done on Photochemistry in the Dacca University.

In 1939 he left Dacca to join the Indian Institute of Science, Bangalore as its Director in succession to Sir C. V. Raman. Here he devoted himself with his characteristic zeal to the further development of the Institute. He introduced several new subjects of study and research such as Power Engineering, Fermentation Technology and High Pressure and Industrial Gas Reactions and smoothed the way for a rapid development of the Indian Institute of Science in the fields of higher Engineering and Technology. The heavy pressure of work at the Institute did not prevent him from actively associating himself with research work carried out by his collaborators.

Two of the contributions made by him and his collaborators working at Bangalore in the field of reactions in industrial gaseous systems deserve mention. They were amongst the earlier workers who suggested the formation of complexes involving the catalyst in the Fischer-Tropsch synthesis of liquid fuel from carbon monoxide and hydrogen. A large number of catalysts were studied including iron-copper systems incorporated with rare oxides; influence of promoters and supporters were also studied. The other important contribution was towards the elucidation of stepwise mechanism of ammonia synthesis from its elements. This involved studies of adsorption of nitrogen and hydrogen and their mixtures by synthetic ammonia by catalysts at high pressure. These were pioneering investigations in India on this very important subject, work on which has yet to be developed on a very extensive and intensive scale. It is interesting that several of his collaborators are actively pursuing investigations on this subject and have attained prominence. In collaboration with Prof. S. K. Bhattacharya and Prof. N. V. C. Shastri he wrote a book entitled "Some Catalytic Gas Reactions of Industrial Importance" and published in 1960. In it an account of the work of Ghosh and his collaborators has been included.

Apart from the initiation and development of research in India in the subjects mentioned earlier, his main contributions to the progress of



science and technology is that he stimulated and provided opportunities to a team of brilliant young scientists to develop their talents. They now occupy positions of importance in several universities and other important research establishments as also in a number of industries.

Objective criticisms of scientific co-workers are most fruitful and play an essential role in the progress of science. Partington's remarks referred to earlier do not seem to serve this purpose. He observed, "Further, in order to get better agreement, the equation for a binary electrolyte is sometimes used, and sometimes that for a ternary electrolyte, for the same substance in different solvents, without any apparent justification" [*Trans. Far. Soc.*, **15**, (1919-20), pp. 98-122].

In this paper Partington also postulated a theory of strong electrolytes which scarcely received any attention at all. Ghosh in his rejoinder (*Trans. Far. Soc.*, **15**, pp. 154-163) pointed out the errors in data quoted by Partington on which he based his criticisms and also dealt in detail with other aspects of his criticisms. The following observations of Ghosh are worth quoting, "In this connection it may be pointed out that in my paper on the electrical conductivity of non-aqueous salt solutions, in 22 tables out of 37, the experimental data are taken from Walden's work. There is thus no justification for Partington's observation that the 'experimental numbers used by Ghosh in testing his equation in non-aqueous solvents are largely drawn from the researches of Carrara, whereas Walden observes that his results are not in agreement with those of Carrara'."

It is unfortunate that some of the mud thrown often sticks and Ghosh declined to have his name proposed for election as a Fellow of the Royal Society as he sensed this. As stated earlier Partington's criticisms did not affect the esteem with which his work was held by leaders of science like Nernst, Planck, Haber, Bragg and Lewis (G.N.), all of whom except Bragg were citizens of countries other than the United Kingdom.

In 1947 he was called to take up the office of the Director-General of Industries and Supplies at New Delhi. One of the tasks assigned to him was to process several industrial schemes in collaboration with European and American experts, his particular interest was on heavy chemical industries, liquefaction of coal, petro-chemicals and refineries. As an active member of the All India Council of Technical Education and President of Principals of Technical Institutions in India he helped the organisation of training in these Institutions. In 1950 he was nominated Director of the proposed Indian Institute of Technology at Kharagpur, the first of a number of similar Institutes of Technology established in India. He built up this magnificent Institute from its very beginning and it meant hard work for four years.

In 1954 he reluctantly left the Kharagpur Institute, the atmosphere and activities of which were congenial to him, because of the insistence of Dr. B. C. Roy to shoulder the responsibilities of the Vice-Chancellorship



of the Calcutta University which had many problems unsolved. One of his first acts was to make a survey of the living conditions of and educational facilities available to students of the University and its affiliated colleges who were not resident in Calcutta. He initiated the establishment of Students' Homes with a view to provide accommodation for purposes of study during the day when they had no class work. But before he could make much progress with his schemes he was invited by the late Prime Minister, Jawaharlal Nehru to be a member of the Planning Commission. He took up his new assignment with characteristic zeal and devoted himself to the development of science and education under the aegis of the Commission. It was towards the end of 1958 that he developed a serious illness to which he ultimately succumbed while still a member of the Planning Commission.

