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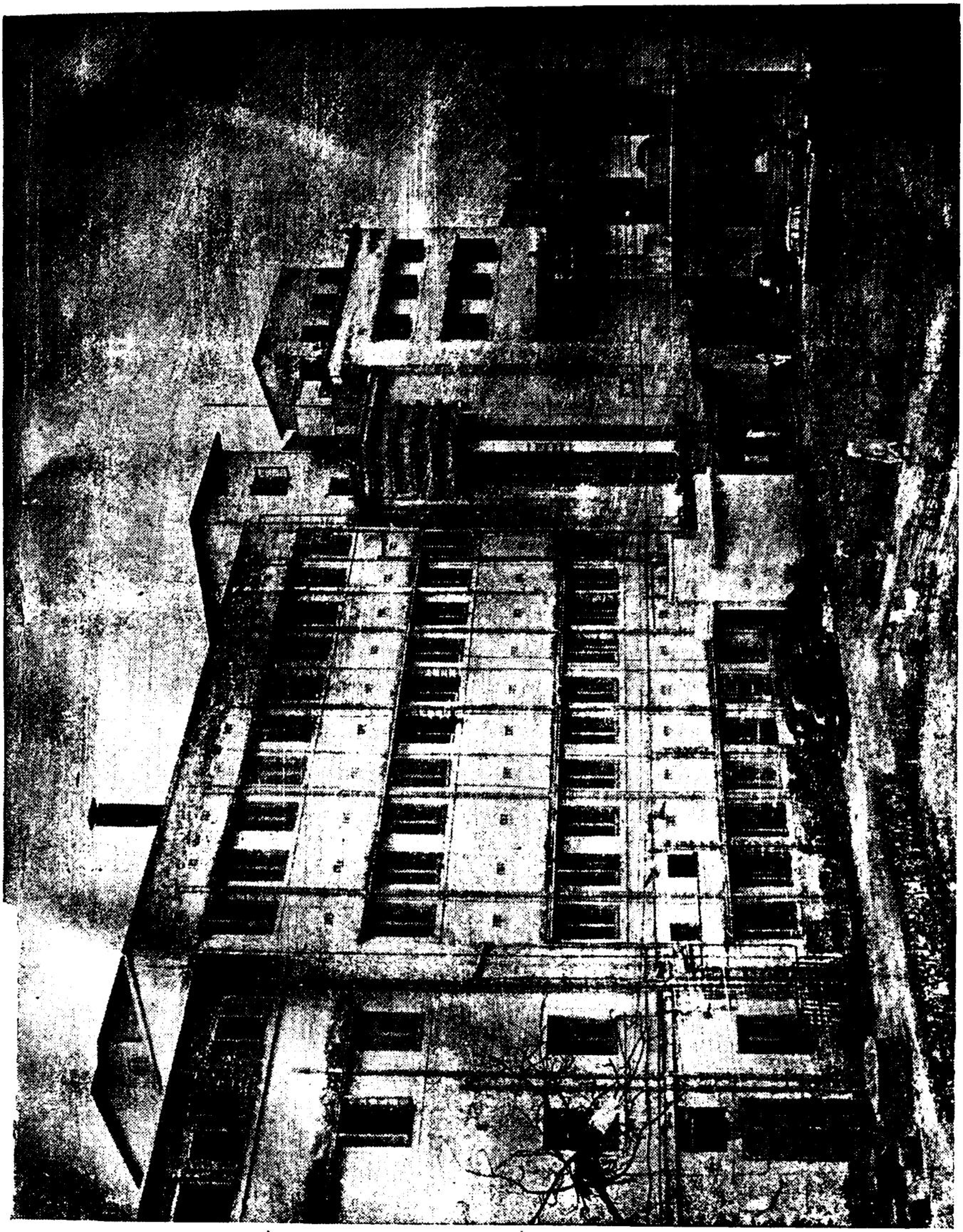

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HISTORICAL

Professor Saha thought of introducing the study of Nuclear physics in India during his last years in the Allahabad University. But the opportunity for doing so did not occur until he came over to Calcutta as Palit Professor of Physics in 1939. In the epoch making discovery of nuclear fission provided further motivation in this direction. He could foresee that this great discovery would lead to much bigger scientific events in the world and he dedicated himself to introducing nuclear physics study and research at Calcutta.

At Professor Saha's instance elementary nuclear physics began to be taught to students from 1941 and two years later in 1943 Nuclear Physics was introduced as one of the subjects of special study at the M.Sc. level of the Pure Physics curriculum of the Calcutta University. It was decided that the Palit Research Laboratory of the University would be reorganised for teaching and reasearch in nuclear science. But such research projects need large funds; and the alien government would not provide with such grant-in-aid. Professor Saha approached different persons including Pandit Jawaharlal Nehru and organisations for private donations. Through the personal efforts of Pandit Jawaharlal Nehru, Calcutta University received a gift from the Dorabji Tata Trust of Bombay to purchase parts of the the first atom smashing machine of the country.

The first building, which later became a part of the Institute, a small two storied building having a covered space of about, 4,000 sq. ft., was erected in 1942 to house this machine. Calcutta University supplemented the grant of the Tatas for this project. Fabrication of the machine was taken up and continued rather slowly due to the difficulty in obtaining materials from abroad during the war period. This condition continued till India became independent in 1947. After the National Government was formed Professor Saha approached the Prime Minister for more grants to purchase components and accessories for the machine, the Cyclotron. The Prime Minister was kind enough to sanction both Capital and Recurring Grants. The machine was put into operation a few years later.

Another group of workers of the Palit Laboratory was engaged with the study of the utilization of theory and methods of physics for the solution of the problems of living systems. This group of research workers served as the nucleus for the present Biophysics Division. In 1944, research work in this direction received support from donation from M/s. Birla Brothers of Calcutta. Another gift made by Rai Bahadur Ranada Prasad Shaha, a well-known businessman of the city, enabled the purchase of one gramme of radium. Another helpful grant came from Dr. B. C. Law, a philanthropist, which helped in the fabrication of the first electron microscope in the country. A gift by Mr. H. M Sur to create the T. C. Sur endowment fund of the Calcutta University to provide for a permanent post for research and teaching in Nuclear Physics also came through efforts of Prof. M. N. Saha.

The necessity for a larger building was being felt since 1945. The small two-storied building which was constructed in 1942 to house the cyclotron was found to be quite inadequate for all the work that were being carried out in the Palit Laboratory in different branches of nuclear sciences. In 1947, Dr. P N. Banerjee, the then Vice -Chancellor of the Calcutta University arranged for a loan of rupees two lacs from the University out of the T. C. Sur Endowment Fund for the construction of a new building. The Government of India was approached for additional funds for the purpose and it sanctioned a sum of rupees 4.7 lacs. The foundation stone of the new building within the premises of the University College of Science & Technology was laid on the 21st April, 1948 by the Hon'ble Dr. S. P. Mukherjee, the then Minister of Industries & Supply in the Central Government. The Institute was formally opened on January 11, 1950 by Professor Madame Joliot Curie.

Since Professor Saha did not have a source of steady recurring grant in the early days for carrying out research work, he had to approach various Government departments and private individuals for financial assistance to carry out his plans of establishing a full fledged research institution devoted to the teaching and reasearch of nuclear and biophysical sciences. At Professor Saha's request, the Vice-Chancellor of the Calcutta University in 1950 approached the Government of India which put forward certain suggestions in reply to put the Institute on an even keel. Negotiations went on between the Calcutta University and the Government of India and finally on 12th May, 1951 the Senate of the Calcutta University framed and passed a resolution framing the constitution of the Institute. On approval of the Government this became the frame work for the Institute. By mutual consent of the University and the Government of India, the Institute has to-day an autonomous Governing Body consisting of representatives of the Government of India and the Calcutta University with the Vice-Chancellor of the Universtiy as its Chairman.

The Institute of Nuclear Physics was founded with the dual objective of teaching including training for higher researches and conducting research in various aspects of nuclear, biophysical and allied sciences and continues to attempt to fulfill these aims as best it can within its resources.

The proposal of having a Hostel for the students of the Institute was approved by the Government of India and an interest-free loan was made available for its construction. The Government of West Bengal also provided with a piece of land contiguous to the premises of the University Colleges of Science & Technology of the Calcutta University. On it the Hostel Building has been erected, the foundation stone being laid on January 19, 1956 by Shri K. D. Malaviya, the then Minister of Natural Resources and Scientific Researches in the Central Government.

Professor Saha remained a life-member of the Governing Body and the Honorary Director of the Institute until his death in 1956.

The authorities of the Institute decided to re-name the Institute after Professor Meghnad Saha, and the "SAHA Institute of Nuclear Physics" came into being.

In 1955 the Government of India has decided to support the Institute more generously and make the organisation more stable by giving block grants for 5 year period instead of adhoc annual grants. Rupees 63 lacs was sanctioned during the first five year period 1955-60. This was increased to rupees 125 lacs during the next five-year period, i.e. 1960–65. To bring the Institute into line with the 5 years plan periods of the Government of India the next five year period will be 1966–71 and the interim year 1965–66 will be tagged on to the plan period to make the needed adjustments. The Institute's proposal for the next period has been examined by an expert committee appointed by the Government of India and it is expected that during the next plan period a sum of around rupees 250 lacs will be the block grant available to the Institute from the Government of India.

The third building of the Institute mainly to house the Biophysis Division has been constructed on a piece of land donated by the Government of West Bengal within the premises of the Bengal Veterinary College at Belgachia. The cost of the building construction together with its services and fittings of approximately Rs- 3.50 lacs. has been met by the Government of India within its five year development programme.

THE WORK OF THE INSTITUTION

The research work of Institute is grouped around the facilities of the Institute in various divisions. There are no firm lines of separation between divisions nor is there meant to be so. This, it is hoped will allow the Institute to derive the benefits of cross fertilization in techniques and ideas. The broad groups or divisions are for administrative purpose placed at present under various senior staff of the Institute as follow:—

(1) The Gas Electronics Group under the Director
(2) The Solid State Physics Group under Prof A. K. Saha.
(3) The Large Molecules Group under Prof. A. K. Saha.
(4) The Theoretical Physics Group under Prof. M. K. Banerjee.
(5) Accelerator Group including Mass Spectrometry under Prof. D. N. Kundu.
(6) The Nuclear Spectroscopy and Nuclear Reactions are placed partly under Prof. A. K. Saha and partly under Prof. D. N. Kundu.
(7) The Electronics and Instrumentation Group under Sri B. M. Banerjee.
(8) The Chemistry Group under Prof. B. C. Purkayastha.
(9) The Biophysics Group under Prof. N. N. Das Gupta.
(10) Technical facilities under the Director.
(11) The Administrative and Service Facilities under the Registrar.
(12) Teaching Facilities in Nuclear Physics and Biophysics for M. Sc. students and in Solid State Physics and Nuclear Physics for Post M. Sc. students under Prof. S. Chatterjee.
(13) Residual activities not falling under these heads are under the Director.

It is hoped that as the work of the Institute develop further other senior staff will share in the responsibilities of taking charge of various groups.

The Accelerator Division headed by Prof. D. N. Kundu, has the cyclotron used chiefly for producing new radioactive isotopes for nuclear spectroscopic studies and for Low energy reaction Studies. It has also a Cockcroft Walton Generator used as a source of 14 Mev neutrons for the production of radioisotopes and for the study of nuclear reactions. In addition to these there are mass-spectrometers developed in this laboratory as also obtained from abroad which are very helpful in separating the atoms and molecules according to their masses.

Inspite of the huge amount of work—both practical and theoretical—that are being carried out throughout the world we are yet a long way off from understanding correctly the laws of the nucleus and it may take many years before one can go to the root of the problem. More and more powerful techniques are being evolved and researches are being carried out. One aspect of such study that of B-ray, spectrometry was started by Prof. A. K. Saha while still a research worker in the Palit Laboratory of Physics. Prof. A. K. Saha is now the Head of the Nuclear Physics Division and at present has also extended his activities to some branches of Molecular and Solid State Physics. In addition, there are well equipped laboratories for nuclear spectroscopy, for the study of nuclear magnetic re-sonance, electron spin resonance, and structural studies with the help of X-rays.

Prof. N. N. Das Gupta, the present Head of the Biophysics Division was with Professor Meghnad Saha in 1946 when he started work on biophysical problems. The work of this division covers the borderline zone of biology and physics. With two electron microscopes capable of very large magnification the workers of this division have been able to study the viruses that cause diseases like small pox, yellow fever and rabies etc. Observations and photography of isolated viruses leading to successful tackling of a large number of medical and biological problems have been possible with results obtained from these instruments. Tracer research in biology and medicine using radioactive isotopes is another type of useful work in this division. Researches in radiation biology is also within the programme of work of this division.

Progress in physics is only possible when the various branches of experimental and mathematical physics are equally developed. It has been said that they are the two eyes of a physical science. Theoretical researches are carried on in the Institute in the Theoretical Nuclear Physics Division headed by Prof. M. K. Banerjee. Though young, this division of the Institute has already made a very good name in its own field.

Development of chemical techniques to which can be applied nuclear sciences is mainly the work of the Nuclear Chemistry Division headed by Prof. B. C. Purkayastha. Problems in Chemistry are tackled with the aid of radioactive tracers. Radioactive nuclei are used to solve problems on analytical, inorganic and physical chemistry.

Shri. B. M. Banerjee is the Head of the Instrumentation Division of the Institute. Experimental researches in nuclear physics require extensive instrumentation most of which is electronic. Any good experimental worker will invariably need newer and belter instruments and apparatus. The Instrumentation Division has been responsible for designing and constructing a number of such important instruments.

The Institute is responsible for conducting courses in Nuclear Physics and Biophysics to the students of the M. Sc. class of the University. It has already been mentioned that an important objective of the Institute is the training of personnel for research in nuclear science. It was felt that the M. Sc. student should have further training before taking up research in nuclear science as a career. With this object in view the Institute started as early as in 1953 a one-year Post M. Sc. training course as preparatory to research open to students from all over India. Such facilities are not available at present anywhere else in India. At present 20 students are admitted every year. Prof. S. Chatterjee is the Head of the Division of teaching and training in various courses at the Institute.

The Institute has a well-equipped Workshop and a band of fine workers. The Library of the Institute feeds not only the students and the research workers of the Institute, but also workers from other departments of the University and other institutes.

Professor B. D. Nagchaudhuri, the Director of the Institute, supervises the work of the various divisions and he has also a number of research workers working directly under him on a low activity tracer work for biological and other use and on plasma physics.

Since its foundation more than a decade ago, the workers of the Institute have contributed about 400 research papers in various scientific journals in India and abroad. Uptil now about 120 students have been given the Associateship Diploma of the Institute, about 40 students have received their Doctorate Degree from the Calcutta University, and 10 students have been awarded the Premchand Roychand Studentship of the Calcutta University. Each division of the Institute has contributed some original work in their respective fields, which has brought international recognition to the Institute. Every year quite a few workers of the Institute are invited to international conferences. A large number of the students of the Institute are now engaged in the universities of Canada, U. S. A., U. S. S. R. and U. K. for their post-doctoral work. Since its start in 1948, the Institute has more than doubled itself in all its activities. Need for more space is being badly felt every moment. Since no space was available within the campus of the University College of Science & Technology, the authorities of the Institute were forced to search for land outside the campus for further extension. The Institute has, received a very handsome gift of a piece of 7½ bigha land from the Kolay family of the city which it is hoped will take care of a part of the problems of extention areas. The Institute is planning for a new building at the Kolay's site and also at Bonhooghly site.

The Governing Body of the Institute at present consists of the following members :

MEMBERS OF THE GOVERNING BODY OF THE INSTITUTE.

Dr. B. Malik—Vice-Chancellor of the Calcutta University, Chairman

Prof. B. D. Nagchaudhuri

Prof. S. N. Bose

Shri P. C. Sen

Dr. R. Ramanna

Shri N. S. Siva

Shri N. C. Chakravarti

Shri S. C. Bhattacharyya

Dr. A. L. Narayan

Shri Y. S. Das

MEMBERS OF THE ADMINISTRATIVE STAFF OF THE INSTITUTE

Prof. B. D. Nagchaudhuri, Director

Shri H. K. Basu, Registrar

Shri G. N. Sarkar, Workshop Superintendent

Sm. P. Hosain, Librarian

Dr. K. P. Chaudhuri, Medical Officer.

