K. Banerjee

# KEDARESWAR BANERJEE

## (1900—1975)

## Elected Fellow 1939

It is a rare privilege to know a great man personally. Rarer still is to be a student of a great scholar. Rarest of all is having the opportunity of growing directly under the guidance of a saint. We had the unique combination of all these privileges through our teacher, guide and moulder, Professor Kedareswar Banerjee, whose life sketch we present in this memoir with great reverence.

### Birth and Education

Kedareswar Banerjee, a pioneer crystallographer in India, was born on September 15, 1900 in a village then called 'Sthal' in the district of Pabna, East Bengal (now Bangladesh). He hailed from a well known Brahmin family of Bikrampur, a Pargana in the district of Dhaka (now in Bangladesh) which had been a famous seat of learning and a cradle of many scholars. His father, Sri Taraknath Banerjee and mother, Srimati Sarojini Devi resided at Hatia (now in Bangladesh) for most of the time, the former practising law at the district courts. Young Kedareswar had his early education in Dhaka having passed the Matriculation Examination in 1917 from the K L Jubilee School and the Intermediate (Science) Examination in 1919 from the Dhaka College (then a leading college in undivided Bengal), both affiliated to the University of Calcutta at that time. He graduated in 1921 from Dhaka (with Honours in Physics) and then moved to Calcutta to complete his Master of Science (Physics) degree in 1923 from the University College of Science, Calcutta.

### Higher Education and Professional Career

His academic career was brilliant all through with first division in all the examinations starting from matriculation. He had secured the second position in the university merit lists, both at the BSc (Hons) and MSc examinations. It might interest some readers to know that he had to take the matric examination thrice on account of cancellation of the examination on two occasions due to leakage of question papers. This is rather amusing, as such things happened even in those days. He was the recipient of university merit scholarships for general proficiency throughout his post-matriculation studies and also the University Silver Medals (twice) for his performance at the BSc and MSc examinations. Later, he bagged the *Griffith*

*Memorial Prize* for his outstanding research contribution. In 1930, he was awarded the degree of Doctor of Science by the University of Calcutta. In 1931, he was selected by the Calcutta University for the award of the *Ghosh Travelling Fellowship* which he availed of to proceed to England and work for one year under Sir William Bragg at the Royal Institution of Great Britian, London, and also to visit some of the prominent laboratories in Europe. During the formative years as a scientist, he came in very close contact with eminent teachers like Sir C V Raman, Sir J C Bose, Dr D M Bose, Professor S N Bose, Professor M N Saha, Sir Willam Bragg and others. With his extreme clarity of thought and a keen desire to advance his pursuits in science, Kedareswar had, thus, a very good grounding of his knowledge in physics and a very clear understanding of the principles of crystallography, a science still in its infancy in those days. His charity of perception and astuteness in conceptual modelling was clearly reflected in his research achievements later.

After obtaining the Master's degree, Kedareswar Banerjee joined the Indian Association for the Cultivation of Science (IACS), Calcutta in 1924 as a research scholar and later served the Chittagong Government College as a lecturer for a year (1927-28), and the Indian Meteorological Department for a short period (1928). He rejoined the IACS as a Research Fellow in 1933 after his return from England (where he had proceeded in 1931). In 1934, he accepted an offer from the University of Dhaka to work as a Reader in Physics and take the position vacated by Professor K S Krishnan, when the latter moved to IACS as its first Mohendra Lal Sircar Professor. He replaced Professor Krishnan for the second time in 1943 when the latter shifted to the University of Allahabad and Professor Banerjee was invited by the IACS Council to take its Mohendra Lal Sircar Professorship. In 1952, Banerjee was invited by the Allahabad University to join as its Professor of Physics, and in 1959, again at the invitation of IACS Council, he was appointed the Director of IACS, an Institute which he had served thrice before. He retired from this post in September 1965, at the age of sixtyfive, but continued to remain attached to the IACS as an Emeritus Professor. In 1965, he moved to Barasat, a suburb of Calcutta, where he lived at his house till death in 1975.

## Contributions to Scientific Knowledge

Professor Banerjee started his research career under Professor C V Raman in 1924, at the historic laboratories of the IACS, then situated at 210, Bowbazar Street, Calcutta. Those were the momentous days when Raman was carrying out his sensational experiments on scattering of light (which later brought him the Nobel Prize) and the elite of Indian physicists were clustering around this great master. Here, Banerjee first measured the stress-op

coefficients of Rocksalt for stresses applied along different directions. He tried to explain the observations with the help of polarisation doublets produced by the displacement of ions in the crystal.