He was made General President of the Indian Science Congress Association in 1939, President of the National Institute of Sciences of India in 1943-44. He filled the office of President of a number of learned scientific societies. He was a member of the Indian Scientific Mission in September, 1944 deputed by the Government of India to the U.K., U.S.A. and Canada which was sponsored by Sir Winston Churchill and arranged by Prof. A. V. Hill. He was a member of several other deputations of scientists sponsored by the Government of India to important scientific conferences such as the Royal Society Empire Scientific Conference, the Commonwealth Scientific Conference (both held in London), the United Nations Scientific Conference on the Conservation and Utilisation of Resources at Lake Success sponsored by President Truman. He visited a very large number of industrial establishments in Europe and America. He had great opportunities of getting himself acquainted with up-to-date developments in a number of heavy chemical industries including those dealing with fertilizers, coke ovens, carbonisations of coal, production of synthetic fuel, petro-chemicals and oil refineries. Experiences he thus gained enabled him to render valuable services to the Government of India for their schemes of development of related industries.

Mr. Jawaharlal Nehru, Dr. Vithaldas Chandavarkar, Dr. Shyamaprasad Mookerjee, Dr. B. C. Roy and Mr. Nalini Ranjan Sarkar are amongst those who appreciated his abilities and it was at their instance that he was invited to fill one or the other post mentioned above after he left the Dacca University.

Ghosh married in June 1922 and had a very happy married life. His wife Nilima Ghosh (nee Palit) identified herself with his activities. He was greatly devoted to his mother and his widowed sister-in-law. He underwent many sacrifices to help his relations. He left behind him three sons, all well placed in life and two daughters who were married to a rich family in East Bengal. Unfortunately partition made a great change in their fortune. His younger brother Dr. B. N. Ghosh was appointed Palit Professor of Chemistry, University of Calcutta.



His memory will be cherished by a large number of his friends and collaborators not only because of his scientific eminence but also for his personal qualities and the services he has rendered to the development of science, education and technology in our country.

J. N. MUKHERJEE

BIBLIOGRAPHY

1914. Alternating current electrolysis. *J. Am. chem. Soc.*, **36**, 2333.
1915. Influence of alternating current on electrolysis by a direct current. *J. Am. chem. Soc.*, **37**, 733.
1915. Relative affinity of metals in non-aqueous solutions and their reactivity in insulating media. *J. phys. Chem., Wash.*, **19**, 720.
1915. A new method of preparing colloids. *Rep. Indian Ass. Sci.*, 87-89 (*J. chem. Soc.*, **112**, 563).
1917. The discharge potential of ions on heated electrodes. *J. phys. Chem., Wash.*, **21**, 426.
1917. (With P. C. RAY & M. L. DEY) Velocity of decomposition and the dissociation constant of nitrous acid. *J. chem. Soc.*, **3**, 413.
1918. The electrical conductivity of acids and bases in aqueous solution. *J. chem. Soc.*, **11**, 790.
1918. Indigenous Drugs of India. Their Scientific Cultivation and Manufacture With Suggestions for the Development of New Industries, Calcutta Butterworth and Co. Ltd., pp. 32.
1918. The abnormality of strong electrolytes—I. The electrical conductivity of aqueous salt solutions. *J. chem. Soc.*, **113**, 449.
1918. The abnormality of strong electrolytes—II. Electrical conductivity of non-aqueous solutions. *J. chem. Soc.*, **113**, 627.
1918. The abnormality of strong electrolytes—III. The osmotic pressure of salt solutions and equilibrium between electrolytes. *J. chem. Soc.*, **113**, 707.
1920. The electrical conductivity of pure salts in the solid and fused states. Determination of the activity coefficients of ions in solid salts. *J. chem. Soc.*, **117**, 823.
1920. Electrical conductivity of potassium, sodium and barium chlorides in mixtures of pyridine and water. *J. chem. Soc.*, **117**, 1390.
1921. A general theory of electrolytic solutions. *Z. phys. Chem.*, **98**, 211.
1924. (With S. C. BISWAS) Extinction coefficients of certain acids and their salts in the ultra-violet. *Z. Elektrochem.*, **30**, 97.
1924. (With A. N. KAPPANA) Electro-deposition of antimony. *J. phys. Chem., Wash.*, **28**, 149.
1924. (With S. MALI) Vapour pressure and chemical constant of CH_2O . *Q. Jl Indian chem. Soc.*, **1**, 37.
1924. (With P. R. CHOWDHURY & A. SEN) Electrode potential of Hg against its ions in aqueous MeOH, acetone and pyridine. *J. Indian chem. Soc.*, **1**, 189 (*Sci. Abstr.*, **28A**, 4870).
1925. (With K. BASU) Bromination of lactic acid and calcium lactate in presence of light. *Q. Jl Indian chem. Soc.*, **2**, 39.
1925. (With J. N. CHAKRAVARTY) Dehydrogenation of MeOH and CH_2O with Cu as catalyst conditions of the equilibrium in the system— $\text{HCHO} \rightleftharpoons \text{CO} + \text{H}_2$. *Q. Jl Indian chem. Soc.*, **2**, 142.
1925. (With S. GUPTA) The isomeric transformation of allocinnamylidene acetic acid into the normal form with Iodine as photocatalyst. *Q. Jl Indian chem. Soc.*, **2**, 241.
1925. (With R. M. PURKAYASTHA) Photochemical reactions in circularly polarised, plane polarised and ordinary light. The velocity of reactions between bromine and (1) Cinnamic acid (2) Stilbene. *Q. Jl Indian chem. Soc.*, **2**, 261.
1925. (With J. MUKHERJEE) Photochemical reaction between bromine and tartaric acid in aqueous solution (I). *Q. Jl Indian chem. Soc.*, **2**, 165.
1925. (With K. M. CHAKRAVARTY) Catalytic formation of CH_4 from Co and H (I), (II). Production of fuel gases rich in CH_4 . *Q. Jl Indian chem. Soc.*, **2**, 150.
1926. (With A. N. KAPPANA) The decomposition of potassium manganonalate in plane polarised, circularly polarised and ordinary light. *Q. Jl Indian chem. Soc.*, **3**, 127.
1926. (With M. N. MITRA) Isomeric transformation of allocinnamylidene acetic acid into the normal form with iodine as photocatalyst in methyl alcohol solution—II. *Q. Jl Indian chem. Soc.*, **3**, 273.
1926. (With J. B. BAKSHI) Preparation of HCHO by the dehydrogenation of methanol: of various catalysts—I. *Q. Jl Indian chem. Soc.*, **3**, 3415.