ABSTRACT OF STATEMENT OF THE EXPENDITURE AND STAFF POSITION OF THE INSTITUTE.

	Year of inception 1951–52	End of 1st five-year development programme period 1959–60	End of 2nd five-year development programme period 1964–65	End of 3rd five-year development programme period* 1970–71 (Expected)
I. (a) Research Staff	17	67	115	148
Assisting Staff	10	46	81	108
(b) Workshop Staff	5	25	36	58
(c) Library Staff	2	6	13	15
(d) Administrative Staff	9	32	48	63
(e) Total Staff	43	176	293	392
II. (a) Laboratory Space (Sq.ft)	15,500	28,000	32,000	1,00,000
(b) Workshop Space (Sq. ft)	1,900	1,900	1,900	5,000
(c) Library Space (Sq. ft.)	2,000	2,000	2,000	5,000
(d) Office Space (Sq. ft.)	1,200	1,200	1,800	3,500
III. Salary (Rupees)	92,748	4,07,936	13,26,000	22,00,000
Maintenance (Rupees)	28,047	3,28,371	6,37,000	10,51,000
Equipment (Rupees)	72,172	6,69,429	8,37,300	15,00,000
Building (Rupees)	1,43,228	50,740	1,40,100	10,00,000
Total (Rupees)	3,36,195	14,56,476	29,40,400	57,51,000
IV. Research (Staff and Material) Expn. (Rs.)	85,746	5,00,722	15,14,394	25,00,000
Workshop (Staff and Material) Expn. (Rs.)	20,438	60,692	1,23,326	2,00,000
Library (Staff and Material Expn. (Rs.)	6,426 }	1,74,893 (Library and Administ. combined)	3,25,880 (Library and Administ. combined)	1,50,000
Administ. Staff and Material (Expn. (Rs.)	8,185 }			3,50,000

* The 3rd Five year development programme period will start in 1966–67 instead of 1965–66. 1965–66 has been considered as interim year for the purpose of bringing the Institute programme period in line with the Government of India plan periods.

BRIEF REVIEW OF THE PROGRESS OF THE INSTITUTE

Gas Electronics Group

Under The Director, research work on theoretical aspects of the plasma was initiated, at the same, effects were directed to develop techniques for experimental work on low temperature plasmas. The initial work was on the interaction of a fast moving charged particle travelling a plasma which started as a consequence of the interest in studying the Cerenkov interaction in plasmas. Later studies were carried out on the Boltzmann distribution function of electrons in a partially ionised plasma under various conditions and in some special cases the theoretical distribution function was evaluated. Further work is going on in two directions, the evaluation of the distribution function in actual cases of interest and the use of the evaluated distribution functions to obtain the various transport parameters of a plasma with object of experimental verification.

On the experimental side a preliminary study of the d. c. conductivity tensor of the partially ionised argon under parallel electric and magnetic fields has been made. This work is being further expanded to study the properties of the plasma under a. c. fields and under various conditions. A 10 centimetre bench has been set up for studying the plasma in this frequency range. Arrangements for other frequency ranges of interest is also being made.

Another part of effort is the study of ion sources which was started much earlier in connection with the development of ion sources for the accelerators and mass spectrometers. At present a duoplasmatron ion source following Von Ardenne has been set up and preliminary work has been done to study the electron temperature and characteristics of the ion source. It is proposed to modify the duoplasmatron ion source to obtain large ion beams at low energies and trap them under suitable arrangements for study of their various properties. A small amount of developmental work in this connection is also expected to be carried out. Some work on solid state plasmas will also be carried out for analogue as well as basic studies in an effort to co-relate the experimental data with various theoretical calculations. The group has received help from all division, particularly from the Instrumentation Division, the workshop, and theoretical Physics Divition. Special acknowledgment is made to all these divisions for their help.

ACCELERATOR DIVISION

I. Second Five-Year Period.

By the end of the First Five-Year Period, the numerical strength of the research workers and the major nuclear machines round which their activities centered, led to the formation of three Sections within the Accelerator Division, viz. (1) The Cyclotron Section, (2) The Neutron Physics (C–W) Section, and (3) The Mass Spectroscopy Section. All the large machines, namely the Cyclotron, the Cockcroft-Walton Neutron Generator and the Mass Spectrometer, designed and constructed by the scholars and technicians of the Division, had just come to a stage of performance with which original research investigations became feasible. A prolonged period of intense development had thus led to a phase of research activities during the initial years of the Second Five-Year Period. All the senior scholars who had devoted years of arduous effort in design and fabrication jobs, completed their dissertations for the doctorate degree with the result that the number of original research publications had a marked rise in number as also in quality and variety of topics.

Activities of the Sections.

1. *Cyclotron.*

In April, 1960, a good internal beam was obtained in the cyclotron with external shims. The shimming combination suggested a tilt in the lids. Magnetic fields measurements with Hall probes were made and by the end of the year, the shimming and arrangements for holding the shims inside were completed. The proton beam current had peak values of 100 to 400 microamperes and averages of 10 to 40 microamperes, the oscillator being operated on chopped 50 cycles. This beam was used for making nuclear bombardments of various target elements. Beta and gamma spectroscopic studies of short-lived isotopes produced by the transmutation of the target nuclei were made with the help of measuring apparatus with which the laboratory was already well equipped. The instrumentation facilities included elaborate counter and scintillation crystal units with precision and highly stabilised electronic circuits. Pulse height analysis was made using a 20-channel and a 512-channel analyser with automatic printers. This programme continued till June, 1962. Radioactive Mn^{51} was produced by the proton bombardment of natural chromium metal and after chemical separation its decay was studied (1960) using a scintillation spectrometer consisting of an anthracene crystal coupled to a photomultiplier tube and a 20-channel pulse height analyser. The nucleus Rh^{97} was next studied (1961) preparing it by the reaction Ru^{96} (p,γ) Rh^{97} by bombarding ruthenium of natural isotopic abundance and also ruthenium enriched in Ru^{96} to 94.88%. This nucleus was found to decay with a half -life of 32 ± 2 minutes by emitting three groups of positrons, by electron captures and as many as twenty gamma rays. The gamma spectrum and conicidence studies of Ru^{100} was made (1961) by producing Rh^{100} with proton bombardment of ruthenium of both natural isotopic abundance and enrichment in Ru^{99} isotope (89.6%) and the energy level scheme of Ru^{100} given. The nucleus Sb^{113} produced by bombarding Sn^{112} enriched to 74.7% with 3.5-MeV protons was found (1962) to decay with a half-life of 6.4 ± 0.5 min. by the emission of two positron groups, electron capture and several gamma rays and on the basis of the energy measurements with scintillation beta and gamma spectrometers, a tentative energy level scheme of Sn^{113} was given. Inspite of the study by several previous investigators, the decay mode of Ag^{103} had considerable uncertainty. The study of this nucleus was made difficult by the presence of Ag^{104} of half-life 69 min. and 27 min. when it was prepared by the usual method using natural palladium foils. To obviate this difficulty, Ag^{103} was produced by the (p,γ) reaction on palladium enriched in Pd^{102} to 50.9% as compared with the natural abundance of 0.96%. The disintegration characteristics of Ag^{103} were studied (1962) leading to the finding of a new positron group and a few new gamma rays and an energy level scheme of Pd^{103} was proposed based on the beta-gamma and gamma-gamma coincidences and sum studies. The half-life and radiations of γ^{85} were studied (1962) by producing this nucleus by (p,γ) reaction from enriched Sr^{84}. Three positron groups and several gamma rays were found and an energy level scheme of Sr^{85} was proposed on the basis of sum and coincidence data. The nucleus In^{107} was found (1962) to decay by positron emission and electron capture and altogether 10 gamma rays were assigned to Cd^{107}. The sum spectra, beta-gamma and gamma-gamma coincidence studies led to a tentative level scheme of Cd^{107}.

The research activities of the cyclotron group was followed by a period of developmental work again. The design studies for the extraction of the cyclotron beam were undertaken. The magnetic fields were measured over the entire pole face to get enough data for calculating the ion trajectories for extraction. The designs of the septum and deflector were made on the basis of the calculated trajectories and these components were fabricated and installed. The high voltage supply and its associated controls for the deflector and the fabrication of the external supports and cooling units for the deflector shoe have been completed. The substation transformer (6000 volts to 400 volts) have been removed to a new location to make room for the experimental apparatus to be used with the external beam. The design of beam bending magnets has been completed and fabrication of one magnet entrusted to a commercial firm. A highly stabilized power supply for the deflection magnet has been procured and installed which will enable us to compensate for the frequency drift of the dee system. Relocation of the various cyclotron components necessary for the laying of the external beam plumbing is in progress.

Among other contributions made by the cyclotron group, a series of investigations involving critical analysis of reaction data and systematics studies revealed systematic trends and shell effects in (n, α) reaction cross sections at 14-Mev. The cross section curve showed dips down at the proton shell and subshell closure positions throughout the mass region. Other details of the curves within and across the shells have been found to be in good agreement with the expectations from the shell-dependent forms of the level density. Probe studies were made for the electron and total ion current output from the hot cathode capillary arc type ion source of the cyclotron. An empirical relation for the alpha disintegration energies for medium heavy elements has been obtained which gives agreement between observed and calculated values within an average of $\pm$ 5%. A low pressure expansion cloud chamber, previously designed and fabricated in the laboratory, was made fully automatic and the alpha-decay of Am^{241} has been studied by photographing the alpha-tracks in a stereo set-up. A matrix method for the resolution and back-scattering corrections in scintillation beta spectroscopy is in progress. The grounded-grid cyclotron oscillator which has been designed and fabricated led to an interesting study of the modes of oscillation of such oscillators and the condition of excitation of these oscillations.

2. *Neutron Physics (C-W Generator)*

The Cockcroft-Walton Generator, designed and construced in our laboratories has been in regular operation during the Second Five-Year Period. It has provided neutron irradaiation facilities not only to the Neutron Physics group here but also to the Solid State and Biophysics groups. Although its unconventional location, with other workers and laboratories in its immediate vicinity, has put serious limitation, inspite of shielding, on the duration of operation, routine bombardments have nevertheless become practicable by properly scheduling the operating hours.

A large number of radioactive nuclei were produced by 14-MeV neutron bombardment of target materials. Both natural and enriched targets were employed whenever necessary chemical procedures were developed in several instances for the fast separation of short-lived activities. A new chemistry laboratory was set up and equipped with conventional facilities like hood with exhaust, centrifuge, balances, etc. The facilities for the measurements of the nuclear radiations were considerably improved by incorporating high-stability and high-precision electronic equipments. Both scintillation crystals and solid state detectors were widely used in conjunction with a 512–channel pulse height analyser.

The decay of Cu^{68} produced by bombarding Zn and Ga with neutrons, showed a half-life of 30$\pm$1 sec. The beta and gamma ray measurements gave three beta groups and four gamma rays. Based on the sum and coincidence spectra, a decay scheme of this nucleus was proposed. Radioactive Lu^{178} was produced by bombarding tantalum with neutrons and separating the Lu fraction by means of radiochemistry. For this purpose a quick method for the chemical separation of Lu had to be worked out. From an analysis of the complicated beta and gamma rays, the presence of a metastable state of half-life 30$\pm$1 min. was suggested. On the basis of detailed coincidence studies, a decay scheme of Lu^{178} was given. A study of Sr^{93} produced by the (n, α)reaction on Zr^{96} also involved the development of a quick and efficient method for the radiochemical separation of Sr from Zr and Y. Three groups of beta particles and eight gamma rays were observed and detailed coincidence measurements led to the decay scheme of Sr^{93}. In course of a study of the decay of Hf^{183} leading to the energy levels of Ta^{183}, a new isomer of Hf^{183} decaying with a half-life of 91 days has been found. Spectroscopic measurements showed two beta groups decaying with a half-life of 91 days and a third beta group decaying with the half-life of 64 min. along with 10 gamma rays from which a tentative level scheme was worked out. A half-life of 7.5 min. has been assigned to Tb^{162} produced by bombarding Ho and Dy with neutrons. Three beta-ray groups and six gamma rays have been incorporated in a decay scheme based on beta-gamma and gamma-gamma coincidences. The half-life of Nb^{98} was found to be 52 min. with an isomer of half-life 1.5 min. A decay scheme of this nucleus produced by neutron bombardment of Mo has been worked out from various measurements on the beta and gamma rays. The half-lives of the first few excited states of Au^{196} have been measured with the help of a fast-slow coincidence circuit using a time to pulse height converter. Measurements were made of the neutron activation cross-section of a few tellurium isotopes.

By using the nuclear emulsion technique, the energy and angular distribution of alpha particles from the (n, α) reaction in it was studied and the spectrum analysed in terms of the evaporation model. Similar studies on light nuclei viz. carbon, nitrogen and oxygen present in the emulsion itself showed that the pick-up and the heavy practicle stripping processes played important roles in the reaction mechanism. The angular distribution of the alpha practicles from the reaction C^{12} (n, α) Be^9 leading to the ground state of Be^9 was found to be asymmetric about 90° in the C.M. system indicating the presence of direct interaction. Theoretical fits to the experimental angular distribution indicated the existence of both the direct and exchange processes in this reaction. Analysis of the angular distribution of the alpha particles from the 0^{16} (n, α) C^{13} in the region of 4 Mev excitation of C^{13} showed that the distribution was peaked in the backward direction near 160° in the C. M. system indicating that the reaction was chiefly governed by the heavy-particle stripping mechanism. Fading of latent image is a well known phenomenon in nuclear emulsions. Although this fading is an undesirable process, it was utilized in the development of an useful method of eradication of background grainsin emulsionplates. A specially interesting feature of this method is that it can be applied after the processing of the plates have already been effected.

In course of the above research throughout the period of five years, several improvements were effected in the neutron generator, particularly in the high voltage terminal and the acceleration tube. The focussing voltage circuit of the generator as also the probe voltage circuit of the r. f. ion source at the high voltage terminal was modified, transistorised and stabilised to conserve space and power and to improve operation. A new r.f. ion source was developed to obtain higher atomic ion output. Provision for using magnetic field was made. An all transistorised oscillator for operating the r.f. ion source was fabricated with newly developed high-frequency high-power transistors. This circuit, when put to use, will eliminate much of the bulky electronic circuits now used at the high voltage terminal. A magnetic beam bending device was fabricated for bending the 400 KeV (max.) deutron beam of the C–W generator. All cooling water lines were modified on a closed system, cooled by a water cooling unit recently installed. It was found necessary to use a good filter to remove all foreign matter including small airbourne biological matter. Equipments have been constructed for the study of the angular distribution and correlation of the out-coming particle from neutron reactions using both scintillation counters and solid state detectors.

3. *Mass Spectrometer.*

The two-directional focussing mass spectrometer designed and constructed in the laboratory worked with an angle of deflection of $\sim\pi\sqrt{2}$, a mean radius of 381 mm and an arc type ion source giving a resolving power of $\sim$ 125. The machine was used for studies on the inelastic collision of ions in gases. The interest on the study of collisions between atoms and ions led to the measurement of the cross section of the reaction $Kr^{+}+Kr\rightarrow Kr+Kr^{+}$ in the energy range of 2 to 7 KeV. The sputtering yields and angular distribution of silver atoms ejected by ions of the noble gasses at energies from 2 to 7 KeV were determined by the tracer method and the results were examined in the light of the momentum transfer theory. On the problem of negative ion-atom collisions, the cross section of $Cl^{-}+Cl\rightarrow Cl+Cl^{-}$ upto the energy of 90 KeV was theoretically calculated by the two-state approximation method. The discharge stability of the arc ion source was improved by the fabrication of suitable filaments and filament leads. For increasing the transmission, a new vacuum chamber with a larger height was designed and fabricated out of stainless steel. For larger ion outputs from the machine, a duoplasmatron ion source has been tested and installed after fabricating necessary power supply and controls. The current from the exit hole at a distance of 28 inches for argon was measured to be 70 to 100 microamperes, the variation being due to different conditions of vaccum. In analysing this ion beam by the 38 cm radius magnetic analyser, it was found that the fringing field deflected the ion beam strongly before it entered the analysing system so that shielding of the fringing field became necessary. With low current in the magnetic analyser, the focal point is being experimentally traced. An ion optical lens system has also been set up for concentrating and focussing the ion beam at the optimum position for the entrance slit. Other useful instrumental additions to the laboratory are one 20 KV 100 mA accelerating voltage supply designed and constructed, one 1500 volt 2 amp current stabilised supply (0.01%) for the main magnet, a 2000 volt 1 amp stabilized (0.1%) voltage supply for the magnet, a +5KV 10mA power supply, ion pump, ion source for solids and miscellaneous measuring instruments. A surface ionization type 3-filament ion source has been developed and used for the measurement of the ionization potential of lithium. A layout plan for a high intensity isotope separator has been made and several components of this machine have been commercially procured.