Sir C V Raman and K R Ramanathan had extended the optical theory of scattering to the phenomenon of scattering of X-rays by liquids. Sogani and others had attempted a comparison of the theory with experimental results. About this time Banerjee studied the phase changes in the liquid alloys of sodium and potassium by X-ray diffraction. These metals were known to form a compound $Na_2K$ in the solid state. He studied the alloys having quantities of Na or K in excess of the amount required for the formation of the compound $Na_2K$. The shift of the diffraction haloes were explained by assuming a periodic arrangement of the group of three atoms, two Na and one K, forming a triangle, and that the excess atoms of Na or K were solutes in the solvent $Na_2K$. The results of these studies on liquid diffraction led him to the idea that there was a correspondence to some degree in the shapes of molecules and the intermolecular forces in the solid and the liquid states. Diffraction lines from densely populated crystal planes were generally present as haloes in liquid diffraction patterns. Modern theories of liquids accept the idea of formation of dynamic clusters or group-like molecules in liquids.

Crystalline structure and their behaviour to incident polarised light or a beam of X-rays indeed fascinated the analysing mind of young Banerjee. He was deeply attracted to the new developing science of crystallography which led him to initiate such studies in India. These pursuits by him were not only of a pioneering nature in India but were contemporary to such studies being carried out in England and other countries. This was, indeed, very creditable in view of the fact that at that time in India even moderately powerful X-ray sources and related equipment were not available. Banerjee had to work with a very weak X-ray source, like that of the Scherrer type X-ray tube run by glass mercury diffusion pumps constructed locally. These involved long exposure hours for recording the diffraction photographs and painstaking attention in the maintenance of vacuum systems. When only a few crystal structure problems had been solved in the world, he undertook the determination of structures of the aromatic ring compounds of Naphthalene and Anthracene. By then W H Bragg had developed the method of determining the atomic positions in crystals by Fourier summation which required determination of the values of the modulii as well as the phases of the crystal structure factors. While the modulii were obtainable from the integrated intensities of the diffraction spots the phases remained unknown. At that time phases were obtained from a trial structure which gave satisfactory agreement between the observed intensities and those calculated from the trial structure. Banerjee thus determined the probable structure of

Naphthalene and Anthracene. Earlier, W H Bragg had proposed that the molecular planes in these crystals were close to the *ac* plane. But Banerjee, on an analysis of the diamagnetic susceptibilities of the crystals (determined by Bhagavantam), argued that the susceptibility was maximum normal to the *bc* plane, and therefore, the molecular plane was nearer to that plane. On the basis of the magnetic data and assuming the carbon rings to be planar, with the hydrogen atoms lying on the same plane, the orientation of the molecules with respect to the three crystallographic axes were determined by Banerjee by comparing the observed intensities with those calculated from the atomic coordinates in the proposed structure. The molecular planes were found to be inclined to all the axes. The atomic coordinates corresponding to this structure differed significantly from those of the structure proposed by Bragg and published by J M Robertson, which had been obtained by using much more extensive and accurate measurements than what one could think of in India at that time. But Banerjee's structure was accepted as the more accurate one and Robertson later used the method of Fourier summation for refining Banerjee's structure using the signs of the 'structure factors' obtained from his structure.

In 1928, Otto developed equations whose roots were functions of the atomic coordinates. When these equations were expressed as a polynomial equated to zero, the coefficients of the terms of the equations were shown to be obtainable from the structure factors and thus the roots could be determined. The method was not, however, useful for structures containing a large number of atoms, but it did show the possibility of setting up equations between the structure factors and the coefficients of the terms which were equal in number to that of atomic coordinates. Since the number of observed structure factors are far greater than the number of unknown parameters, the coefficients of the terms could be eliminated and simple relations between structure factors obtained. Banerjee obtained such inter-relations and from them found out the signs of the structure factors of anthracene from the observed intensities. These signs agreed with those obtained from Robertson's structure. This method, which now goes by his name, was the first successful attempt of determining a crystal structure directly from the observed intensities, and though it has now been superseded by more powerful methods, it is still acknowledged as a pioneering work amongst the direct methods ; in any case, he was much ahead of his times in his approach. This work was carried out partly in England but more at the Indian Association for the Cultivation of Science where he was a research fellow after returning from England.