1927. A relative mass of a protein and an electron. *Naturwissenschaften*, **15**, 445.
1927. Pharmacy in India. *Pharm. J.*, **118**, 76.
1927. (With J. MUKHERJEE) Photochemical oxidation of lauco-malachite green by means of uranyl nitrate in chloroacetic acid solution. *Q. J. Indian chem. Soc.*, **4**, 343.
1927. (With R. M. PURKAYASTHA) Photochemical reaction between bromine and (1) cinnamic acid (2) stilbene II. *Q. J. Indian chem. Soc.*, **4**, 409.
1927. (With R. M. PURKAYASTHA) Photobromination of cinnamic acid and stilbene III. *Q. J. Indian chem. Soc.*, **4**, 553.
1927. (With K. CHAKRAVARTY) Catalytic formation of methane from carbon monoxide and hydrogen—III. A study of various catalysts. *Q. J. Indian chem. Soc.*, **4**, 431.
1928. (With B. N. MITRA) Extinction coefficients of mixtures of uranyl nitrate and organic acids in the ultra-violet as experimental evidence in favour of the formation of unstable intermediate compounds. *Q. J. Indian chem. Soc.*, **4**, 353.
1928. (With K. P. BASU & S. C. BHATTACHARYYA) Photobromination of m-nitrobenzylidene malonic ester. II. *J. Indian chem. Soc.*, **5**, 183.
1928. (With B. N. MITRA) Extinction coefficients of mixtures of ferric chloride and organic acids in the ultra-violet as experimental evidence in favour of formation of unstable intermediate compounds—II. *J. Indian chem. Soc.*, **5**, 191.
1928. (With T. L. KASTURIRANGACHARIA) Extinction coefficients of HgCl and organic acids in the ultra-violet as experimental evidence in favour of the formation of unstable intermediate compounds—III. *J. Indian chem. Soc.*, **5**, 569.
1928. A kinetical explanation of photosynthesis based on Harder's results with Fontinalis. *Jber. wiss. Bot.*, **69**, 572.
1928. (With K. CHAKRAVARTY) Catalytic preparation of a gas rich in methane from a mixture of water gas and steam. *Proc. 15th Indian Sci. Congr.*, p. 148.
1929. (With J. MUKHERJEE) Photochemical reaction between glucose and H₂O₂ in acid medium with tungstic acid sol as photocatalyst. I. *J. Indian chem. Soc.*, **6**, 231.
1929. (With R. M. PURKAYASTHA) Photochemical reduction of ferric salts by mandelic, lactic and tartaric acids. *J. Indian chem. Soc.*, **6**, 872.
1929. (With S. N. CHAKRABARTI) Extinction coefficients of mixture of CuSO₄ with glucose glycerol and H. COON_a in the ultra-violet as experimental evidence in favour of the formation of unstable intermediate compounds—IV. *J. Indian chem. Soc.*, **6**, 871.
1929. (With S. N. CHAKRABARTI) Absorption spectra of mixtures of dilute solution of CuSO₄ and NaSO₃ in the red and ultra-violet. *J. Indian chem. Soc.*, **6**, 823.
1929. (With S. C. DUTTA) Variation of surface tension of aqueous solutions of certain dye-stuffs with time. *J. Indian chem. Soc.*, **6**, 903.
1929. (With S. K. NANDY) Photochemical decomposition of acetaldehyde solution. *J. Indian chem. Soc.*, **6**, 911.
1929. (With S. K. NANDY) Photochemical oxidation of formaldehyde by H₂O₂ in acid medium with tungstic acid sol as photocatalyst. *J. Indian chem. Soc.*, **6**, 975.
1930. (With R. M. PURKAYASTHA) Quantum yield during photobromination of organic hydrazides as a function of the frequency of the activating light. *Z. phys. Chem.*, **B**, **9**, 154.
1930. (With R. M. PURKAYASTHA) Differences in the mechanism of addition and substitution processes during the photobromination of organic compounds. *Z. phys. Chem.*, **B**, **9**, 154.
1930. (With D. N. DAS GUPTA, N. C. ROY & H. K. CHATTERJEE) Studies on the photosensitizing action by iodine; isomeric transformation of allo-cinnamylidene acetic acid into the normal form in methanol, ethyl alcohol, chloroform, and mixtures of alcohol, chloroform and water. *J. phys. Chem.*, **34**, 2771.
1931. (With B. C. KAR) Raman effect in the ultra-violet region. *J. phys. Chem.*, **35**, 1735.
1931. Method for the determination of titanium as phosphate. *J. Indian chem. Soc.*, **8**, 695.
1931. (With K. M. CHAKRAVARTY & J. B. BAKSHI) Catalytic formation of methane from Ca and H the simultaneous acceleration of the water gas and Armstrong-Hilditch reactions. *Z. Electrochem.*, **37**, 775.
1931. (With S. B. SENGUPTA) Optical properties of chlorophyll I. Absorption of light by solutions and suspensions of chlorophyll-a and chlorophyll-β and their mixtures. *J. Indian chem. Soc.*, **8**, 581.
1932. (With B. C. CHAKRAVARTY) Dark reaction between HgCl₂ and NH₄ oxalate catalysed by NH-persulphate. Proof of formation of an intermediate compound of HgCl and the oxalate ion. *Z. phys. Chem.*, **A**, **158**, 265.
1932. (With M. C. NATH) Variation of the surface tension of aqueous solutions of certain complex organic substances with time. *J. phys. Chem.*, **36**, 1916.
1932. (With S. N. RAY CHOWDHURY & S. C. GANGULY) Oxidation reduction potential I. Cystine. *J. Indian chem. Soc.*, **9**, 43.
1932. (With S. K. DAS) Raman effect in inorganic compounds. *J. phys. Chem.*, **36**, 586.
1933. (With R. M. PURKAYASTHA) The dependence of quantum efficiency on the frequency of effective monochromatic radiation in photochemical reaction. *J. Indian chem. Soc.*, **10**, 274.