THIRD FIVE-YEAR PLAN.

The programme of work of this Division during 1966–71 will be in continuation of the work already in progress. This includes research activities with radio-isotopes prepared in the Cyclotron and Cockcroft-Walton Generator. The work on extraction system and reaction chamber is expected to be completed. In addition the Division will make effort to the study of Accelerator techniques and the construction of the time-of-flight arrangement for the study of neutron reactions. The Division also expects to devote some effort on the development of High Intensity Mass Spectrometry during the next five-year period. The Division also plans to work on Thin Film and Surface Physics and on the problems of High Vacuum and Ion Sources. A new big accelerator is the major development item resubmitted during the current five -year period which, it is emphasised, should be our pivotal item.

1. *Cyclotron*

The activity of the group in broad outline would be the following:

(i) The development of the external beam facilities, currently in progress, will be completed. The mechining and installation of the deflecting magnet, the stabilization of the magnet current, the fabrication of the beam channel and the construction of the reaction chamber will be finalized.

(ii) After a period of work with the external proton beam of energy 3.5 MeV, facilities for acceleration of deuterons and other ions will be taken up. Magnetic field measurements may be made to change the shimming for operation with deuterons, and with other ions.

(iii) Modification programme of the cyclotron facility by model studies. It has been past experience that without proper model studies, changes on the existing machine have been very time-consuming.

2. *Mass Spectrometer*

For extending the scope of nuclear researches in our Mass Spectroscopy Section, it is intended to incorporate within its instrumental facilities one high-transmission, high-resolution mass spectrometer. This development would make possible the identification of the mass number of unknown radionuclides produced with our nuclear accelerators. After the identification, thin sources of the appropriate nuclei would be obtainable for further studies on the disintergration and energy level characteristics in conjunction with other nuclear measuring instruments with which the Institute is well equipped. The high output of the machine would also make possible researches on thin films under ion impact. The potentiality of the existing two directional mass spectrometer, already augmented by the incorporation of improved ion sources and high stability would also be used for researches.

The main developments would thus involve the setting up of the Isotope Separator Laboratory for which most of the necessary equipments are expected to be available during the second 5-year and the interim one year periods. The other equipments procured or constructed would enable minor modifications of components of the existing two directional focussing mass spectrometer.

3. *Cockcroft-Walton Generator*

For the full utilization of the Cockcroft-Walton Generator for neutron studies, the machine would be shifted to a new site and supporting laboratories around it will be developed when building constructions are over. The machine will be further improved by the incorporation of analysing and switching magnets, beam transportation, quadrupole magnets, control console and other equipments.

4. *High-Flux Neutron Generator*

The low intensity 14-MeV neutron generator in our laboratory is inadequate to meet the needs of our Neutron Research group. The importance of a high flux neutron generator had been stressed at the time of drawing up of the second 5-year plan. The construction of a suitable unit was proposed but could not materialise in practice. A high flux neutron generator of the voltage multiplier type which can be pulsed and can go higher in energy will not be a very costly machine and will retain its usefulness for several years to come. Since five years have already gone by, it is proposed to buy a machine if foreign exchanges become available; otherwise some components would be purchased and the rest constructed in our laboratories.

5. *Nuclear Emulsion*

With existing facilities for nuclear studies using nuclear emulsions, the energies and angular distribution of the outcoming particles in several nuclear reactions have been measured. The analysis of the data in the light of stripping, peak-up, heavy-particle stripping, knock-on, etc. processes have given useful insight into the reaction mechanisms involved. These works would be continued and enlarged in scope.

6. *Neutron Research*

The scope of work of the Neutron Research group would be extended so that systematic and critical studies of neutron reactions may be undertaken with facilities for angular distribution and correlation studies. The outcoming particles would be analysed using conventional or solid state detectors as the experimental situation would demand. The reaction chamber and a few other apparatus have already been constructed and are being tested on the existing Cockcroft-Walton Generator. Full use of the instruments would be possible when a generator yielding higher flux of neutrons becomes available.

7. *Ion Source & High Vacuum*

An ion-source is a vital component of every accelerator. Different Accelerators need widely different types of ion sources. Researches on ion sources have recently led to developments which have remarkably improved the performance of most modern accelerators. The ion sources used in our accelerators have been designed and fabricated in our laboratories and a limited amount of research already carried out here has been published. It would be desirable to continue the studies on the mechanism of ionisation of gas under different excitation conditions and on more efficient mechanisms of extractions of the ion current from the plasma. The consequent developmental work leading to the fabrications of necessary sources should be an important activity in an accelerator set up.

The techniques and practices in High Vacuum are also important in every accelerator. Through the years experience in this field has accumulated in our laboratories. It would be desirable to continue the efforts of this group towards production of higher vacuum and its utilization in different experimental situations. The need of these developments will be felt in our accelerator developments and also in our studies on thin films and surfaces.

8. *Film & Surface Physics*

Considerable attention has in recent times been focussed on the physics of surfaces and thin films. Researches on the structure, mechnaical properties, magnetisation and other physical characteristics have raised problems which are of much interest. Vacuum evaporation and other conventional methods off deposition of materials have been largely employed. The characteristics of deposition under energetic ion impact need to be contrasted with available data. Moreover, studies on the structural changes of crystaline solids under such ion impacts are contemplated.

The High intensity Mass- spectrometer already under construction would provide the necessary ions. Electron defraction studies would be undertaken for obtaining information on the structure of the materials.

IV. Concluding Remarks

Numerous difficulties beset the way of progress in experimental research of the above magnitudes in our country. Apart from the total funds made available for all the developments and researches, shortage of foreign exchange and non-availability of necessary materials and components make it impossible to hold to any time schedule. No financial grant was made for any equipment for the interim year 1965–1966. It is hoped that the funds sanctioned for the Third Five-Year Period, although not yet announced, would make it possible for the Division to continue and further enlarge its fields of development and research as outlined above. The Division acknowledges the various technical and material help received from other Divisions of the Institute. Without the co-operation, most readily offered by the Instrumentation and Radiochemistry Divisions, many items in its plan would have been extremely difficult to carry out. This Division was the original nucleus round which the present Institute gradually took shape and therefore, it enjoys a sense of organic unity with all the activities of the numerous other groups of research workers who constitute the pattern of the Institute to-day.

NUCLEAR PHYSICS DIVISION

Report by Head of Division Prof. A. K. Saha

The work of this Division can be broadly divided under three headings :

1) Nuclear Spectroscopy
2) Solid State and Molecular Physics
3) Molecular Biology

Nuclear spectroscopy programe is concerned with continuation of spectroscopy work of the past and some theoretical work on nuclear models and nuclear reactions. The isotopes examined were those that could be imported or made with our cyclotron. The work of this section is greatly handicapped by absence of an accelerator in the medium energy region. A major part of the solid state and molecular physics programe is concerned with the continuation of magnetic resonance work and programmes have been initiated in the fields of epr, nqr and microwave absorption spectroscopy. Theoretical work on various problems of Solid State and Molecular Physics has started. In the past plan period we had started X-ray diffraction studies of structural problems in solid state and molecular biology. This laboratory is now almost complete. A start has been made of a study of collagens.

An account of past work and future programme and the facilities available will be given separately for each section. The major facilities to be developed in the next plan would be

1) installation of a liquid He plant and a cryogenic laboratory.

2) installation of an electron microscope for molecular biology and solid state studies.

3) setting up of a crystal growing laboratory.

1. Nuclear Spectroscopy

Review of the work carried out in the last 5 years (1960–65)

The nuclear spectroscopy laboratory of this institute has developed many techniques for the study of decay schemes of nuclei and has made substantial contribution in this field. The decay scheme measurements of the internal conversion coefficients, ratios of various internal conversion coefficients; end-energy, intensity and log ft-values of the beta transitions, gamma-gamma and beta-gamma coincidences, gamma-gamma directional angular correlation and short life times have been undertaken by Dr. R. L. Bhattacharya and his coworkers. Theoretical analysis of nuclear structure in connection with these decay scheme studies were also undertaken in some cases. The case of Sr^{88} studied by S. Sastri can be mentioned as an example. One hole-one-particle shell model configuration was considered in this case to calculate various transitions. Some progress has already been made in the studies in the field of angular correlation in a magnetic field, very short lifetime for electric monopole radiation and shape factor for beta-transitions. The necessary instrument for the investigations made so far has also been a part of the development work undertaken in this laboratory.

Facilities available in this laboratory

1) A Siegbahn-Slätis beta-ray spectrometer which has been modified by incorporating beta-gamma coincidence counting arrangement using scintillation detectors.

2) Slow-fast coincidence spectrometer using scintillation counters to study angular correlation beta-gamma and gamma-gamma coincidence.

3) Delayed coincidence apparatus for half-life measurements in the nanosecond region.

4) Total absorption gamma-ray spectrometer using 10 cm × 10 cm NaI(TI) phosphor.

5) Dry-chamber phosphor polishing and canning

6) Solid-state alpha and beta spectrometers.

Plan for the next six years (1965—71)

The future programme of work in the field of nuclear spectroscopy to be carried out by Dr. R. L. Bhattacharya and his coworkers includes (a) measurement of the shape-factors of a beta-decays, (b) determination of nuclear g-factor, (c) measurement of E2-Ml mixing ratio with Mossbauer spectrometer, (d) studies of electric monopole radiation etc. The setting up of necessary equipments like γ—γ angular correlation apparatus, e-e coincidence spectrometer, coincedence spectremeter for study of β—γ circular polarisation correlations, time-amplitude converter to study very short life times, Mössbauer spectrometer, etc., has already been undertaken.

II. Theoretical Nuclear Physics

The interests of the theoretical work taken up by Dr. P. N Mukherji and coworkers mainly lies in the analysis of nuclear reactions and a detailed study of shell-model and unified model of nuclei. These are of importance as present day nuclear reaction studies have started giving important and accurate data on energy levels of nuclei.

III. Theoretical Solid State Physics and Molecular Physics

Review of the work carried in the last five years (1960–65)

Investigations are being carried out on the properties of crystalline solids in the following lines by Dr. D. K. Roy and his coworkers :—

1. Investigation of the origin of the crystalline electric fields for rare earth ions in crystals

2. Formulation of generalised spin-Hamiltonian formalism for paramagnetic ions in crystals

3. Study of vibration in solids

4. Study of wave functions in molecules and solids.

From the brief summary of each of these topics given below, the results that have so far been achieved and the work that are now in progress will be evident.

Considerable data are now available on the crystalline electric field splitting of the energy levels of rare earth ions in crystals of different symmetries. Optical absorption and e.p.r. have mostly been done on crystals of low symmetry, either hexagonal or orthorhombic and only recently work has started on crystals of cubic symmetry. The main difficulty in interpretting the splittings of the levels of ions in crystals of low symmetry is the presence of a large number of crystal field parameters. This number is particularly high for rare earth ions with unpaired electrons of $l = 3$ as compared with those of transition group ions with unpaired electrons of $l = 2$. It is therefore convenient if one can reduce the number of unkwnon constants by order of magnitude calculations of the crystalline electric field parameters, particularly the ratio of parameters with the same value of n. Work was undertaken by Dr. D. K. Ray to see how far it is possible to theoretically account for the experimentally known crystal field parameters using a simple ionic model. The ionic model is more valid for rare earth ions due to the fact that 4f electrons spread less than the 3d electrons making the overlap with ligand ions small. Taking account of the induced moments on the various ions, crystals field parameters were evaluated. Next, the presence of 5s and 5p closed shells of electrons between the 4f functions and the ligand ion orbitals makes the question of screening of the crystalline electric potential particularly important for Re ions. Using elaborate variational method Ray evaluated the shielding parameter for one of the crystal field parameters (A^2_0). But such calculations are too laborious due to the nature of the wave function used. In order to draw important qualitative conclusions about the shielding effect of the closed shells of electrons on the crystal field parameters and the electric field gradient produced at the nuclear sites, analytical expressions have been derived by M. N. Ghatikar, A. K. Raychoudhuri and Dr. D. K. Ray for these parameters using hydrogenic orbitals with appropriate screening constants. The dependence of the shielding parameters on the atomic screening constant is clearly indicated. The shielding of the crystal field parameters A_m^l corresponding to different values of l is shown to fall off as l increases and for most of the orbitals the sign of the shielding parameter is such that it acts as a shielding rather than an anti-shielding. General expressions have been derived for the shielding of nuclear moment of any order of magnitude which show that the radial contributions increase with the increase in the value of l for any particular orbital.

In the next work in connection with crystal field investigations, the limitation of variational method in evaluating distortions of 5s and 5p orbitals due to crystal field or nuclear moment has been found out and it is shown that accurate solution of first order Schrödinger equation can only be obtained by numerical methods. Following these methods accurate values of shielding for crystal field parameter A_0^2 as well as Sternheimer R factors which takes account of the change of the field gradient produced by the 4f electrons at the nuclear site due to the interaction between closed shells of electrons and nuclear quadrupole moment, are now being carried out. These values of R factor may be compard with those used by Mössbauer and his coworkers for explaining Mössbauer experiments in rare earth ethylsulphates.

A new method of deriving the spin-Hamiltonian of a paramagnetic system in crystals has recently been worked out by T. Ray of this group from symmetry principles. The Hamiltonian thus derived includes all possible spin operators allowed by the symmetry and in general has more terms than those considered in the usual spin-Hamiltonian. The method is based on the fact that the Spin-Hamiltonian follows the symmetry of the crystal and so must belong to the Γ^co--representation of the crystal point group. The Hamiltonian will thus be a sum of all independent operators which belong to this representation. By using the idea of crystal field Clebsch-Gordon coefficients all such operators can easily be written down. The method was applied by T. Ray to the case of cubic symmetry and the importance of many terms usually neglected in the usual spin Hamiltonian was shown conclusively for a few cases. This formalism has now been applied to the case of rare earth trichlorides by M. N. Ghatikar and T. Ray. Zeeman field dependent quadrupole terms have been obtained in this case and numerical estimates are now being made for different rare earth trichlorides in order to see whether it would be possible to observe any change in the splitting of Mössbauer lines due to the application of external magnetic field.

There are many physical phenomena associated with vibrations in solids. This group is particularly interested in (i) finding the importance anharmonic terms on physical parameters,(ii) estimating spin lattice relaxation in solids (either nuclear quadrupole or electron paramagnetic from spin-phonon interactions, (iii) evaluating the effects of localised modes around impurities in solids on magnetic relaxations, (iv) developing a better model for the calculation of phonon spectra in solids and (v) finding connection between vibrations and phase transitions in solids. A start has just been in this programme of work. First, it has been possible to develop a general method of deriving the potential of vibrating system. Following the same formalism as developed by T. Ray for deriving the form of generalised spin Hamiltonian, P. Rudra and D. K. Ray have been able to write down the exact form of harmonic of any order of anharmonic potential in terms of symmetry coordinates of the system. The method is applicable both to the case of molecules as well as crystals. The effect of cubic and quartic anharmonic terms to the free energy and specific heat of a linear chain has been worked out. Secondly, expressions for spin-lattice relaxation rates have been derived for nuclear magnetic systems which contain all the terms allowed by the symmetry of the crystal. These expressions are independent of any order phonon and contain a number of constants which can be evaluated from the angular variation of the relaxation rates with respect to the Zeeman field. Moreover, these constants can also be determined from theoretical models and compared with the values obtained experimentally.