During his stay at Dhaka, he started crystal structure analysis of organic crystals in a big way which, with his clear conception about crystallographic symmetries and basic principles of crystal structure analysis, continu

throughout his academic life till late sixties. During 1934-43 (Dhaka), he completed the study for a number of crystals. He successfully determined the crystal structure of anthraquinone by two-dimensional Fourier synthesis in collaboration with S N Sen. An interesting finding in this study was the correct fundamental unit cell to be monoclinic instead of orthorhombic as determined by crystallographers earlier. The pseudo-orthorhombic character of the crystal was found to be really due to the accidental circumstance that, in the monoclinic cell, the length of the *b*-axis (15.85) was approximately double that of the *c*-axis (7.92). Of the several crystals studied by Banerjee and his collaborators during 1940-60 (Dhaka, Calcutta and Allahabad), particular mention may be made of diphenyl, phenanthrene, anthrone, phthalic anhydride, benzalazine, phloroglucine dihydrate and anthraquinone. These studies revealed some very interesting findings and led to new innovations in the methodology. For example, while defining the crystal structure of anthraquinone on a 3—dimensional model, whose structure had been determined by Banerjee and Sen previously, he observed a few weak reflections forbidden by the space-group extinction. These reflections were shown to be due to successive reflections from two planes known as Reninger reflections. The effect of these reflections on Fourier synthesis terms was also pointed out by him. In this determination an innovation was made regarding the evaluation of the anisotropic temperature factor by obtaining it from electron distribution plotted without this correction. This automatically takes into account the effect of overlapping of electron density of adjacent atoms. In the case of anthrone, a remarkable phenomenon was observed. The chemical formula with one oxygen on one side and two hydrogen atoms on the other side is not regularly repeated in the same way, but oxygen and hydrogen atoms are arranged in a random way on either side of the molecule, although the carbon structure maintains complete regularity as is expected in a crystal.

For a short while, Banerjee and his students, undertook some interesting studies in X-ray diffraction of jute fibres, isomorphism of fluoberyllates and sulphates, structure of nickel catalysts and isodiffusion lines of diffused reflexions.

Another area which attracted considerable attention of Banerjee was thermal diffuse scattering of X-rays from crystals, a field in which great interest was evolving during 1940-41 through the investigations of J Laval in France, Max Born in England and Sir C V Raman in Bangalore. Banerjee started experimental study of the diffuse spots observed in the Laue photographs. The diffuse spots and streaks observed in the Laue photographs of a number of organic crystals were thus studied by him and his collaborators. The diffuse spots which are generally associated with strong Laue spots were due to the reflexion of the characteristic X-rays from the planes perturbed by thermal waves. The thermal wave vector responsible for diffuse scattering is

obtained from the reciprocal lattice construction corresponding to the Laue photographs concerned from the condition, $\mathbf{K}_H + \mathbf{K}_T = \mathbf{K}_O$, where $\mathbf{K}_H$ is a reciprocal lattice vector, $\mathbf{K}_T$ is the thermal wave vector and $\mathbf{K}_O$ is the incident beam wave vector. Since the frequency of the incident wave ($\sim 10^{18}$) is very large compared to the thermal wave frequency ($\sim 10^{13}$), the frequency change cannot be measured from X-ray scattering. The analysis of the frequency distribution in crystals from a study of the X-ray diffuse reflexions is impossible, particularly in crystals having a large number of atoms per unit cell. The diffuse scattering in the vicinity of the Laue spots (due to very small thermal wave vectors) are due mainly to the accoustic thermal waves and the intensities in this case are determined by the elastic coefficients of the crystals. This provides a lucid method of measuring elastic constants of crystals by using X-ray diffraction techniques, particularly, in the case of lower symmetry crystals. The elastic constants of a few organic crystals have been determined from the intensities of diffuse reflections at the laboratories of the Indian Association for the Cultivation of Science and Allahabad University by Banerjee's collaborators. All the required corrections for this method have been systematised and accuracy of the method perfected by his group. In the case of benzil, a very interesting set of continuous streaks running through the spots were observed. Similar streaks have been observed in ice and $NH_4F$. The origin of these streaks has not been explained as yet from lattice dynamics. Banerjee suggested that these streaks correspond to planar extensions in the reciprocal lattice due to some extraneous low frequency vibrations normal to these planes. Attempts were also made to obtain vibration parameters of the crystal lattice by a study of the elastic spectrum from the distribution of the intensities of diffuse reflections. These attempts led to substantial work in the theory of phonons in crystals and metals, in electrons in disordered systems, on the transport properties in disordered alloys and spin glasses, etc.

During Banerjee's studies on diffuse reflections, he observed that by using a perfect crystal face the diffuse reflections, deviations of a few minutes of an arc from the Bragg angles could be very easily recorded and studied. This led him to develop a new technique for the study of small angle X-ray scattering. From 1940 onwards Guinier in France developed the theory of low angle scattering of X-rays from composite samples consisting of domains with varying electron densities. This theory proved to be useful in estimating the sizes and shapes of crystalline particles in heterogeneous and semicrystalline materials by a study of the observed distribution of intensities at low angles. But the accurate measurement of the intensities at such small angles was a difficult problem. Banerjee devised an elegant technique for recording X-ray scattering at narrow angles with shorter exposure time. His method may be summarised in principle as follows :