1934. (With K. M. CHAKRAVARTY & J. B. BAKSHI) Simultaneous determination of the equilibrium constants of the reactions ($\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$; $2\text{CO} + 2\text{H}_2 \rightleftharpoons \text{CO}_2 + \text{CH}_4$; $\text{CO} + 3\text{H}_2 \rightleftharpoons \text{CH}_4 + \text{H}_2\text{O}$; $\text{CO}_2 + 4\text{H}_2 \rightleftharpoons \text{CH}_4 + 2\text{H}_2\text{O}$) by using activated Ni-catalysts. *Z. anorg. allg. Chem.*, **217**, 277.
1934. (With B. C. KAR) Oxidation of mercaptocompounds by hydrogen peroxide at room temperatures in the presence of inorganic catalysis. I. The oxidation of cystine and dithioglycolic acid in the presence of tungstic acid and molybdic acid sols. *J. Indian chem. Soc.*, **11**, 485.
1934. (With D. S. NARAYANAMURTHI & D. N. DAS) Investigation of the photosensitizing effect of Iodine. The isomeric corrosion of allo-Cinnamylidene acetic acid into the normal form I. *Z. phys. Chem.*, B, **26**, 255.
1934. (With S. C. GANGULY) The reduction potential cystine-cystene mixtures. *Biochem. J.*, **28**, 381.
1934. (With S. B. SENGUPTA) Photochemical reduction of methyl red by phenylhydrazine with chlorophyll solution as a photosensitizer. *J. Indian chem. Soc.*, **11**, 65.
1935. (With S. C. SENGUPTA) The oxidation reduction potential of glutathione. *Biochem. Z.*, **279**, 296.
1935. (With D. S. NARAYANAMURTHI & N. K. ROY) The photochemical oxidation of mandelic acid by methylene blue with uranyl nitrate as photosensitizer. *Z. phys. Chem.*, B, **19**, 236.
1935. (With SUKUMAR SEN) Synthesis of higher paraffins from water gas. Use of promoters for activating iron—copper catalyst. *J. Indian chem. Soc.*, **12**, 53.
1935. (With P. C. RAKSHIT) Oxidation of sugars by air in the presence of ceric hydroxide sol and cerous hydroxide gels. *J. Indian chem. Soc.*, **12**, 357.
1936. (With B. B. RAY) The photochemical oxidation of mandelic acid by bromine with uranyl salts as ultra violet sensitizers. *Z. phys. Chem.*, B, **32**, 158.
1936. (With S. K. BHATTACHARYYA) The effect of radiation with various wave-lengths on the oxidation of mandelic acid by Bromine. *Z. phys. Chem.*, B, **31**, 420.
1936. (With S. K. BHATTACHARYYA & S. C. BHATTACHARYYA) The photobromination of acetylene dichloride in the gas phase and in solutions of carbon tetrachloride. *Z. phys. Chem.*, B, **32**, 145.
1936. (With B. B. RAY) Oxidation of chloroacetic acid by KMnO_4 at wave lengths 366, and 436 m with uranyl salt as photosensitizer. *J. Indian chem. Soc.*, **13**, 1.
1936. (With T. BANERJEE & B. BHATTA) The photo-oxidation of succinic acid by methylene blue with uranyl salts as sensitizers. *Z. phys. Chem.*, B, **32**, 163.
1936. (With P. C. RAKSHIT) Auto-oxidation of ascorbic acid and its inhibition by sulphur compounds. *Biochem. Z.*, **289**, 15.
1937. (With B. C. KAR) Oxidation of sulphhydryl bodies by hydrogen peroxide in the presence of inorganic catalysis—II. Oxidation of cystine by means of hydrogen peroxide in the presence of Vanadic acid sol. *J. Indian chem. Soc.*, **14**, 249.
1937. (With T. L. RAMACHAR) The oxidation reduction potential of ascorbic acid (Vitamin C). *Z. Physiol. Chem.*, **24**, 115.
1937. (With P. C. RAKSHIT) Dissociation constants of ascorbic acid. *Biochem. Z.*, **289**, 395.
1937. (With T. BANERJEE, K. K. BHATTACHARYA & S. A. KHAN) Photochemical reduction of molybdic acid sol by glucose, formaldehyde, ethyl alcohol, sodium hypophosphite, leucine, glutamic acid and α -alanine. *J. Indian chem. Soc.*, **14**, 539.
1937. (With T. BANERJEE & S. K. MUKHERJEE) Photochemical reactions with some inorganic colloids as active agents under the influence of light in various states of polarisation. I. Tungstic acid, molybdic acid, chromic tungstate, etc. as photoactive agents; optical properties of three sols. Circular dichromism in the ultra-violet. *J. Indian chem. Soc.*, **14**, 495.
1937. (With T. BANERJEE, S. K. BHATTACHARYYA & S. K. DAS GUPTA) Photochemical reduction of tungstic acid sol by glucose, levulose, formaldehyde, lactic acid, sodium hypophosphite, leucine and glutamic Acid. *J. Indian chem. Soc.*, **14**, 519.
1937. (With T. BANERJEE & S. A. KHAN) The effect of pH on the photo-reduction of tungstic acid sol in unpolarised light. *J. Indian chem. Soc.*, **14**, 547.
1937. (With S. K. BHATTACHARYYA) Photochemical reduction of canadic acid sol with ethyl alcohol in acid medium. *J. Indian chem. Soc.*, **14**, 551.
1937. (With T. BANERJEE & J. C. BOSE) Photochemical reduction of uranic acid sol by sodium tartrate. *J. Indian chem. Soc.*, **14**, 559.
1937. (With T. BANERJEE) Internal filter action of reduced tungstic acid and molybdic acid sols. *J. Indian chem. Soc.*, **14**, 575.
1937. (With T. BANERJEE, S. K. NANDY & N. GUPTA) Photochemical oxidation of alcohol and glucose by iodine in acid medium with tungstic acid sol as photosensitizer. *J. Indian chem. Soc.*, **14**, 581.
1937. (With T. BANERJEE & S. K. BHATTACHARYYA) Photochemical oxidation of glucose by potassium indigotetrasulphonate with tungstic acid sol as photocatalyst. *J. Indian chem. Soc.*, **14**, 589.