In the work on the wave functions in molecules and crystals, the interest was mainly in orbitals when placed in a molecular or crystalline environment. Work was started by J. Lahiri and Dr. A. Mukherjee with the calculation of distortion of a hydrogen atom in presence of a proton and its possible effect on the field gradient at the hydrogen atom site. Dr. S. K. Sinha and A. K. Roy Chowdhury completed a theoretical work on the chemical shift in molecules.

Facilities available

For theoretical work during the period under review we required computational and library facilities only. Absence of any good electronic computer in or around Calcutta was greatly felt. We have tried to do computations in TIFR, Bombay, I.I.T., Kanpur and also in HAL, Bangalore and the Indian Statistical Institute, Calcutta. The main difficulty in these works was the distance of the computation centre from Calcutta.

Plan for the next six years (1965-71.)

In addition to the lines of work already undertaken e.g. origin of crystalline electric field for rare earth ions in crystals, vibrations in solids and wave function in molecules and crystals Dr. D. K. Roy and his coworkers propose to start new investigations on metals and origin of exchange for rare earth ions in crystals.

In the case of electric field for rare earth ions in crystals this group will study the effect of covalent bonding on the crystal field parameters. Recent endor experiments of Tm^{2+} in CaF_2 reveal the existence of appreciable exchange interaction for this group of ions. The interesting part of this problem is expected to be the possible effect of closed shells of 5s and 5p electron lying between 4f and the ligand electron on the covalency parameter. It is proposed to investigate this in detail as also the origin of exchange (isotropic) as well as anisotropic interaction between rare earth ions. Work is already in progress.

The studies on vibrations in solids indicated in this report earlier will continue.

Study of rare earth metals is of particular interest to this group because of the localised nature of the 4f electrons and possible effect of conduction electrons on the magnetic properties of these metals. We are particularly interested in finding the distortion of electronic functions on the Fermi surface due to the application of Zeeman and electric field and the effect that those distorted functions produce on the various physical parameters like electric field gradient, knight shift, crystal field parameters, etc. Thermal conductivity for these metals also will be studied because of the possible effect of crystal field splitting of electronic terms and Zeeman field. Studies of magnetic properties of ion group metals in the superconductivity phase is also been contemplated.

The importance of self-consistence in the calculation of atomic wave function and hence of many properties of atoms are well known. We have extended the method for use in considering the effect of a perturbing Hamiltonian. Numerical applications of this method in calculating the dipole and quadrupole polarisability of the Be atom is in progress. The method is intended to be applied to the calculation of other atomic properties like exchange polarisation, chemical shift, etc.

Facilities required

For smooth running of computational work an IBM Card Punch 026 Model I Machine will have to be installed. This will enable the group to have the programme and data cards punched here and these facilities the computations being done at any IBM centre in India.

IV. N. M. R. Spectroscopy

Review of the work carried out in the last five years (1960-65)

The progress was concerned broadly with the following research activity :

(1) Spin echo—The theoretical analysis of spin echo phenomenon was extended and reevaluated on the basis of a stochastic model by Dr. S. K. Ghosh Roy.

(2) Crystal structure studies by nmr — MgF_2 and thiourea.

(3) Free induction decay studies by pulse nmr technique in solids (polycrystalline MgF_2) by Dr. S. K. Ghosh Roy and his coworkers.

(4) Wide-line nmr studies of N^{14} Resonances in the following fields : This programme of work was taken up by Dr. M. Bose and her coworkers.

(a) Chemical shifts of N^{14} resonances in azaaromatics as well as substituted aromatics and aliphatics have been investigated and attempts to correlate shifts with electronic structure have been made. Effects of conjugation and hyperconjugation as well as charge transfer interaction were evaluated. The effect of symmetry on quadrupolar relaxation has been investigated from N^{14} line-width studies.

(b) Proton exchange reaction between pyridine and pyridinum ion has been studied by measuring the pH dependent shifts and line-widths in different mixtures of pyridine and Hcl in water.

(c) Anomalous shifts in paramagnetic nitrates — Evidence for hyperfine interaction occurring in ion-pairs in concentrated solutions of transition metal and rare-earth nitrates is presented from N^{14} resonances studies. As compared to a diamagnetic nitrate Fe, Co, Ni and Cr exhibit no shift at all, whereas Cu exhibits 81 ppm shift and Mn extraordinarily large negative shift. On the contrary, all the rare earth nitrates investigated viz. Pr, Nd, Sm, Gd, Dy, Tb exhibit considerable shifts. Absence of shifts in Fe, Co, Ni and Cr possibly arise from the high stability of the aquo-complex which prevents rare-earths investigated to conform to much lower stability of the aquated cations. The absence of shifts in Cu $(NO_3)_2$ and Mn $(NO_3)_2$ complexed with ethylenediamine in a convincing evidence of specific interaction effects in the ion-pair. This isotropic hyperfine interaction is the result of the combined contact and pseudo-contact interactions occurring in the ion-pair. The contact part arises from covalent bonding between the cation and the 2s, 2p, orbitals of oxygen resulting in a finite spin density on O, which is transmitted to N. The pseudocontact term is relatively more important for the rare-earths which exhibit strong g anisotropy.

(d) O^{17} studies in paramagnetic nitrates were unsuccessful due to the low S/N ratio of the unenriched sample.

Work in progress :— The following programme has been taken up by Dr. M. Bose and her coworkers

A. *Wide-line work*

(1) Critical survey of methods of measurements of relaxation times by steady state techniques, particularly the problem of determining H_r, the RF magnetic field.

(2) Relaxation time measurements of H, F and N^{14} at high and low temperatures in diamagnetic solids and liquids.

(3) Relaxation times at low temperatures for paramagnetic solids and liquids.

(4) Shifts and linewidths in the molten state as well as transition to the melt.

(5) A project is being prepared for electron-nuclear double resonance work both with regard to Overhauser and endor techiques.

B. *High Resolution Work*

(1) Analysis of substituted aza-aromatic viz., the lutidines and the picolines.

(2) Preliminary work on nuclear double resonance.

(3) Preliminary work on paramagnetic chelates.

C. *Crystal Growth*

Considerable progress have been made in the crystal growth laboratory. A program of crystal growth from solution has been undertaken and a few sample crystals of $NaClO_3$, $NiSO_4$ and $MnSO_4$ crystals were grown by slowly lowering the temperature of the thermostat (manual control). The mechanical device of automatic lowering of temperature has been completed now. However, arrangements for crystal rotation at a slow speed have yet to be incorporated.

Description of the techniques developed and facilities available in the laboratory

1) Spin echo apparatus developed in the laboratory by Dr. S. K. Ghosh Roy,

2) Varian Wide-line Spectrometer (V 4200 B) in the frequency range 2–16 Mc with 4012A 12″ magnet.

3) V4540 Variable temperature accessory for the Wide-line Spectrometer (from liquid Nitrogen temperature to 300°C)

4) Varian HR–100 Spectrometer (High Resolution unit at 100 Mc) with V4014 12″ magnet and super- stabiliser system, magnet coolant control system, nmr integrator etc.

5) Test Equipments : 555 Tetronix oscilloscope (dual beam) TF1245-1246 Marconi Q meter (40 kc–50 Mc), Valve Tester 45C (Tayler Elec. Inst.) 202A HP-low frequency generator etc.

6) Chemical Laboratory for preparation, purification and analysis of samples for nmr–epr work, deuterium substitution techniques essential for simplifying complex magnetic resonance spectra have been developed

7) Equipment for Crystal Growth from solution.

Plan for the next six years (1965-71)

Dr. M. Bose and her coworkers expect to work on the following broad research areas:

1. *High Resolution nmr — 100 Mc/s*

a) Proton and fluorine contact shifts in paramagnetic metal chelates and free radicals to determine the magnitude and the sign of the hyperfine coupling constant.

b) Double resonance work on proton-proton spin decoupling sign of coupling constant and relaxation time measurement of different proton groups.

c) Exchange and complex formation reactions.

d) 100 Mc/s work on single crystals.

e) Extended high resolution nmr work to nuclei other than proton p^{31}, B^{11}, C^{13}, 0^{17}, N^{14} etc.

2. *Nmr–epr Investigation in Biological Systems*

a) Metal binding in biological system by magnetic resonance techniques.
b) Enzymatic oxidation reduction systems using high resolution nmr-epr.
c) Proton mapping of amino group protons in aminoacids as a preliminary to aminoacid analysis in mixtures and determining the aminoacid fraction in helical and non-helical situations.

Dr. S. K. Ghose Roy and Dr. S. K. Sinha propose to start the follow-research programme.

3. Extended magnetic resonance work to Liquid Helium temperatures.

4. Development of equipment for ferromagnetic resonance work at 250-500 Mc/s.

5. Study of spin lattice interaction (spin-phonon coupling) using ultrasonic irradiation :—

a) Study of those properties of solids which are strongly coupled to the lattice and hence modifies the propagation behaviour of ultrasound in crystals. Particular emphasis to be given to the study of crystal dislocations, phonon-phonon and electron-phonon interactions (which give rise to nonresonant ultrasonic attenuation) and phonon-spin (both nuclear and electronic) interaction (which produces ultrasonic attenuation).

b) Determination of second and third-order elastic constants of crystals from measurements of ultrasonic velocity and from "optional diffraction of ultrasound" in crystals.

New Techniques and Facilities to be developed

1) Double resonance techniques for spin-spin decoupling studies.
2) Development of liquid helium dewar for nmr studies.
3) Development of a 100 Mc nmr probe for study of solids at liquid N_2 temperatures.
4) Development of ferromagnetic resonance spectrometer by Dr. S K. Ghosh Roy.
5) Development of Ultrasonic techniques in NMR studies by Dr. S. K. Sinha.

V. EPR SPECTROSCOPY

Review of the work done in the last five years (1960–65)

The following is a report of the work done by Dr. R. Roy and his coworkers. An X-band esr Spectrometer employing 100 Kc/s field modulation has been designed and constructed. Microwave components like cylindrical H_{011} mode cavity, co-axially-fed resonant cavities, klystron mounts, waveguide sections and slide-screw-tuners have all been fabricated; electronic equipments like klystron power supply, 100 Kc/s crystal-oscillator cum power amplifier, tuned and video amplifiers, phase-sensitive detection assembly with provision for pen-recording, have been designed and developed for the spectrometer. The sensitivity of this spectrometer is of the order of 10^{15} free radical concentration at room temperature—in the crystal-video system; with the p.s.d. assembly, less than 10^{13} free radicals of solid polycrystalline diphenyl picryl hydrazl can be detected.

For obtaining long-term stability in esr spectroscopy work, it is essential to eliminate frequency drift of the Klystron generator from the resonant frequency of the sample cavity. With this object, an automatic frequency control circuit employing 29.8 Mc/s modulation on the 3 cm microwave and a phase discriminator has been developed. The circuit employed is a modified version of Pound stabilizer, and it is expected that a stability of the order of 1 part in 10^8 will be obtainable by maintaining the interlock of klystron frequency with the resonant frequency of the sample cavity.

Description of techniques developed and facilities available in the laboratory

(i) An X-band esr spectrometer with phase sensitive detection system, AFC interlock and cylindrical resonant cavities, suitable for g-anisotropy measurements.
(ii) A nine-inch Varian (V–4324) electromagnet with water-cooling arrangement and the Varian (V–2501) transistorized stabilized power supply.
(iii) Primary frequency standard — GR type No. 1100A.
(iv) Electronic counter (type hp 524D) with transfer oscillator

(v) Test equipments :

(1) Signal generator (2) Q-meter (3) valve characteristics meter (4) VTVM, (5) audio oscillator, (6) Impedance bridge, (7) Oscilloscopes, (8) Penrecorders, (9) Microwave power meter, (10) Standing-Wave indicator, (11) Low frequency function generator and (12) VHF detector.

(vi) Microwave components like Attenuators, Termination units, Adjustable short, magic tees, twists and bends, detectors, mounts, directional couplers, frequency-meter, universal probe carriage with slotted lines, and a Harmonic Mixer.

Plan for next Six Years (1965–71)

A. *Scheme for proposed Research*

The following program will be taken up by Dr. R. Roy and coworkers.

(1) X-band ESR spectrometer will be converted for dual modulation impressed on a rectangular H_{014} cavity. The signals from a known and one unknown samples-simultaneously introduced inside the cavity will be detected and amplified in separate channels and recorded on a dual pen-recorder; comparative studies on the g-values of spectra or the concentration of free radicals in unknown samples will be advantageously carried out with such a dual-cavity system.

(2) ESR spectrometer at 1.25 cm with superheterodyne detection system not only holds a promise for increased sensitivity, but in such a system modulation broadening as indispensibly associated with 100 Kc/s field-modulation system, will not be present. Hyperfine splitting of spectra as arising in liquid samples will be detectable in this spectrometer. Further studies with ENDOR technique will be carried out at liquid helium temperatures with this spectrometer, after incorporating a high power microwave source and an R/F oscillator unit exciting the simultaneous nuclear magnetic resonance in the sample.

(3) ESR spectrometer at 8 mm wavelength (R-band) will be developed for the detection of unpaired spins of concentration as low as 5×10^9.

(4) Non-resonant absorption by water molecules in an aqueous sample held in the microwave cavity, seriously reduces the cavity—Q, thus hampering the S/N ratio of ESR signal. To avoid this difficulty, an ESR spectrometer at UHF (around 350 Mc/s) will be set up. This will be useful for studies on free radicals in biological samples.

(5) Amplification of X-band microwave prior to detection in the crystal diode — would definitely augment the S/N ratio. With this end in view, it is proposed to set up a "Ruby" MASER pumped at Q-band frequencies for ultimate amplification of the ESR signal.

A method has been developed for obtaining crystal parameters for half integral spins by study of rotation patterns of splitting of NQR lines in low Zeeman field for rotations about the Rf field axis and about an axis perpendicular to the Rf field axis. The method is particularly useful when the cone of zero splitting does not exist.

B. *New Techniques and facilities to be developed :*

(i) Development of a rectangular H_{012} cavity capable of holding flat quartz cells, with provision for flow of aqueous solution—for studying reaction kinetics of free-radicals in biological samples in the X-band spectrometer.

(ii) Development of a rectangular H_{014} cavity with quartz window for studying free radicals due to radiation damage in solid samples irradiated in situ by gamma-rays and slow neutrons, (for X-band spectrometer).

(iii) An ESR spectrometer at 1.25 cm wavelength employing superheterodyne method of detection together with arrangements for ENDOR studies.

(iv) A highly sensitive ESR spectrometer at 8 mm wavelength.

(v) An ESR spectormeter at UHF (at 350 Mc/s) for studying free radicals in biological samples in aquoues solution.

(vi) Pulsed Magnetron sources for relaxation time measurements employing saturation technique.

(vii) "Maser" pre-amplification for improving S/N ratio of ESR signals in X-band.

(viii) Chopper-stabilized High-tension supplies for (1) Electromagnet for Spin-echo spectrometer and (2) Electromagnet for Varian Wide-Line NMR spectrometer.

VI. NQR Spectroscopy

Review of the work done in the last two years (1963–65)

The following is a report of Dr. R. Roy and his coworkers. An NQR spectrometer employing quenched super-regenerative oscillating detectors with frequency modulation impressed with a varicap and a phase-sensitive detection assembly at 200 cps, has been developed. This detector circuit is a modified version of Dean's super-regenerative circuit, and it operated over the range 25 Mc/s to 38 Mc/s—suitable for studies of NQR of Cl^{35} & Cl^{37}.

For obtaining low Zeeman fields, Helmholtz's coil assembly with stabilized current supply unit are being developed. An NQR probe assembly, having facilities for rotation of a single crystal around three mutually perpendicular axes is being developed. This probe together with the low Zeeman field will be employed for determining the assymmetry parameter and the structure of crystals from the split Zeeman spectra.

A method has been developed by Dr. A. K. Saha for obtaining crystal parameters for half integral spins by study of rotation patterns of splitting of NQR lines in low Zeeman field for rotations about the Rf field axis and about an axis perpendicular to the Rf field axis and the Zeeman field axis. The method is particularly useful when the one of zero splitting dose not exist.