*A narrow pencil of X-rays is incident on a scatterer. The direct and the low angle scattered beams are reflected by a crystal plane. When the scattered beam falls on the crystal plane at the Bragg angle for the characteristic ray, the intensity of the reflected beam corresponds to the intensity of the scattered beam. The reflection of the direct beam corresponds to the Laue reflexion from the crystal plane. By rotating the crystal plane successively through various small angles, the scattering at different angles can be easily recorded. The lowest angle of scattering which can be approached is limited by the spread of the main Laue reflexion. For a perfect crystal face, the spread is only a few seconds of an arc. In the usual methods, the incident beam is first monochromatised by reflexion from a crystal plane and then a narrow pencil of this beam is scattered by the scatterer. The scattered beam is recorded at a large distance causing a large reduction of intensity. In Banerjee's method monochromatisation is automatically achieved by removing the incident direct beam by Laue reflexion and the distance of the recording film need not be very large. This brings in a substantial reduction in the time of exposure .*

Besides structure analysis of single crystals and diffused scattering from them, structure of glasses of various kinds and coal also engaged Banerjee's mind for some time. For example, he and his students have made extensive studies on the nature of alkali halides and colouring materials dissolved in the glasses. It was established that above a certain percentage of the alkali halide solutes, the vitreous Borax and Borates were devitrified, i.e. Borax and borate glasses developed crystalline phases. The mechanism of devitrification and nature of glass fibres were also studied. He also systematised the method of testing the efficiency of coal-washing by *X*-ray diffraction studies of the samples. Mineral contents and particle sizes of the minerals of several coal samples have been studied by his group and atomic distribution in the amorphous matrix determined.

What has been said above is not really a total work account of the great Professor ; it is merely a narrative of the different fields of X-ray crystallography and their application, which engaged, for most of the time, the attention of this bright physicist. In order to be truely appreciative of the great mind that worked within him one must place himself within the boundaries of physics, and particularly of crystal physics, that limited human knowledge in the late twenties when neither the physical concepts of behaviour of molecular species within a solid continuum were so well understood, nor the computational facilities available were anywhere near the present capabilities thrown open by the electronic data processing techniques.

## Contribution to Advancement of Science and Education

Perhaps the most significant contribution that Banerjee made towards advancement of science was the creation of schools of research wherever he went during his career, equipping them with a variety of instruments and devices required for X-ray diffraction and related studies, half of which were improvised with local resources, giving them a future-oriented programme and

leaving behind a band of young, energetic workers throbbing with activity and warmth. These schools, in turn, sent out dedicated workers to several other institutions as torch bearers of his scientific tradition. The crystallographic centres of Dhaka, Allahabad, Roorkee, Burdwan and Lucknow Universities, the Indian Institutes of Technology at Kharagpur, Kanpur, Madras and Bombay, the IACS and Presidency College at Calcutta, the Projects and Development India Ltd., Sindri (Dhanbad) a Government owned company and the Geological Survey of India at Calcutta have been set up either directly by him, or through his students, but all on account of the high scientific ideals he lived for.

## Personal Qualities

Professor Banerjee used to reveal his human grandeur probably at his best in the company of students. His love and concern for them was reflected in all his thoughts and actions. Whenever possible, such as at all extra curricular or cultural functions organised by the students, he used every opportunity to spend long hours with youngsters and enjoyed their company. Though he had, generally, a small number of research students working directly with him at any time, he did not belong to these groups only but had close contacts with the wider section of the student community. Students, too, readily identified him to be a rare personality with a very affectionate mind and unassuming manners. Quite often, students of other Faculties/Departments, or independent research workers flocked around him to seek his guidance on their own pursuites. Here was a professor who was as sympathetic to them as to his own group, who provided them special experimental facilities in his laboratories often causing constraints to his own group in those days of scarce resources. He was, in fact, every body's 'Guru'. He encouraged advancement of every individual working under him as an independent scientist. He was very reluctant to put his own name in the publications on work carried out with his students, unless he himself had been the principal contributor. All these workers who came in contact with him were moulded into one large family by themselves, working under extremely congenial and homely atmosphere. His affection and concern knew no bounds. His students were, in reality, as close to him, if not closer, as his own family members. Many cases are known where he discussed important personal matters with his students even before he opened his mind to his wife or children. In matters of selection of personnel for awards, recruitments, promotions, or any other merit selection involving his own students *vis-a-vis* others, he was known for his fairness. Innumerable cases can be cited where those who were apparently very close to him lost on demands of fairness. He always looked to the interest of the organization he was advising. Honest of purpose was always foremost in his thoughts.