1937. Photochemical oxidation of glucose by methylene blue with uranic acid sol as photosensitizer. *J. Indian chem. Soc.*, **14**, 597.
1937. (With S. K. BHATTACHARYYA) Photoiodination of phenyl acetylene, dicyclo-pentadine and α -amylene in wavelengths 546 m, 43 m & 360 m in solvents of CCl_4 & C_6H_6 . *Sci. & Cult.*, **3**, 120.
1937. (With P. C. RAKSHIT) Inhibition of auto-oxidation of different compounds by sulphhydryls. *Biochem. Z.*, **294**, 330.
1937. (With S. K. BHATTACHARYYA & M. L. NARASINHAMURTY) Effect of simultaneous action of radiations of different frequencies on the bromination of cinnamic acid and stilbene. *J. Indian chem. Soc.*, **14**, 452.
1938. The physicochemical properties of ascorbic acid. *J. Indian chem. Soc.*, **15**, 1.
1938. (With T. BANERJEE) Influence of circularly polarised light on photochemical reactions with pre-excited colloids as photosensitizer. *Electrowärme Düsseldorf*, **8**, 617.
1938. (With P. C. RAKSHIT) Physico-chemical properties of ascorbic and dehydro-ascorbic acids. *Biochem. Z.*, **299**, 394.
1938. (With S. B. SEN GUPTA). Fluorescence, absorption spectra and electrical conductivity of fluoresceine, rhodamine and acriflavine in aqueous solution. *Z. phys. Chem.*, **B41**, 117.
1939. (With T. BANERJEE) The mechanism of photochemical reactions of some inorganic colloids. The effect of light in various circularly polarised states—A review. *Z. Kolloidzeitschrift*, **86**, 372.
1939. Production of optically active substances and metallic films of silver, platinum and palladium by means of circularly polarised light. *J. Indian chem. Soc.*, **16**, 51.
1940. (With N. G. BASAK) Studies on the cataphoretic speed of sol particles as dependent on the reduction oxidation potential of the liquid medium. *J. Indian chem. Soc.*, **17**, 721-729.
1941. (With S. K. BHATTACHARYYA, M. M. DUTTA & M. J. RAO) Iodination I. Equilibrium in systems of iodine and various unsaturated compounds in the dark in different nonpolar solvents. *J. Indian chem. Soc.*, **18**, 171-176.
1941. (With S. K. BHATTACHARYYA, M. M. DUTTA & M. J. RAO) Iodination II. Iodination of different unsaturated organic compounds in the dark in different monopolar solvents. *J. Indian chem. Soc.*, **18**, 245-252.
1942. (With S. K. BHATTACHARYYA) Photochemical oxidation of cinnamic acid in U. V. light of 254 m. *J. Indian chem. Soc.*, **19**, 503-506.
1942. (With S. K. BHATTACHARYYA & K. R. KAR) Photochemical oxidation of mandelic acid by Br with tungstic acid sol as sensitizer in ultra-violet light of 354 m. *J. Indian chem. Soc.*, **19**, 507-509.
1943. (With S. K. BHATTACHARYYA) Photochemical studies in gels I. The reduction of FeCl by mandelic acid in light of different frequencies in Th phosphate gel as a solvent medium. *J. Indian chem. Soc.*, **20**, 377-381.
1945. (With A. N. ROY) Catalytic formation of diolefins from monoolefins. *Curr. Sci.*, **14**, 156-157.
1945. (With A. B. BISWAS) Photochemical studies of complex acid. I. Decomposition of ammonium molybdate with NaOH and HCl. II. Conductometric and glass-electrode titration of molybdic acid sol. *J. Indian chem. Soc.*, **22**, 287-294, 295-300.
1945. (With S. R. GUHA & A. N. ROY) Chemical equilibrium in styrene formation from ethylbenzene at low pressures. *Curr. Sci.*, **14**, 269.
1945. (With S. L. SASTRY) Chromium oxide as a promoter in catalysts for the Fischer-Tropsch synthesis. *Nature, Lond.*, **156**, 506-507.
1945. (With C. D. SRINIVASAN & A. N. ROY) Catalytic dehydrogenation of butene to butadiene. *Curr. Sci.*, **14**, 301-302.
1946. (With S. R. GUHA) Heat of reaction, free energy of reaction, and entropy change in formation of 1, 3-butadiene from 1-butene. *Curr. Sci.*, **15**, 125-126.
1946. (With C. D. SRINIVASAN & V. ARAVAMUTHAN) A new catalytic reaction in the vapour phase: Allyl alcohol from glycerol. *Curr. Sci.*, **15**, 160-161.
1946. (With V. M. C. SASTRI & K. A. KINI) Adsorption of H and CO and their mixtures on Fischer-Tropsch Catalyst. I. *Curr. Sci.*, **15**, 282-283.
1946. (With A. N. RAY) Chemical equilibrium in 1, 3-butadiene formation from 1-butene at low pressures. *Proc. natn. Inst. Sci. India*, **12**, 97-102.
1946. (With A. N. ROY) Poisoning and promotion of chromium oxide catalysts in the dehydrogenation of mono-olefins to diolefins. *Proc. natn. Inst. Sci. India*, **12**, 103-106.
1946. Catalytic dehydrogenation of 1 butene in the presence of air at reduced pressure. *Proc. natn. Inst. Sci. India*, **12**, 107-110.
1946. (With A. N. ROY) Chemical equilibrium in isoprene formation from 3-methyl-1-6 at low pressure. *Proc. natn. Inst. Sci. India*, **12**, 111-114.
1946. Heat of reaction, free energy of reaction, and entropy in the dehydrogenation equilibrium of paraffin in olefin isomers-diolefins of the isopentane and butane series. *Proc. natn. Inst. Sci. India*, **12**, 115-122.