Plan for the next six years (1965-71)

The following work will be taken up by Dr. R. Roy and coworkers (1) The NQR studies in nitrogen nuclei necessitate low R/F oscillator level in order to avoid saturation effects. However, frequency modulation of such an oscillator is associated with spurious amplitude modulation signals. A modified Robinson type oscillator in the range 1—4 Mc/s with compensating network for avoiding spurious A.M.,—will be developed for the studies on N^{14} quadrupole resonance in $CH_2(CN)_2$ and hexa-methylene tetramine, at liquid air temperatures.

(2) An NQR spectrometer employing externally quenched super-regenerative frequency-modulated push-pull oscillator having shorted transmission lines at the plates as well as the cathodes,—will be set up. This spectrometer will be used for studies of resonances on Br^{81} and 1^{17} nuclei at frequencies lying between 200 Mc/s to 300 Mc/s.

VII. Microwave Spectroscopy

Review of the work carried out in last five years period (1960-65)

The following is a report of the work taken up by Dr. D. K. Ghosh and his coworkers.

The electronic apparatus were built here in our laboratory which included, stabilized power supply for the klystrons, square wave generator, r-f amplifier and oscillator, phase sensitive detector, phase shifter, low frequency amplifier, saw tooth generator and stabilized power packs. Microwave transition components, stark cell, wave guide flanges, klystron mount were prepared here in our laboratory. Microwave components imported include attenuators, directional couplers, crystal detectors, wave-meter, klystrons and wave guide tubings.

A Leybold rotary pump with a three stage Leybold oil diffusion pump and a combined pirani-ionisation guage is being used to maintain and measure a vacuum of the order of 10^{-5} mm. of Hg.

Varian G-10 recorder has also been imported for recording spectra. A 1 r.p.m synchronous motor which has been geared down to 1 rev/hour has been coupled to the tuning knob of the klystron.

A K–band gaseous microwave spectrometer with 100 Kc/sec square wave modulation was set up here. $N^{14}H_3$ lines (intensity ranging from 4.3×10^{-4} to

7.9×10^{-7}) were observed after proper phase sensitive detection on an ordinary oscilloscope. The sensitivity calibration of the spectrometer is under investigation at present using methyl alcohol which has been investigated by previous workers. Attempts are being made to obtain the stark patterns of this sample, and to improve the sensitivity and resolution of the spectrometer.

A complete data chart of an up to date microwave spectroscopic results has been completed.

Description of techniques developed and facilities available in the laboratory

1. K-band gaseous microwave spectrometer

2. Microwave K–band transition elements, flanges have also been prepared in the laboratory.

3. Three frequency multiplier unit (100 Kc/sec to 900 Mc/sec.) to determine the frequency of the spectral line accurately (accuracy 1 in 10^7) is being completed and it is expected to be ready for use very soon.

4. Test equipments we have in our section includes :

a) Q-meter, b) High Vacuum facilities (up to 10^{-6} mm of Hg), c) VTVM d) Rf. generator, e) Avometers f) Hf. leak detector, g) Water cooled diffusion pump.

Plan or the next six years (1965–71)

The following work will be taken up by Dr. D. K. Ghosh and his coworkers The K-band spectrometer for investigation of rotational transition of molecules in the gaseous state with stark modulation has been set up. It may be mentioned that the weakest absorption line of $N^{14}H_3$ have already been observed on an ordinary oscilloscope. The sensitivity calibration of the spectrometer is yet to be completed. At present the plan is to use a calibrated cavity wavemeter itself having been pre-calibrated against standard lines. The generators of more accurate frequency markers will be included in the system. It is proposed to set up a a frequency standard for accurate frequency determination of lines. In order to do this a frequency multiplier unit is being fabricated to couple it to a 100 kc G. R. frequency standard that we already have.

The outlook for the next five years, on the other hand, is the expansion of the laboratory to all fronts. Basic research on the problem mentioned hereinafter will proceed with the instrument already constructed. It is proposed to push the range of investigation into the milimeter range of wavelength. Spectral transitions of matter becomes stronger and more abundant as the frequency is increased. Many light molecules exhibit rotational transitions at such frequencies as also the higher rotational transitions of comparitively heavier molecules. With this end in view a V-band (8 mm) spectrometer is to be built having more or less the same features as the K-band spectrometer. Interest is also centered on a closed examination of hyperfine lines. To enable us to do this, a beam maser spectrometer is to be constructed. The expectional resolving power of maser spectrometer arises directly from the use of a beam, with its reduced randomness of molecular motion. Hence the lines are much narrower than the normal Doppler width, being only a few kilocycles wide. This results in a resolution several times better than that attainable in a normal spectrometer and in a corresponding higher frequency measurement. Many magnetic hyperfine structure and small quadrupole coupling can thus only be resolved by reducing Doppler width of the lines.

A Molecular Beam Resonance Spectrometer in the microwave region will be set up. The type of device allows high resolution because the molecules whose transitions are detected are travelling more or less in one direction along the axis of the apparatus and Doppler effect can therefore be reduced.

Broadly the research programe is concerned with the following research areas:

(1) Study of line shapes and line width to pin-point their origins in different cases, to determine the relative magnitudes of different interactions, and to test the goodness of fit with some existing theoretical formulae. A detailed study of the line shapes will result in determining the contribution of higher grade moments in the respective molecular interactions.

(2) Determination of structural parameters of molecules, viz., bond lengths and bond angles.

Also study of the effect of zero-point vibrations on the accuracy of molecular parameters.

(3) Detailed investigation of the Stark effect in Molecules. Determination of electric dipole moments.

(4) Verification and modifications, if appreciable, of the existing molecular parameters from studies on high J rotational transitions.

(5) Study of the influence of molecular symmetry on the rotational energy levels of the molecules. Theoretical prediction of rotational energy levels.

(6) (a) Investigation of centrifugal distortion corrections in molecules in different rotation and vibration states.
(b) Study of hindered rotaional effects. Determination of barrier height from investigations on internal rotational splittings in molecules.

New techniques and facilities to be developed

(1) V–band microwave spectrometer (26 to 40 KMc/sec.)

(2) Beam maser Spectrometer.

(3) Molecular beam Spectrometer.

VII. Crystallography and Molecular Biology

The ever increasing need for this division for obtaining precise information on single crystals, microcrystals and polycrystalline aggregates of metals, alloys etc. initiated us to start a section of X-ray crystallography and crystal physics during the last 5 year plan period. The primary phase of our programme was directed towards the setting up of laboratories and the development of the basic techniques. A brief survey of the already available facilities in our laboratory, gives a very encourging picture of the development, but much more remains to be done yet. The research activities of this section were guided by Dr. N. N. Saha and were not limited only to the stipulated scheme of works above, but were also directed to one of the most fascinating fields of science viz. molecular biology. The knowledge of molecular structure is essential in understanding the behaviours, properties and function of the biological molecules. In view of the satisfactory progress it has naturally been our desire to persue this line of research in a wider perspective from maximum possible angles of attack.

Review of the work carried out in the last 5 year period (1960–65)

a) The following is programme of work taken up by Dr. N. N. Saha and his coworkers. Study of crystals like In Sb, BiTe and $BiTeSe_2$ which are grown in our laboratory and thin films of Cu, Ag, Ni, etc. have been made by back reflexion, powder and rotation methods. Study of these crystals and thin films has also been made by optical and other methods. Some of the advanced X-ray diffraction techniques for studying the single crystals have been developed and study on some carcinogenic and other crystals of low molecular weight is already in progress. Facilities for Fourier and Patterson synthesis are already available.

b) Regarding our study of the molecules of biological origin, mention may be made of the shark fin collagen, normal and diseased human bones, sorolin, lactoglobulin etc. Some interesting findings on the molecular structure of human bones have been obtained. The programme for studying single crystals of β-lactoglobulin is already in hand and will be excuted in active co-operation with Bose Institute in Calcutta. With the limited resources at our disposal our attempt was naturally on a very modest scale, but our finding in this line, exciting as they are, encouraged us to make an elaborate scheme in Molecular Biology for the next plan period.

Description of techniques developed and facilities available in the laboratory

1. Wide angle X-ray diffraction.
2. Small angle X-ray diffraction
3. Weissenburg, rotation and oscillation methods.

4. Polarisation microscopy and optical microscopy.
5. Resistance furnaces for growing crystals.
6. Ordinary microtones.
7. Biochemical and physicochemical techniques.
8. Zero degree room for handling protein molecules.
9. Paper chromatography equipment.
10. Etching technique.
11. Crystal model making techniques.
12. Fabrication of flat X-ray cameras and other gadgets for comparison and other special type of X-ray diffraction photographs
13. Electrophoresis equipment.
14. High temperature X-ray camera.

Plan for the next six years (1965–71)

The following is a biref heading of the research problems in crystallography and molecular biology with which Dr. N. N. Saha and his coworkers are to be concerned in the next six years.

1. Structural analysis by X-ray diffraction methods :—

(a) single crystals, microcyrstals and polycrystalline aggregates

(b) molecules of biological origin e. g. collagen, keratin and conjugated proteins.

2. *Biogenesis :*

(a) Collagen, keratin and chitin in biological systems.

(b) Role of enzymes and mucopolysaccharides in biogenesis

3. Study of mechanism of calcification in bones of different biologicals systems

4. Study of mechanism of muscular relaxation and contraction.

5. Study of mechanism of enzyme reactions in biological systems and enzymology.

6. Study of bacterial DNA and RNA.

7. Ultrastructural study of biological systems.

8. Study of functional phenomena in living systems by tracer techniques.

9. Quantum Biology

New Techniques and facilities to be developed

A. Some Wide angle X-ray diffraction methods

1. (a) Precession diagram, (b) Heavy metal and isomorphous replacement method.

2. Intensity measurements microphotometry, diffractometry, etc.

3. Computation : Structure factor, etc.

4. Fourier and patterson projections etc.

B. Small Angle X-ray diffraction method (High intensity tubes, monochromates)

C. Electron microscopic methods

(a) Sonic disintegration, (b) Section cutting, (c) Shadowing, (d) Staining.

D. Optical methods :

(a) Optical transform method, b) Spectroscopic methods—visible, U-V (c) Light scattering, (d) Microscopic methods—polarising microscope, phase contrast, interference microscope, (e) spectropolarimetric techniques including optical rotatory dispersion, (f) micro-fluorometry for reflectance measurement.

E. Ultracentrifugation

F. Biological techniques

G. Tracer techniques

H. Physco-chemical methods :

1. Microanalysis, 2. Electrophoretic techniques, 3. Paper and column chromatography, 4. Viscometry, 5. Osmometry, 6. pH-titrations, 7. Amino acid analysis, 8. Fluorimetry, 9. Polarographic techniques.

BIOPHYSICS DIVISION

The activities of this Division include (1) teaching of Biophysics at the M. Sc. and Post-M. Sc. levels and (2) researches in electron microscopy, radiation biology, molecular genetics and physical biology. About 75 research papers have been published from this Division. Eleven Doctorates and about 40 M. Sc.'s in Biophysics have been trained up. Some of the works from this Division have been cited in International Reviews and monographs. In appreciation of the original electron microscopic and radioactive tracer work on leprosy carried out in this Division, the International Atomic Energy Agency of the United Nations, deputed one of the senior staff members of the Biophysics Division as an advisor to the Govt. of Mali, West Africa, for expert advice in setting up a research laboratory in this field.

A brief description of the activities of this Division is given below.

Biophysics Teaching

In 1957, this Division was able to organise a course of studies in Biophysics at the M. Sc. level of Calcutta University. This course aims at preparing the student not only to achieve a general familiarity with biological systems but also attain a mastery of the physical sciences, so that he can participate, first hand, in some of the most exciting scientific advances of our day. The curriculum for this course has been prepared in conformity with the teaching programmes of the Biophysics Departments of the Universities of Chicago, Yale, Stanford, California, etc. The approach to the biological problems is largely based on the powerful method of physics and physical chemistry.

At present several pre-doctoral students are working for D. Phil. (Science) degrees of Calcutta University. Topics of Research of these candidates are given below :

1. Studies on the Albumin Molecule with Diffusion and Related Physico-chemical Techniques (Amala Chatterjee).
2. Electron Microscopic Investigations on Normal and Abnormal Haemoglobins (D. N. Misra).
3. Scattering of Electrons by Biological Specimens and Determination of Their Mass Thickness (N. H. Sarkar).
4. Studies on Some Proteins with Special Reference to the Effect of Electron Stains (P. Ganguly).
5. Cellular Response to Radiation and Radiation Damage to its DNA (M. Sarkar).
6. Molecular Autoradiography of DNA (S. Sarkar).
7. U. V. Spectrophotometric Studies on the Denaturation of Proteins by Electron Stains (A. B. Sanyal).
8. Altered Nucleic Acid and Protein Synthesis in Host Bacteria Infected with Bacteriophages (S. Pal Chaudhuri).
9. Studies on the Growth of Bacteriophages (B. Datta.)
10. Biophysical Studies on Ribosomes (N. Ghosh).

Current Research

Research activities are organised under the following sections

Electron Microscopy Section is concerned with studies on the shape, size, fine structure of biologically important macro-molecules and their arrangement on the sub-cellular level. Simultaneously with these studies, attempts are constantly being made to improve the technique of electron microscopy, by detailed study of electron staining, shadow casting and related techniques.

Cellular Ultrastructure Section is concerned with the submicroscopic morphology of protozoa and bacteria, macromolecular organisation of the chromosomes, the macro- and micro-nuclei of Ciliates, and the chromosome-nucleobus interrelationship.

Radiation Biology Section is engaged in investigations on the action of ionising radiation on the different functions of the living cell such as growth, synthesis of proteins, nucleic acids, transfer of genetic information etc. The main objective is to try to relate the primary effect of radiation on cellular macromolecules with the observed biological effect.

Physical Biology Section concentrates on characterisation of individual components of biological systems with the help of various physical techniques, e. g. ultracentrifugation, diffusion, viscosity and U. V. absorption spectrophotometry. The components of primary interest are the large macromolecules which possess the diversity of structure and properties needed for life processes.

Molecular Genetic Section : The objective of this section is to investigate the problems of replication, transmission and directive functions of the genetic material at the molecular level. The experimental system chosen for these studies mainly consists of bacteriophages and bacteria infected with them.

A brief description of the researches carried out during the period 1961–1964 is given below.

RESEARCHES IN ELECTRON MICROSCOPY SECTION:

a) *Theoretical studies of electron scattering cross-section for atoms of biological interest:*

The electron scattering by biological samples have been extensivelyi nvestigated. Defects of the electron scattering formulae based on the Thomas-Fermi atom model and of Leisegang's formula have been studied in relation to image constrast problems in electron microscopy. The differential and total elastic and inelastic scattering cross-sections of the carbonaceous matter have been estimated theoretically with a more realistic charge distribution for the electrons in the carbon atom. The agreement of the several experimental results with the present theory is much better than with the existing theories of Lenz, Leisegang and Burge and Smith.

b) *Correlation of contrast in electron micrographs with the mass thickness of biological specimens :*

The technique of "quantitative electron microscopy" has been developed which enables an estimation of the distribution of mass in biological samples, The method has been successfully applied to determine the dry mass thickness of the cell membranes of *Bacterium coli* , human normal and diseased erythrocytes and the flagellate form of *Leishmania donovani* and of TMV, Yeast, RNP, bacteriophage tail and polystyrene latex particles.

c) *Measurement of the distortion of particles produced by shadowing* :

Metal shadowing is a standard technique utilised in increasing contrast of small biological molecules in their electron microscopic investigations. Distortions produced by the metal shadowing were measured on a large number of particles of known dimensions. Distorations were found to be dependent on on particle sizes. Empirical relations between distortions and particle sizes have been deduced. These relations were found useful in deducing true dimensions of small biological particles (e. g., Haemoglobin molecules, Yeast, RNP particles, DNA molecules, etc.) from their shadowed electron micrographs.