## Banerjee and the Non-Cooperation Movement

Kedar (a short name derived from Kedareswar) had a brief touch and go with the Indian political movement against the British. However, he continued to take interest in the political activities throughout his life. In September 1920, Mohandas Karamchand Gandhi had given a call for the Non-Cooperation Movement at the special session of the Indian National Congress party held at Calcutta. In December 1920, the Annual session of the Congress also passed this resolution, and so also did the All India Students Congress (December 1920). The Bengal Unit of the Congress, led by figures like C R Das, Bipin Chandra Pal and others, had earlier opposed this proposal, but later accepted the call when the Annual Congress approved the resolution. This resolution required complete non-cooperation with the British and their system : no practice at the courts by Indian lawyers, no service at any office under the British Government, no attendance at any Government recognised school/college/university by any Indian student, no work at the banks, post offices, airports, docks, railway stations or British-owned commercial houses. All national resources were to be mobilised against the British. The movement called for all kinds of sacrifices, like in a war. This call attracted a massive support from the Indian masses. Young Kedareswar also came forward to join this movement. He stopped going to the college from September 1920. He boycotted the prize distribution function at the Dhaka College in November 1920 where he was to receive a medal himself, since the function was to be presided by the Governor and later did not appear for the Final Test Examination for his BSc (December 1920). The college sent him up for the final examination without his having passed the qualifying tests, but he did not pay the university fees.

At the time of Non-Cooperation movement he regularly visited the seat of a revolutionary group of students of the Dhaka College. This seat was at room No N-10, Dhaka College Hostel, later known as Dhaka Hall. This room was occupied jointly by Jagadish Bhattacharya (who later served the British Government but was dismissed on account of his political affiliations) and Sisir Kumar Chakravorty (whose sister Kedar married later). Both of them were brilliant students and so also were many other students who came to this centre, like Kali Pada Basu (who later became Advisor to the Planning Commission in independent India). These brilliant students gave up their academic pursuits to join the Indian Independence Movement. It was only natural for Kedareswar, who had been so deeply moved by the call given by Gandhi, to do the same. For a while, he joined a violent revolutionary sect, the 'Anusheelan Samity' led by Pulin Das, but later left it since he, basically, was against violence. Another brilliant scholar of that time, Dr Prafulla Chandra Ghosh who had topped at his BA and MA examinations, and was ten years elder to Kedar was also an active political worker. Dr Ghosh

himself was leading a socio-political group and had an eye on Kedar. In Ghosh's group were Hari Pada Chatterji and Deben Sen, who were later Members of the Indian Parliament and also Sikhi Bhusan Dutta. Most of these comrades of Kedareswar are well known freedom fighters from Bengal and have served long prison terms in their career. Prafulla Chandra Ghosh later became the first Chief Minister of Bengal in independent India (1947). As Kedar joined these movements, he came to be quite an active political worker himself, mobilising resources for the nationalist movement and organising student forces for the cause.

*From Politics to Science*

The budding scientist would have lost his career, had not something radical happened. Kedareswar was at that time living at Sabji Mahal, Dhaka, with his uncle (father's elder brother), Jagadbandhu Banerjee, a man of very strong principles and a dominating personality. He was a strict disciplinarian. In fact, he was the man who had made the deepest dent on Kedar's mind, in the making of his character, in moulding out the man that he was. Jagadbandhu Baboo, who was then the Manager of the 'Koatile Brick Fields', Dhaka, had spotted the genius in Kedar. One fine morning, Jagadbandhu Baboo, practically, kidnapped Kedar out from his political circle. He took Kedar to the brick-fields during the day and kept him at home in the evenings under strict surveillance for several months. Kedar was thus kept totally out of the reach of his friends and was forcibly taken to the examination hall. He was made to appear at the BSc examination under compulsion, with Jagadbandhu Baboo himself waiting outside the hall to whisk away the child home as soon as the papers were over. Then came the results of Kedar's BSc (Hons) and the consequent award of the University Silver Medal to him. The course of his career was changed. Kedareswar would have been a totally different person had not Jagadbandhu Baboo intervened. The old man was himself a staunch nationalist and a great sympathiser of the Independence Movement. What factors led him to behave this way are not known. Perhaps, Kedar's genius and the obvious potential of a bright academic future for the child prompted the old man to react this way.

Kedareswar continued his support for the nationalist cause after leaving active politics. When in 1921, Prafulla Ghosh formed the *Abhoy Ashram*, a socio-political organization which worked for the political and economic emancipation of the Indian people, Kedar became an active supporter. He collected funds and assisted many constructive activities of this body. When in 1933, Sisir Kumar Chakravorty was released from jail after serving about a year as a political prisoner, Kedareswar who had just returned from England then, received Chakraborty at the prison gate. Because of Kadar

political leanings, Dr Prafulla Chandra Ghosh had been a frequent visitor to his house till a few years before his death. *Abhoy Ashram*, too, enjoyed the patronage of Kedareswar till his last days.