1947. (With S. K. BHATTACHARYYA, M. S. MUTHANNA & S. C. MITRA) Electrolytic reactions on porous carbon anodes. I. Preparation of p-benzoquinone by the oxidation of benzene. *Curr. Sci.*, **16**, 87.
1947. (With S. K. BHATTACHARYYA, M. R. A. RAO, M. S. MUTHANNA & R. B. PATNAIK) Preparation of chlorobenzene from benzene. *Curr. Sci.*, **16**, 87-88.
1947. (With S. K. BHATTACHARYYA, M. S. MUTHANNA & A. D. PATANKAR) Preparation of ethylene chlorohydrine and ethylene glycol from ethylene. *Curr. Sci.*, **16**, 88.
1947. (With S. K. BHATTACHARYYA, M. S. MUTHANNA & R. K. PARIKH) Preparation of chloral from alcohol. *Curr. Sci.*, **16**, 88.
1947. (With A. N. ROY & N. V. KRISHNAMURTY) Catalytic dimerisation of acetylene to monovinylacetylene at medium high pressures. *J. scient. ind. Res.*, **6**, 1-4.
1947. (With S. RAMDAS GUHA) Thermodynamic characteristics of the equilibrium 1-butene 1:3 butadiene + H₂. *Curr. Sci.*, **16**, 252.
1947. (With S. K. BHATTACHARYYA) Photochemical studies in sols and gels. I. Oxidation of glycerol by methylene blue in light of different frequencies with colloidal zinc oxide as the photosensitizer in media of thixotropic aluminium hydroxide sol and gels. *Proc. natn. Inst. Sci.*, **13**, 73-85.
1947. (With S. K. BHATTACHARYYA & R. BANERJEE) The reduction of FeCl₃ by mandelic acid in light of different frequencies in media of thixotropic thorium phosphate and thorium molybdate sols and gels. *Proc. natn. Inst. Sci. India*, **13**, 87-97.
1947. Rubber latex composition. *Indiaman*, **32**, 970.
1947. (With N. G. BASAK & G. N. BADAUN) Nickel thoria kieselguhr (100:18:100) catalyst for the Fischer-Tropsch reaction II. *Curr. Sci.*, **19**, 353.
1947. (With N. G. BASAK & C. VENKATESAN) Nickel thoria kieselguhr (100:18:100) catalyst for the Fischer-Tropsch synthesis at medium pressure. *Curr. Sci.*, **16**, 377.
1947. (With N. G. BASAK & G. N. BADAUN) Nickel thoria kieselguhr catalyst for the Fischer-Tropsch reaction. *Curr. Sci.*, **16**, 318-319.
1948. (With N. G. BASAK) Chromium oxide as a catalyst promoter for Fischer-Tropsch synthesis at medium pressures. *Petroleum (Lond.)*, **11**, 131-132, 146.
1950. (With S. RAM DAS GUHA) Chemical equilibrium in vinylnaphthalene formation from ethyl-naphthalene at low pressures. *Petroleum, Lond.*, **13**, 283.
1950. (With M. V. C. SASTRI & K. A. KINI) Mixed adsorption of hydrogen and carbon monoxide of Fischer-Tropsch catalysts. *Research, Lond.*, **3**, 584.