Researches on the Ultrastructure of Cells

a) *Nuclear and cytoplasmic division of leptomonad form of L. donovani* :

A detailed study of the different stages of nuclear and cytoplasmic division of leptomonad form of *Leishmania donovani* — the Kala-azar parasite was made. During that investigation evidence of abnormal nuclear division was observed. Eight chromatinic bodies were counted in the metaphase plate of this parasite. In mitotic anaphase eight chromatids were visible in each pole of the nucleus, where four chromatids were found in the meiotic anaphase I and as a result of abnormal division four haploid cells were produced.

b) *Growth rate of leptomonad form of L. donavani* :

The growth rate and the time schedule of the mitotic cycle of the leptomonad form of *Leishmania donovani*, the Kala-azar parasite, were studied. The numbers of cells in the different division stages were estimated by photomicroscopy after Feulgen staining which were also confirmed by electron micrographs of ultra-thin sections. The observed time intervals of resting, prophase, metaphase, anaphase, telophase and binucleate stage were 15.2, 1.1, 3.9, 1.1, 0.9 and 1.8 hr. respectively; the total generation time was 24 hrs.

c) *Ultrastructure of Trichomonas criceti* :

Electron microscopic investigations were made on the ultrathin sections of *Trichomonas criceti*, obtained from the caecum of the hamster. The parabasal body consisted of a number of thick walled, long-.lamellar structures. The parabasal filament was attached to the parabasal body. The ultrastructure of anterior flagella, recurrent flagella, udulating membrane, etc. were thoroughly studied. The axostyle was found to be limited by a double layered membrane, inside which a number of rounded, filamentous or granular structures were found. The costa was seen to be composed of a number of double walled disk-like structures.

d) *Electron microscopic studies on the ultrastructures of normal and diseased human red blood cells :*

Normal adult and faetal red cells and those from patients suffering from thalassaemic trait, from hereditary spherocytosis have been studied under the electron microscope. The sections of the normal adult and foetal cells had homogeneous interior. Some spherocytes showed the presence of small vacuoles and inclusions in them while others were homogeneous like the normal cells. A good number of the sections of the thalassaemic cells showed a big central vacuole with a characteristic inclusion.

Plasma membranes of the above cells were studied by shadowing technique. Membranes of the diseased cells showed characteristic textures. Thalassaemia minor cell-membranes appeared coarser than the normal ones. Membranes of the spherocytes appeared thinner though their texture appeared similar to that of the normal ones.

RESEARCHES IN RADIATION BIOLOGY :

Effect of radiation on DNA in vivo and in virto :

DNA the genetic material of a cell is considered to be likely site for the radiation damage to cell. To test if any damgae to DNA could be detected, it was collected from the X-irradiated *E. coli* and studied with ultraviolet absorption technique, ultracentrifugal analysis and electron microscopy. For comparison DNA collected in the laboratory from the non-irradiated *E. coli* was also exposed to X-rays at different dose levels and studied with the same techniques. It was observed that when DNA was irradiated *in vitro* with dose of about 15 kilo roentgens, the rise in optical density at 260*m* compared with control, was 18% whereas under similar condition of *in vivo* irradiation no such rise in optical density could be detected. The sedimentation constant from the ultracentrifugal analysis of the DNA from irradiated and from non-irradiated cells did not show significant difference. These results could possibly be explained by the fact that intracellular DNA most affected by raidation became fibrous. Such fibrous DNA is not extractable by the common procedures of DNA separation.

b) *Influence of RNA'se on the survival of irradiated bacteria* :

It has beeno bserved that as a result of the incubation of irradiated bacteira in the presence of RNA'se there was 40 fold increase in survival for X-irradiated cells (survival level 0.1%) and two fold increase for U.V. irradiated cells (survival level 0.1%). Also RNA'se was predominantly a reactivator and not a protector. The magnitude of the reactivation depended on the amount of RNA'se and reached a saturation value at the concentration 25μg/ml. of the enzyme. The differential analysis of the influence of RNA'se on X-irradiated and U:V. irradiated cells showed that the mechanism of inactivation by X-rays and U.V. rays were different even though there might be some overlap.

c) *Influence of incorporated P–32 decay and heat on the X-ray sensitivity of E. coli:*

The effect of incorporated P-32 decay and that of heat treatment at 52°C on the X-ray sensitivity of *E. coli* cells were studied. Due to incorporated P-32 decay, the cells became more sensitive to X-rays. That such incrase in sensitivity was not due to any change in strain was proved by further subculture of the cells. Due to heat treatment also the cells became more sensitive to X-rays, increase in sensitivity depending on the amount of heat treatment. X-irradiated cells also had a higher heat inactivation rate.

When heated cells were incubated at the suboptimal temperature of 20°C for 24 hrs. before plating, the cells showed high amount of recovery of the colony forming ability. The maximum recovery obtainable depended on the initial number of heat survivors and was 65%. No such recovery was observed with X-irradiated cells, heated or not.

d) *Effect of X-rays on bacterial ribosomes :*

There is a growing evidence that the ribonucleoprotein (RNP) particles of the cell are the centres of protein synthesis, though not all of them area active in the process. Attempts have been made to study the effects of ionising radiation on such ribosomal centres of protein synthesis in the cell.

Crude extracts from starved, non-irradiated and irradiated *E. coli* cells were collected in M/300 phosphate buffer containing .01 M Mg^{++}. These extracts were then analysed in a Spinco ultracentrifuge, Model E at 39,460 revolutions per minute. The radiated cells were found to contain diminished amounts of free RNA and 88S ribosomes. Starved cells also showed similar effects. At the various doses used, upto 90 kilo-rads, it was observed that 70S particles were not effected whereas, the amount of 88S particles was greatly diminished. It was concluded that the enzyme system that controled the conversion of 70S to 88S particles was very susceptible to radiation damage.

Researches in Physical Biology :

a) *Physico-chemical studies on Bovine Plasma Albumin molecules :*

With the help of Jamin interference method, the diffusion coefficient of bovine plasma albumin has been measured over a range of protein concentration at 25°C. The diffusion coefficient of palsma albumin at 25° C has been found to depend linearly on protein concentration with a small negative slope. The theoretical basis of this finding has been obtained from the equations of Mandelkern and Flory.

Electron microscopic studies of bovine albumin molecules have been carried out. Electron micrographs show that the anhydrous molecule is asymmetric in shape and consists of two approximately spherical sub-units, each with a diameter of about 41 Å. This finding supports the existing data on the asymmetry of the hydrated plasma albumin molecule and lends experimental support to the idea of sub-unit structure of the molecule hypothesised by a number of workers from indirect chemical studies.

The shape and size of the hydrated bovine plasma albumin molecule have been deduced from the present measured values of $D^{0}_{25,W}$ and intrinsic viscosity, $[\eta]$. Both the deductions are in satisfactory agreement with each other and reveal that the hydrodynamic molecule can be explained as an ellipsoid of revolution of axial ratio between 4 to 4.4.

b) *Interaction of electron stains with proteins :*

The negative staining technique is now widely used for electron microscopic elucidation of structural details of viruses, proteins and nucleic acids. For this technique to be successful, it is essential that the stain must not interact with the specimen to be stained. The interaction characteristics of phosphotungstate (PTA), a widely used electron stain, on the physicochemical properties of haemoglobin has been investigated by ultracentrifugal and ultraviolet absorption spectoscopy. It has been observed that interaction with PTA leads to aggregation of the protein molecules at almost all pH values. This aggregation effect may be reduced by prior fixation of the protein in formalin.

Besides phosphotungstate, another electron stain uranyl acetate has also been investigated. The inherent pH of uranyl acetate is so low that it cannot be used for negative staining of many proteins. Since the pH of uranyl acetate can be adjusted only slightly by conventional methods, a complex, uranyl tartarate was prepared whose pH can be easily varied upto 9.5. Interaction of this complex with haemoglobin has been studied and the safe pH region for successful negative staining determined.

c) *Ultracentrifugal study on human haemoglobins A, F and E:*

Recent studies have brought to light a large number of human haemoglobin variants which differ from one another in electrophoretic mobility, amino acid composition, crystal shape and size etc. In view of these known differences an investigation was carried out to find if human haemoglobins A, F an E could be distinguished from one another on the basis of their sedimentation properties. No previous sediments tion study on Hb-E has been reported. Detailed studies on the concentration dependence of the sedimentation coefficient of these three human haemoglobin variants showed that Hb-A and Hb-E have similar sedimentation properties while Hb-F appeared to possess a slightly higher sedimentation coefficient.

The effect of NaCl on sedimentation coefficient of haemoglobin has also been studied. It has been observed that in 0.0 M or in 0.1 M NaCl solution the

S-value increases linearly with decreasing protien concentration. No evidence of dissociation could be found even at a concentration of 0.03% . In 0.5 M or in 2.0 M salt solutions the sedimentation coefficients were consistently lower than those obtained with 0.0 M or with 0.1 M solution. However, the most interesting point was that below 0.3% protein concentration the S-values decreased progressively with decreasing protein concentration. This has been explained to be due to the dissociation of haemoglobin molecules into sub-units.

Sedimentation studies on hemoglobin in buffers of different pH values showed that the protein molecules remained intact in the pH range 6.0 to 9.5; on either side of this pH range the molecules dissociated into sub-units.

d) *Studies on the size and ultrastructure of normal and pathogenic human haemoglobin molecules :*

Normal adult haemoglobin (Hb-A), faetal haemoglobin (Hb-F) and an abnormal haemoglobin variant (Hb-E) were electron micrographed utilising metal shadowing and negative staining techniques.

Measurements on the shadowed micrographs gave the dimensions 55.2 ± 9.8 Å. U. and 55.5 ± 9.7 Å. U. for Hb-A and Hb-F molecules. The molecules were thus found to have same dimensions approximately. The shadowed preparations showed the presence of a hole through some of the molecules and the others were found to show clear sub-units. The negatively stained micrographs gave for the first time clear information about the ultrastructures of the haemoglobin molecules. The presence of four sub-units was clearly demonstrated by many molecules. Many other molecules showed clearly a central hole.

Researches in Molecular Genetics:

a) *Transmission of genetic message by φX 174 :*

It is known that genetic information in living matter resides in the DNA molecules. The problem is to study how φX174, which is a single-strandde DNA-bacteriophage, carries the genetic information. It is found that immediately after the infection of the host bacteria, *E. coli* C, by φX174, the complement to the infetcting DNA results and this has been called the replicating form (RF) of φX-DNA. In order to find which of the two strands of the RF is responsible for the transmission of genetic message, the complexes of (i) P-32 labelled *E. coli* C and P-32 labeled φX 174, (ii) P-32 labelled *E. coli* C and non-labeled φX174, and (iii) non-laneled *E. coli* C and P-32 labeled φX174, were stored at 4°C after 4 min. growth at 37°C. It was known that during this time of growth RF was formed. The study of survival of the phage-bacteria complexes with time of storage at 4°C due to the decay of radioactive phosphorus should, therefore, identify the strand, integrety of which is essential for the transmission of the genetic message. Experiments are still in progress, but preliminary results indicate that the integrety of the infecting DNA strand of ϕX174 is necessary for the transcription of genetic message.

b) *Changes in sensitivity towards X-irradiation of ϕX174 and T2 bacteriophages after survival of ingested P-32 decay :*

The efficiency of killing bacteriophage T2 due to ingested P-32 decay is 0.1 and that of ϕX174 is 0.1 indicating that about one out of ten disintegration kills the T2 phage particle, whereas every disintegration is lethal in the case of ϕX174. So it may be expected that a population of labeled phages, survivang a given number of ingested P-32 decay, should exhibit unchanged sensitivity towards X-rays in the case of ϕX174, but an altered sensitivity in the case of T2. It was observed that the slopes of the survival curves due to X-irradiation of non-labeled ϕX174 and that of labeled ϕX174, 99.8% of which have been inactivated due to ingested P-32 decay were same. But from the slope of the survival curves due to X-irradiation of labeled and non-labelled T2 it was observed that, under identical conditions, labeled T2 surviving P-32 decay was more sensitive to X-rays than non-labeled T2.

c) *Investigations on the macromolecular synthesis in normal and X-irradiated cells due to infection with ϕX174:*

On irradiation with 40 kilorads of X-rays, only 0.1% of the cells were able to form colonies but 20% of the cells still sustained the growth of bacteriophage ϕX174. This indicated that the synthetic machineries responsible for bacterial growth and division were seriously damaged but the mechanisms for phage multiplication were less hurt. The inactivated infected *E. coli* C were used to study macro-molecular synthesis induced by ϕX infection.

The radioactive P-32 uptake in the normal cells and the normal cells infected with ϕX174 remained equal; but a stimulation of P-32 uptake in the infected irradiated cells was observed in comparison with irradiated uninfected control.

Fractionations further indicated that enhanced uptake of P-32 was mostly in RNA and to a lesser extent in DNA fractions. The excess P-32 in the RNA fraction was found to be associated with the phenol plus interphase layer when the infected cells were shaken with water-saturated phenol.

NUCLEAR CHEMISTRY

The following plans for research and developments were taken up since 1955. Objects of the plan were to develop chemical techniques that find applications in nuclear sicence, work in nuclear chemistry and solve original problems in chemistry with the aid of radioactive tracers. In addition to teaching post M. Sc.

and M. Sc. classes the following lines of research and developments were therefore thought of :

Unit A: Inorganic chemistry.

1) Original problems of inorganic chemistry with the help of radioactive tracers.
2) Target reactions and separations of active nuclei from the bulk of inactive material.
3) Study of heavy elements.
4) Study of the chemistry of rare elements with radioactive isotopes.
5) Study of seperation chemistry.
6) Radiochemical study of nuclear fission.

Unit B : Analytical Chemistry.

1) Semi-micro and micro technology with special reference to study of nuclear science.
2) Application of radioactive nuclei to analytical chemistry.
3) Study of minerals with special reference to incorporation of trace constituents and development of technuiques to improve upon the method of recovery of uranium, rare-earths and rare elements that find applications in nuclear science.

Unit C : Physical Chemistry.

1) Application of radioactive nuclei to the problems of physical chemistry.
2) Study of isotope separation with the help of radioactive and stable tracers.
3) Study of radiation chemistry.

Some developments of all these units require a bigger staff, more money and space, The policy adopted was to follow a course of steady progress and a slow continuous expansion.

Research activity of the nuclear chemistry division is mainly concentrated on applications of radioactive nuclei to solutions of problems relating to analytical inorganic and physical chemistry and development of radio-chemical technology.

Attempts have been made to improve upon radiometric methods of analysis. Silver upto 10^{-6} gm has been estimated with I^{131} as indicator. I^{131} has also been used for micro determination of aluminium, mercury, cadmium, bismuth and palladium. In case of silver and palladium it has been observed that a carrier like zirconium phosphate under suitable experimental conditions takes up the corresponding iodide quantitatively. These observations have enabled us to estimate tracer amount of (10^{-6} gms) of silver and palladium. P^{32} has been used to find out new and simple methods for the determination of scandium and zirconium as pyrophosphates. With the help of thallous iodide as carrier it has been possible to estimate scandium and zirconium at tracer level. Details as regards the role of the carrier requires further study.

Flourimetric estimation of low uranium contents in natural substances has been developed. An easy and reliable method for the quantitative isolation of submicro gramme amount of uranium free from quenching material has been devised. It has enabled us to estimate even 10^{-7} gms of uranium present per litre of water in the hot springs of Bakreswar within an accuracy of $\pm 5\%$. Successful attempts have been made to develop simple and accurate methods for quantitative recovery of traces of uranium present in natural substances like coal ash etc. which is ultimately estimated by a fluorimeter. Methods of determination of rare earths by isotopic dilution have been improved. An easy laboratory method for the decontamination of trace amount of rare earths and thorium from uranium, beryllium, zirconium and aluminium has been developed.

In our earlier studies a method for quantitative seperation of carrier free UX_1 from U_1 through coprecipitation with calcium oxalate and subsequent operations was developed. A much more simplified and quicker method has been found out by complexing U_1 with NH_4CNS and adsorbing UX_1 on a coloumn of glass wool. UX_1 was later on recovered from the glass wool by eluting with nitric acid. It has been found that a similar method based on complexing Ra-D with ammonium acetate gives a quick quantitative seperation of carrier free Ra-E from its mother. Radiochemical purity of the product is 99.9%.