Although Kedareswar had not for long been an active member of any political party, he had always been a strong sympathiser of the political movements in India. He held strong views about the way these movements should be continued. During his later life, Kedareswar expressed extreme dissatisfaction and frustration because of noticeable moral degradation amongst the politicians in India. He never supported violence and believed in negotiated settlement in true spirits of democratic principles a factor which contributed to his ability in tackling the labour problems at the IACS later, when he was confronted with labour unrest. Banerjee, on account of his sympathies with the worker's cause, was profoundly respected in such negotiations. In fact, he came to be known for his astuteness on the discussion table for subjects covering political issues. He was fairely well read on matters covering theory and practice of world political movements.

## Family

His personal life was equally exemplary. He married Amiya in February 1925, a girl who hailed from the village Rujdi of Vikrampur, Pargana Dist. Dhaka (now in Bangladesh). Her brother, Sisir Chakraborty had been a co-worker of Kedar in the Non-Cooperation Movement during 1920--21 at Dhaka. Amiya was a shy little girl when she came into his life, but gradually assumed enormous responsibilities in providing support to Kedar in leading the life of high ideals that he believed in. They had four daughters, Gita, Anita, Manjusree and Purnima and two sons, Ashoke and Ranjan. The daughters are settled in happy families in India ; the sons are working abroad, one in USA and the other in Canada both having nice little families themselves. Kedareswar, who had himself been brought up under the great influence of his *Jathamoshai*, Jagadbandhu Banerjee, led a life of strict self-discipline and sacrifice. He believed that the purpose of earning a good livelihood was only two fold : first, to keep a sound physical and mental health, and second, to provide good education to all members of the family. Kedar fully satisfied these requirements. He gave the highest possible education to all his sons, daughters and other family members. His family did not consist of his children alone, many others came from far and wide to make their abode at his house—from relatives and friends, and often from those who were only remotely known to Kedar or his wife. Whosoever came to their house, received all support to live as members of one family and education ; and this was not easy. His father had entrusted with him rather a large number of dependents to look after. Kedars were men of limited means. It, therefore, required considerable sacrifice for them to take this burden. Kedar and Amiya were both affectionate towards all those who lived at their

house, and everybody, including the students that flocked around Kedareswar found in that abode a true home. The contributions that Amiya made in managing this home must be recalled with appreciation. It was her deep sense of sacrifice and devotion to her husband's ideals that enabled her to fulfil those objectives.

As reported earlier, his uncle, Jagadbandhu Baboo had influenced Kedar's personal character immensely. Kedar often used to say that he had only followed the foot-prints set before him by his *Jathamoshai*. There was no place for indiscipline in his thinking. Kadar was a firm believer in family sentiments, but not necessarily in family traditions. He often said, keeping one self locked within the restrictions imposed by tradition could impede forward thinking. Although he was born and had been brought up in an extremely orthodox Hindu Brahmin family, he was highly liberal in his thoughts and beliefs. At a dinner given on the occasion of his brother's marriage in 1940 at his Dhaka residence at Shegunbagan, he included chicken curry as an item in the menu and arranged Moslem and Hindu invitees (including Brahmins) to sit together for dinner. Those who know things prevailing in India in those days would agree that these acts were unthinkable in a Brahmin society at that time. He did not believe in superstition and always decided things on rational analysis. This trait in his character was another significant contribution made by Jagadbandhu Baboo. Many men are known who disown superstitions in words but few really go ahead with a conviction as strong as had been seen in the case of Kedareswar. His ideas on social permissiveness, undesirability of the caste restrictions for Hindu marriage, his total disbelief in many taboos of the Hindu mind, etc., place him atleast half a century ahead of his time. Another interesting trait in his character was his forgetfulness or better described, absent-mindedness. Cases are known where he invited students for lunch at his house but forgot to inform his wife and turn up himself back from the laboratory, when a smiling Mrs Banerjee, who knew her husband well, played the role of an excellent host with minimum embarassment to the invitees.

Professor's leisure hours were mostly spent on reading. He was, in fact, a voracious reader and although any kind of published matter could engage long hours of his time, but the more popular subjects, apart from his own field of specialisation, were political history, philosophy and social sciences. He took keen interest in popularisation of science and had been a regular contributor to several magazines specialising in general scientific writing. Playing tennis and gardening had also been his hobbies during the earlier life.

*A True Saint*

Great as he was, he was extremely kind and affectionate in his mind, gene-
rally shy in approach, and very soft spoken on the lips. Perhaps no o-

arounds us, not even amongst his family members, has ever seen him rebuking anybody or using harsh words to express annoyance ; cooly walking off from the scene was the utmost he did to show his displeasure. And this worked like the commandments of religion it was almost impossible to ignore his disapproval.