1950. (With M. V. C. SASTRI & S. VEDARAMAN) Adsorption studies on MOH—synthesis catalysts (1) adsorption of CO and H on ZnO-Cr oxide mixture. *Curr. Sci.*, **19**, 342.
1951. (With B. P. GYANI) Viscosity of glucose, urea, and gelatin solutions and some properties of the dissolved particles. *J. Indian chem. Soc.*, **30**, 349.
1952. (With S. K. BHATTACHARYYA, M. S. MUTHANNA & C. R. MITRA) Electrolytic reactions on porous carbon anodes. I. The preparation of p-benzoquinone by the oxidation of benzene. *J. scient. ind. Res.*, **11B**, 356.
1952. (With S. K. BHATTACHARYYA, M. S. MUTHANNA & R. K. PARIKH) The preparation of chloral from alcohol. *J. scient. ind. Res.*, **11B**, 371.
1952. (With S. K. BHATTACHARYYA, M. R. A. RAO, M. S. MUTHANNA & R. B. PATNAIK) The preparation of chlorobenzene from benzene. *J. scient. ind. Res.*, **11B**, 361.
1952. (With B. P. GYANI) Viscosity of isoelectric gelatin solutions. *J. Indian chem. Soc.*, **29**, 45.
1952. (With S. K. BHATTACHARYYA, S. N. GOPALASWAMY & V. S. RAMACHANDRAN) Differential thermal analysis of catalyst powders I. Differential thermal analysis of chromic oxide gel. *J. scient. ind. Res.*, **11B**, 547.
1952. (With M. V. C. SASTRI & G. S. KAMATH) Adsorption of hydrogen and of carbon monoxide by a new catalyst, with a view to the synthesis of methanol. *J. chem. Phys.*, **49**, 500.
1952. (With M. V. C. SASTRI & K. A. KINI) Adsorption of hydrogen and carbon monoxide and their mixtures by cobalt Fischer-Tropsch catalysts. *Indian Engg. Chem.*, **44**, 2463.
1953. (With B. P. GYANI) Combination of acids and alkalis with gelatin. *J. Indian chem. Soc.*, **30**, 755.
1954. (With B. N. GHOSH-MAZUMDAR, A. K. BOSE & R. SENGUPTA) Mixed orthoesters of titanium. *Res. corres. suppl. to Research, Lond.*, **7**, 4, 526.
1954. (With B. P. GYANI) Temperature variation of particle weight and size in isoelectric gelatin sols. *J. Indian chem. Soc.*, **31**, 946.
1955. (With M. V. C. SASTRI & T. S. VISWANATHAN) Transformation in the substrate formed on a cobalt Fischer-Tropsch catalyst. *Res. corres. suppl. to Research, Lond.*, **8**, No. 1, 55.
1955. (With B. N. GHOSH-MAZUMDAR, A. K. BOSE & R. SENGUPTA) Orthoesters of titanium. *J. Indian chem. Soc.*, **31**, 683.
1956. (With S. K. BHATTACHARYYA & D. K. R. CHAUDHURI) The synthesis on methyl vinyl ether. Reaction of acetylene & methanol. *Petroleum, Lond.*, **19**, 358.
1957. (With S. K. BHATTACHARYYA & V. S. RAMACHANDRAN) Application of differential thermal analysis to the study of solid catalysts-systems. Cr₂O₃, Fe₂O₃ and Cr₂O₃-Fe₂O₃. *Adv. Catalysis*, **9**, 1.