Mechanism of the uptake of tetravalent actinides by bismuth phosphate has been studied. UX_1 was taken as a representative of the tetravalent actinides. Distribution studies using bismuth phosphate as a carrier and UX_1 as tracer indicate that Doerner Hoskins distribution factor (χ) is constant. But when freshly precipatated bismuth phosphate in contact with the mother liquor containing the tracer was allowed to equilibrate, the homogeneous distribution factor (D) was not constant. This brings in an indication that freshly precipitated bismuth phosphate differs in morphology from aged samples. The constancy of of χ is a strong evidence that freshly precipitated bismuth phosphate takes up tetravalent actinides through mixed crystal formation. Experimental conditions that give a clear cut separation of tetravalent actinides free from any rare earth and yttrium activity have been found out. UX_1 in question remains embedded in large amount of bismuth phosphate and an easy method of removing bismuth and phosphoric acid to get the carrier free product is under investigation. Another method of removing UX_1 (tetravalent actinides) has been developed by the study of its uptake by bismuth iodate. Bismuth and iodine in question can be easily removed and a quantitative recovery of UX_1 in carrier free state is feasible. It has been found that under the experimental conditions the product is practically free from ter-and hexa-valent actinides.

Study of mixed crystal formation with radioactive nuclei has been under investigation since 1955. One of the objectives of the study is to get some insight into the nature of uptake through mixed crystal formation with special reference to uptakes which take place through anamolus mixed crystal formation as defined by Hahn. Uptake of rare earths and thorium by calcium compounds has been the subject matter of study in some details. It has been shown that out of the three hydrates of calcium oxalate known to us it is only the calcium oxalate dihydrate which takes up rare earths and thorium (UX_1) through mixed crystal formation. Uptake in case of mono and trihydrate takes place through adsorption. It has been shown that in the case of UX_1 a very unstable species of the guest takes the role of uptake through mixed crystal formation. In the case of calcium sulphate as host it has been found that an unstable form of gypsum (probably rhombic gypsum) is responsible for the uptake of rare earths and thorium through mixed crystal formation. Role of unstable hosts and unstable guests in this type of uptake may be of great help in expanding our knowledge in this branch of study. From our study of $PbCrO_4$ as host and Ag^{110} as guest positive evidence has been derived as regards the role of unstable species at tracer concentration and conclusion has been arrived at that a few system of anomalous mixed crystal formation in radiochemistry as studied by Hahn may be due to the breeding up of analogous morphological structure and the process can be looked upon as normal course of affairs. The study in greater details may explain many of the phenomena as regards the presence of trace constituents in minerals and rocks.

The nature of the guest species when incorporated in host lattice has also been studied. It has been argued that the incorporation of rare earth and thorium takes place in both of calcium oxalate and calcium sulphate lattices through double salt formation. A strong indirect evidence has been found in case of calcium sulphate system that the uptake takes place through double salt formation. The range and other aspects of these two systems have been studied in details.

The study of uptake of Sr-89 by different forms of calcium sulphate (gypsum anhydrite and hemihydrate) has yielded interesting results. It has been observed that it is only the anhydrite which takes up Sr-89 through mixed crystal formation It is of interest to point out that inspite of much lower solubility of strontium sulphate than that of the host in question, the partition factor is much lower than unity which sets forth a strong evidence in favour of geochemical observation that strontium clacium ratio is greater in sea than that observed in land.

It is gratifying to mention that a new method of determining transition temperature through the study of mixed crystal formation by radioactive tracers has been developed. It refers to transition temperature of the guest compounds analogous in structure to that of the host. Application of this method to the study of solid state chemistry of rare elements and specially in case of those phases whose existence can only be visualised through mixed crystal formation will be of great help to expand our knowledge. Radioactive nuclei thus find a new interesting and useful method of application where classical method of approach has no access. Application of this new approach in different systems is under investigation.

Application of radioactive nuclei to the study of the chemistry of rare elements has been pursued. It has been shown that ferric sulphate takes up scandium (Sc–46) through mixed crystal formation. In case of europium and yttrium uptake follows an adsorption isotherm. Violet chromium chloride $CrCl_3 6H_20$) and aluminium chloride ($AlCl_3 6H_20$) take up scandium through mixed crystal formation. Further work is in progress. Search for getting an evidence on the existence of scandium alum with Sc–46 has been pursued for a long time. It has been shown that ammonium ferric alum takes up scandium through mixed crystal formation, which has been argued as an evidence on the existence of thus far unknown scandium alum. By partition measurements at different tempertures it has also been shown that scandium alum is not stable above 4°C. From the value of the partition factor it can be inferred that the alum in question is highly soluble. Inference has been derived that due to simultaneous existence of less soluble phases isolation of such an interesting compound may never be possible. Similar study with TI–204 and In–114 has set forth strong evidence on the existence of ammonium thallic alum and potassium indium alum. Details of this study and isolation of these interesting compounds require further study.

It is well known that study of tetrahydrated double sulphate of the composition $RM(S0_4)_2 4H_20$ where R stands for alkali metals and M for tervalent elements is not complete. From distribution studies with $(NH_4) Ce (S0_4)_2$. $4H_40$ and $(NH_4)TI(S0_4)_2$. $4H_20$ as hosts and Y–91, Eu—152 & 154, Tb—160, Tm—170, Bi—210 (Ra—E), Fe—55,59, In—114, Sc—46, as guests findings have been derived that all tervalent elements form tetrahydrated double sulphates. From morphological point of view rare earths and rare earth analogues like yttrium and bismuth fall into one group and aluminium, scandium, indium, thallic thallium and iron(ic) etc. belong to another group.

Transition temperature (4°C) of thus far unkown tetrahydrated double sulphate of scandium has been determined by the new method developed by us. It has been furhter observed that anhydrous double sulphate is stable even at 3°C and is much less soluble than the hydrated compound. Any attempt to isolate the hydrated compound through breeding over $(NH_4)TI(S0_4)_2$. $4H_20$ containing above 14 mole % of scandium results in the formation of a mixture of $(NH_4)Sc(S0_4)_2$ and $(NH_4)TI(S0_4)_2$. $4H_20$. Uptil now we have succeeded to isolate the tetrahydrated double sulphate containing upto 14 mole % scandium through breeding process at 3°C. Attempts are now being made to isolate the pure compound.

It should be mentioned that only those interesting aspects which cannot be done through classical chemical approach has been done with radioactive nuclei as a tool.

In addition to the extension of the work already started we are giving special stress to the following lines during the next a few years.

(a) Application of mixed crystal formation in problems of classical chemistry with radioactive indicators.

(b) Development of technology as regards measuring low level activity.

(c) Radioactivation analysis.

(d) Radiation chemistry.

(e) Separation chemistry.

(f) Target reactions with special reference to high energy projectiles.

(g) Radio-chemical study of fission products.

INSTRUMENTATION DIVISION

Activities in the Period 1960–65

Construction of Instruments

This division successfully undertook construction of the following big instruments.

(1) Sorting unit and Window amplifiers of two eighteen channel Pulse height analyzers.

(2) Three complete γ– ray spectrometers involving three (a) Scintillation heads each comprising a Sodium iodide crystal, Photomultiplier and preamplifier, (b) Linear amplifiers with delay line pulse shapers, (c) Single channel Pulse height analyzers (modified Francis Bell type), (d) Scalers, (e) Power supply units. Two of these units have been and still are in constant use by the Post M. Sc. and M. Sc. teaching laboratories. The third has been and is a stand by.

Of the important small units developed mention may be made of

(1) "Distributed amplifiers" — four types — giving a variety of performance specifications. Two of these are for fast oscilloscopes, and one of them has a bandwidth of 350 Mc/s.

(2) Transistorized scalers and counters. Two of the scalers constructed has resolving time of 3 microseconds and scaling factor of 4000. A third has a

resolving time of 0.5 microsecond and scaling factor of 8000. Two transistorized counters have been constructed with a scaling ratio of 1000. These units run from self contained batteries and the total power consumption is less than three watts.

(3) Transistor wide band amplifiers having a pulse rise time of 5 nano-seconds and capable of a pulse output of seven volts.

(4) Two types Dekatron scaler circuits using tubes, but having low power consumption.

Research work

Theoretical analysis of binary scaling circuits formed an important subject matter of the thesis of Sm. Sneha Choudhury on which she received her D. Phil degree in 1963.

High order harmonic generation using pulse drive formed the other important research activity of this division. Shri K. S. Patel submitted his D. Phil. thesis on this subject in January, 1965. The experiences and know how acquired in this field is being applied to the development of a microwave frequency standard.

The transistor drive circuit developed by this division forms the basis of transistorized scalers and counters and is remarkable for its performance, simplicity, reliability and low power consumption.

Co-operation with other Divisions

Advisory help and guidance was given to D. N. Basu Mallik in the design of the new cyclotron oscillator.

The programme and projects of this division are:

(a) Development of microwave standard frequency sources using transistor and varactor diode harmonic generators.

(b) Study and development of parametric amplifiers using varactor diodes.

(c) Development of α and β spectrometers using semi-conductor detectors; development of mass identification system using E, and dE/dx semi conductor detectors.

(d) Particle identification systems using pulse shape discrimination.

(e) Design of transistorized oscilloscopes.

(f) Development of fast amplifiers and counting circuits using transistors and tunnel diodes.

(g) Development of ferrite core transformers for transistor circuitry.

(h) Development of high Power D.C. to A.C. Inverters using transistors.

(i) Construction of an Induction furnace, di-electric heater and a Plasma torch.

(j) Study and application of digital computer technique to nuclear data processing.

(k) Development of techniques for the constructions of microwave components and Instruments.

THEORETICAL NUCLEAR PHYSICS DIVISION

Since 1961 the Theoretical Nuclear Physics Division has grown almost by an order of magnitude. There are six staff members and eighteen research students Among the research students six have DAE senior fellowships, four have DAE junior fellowships, one has cultural exchange fellowship of the Government of India and the rest have research assistantship of this Institute. So far the influx of research students every year has been greater than the eflux. We expect that from 1965 onward the two rates will be equal.

Before 1961 low energy nuclear physics was the sole interest of this Division. Since Professor T. Pradhan and Dr. B. Dutta Roy joined this Division in summer 1962 and Fall 1963 respectively, they have built up a group of workers in elementary particle and high energy physics. The nuclear physics group also has been further strengthened during the last three years and the interests of the group now include apart from earlier interest in nuclear problems, many-body problems and formal reaction theories. In short, we have progressed somewhat towards our goal of building up a balanced theoretical physics group.

To give an idea of the activities of this Division we list below the number of students working in different fields of interest :

1) Nuclear Structure — 6
2) Nuclear Reaction and Scattering Theories — 3
3) Field Theory — 2
4) Dispersion Theory — 3
5) Unitary Symmetry — 1
6) Electron gas and Plasma Physics — 2
7) Many-body Problems — 1.

TEACHING DIVISION

The programme of teaching was undertaken at this Institute with the aim of training personnel in nuclear science. The object is to impart advanced training in theoretical and experimental nuclear physics so that the students would qualify for (a) Undertaking research work in some branch of nuclear physics (b) absorption in the different projects of the Atomic Energy Commission of India, (c) Teaching nuclear science in different universities and technical colleges, (d) Utilizing nuclear sicence as a tool of research in medicine, biology, chemistry and other sciences, The one-year associateship diploma course which started its eleventh session has fulfilled its object and the programme can be considered very successful during the period 54–64. A total of 140 students have been awarded the associateship diploma. 31 of these students have already received their doctorate degrees from Calcutta and other universities and many others are engaged in Ph. D. researches. Quite a few of our ex-students have achieved academic distinctions and are already holding responsible positions in various institutions.

It is however felt that there is much room for improvement in the program itself. The courses as given at present have a definite bias on the theoretical side. In future it is proposed to put substantial weightage on experimental subjects.

Plans for 1965–66 and 1966–71

In the present framework, recruitment of the needed personnel as well as a few additions and adjustments in the course will be necessary for the betterment of the programme. At the moment we are offering specialisation in (a) nuclear physics, (b) molecular and solid state physics. It has been our experience that the students will benefit very much if they are subdivided further as follows. (a) Theoretical Nuclear Physics, (b) Experimental Nuclear Physics, (c) Theoretical Molecular and Solid State Physics, (d) Experimental Molecular and Solid State Physics. This would however mean giving 4 sets of courses simultaneously during the last 5 month period of the course. The laboratory will expand to include more modern experiments in nuclear physics.

ASSOCIATESHIP COURSE SYLLABUS

Basic Courses :

1. Phenomenological Nuclear Physics

(a) Definitions, nomenclatures, Rutherford's α— scattering experiment.

(b) Nuclear spins, statistics, magnetic moment, quadrupole moment—measurements of.

(c) Nuclear mass, mass spectrometers. semi emperical mass formula and its applications.

(d) Deuteron problem.

(e) Low energy *np* and *pp*-scattering, scattering in ortho and para hydrogen.

(f) Nuclear force—nature of.

(g) Alpha decay.

(h) Beta decay.

(i) Shell model and collective models of nuclei,

(j) Experimental methods in nuclear spectroscopy.

(k) Theory of multipole expansion and gamma decay. Internal conversion.

(l) Nuclear reactions—general, stripping reactions and their use to locate single particle shell model states.

(m) Compound nucleus and the Breit Weigner equation. (n, n') and (n, γ) reactions.

(n) Nuclear fission.

(o) Nuclear isomers.

2. Phenomenological Solid State Physics

(a) Basic concepts of crystal symmetry

Historical introduction ; definition of groups ; orthogonal transformation—proper and improper rotations—crystallographic point groups; translation group—basic primitive translation and crystal lattice ; space groups—symmorphic and non-symmorphic ; Bravais lattice—miller indices—simple crystal structures.

(b) Lattice energy in solids

Different types of crystals ; molecular crystals-origin of Van der Wall's type forces—physical properties ; ionic crystals—Coulomb interaction—short range repulsive force-Madelung constant ; covalent crystals-characteristics of covalent bonds—case of H_2^+ —ion—Born-Oppenheimer approximation-molecular orbital and valence bond theories ; hydrogen bonded crystals ; metallic crystals.

(c) Specific heat in solids

Dulong-Petit's law—Einstein's theory—Debye's theory—basic limitations of these theories ; lattice dynamics—normal modes of vibration ; one dimensional simple Born-Von-Karman lattice-Brillouin zone and k-space-group velocity and phase velociety of vibrational waves in k-space-$g(\gamma)$ -spectrum or phonon distribution function ; one dimensional Born-Von-Karman lattice with a basic acoustical and optical branches of vibrational frequencies- $g(\gamma)$ -spectrum for these branches ; extension to three dimensional case-nature of forces between lattice points-rotations of the equations of motion in three dimentions-Brillouin zone in three dimention- $g(\gamma)$ -spectrum ; contribution of spins to specific heat-Schottky anomaly ; contribution from conduction electronics (in short).

(d) Thermal conductivity in solids

Debye's expression for thermal conductivity-mean free path of phonons-origin of thermal conductivity in solids, idea of different phonon, scattering processes, basic idea of field quantization, annihilation and creation operators-formal expression for thermal conductivity, contribution from static imperfections, elastic and inelastic scattering, contribution from anharmonic cubic potentials, Umklapp process, contribution from boundary scattering.

(e) Magnetic properties of solids

(f) Electron theory of metals

3. Classical Mechanics

(a) Mechanics of a system of particles, constraints, D'Alemert's principle and Lagrange's equation.

(b) Variational principle and Lagrange's equation.

(c) The Hamilton's equation of motion.

(d) Hamilton Jacobi Theory.

(e) Poisson brackets.

4. Basic Mathematics

(A) *Complex Variables*

(a) Continuity conditions and analyticity conditions of a complex function $f(z)$.

(b) Definite integrals of $f(z)$ along a rectifiable arc c.

(c) Connectivity of a region.

(d) Cauchy's fundamental theorem.

(e) Cauchy's integral formula.

(f) Cauchy-Taylor's theorem.

(g) Liouvilles theorem (also generalised).