His humility is now a legend. 'To be good and to do good to all you come across' was his motto. And yet the strength of his mind, the unshakable beliefs that he maintained on the righteousness of a cause, the bold expression of his views on matters involving truth and knowledge are too well known which made a mark even on the minds of those who opposed him on issues. He never bent before power or agreed to an unjust suggestion. He was not bound by shackles of worldly possessions. He was above personal pleasures of life. He had lived a life of noble deeds and thoughts that brought him satisfaction, selfcomposition, freedom from worries and freedom from fear. He was a true saint.

On the evening of April 30, 1975, while strolling on the roof of his house at Barasat, about 25 Km from Calcutta, enjoying the cool breeze of a pleasant Bengal summer, he suddenly felt sick and died before a physician could arrive. It was a case of cardiac arrest. A star vanished but the twinkle remains.

K C Banerji
R K Sen

## BIBLIOGRAPHY


1925—26. (With Raman C V) The optical properties of emethyst. Quartz. *Trans. opt. Soc. (London)*, **26,** 289-292.

1926. Permanent deformations by contact of solids. *Indian J. Phys.*, **1,** 59-74.

1928. Theory of photo elasticity, *ibid*, Part II. **2,** 195-242.

1929. X—ray diffraction in liquid alloys of sodium and potassium. *ibid*, **3,** Pt. III, 399-408.

1930. Liquid structure and X—ray diffraction in liquids, *ibid*, **4,** Pt. VII, 541-566.

— Orientation of the benzene rings in nephthalene and anthracene. *ibid*, **6,** Pt. VIII, 557-573.

— Structure of naphthalene and anthracene. *Nature*, **125,** 456,

1931. Relation of liquid to crystalline state. *ibid*, **127,** 92-93.

1933. Determination of the signs of the Fourier terms in complete crystal structure analysis. *Proc. R. Soc.*, **141,** 188-193.

1934. Determination of atomic position in paranitrobenzene by Fourier analysis method. *Phil. Mag.*, **18,** 1004-1008.

— Vibration of molecules having octahedral symmetry. *Proc. Indian Acad. Sci.* **1,** 250.

— Dynamical theory of diamond lattice. I. *ibid*, **1,** 333.

— Dynamical theory of diamond lattice, II. Elastic properties. *ibid*, **1,** 841.

1935. Molecular vibrations, symposium on molecular vibrations.
— (With SINHA K L) Structure of Benzil. *Sci. Cult.*, **1**, 301.
— (With CHANDRA A C) X—ray study of cholosteral. *ibid*, **1**, 362.
— (With GUHA B C) Space group — atomic arrangements in anthraquinone crystals. *Indian J. Phys.*, IX, Pt. III, 287-294.
— Dynamical theory of diamond lattice. III. Diamond graphite conversion. *Proc. Indian Acad. Sci.*, **2**, 143.
— (With RAMAN C V) Diffraction of light by high frequency sound waves. I *ibid*, **2**, 406.
— (With RAMAN C V) Diffraction of light by high frequency sound waves. II. *ibid*, **2**, 413.
— What are cosmic rays ? *Curr. Sci.*, **4**, 335.
1936. (With RAMAN C V) Diffraction of light by high frequency sound waves III. *ibid*, **3**, 75.
— (With RAMAN C V) Diffraction of light by high freqency sound waves IV. *ibid*, **3**, 119.
— (With RAMAN C V) Diffraction of light by high frequency sound waves V. *ibid*, **3**, 456.
— Diffraction of light by high frequency sound waves. *ibid*, **4**, 222.
— Visibility of ultrasonic waves and its periodic variations. *ibid*, **4**, 262.
Diffraction of light by supersonic waves. *ibid*, **4**, 499.
— Visibility of ultrasonic waves in liquids. *ibid*, **4**, 540.
— (With RAMAN C V) Diffraction of light by ultrasonic waves. *Nature*, 616.
— (With BORN MAX) The neutrino theory of light. I. *Proc. Indian Acad. Sci.*, **3**, 318.
— Neutrinos and light quanta. *ibid*, **3**, 448.
1937. (With BORN, MAX) Neutrino theory of light. II. *ibid*, **3**, 331.
— Decay as due to a neutrino shower. *Nature*, **140**, 278.
— (With SINHA K L) Structure of aromatic organic crystals Part I Acenphthene, *Indian J. Phys.*, XI, **11**, 21-35.
1938. Vibration of molecules having tetrahedras symmetry. *ibid*, 681.
— (With MUELLER H) Diffraction of light by supersonic waves. *Nature*, **141**, 37.
— Diffraction of light by supersonic waves in sclids. *Proc. Camb. Phil Soc.*, **34**, 213.
— (With BAR R *and* LEVI F) Zur theorie des durchanges von ultraschell Wellen durch eine Platte. Helv. *Helv. Phys. Acts.*, 11.
(With LEVI F) Zur theorie des durchangs von ultraschell Wellen durch eine Platte. *ibid*, **11**, 408.
— (With HAQUE A) Structure of aromatic organic crystals, Part III. Benzophenene. *Indian J. Phys.*, XII, **12**, 87-94.
— (With AHMED R) Structure of aromatic organic crystals Part IV Phloroglucine dihydrate. *ibid*, XII, 249-258.
— (With HAQUE A) Space group of creatinine. *ibid*, XII, 193-194.
— (With BHATTACHARYA J) On magnetic anisotropy of crystals in relation to crystalline structure. *Sci. Cult.*, IV, 60.
— (With SENGUPTA S N) Electron density map of anthraquinone. *ibid*, III, 570.
— (With AHMED R) Space group of methylene amino acotonitrite. *ibid*, III, 570.
1939. (With BHATTACHARYA J) Diamagnetic susceptibilities of some non-aromatic organic crystals. *Z. Kristallogr.* (*A*), **100**, 420—426.
— Address to German Physical Society (Printed address).
— Theorien der lichtbeung an ultraschell Wellen. I. *Akustiscues. Zeitschrift*, **4** 289.