1957. (With S. K. BHATTACHARYYA & V. S. RAMACHANDRAN) Application of differential thermal analysis to the study of solid catalysts-systems. Cr_2O_3 , Fe_2O_3 , and $\text{Cr}_2\text{O}_3\text{-Fe}_2\text{O}_3$. *Adv. Catalysis*, **9**, 114.
1958. (With M. V. C. SASTRI & T. S. VISWANATHAN) Adsorption on heterogeneous catalysts. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 1).
1958. (With S. K. BHATTACHARYYA) Synthesis of ammonia. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 51).
1958. (With S. K. BHATTACHARYYA) Synthesis of urea. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 117).
1958. (With S. K. BHATTACHARYYA) Synthetic oil from coal Fischer-Tropsch and related process. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 133).
1958. (With S. K. BHATTACHARYYA) Synthetic oil from coal-hydrogenation of coal & tar (Bergins process). Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 241).
1958. (With S. K. BHATTACHARYYA & DHARAM VIR). Synthesis of higher alcohols. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 329).
1958. (With S. K. BHATTACHARYYA) Synthesis of methanol. Maharaja Sayajirao Gaekwad Honor. Lectures, 1948-49 (Univ. of Baroda Research India, p. 287).
1958. (With S. K. BHATTACHARYYA & M. V. C. SASTRI) Some catalytic gas reactions of industrial importance. Baroda, India, Oriental Institute, p. 355.