1940. (With RAMAN C V) Quantum theory of X-ray reflection in crystals. *Proc. Indian Acad. Sci.*, 427.
— (With RAMAN C V) Quantum theory of X-ray reflection. *C. R. Reddy Volume.*
— (With GANGULY M) Determination of the structure of *m*—nitrobenzene by Patterson—Fourier Summation. *Indian J. Phys.*, **XIV**, 231-236.
— Application of the Fourier analysis methods to the determinations of atomic arrangements in crystals, *Dacca Univ. Stud.*, **6**, 1-14.
1941. (With ROY A K) The structure of jute fibre by X-ray diffraction method. *Proc. natn., Inst. Sci., India*, **7**, 377-382.
— (With CHELAM E V) Intensities of Raman Lines. *ibid*, **XII**
1944. (With BOSE C R) Secondary non-laue reflections from phloroglucine dihydrate. *Nature*, **153**, 23.
1945. On the extra reflections in the Laue photographs of phloroglucine dihydrate crystal. *Sci. Cult.*, **10**, 349.
— (With SEN R K *and* KHAN M F) Extra non-radial streaks and sharp reflections in Benzil crystals. *Proc. natn. Inst. Sci., India.* **11**, 4.
— (With MAZUMDAR S K *and* BANERJEE B K) X-ray studies of the solutions of alkali halides in borex $B_2O_3$ glass system. *Nature*, **156**, 423.
1946. Vibration of a linear lattice. *Bull. Phil. Soc.*, Patna.
1947. Dearrangements in atomic architecture. *Pres. Addr. Indian Sci. Congr.*
1948. (With MAZUMDAR S K *and* BANERJEE B K) Constitution of alkli Halide borate glasses, *Sci. Cult.*, **13**, 468.
— (With ROY S K) Vibration of an infinite linear lattice. I. *Proc. Indian Acad. Sci.*, 28.
— (With ROY S K) Vibration of an infinite linear lattice. II. *ibid*, 31.
— Dynamics of real crystals. *Nature*, 151.
1951. (With MOITRA J C) On a method of studying small angle scattering of monochromatic X—rays. *Sci. Cult.*, **16**, 531.
— (With MOITRA J C) On a method of studying small angle scattering of monochromatic X—rays. *Indian J. Phys.*, **25**, 141.
1954. Small Fourier terms in crystals structure analysis and renniger effect. *Proc. natn. Acad. Sci. India*, Parts IV—V, **23**, 139.
1956. Introduction. *Proc. Phys. Solid, State. Nat. Acad. Sci.*, **25**, 47-49.
1959. Introduction. *Proc. Symp. Crystal Phys. natn. Inst. Sci.*, (*India*).
1960. Modern developments in crystal st. analysis. *Phys. Teach.*, **2**, No. 1, 15 19.
— (With SRIVASTAVA S N) Statistical structure of anthrone. *Indian J. Phys.*, **34**, 184.
1962. Development of X—ray crystallographic research in India-*Fifty years of X-ray Crystallography.* International Union of Crystallography. p. 514.
1964. Forty years of X-ray. Diffraction studies in India (B. B. Roy Memorial lectures) *Phys. Teach.*, **16**, 1-8.
1965. *Pres. Addr. Natn. Sci. Sect.* National Academy of Sciences India,
— (With SEN R K) *and* MUKHERJEE B N Thermal diffuse scattering of X-rays. *Prof S N Bose, Seventieth Brithday Commemoration Volume.* Part II, 11-20.
1967. *Gen. Pres. Addr.*, National Academy of Sciences, India.