(h) Ordinary point, zero, pole, essential system, branch points, meromorphic functions.

(i) Lorentz series.

(j) Cauchy's residue theorem.

(k) Contour integrals.

(l) Maximum modulus theorem.

i) Praghmen–Lindelof theorem

(m) Analytic continuation.

i) Simple examples.

ii) Studies of such analytic continuation for Bessel function, hypergeometric function and gamma function.

(B) *Differential Equations*

(a) Second order, linear, (Hypergeometric, Bessel and Legendre)

(i) Series solution method.

(ii) Integral forms of solution.

(b) (i) Fredholm forms.

(ii) Volterra forms.

5. NUCLEAR DETECTORS AND GENERAL LABORATORY PRACTICES

(a) Radiation dosimetry.

(b) Protection from electrical hazards.

(c) Ionization chamber.

(d) Proportional and G. M. counter.

(e) Scintillation counter.

(f) Solid state detector.

(g) Cloud chamber and Bubble chamber.

(h) Coincidence technique.

6. ELECTRONICS

1. Introduction; thermionic emission; Child Langmuir law, physics of the electron flow and space charge distribution. Child Langmuir for triodes and multi-electrode tubes. Deviations from Childs law; tube characteristic curves; tube factors.

2. Characteristics of typical electron tubes. Application as R. C. amplifier; load lines; output voltage swing available.

3. Amplifiers in cascade; battery coupling; condenser coupling; distortion in wave shape; sag and undershoot.

4. Properties of resonant circuits; Q; bandwidth; sharpness of resonance. Parallel resonant circuit; resonant impedence.

5. Feedback in amplifiers; positive and negative feedback; oscillators; equivalent circuit, Barkhansen criterion.

6. Resistence capacitence null networks; phase shift oscillators; twin T selective circuit and oscillators. Wien bridge oscillator.

7. Multivibrators; free running plate coupled multi; period calculation; monostable, astable, bistable multi.

8. Cathode coupled multi; Eccles Jordon trigger circuit; region of bistable operation.

9. Schmitt trigger circuit; amplitude discriminator; binary scaler.

10. Cathode follower circuit; output impedence; gain.

11. Decade scaler using binary units; dekatron.

12. & 13. Cathode ray oscillograph; time bases; triggered and recurrent time bases.

14. Voltage stabilisers, V. R. tubes.

15. Transformers; ideal transformer; pulse transformers using ferrite cores; blocking oscillators.

16. Limiting performance of amplifiers; bandwidth; distortion non-linear, harmonic; rise time, overshoot; sag, under-shoot.

17. Fourier components of a time variation; square and triangular pulses; distribution of fourier components. Relation between system time response and frequency bandwidth; rise time and upper cut off frequency.

18. Transmission line theory; co-axial cables; termination in characteristic impedence; reflection; direct wave and reflected wave; open circuited and short circuited lines.

19. Reflection co-efficient; filter theory, characteristic impedence; transmission and phase shift; transmission and attenuation bands.

20. Secondary emission pentodes; fast pulse generator using secondary emission pentodes.

21. 22, 23, 24 Lectures on pulse height analysers.

25. Semi-conductors; impurity conduction; holes and electrons *pN* junction; conduction with forward and reverse bias.

26. Depletion layer; carrier densities; thermal and drift velocities; diffusion of carriers; recombination; life time; transistor action; current transfer ratio; power gain.

27. Transistor construction; alloy, grown junction, diffused junction and mesa types; impurity densities and resistivities in the different regions of typical transistors; dimensions.

28. Transistor characteristics; input, transfer and output characteristics; internal feedback, typical transistor characteristics and figures; comparison with vacuum triodes.

Common base, common emitter and common collector circuits, input resistance *vs* load resistance; output resistance *vs* source resistance; voltage gain; current gain.

The transistor; a current actuated device in contrast with vacuum triode a voltage actuated device; high frequency limitations.

7. Classical Electrodynamics

(a) The electrostatic field in vacuum, boundary condition and relation of microscopic to macroscopic fields, potential problems.

(b) Potential problems.

(c) Energy relations, forces in the electrostatic field, currents and their interaction.

(d) Maxwell's equations.

(e) Equations of motions of a charge in a field, the electromagnetic field tensor, second pair of Maxwell's equations.

(f) Invariants of the field, microscopic and macroscopic fields, propagation of electromagnetic waves in conducting media ; general covariant forms of Maxwell's eqn., force eqn. in a covariant form.

(g) Application to microwave.

(h) Electrodynamics of a accelerators.

(i) Retarded potential.

(j) Elementary introduction of plasma.

(k) Material media and dielectric properties of crystals.

(l) Super conductivity.

8. Statistical Physics

A. Statistical theory of systems in thermodynamic equilibrium.

(a) *Gibb's ensemble theory :*

Microcanonical, canonical and grand canonical ensembles. Ergodic hypothesis. Bloch equation for partition function and its perturbation solution by means propagators. Explicit evaluation of partition function for perfect Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein and relativistic gas.

(b) *Theory of distribution functions :*

Definition, heirarchy of equations for distribution functions. Pair distribution function ; its relation with thermodynamic functions and scattering of light by gases and liquids.

(c) *Equation of state for real gases :*

Neutral, ionised and degenerate gases.

B. Statistical theory of systems approaching thermodynamic equilibrium.

(a) *Time evolution towards equilibrium :*

Boltzmann equation, Pauli master equation.

(b) *Time evolution when external forces or constraints are present.*

Time correlation function. Onsager's relations. Kubo's formula for transport coefficients. Fluctuation-dissipation theorem.

9. Elementary Quantum Mechanics

(Non-relativistic)

(a) Physical basis of quantum mechanics.

(b) The Schrodinger wave equation, Eigen functions and Eigen values.

(c) Discrete Eigen values, potential problems.

(d) Continuous Eigen values, scattering theory.

(e) Approximate methods of solving Schrodinger equations, perturbation theory (time dependent and time independent), Born approximation, variation method, W.K.B. approximation.

(f) Angular momentum.

NUCLEAR PHYSICS SPECIALISATION

10. Advanced Quantum Mechanics

1. Dirac *c*-number theory of the electron.
2. Klein-Gordon equation.
3. Equation for a massive vector "field".
4. Electromagnetic equations.
5. Covariance and relativistic transformations.
6. Classical Lagrangian theory of fields-invariances and conservation laws.
7. Shortcomings of *c*-number theories.
8. Quantization of fields.
   (a) Scalar field.
   (b) Dirac spinor field.
   (c) Massive vector field.
   (d) Electromagnetic field.
9. Invariant propagator functions.

11. Theoretical Nuclear Physics

1. Two body problem : (a) deuteron problem ; (b) *n-p* scattering ; (c) *p-p* scattering.

2. Nuclear Structure : (a) Shell model ; (b) colective model.

3. Nuclear reactions : (a) general theory (R-matrix formalism); (b) compound nucleus ; (c) direct interactions ; (d) optical model.

12. Experimental Nuclear Physics

(a) Experimental techniques :
Accelerators ;
Measurements of energy,
momentum,
mass,
spin etc. ;
Nuclear instruments.

(b) Beta and Gamma-ray spectroscopy.

(c) Nuclear reactions.

(d) Experiments with neutrons.

13. Introductory Elementary Particle Physics

THEORY

1. *Theory of interacting fields :*

Covarient perturbation theory and Feynmann diagrams. Yang-Feldman formalism. $L\ S\ t$ formalism. Lee model. Chew-Low theory of $\pi\ N$ scattering and photoproduction of pions.

2. *Dispersion theory :*

Substitution laws and crossing symmetry, unitarity and analytic continuation. One dimensional dispersion relations. Pole approximation. Dispersion relations for particle wave amplitudes and N/D method. Pomeranchuk theorem. Regge pole theory applications to NN, $\pi\ N$, KN scattering and form factors.

3. *Strong Interactions :*

Gell-Mann-Nishijima scheme of classification of elementary particles. Quantum numbers of π , N,Ω, $\Sigma \equiv K$ and resonances. Symmetries in strong interactions, charge independence, global symmetry, unitary symmetry. Gauge theory of elementary particles.

4. *Weak Interactions :*

Pre-history of weak interaction physics. Breakdown of conservation laws. Two component theory. Present status of β-decay, K-capture, μ-decay, μ-capture and inverse of β -decay. Decays of strange particles and selection rules.

Universal Fermi interaction-conserved vector current and partially conserved axial vector current. Weak global symmetry. Sakata model for leptons.

EXPERIMENT

5. *Detectors :*

Cloud chamber, spark chamber, bubble chamber, emulsion technique.

6. *Particle Detection :*

Detection of π $(\pm)$ $\pi^{(0)}+$, $e^{(0)}$, $\mu^{(\pm)}$ k-mesons $\Omega^{(0)}$, $\Sigma^{(\pm)}$ $\Sigma^{(0)}$, $\Xi^{(0)}$, $\Xi^{(-)}$, $p^{(-)}$, ν and measurements of their mass, energy and lifetime.

MOLECULAR AND SOLID STATE PHYSICS SPECIALISATION

14. Group theory and its application to solid state physics : definition of a group, sub-group, class ; representations of a group ; group character ; direct product of groups ; examples of groups-cyclic group, symmetric group, unitary group, rotation group, (three dimentional and two dimensional) dihedral groups ; crystallographic point groups ; application of group theory to atomic spectra ; application to molecular structure calculations ; application to crystal field calculations ; application to molecular vibrations.

15. Structure and general properties of solids : atomic structure ; molecular structure ; crystal structure ; cohesive energy of crystals ; elastic constants of solids ; diffusion in solids ; band theory of solids.

16. Magnetic properties of solids : susceptibility of pure solids ; N.M.R. to study magnetic properties of solids ; magnetic properties of impurity ions in crystals ; susceptibility, e.p.r. ; paramagnetism ; ferromagnetism ; anti ferromagnetism ; ferrimagnetism ; semi conductors.

17. Thermal properties of solids : lattice heat capacity of solids and metals; thermal conductivity of solids ; thermal expansion ; phase changes in solids ; very low temperature behaviour of solids including helium.

18. Electrical properties of solids : dielectric constants and polarizibility factors ; dielectric relaxation ; ferroelectric crystals ; anti ferroelectric crystals ; ferrielectric crystals ; electric conductivity in solids and metals ; electrical properties of semi-conductors.

19. Selected topics in crystallography and crystal structure : introduction-role of X-rays in crystallography ; symmetry elements and symmetry groups-point groups and space groups ; lattices-direct and reciprocal lattice ; concepts of diffraction of X-rays by crystals ; intensity of diffracted X-rays ; methods in crystal analysis ; modern experimental techniques ; applications with special reference to the physics of the solid state.

20. The chemical bond with particular reference to solids.

Bonding in Molecules : Emperical classification simple and complex, saturated and unsaturated molecules etc. types of bonds, ionic and covalent, coordinate bond, hydrogen bond etc,

2. Quantum mechanical treatment of the chemical bond:

Valence bond method, directed valence bonds as the basis of stereochemistry;

Molecular orbital methods

Bonds in Solids:

1. Non-metallic solids: molecular crystals; covalent crystals; ionic crystals (simple and complex)

2. Metals and alloys.

LABORATORY WORK

I. *General Laboratory Practices:*

(1) Tracing and testing of (i) a power-pack, (ii) scaling circuit and (iii) linear amplifier.

(2) Measurement of the static-characteristics of transistors.

(3) Measurement of the characteristics of a G-M counter: plateau, chi-square test, dead-time.

II. *Experiments:*

(1) Determination of the range of beta-rays in Al, and hence finding out the end-energy using Glendenin's relation.

(2) Determination of the strength of the beta-source by applying necessary corrections e.g. back scattering and absorption in the source and air, etc.

(3) Measurement of the beta-spectra (using scintillation counters) of a few given radio-isotopes and finding the end-energies from the Kurie-plot of these spectra (Cs^{137}, Co^{60}, Hg^{203}, Ca^{45}, Pm^{147}).

(4) Measurement of the K/L ratio for the given sources using

(i) the Sieghbahn-Slatis beta spectrometer.

(ii) solid state type beta-spectrometer.

(5) Measurements of the half-life of In^{116}.

(6) Calibration of the solid-state type alpha-spectrometer and hence finding out the energy of the alpha particles from unknown sources.

(7) Measurement of the absorption coefficient of the gamma ray from Co-60 in Pb, Al, Ag, Cd, Fe using scintillation gamma spectrometer as a detector.

(8) Measurement of the photo fraction and resolution of a gamma spectrometer at various energies (100Kev-1 Mev). Evaluation of the relative intensities of the gamma ray from the given source.

(9) Study of the general characteristics of a coincidence gamma spectrometer, Resolving time, G/R ratio and source strength.

(10) Establishing the general relations between different radiations found in the decay of a radioactive isotope.

(11) Measurement of the mean-life of neutrons in water.

WORKSHOP SECTION

Report of the Workshop from the year 1961—1965

Since the time the last report was published, the Workshop has gone long strides towards its expansion as far as the available space permitted. Two machine tools, namely, one 160 ton capacity hydraulic press and one H.M.T. Precision Lathe have been installed very recently. This press is a versatile one. Powder metallurgy and making of ferrites can be developed with this. With these two additions, the total number of machine tools in the Workshop are now 30.

Besdies the maintenance and servicing of the research machines such as the cyclotron, the neutron generator, the N.M.R's and E.P.R..'s, the mass spectroscope, the electron microscopes and other research apparatus, the Workshop also constructs equipment and apparatus as per need of the various laboratories. During the period under review the following apparatus worth mentioning were constructed in the Workshop.

1. Housing and Co-ax. line for the cyclotron grounded grid oscillator
2. 1/3 ton 60° focussing magnet
3. Carriage for zone melting furnace with automatic quick return.
4. Wire Saw for cutting thin sections of ferrite and silicon
5. Duoplasmatron Ion Source
6. Sector type X-ray plate holder
7. Damping bearing for a high speed rotor
8. 4″ diffusion pumps and baffles
9. Variable leak valves
10. Vacuum valves and gates
11. Demorentable Penning guage
13. Mcleod guages
13. Stark modulation cell for Microwave spectroscopy and other microwave plumbings
14. Crystal Models
15. Counter filling systems
16. Glass metal seals.

The Workshop has a development programme of its own, since it is felt that this Workshop should be utilised to its fullest extent in developing certain items that would be very useful to research. Also, the purchase of such items from outside would be very difficult for paucity of foreign exchange. With this view the construction of the following items has been undertaken and some progress has been made :

1. Metal evaporation chamber
2. Liquid-air traps
3. All types of Vacuum guages
4. Microwave components
5. Ultra High Vacuum Pump.

The Workshop suffers from lack of space at the present moment, but hopes to overcome this in the next 5-year plan.

LIBRARY SECTION

The Library within this past few years has grown along with the other departments. It has undertaken scientific documentation as well as collection and dissemination of technical information whenever it was needed, Photocopying services were undertaken. Microfilms are procured by the Library for the research staff. Though the library did not have any translation facilities, it procured the translations from either IASLIC and INSDOC or Private sources.

The present holdings of the library are 12,204 books and bound volumes of periodicals. The library has a fine collection of 7,776 technical reports. Besides it subscribes to 210 scientific and technical periodicals, and it gets 109 periodicals either as gift or exchange.

Due to acute shortage of space, the library is forced to curtail some of its facilities to the University students. In the next plan period it is planning to give the microfilming facilities to the staff of the Institute. The scientific documentation needs of the research staff will be met fully from the new plan period. To facilitate this work, one of the staff members was sent for training in documentation and reprography.

LIST OF RESEARCH STAFF

I.	Dr. B. D. Nagchaudhuri ..	Director
	Dr. J. K. D. Verma ..	Reader
	Dr. S. K. Majumdar ..	Reader
	Dr. Jayanta Basu ..	Reader
	Dr. S. N. Sen Gupta ..	Senior Research Assistant
	Dr. N. K. Majumdar ..	Senior Research Assistant
	Shri S. C. Jamdar ..	Research Fellow
	Shri D. K. Bose ..	Research Fellow
	Shri P. S. Nair ..	Research Fellow
	Miss. Chitra Dutta ..	Research Fellow
	Dr. B. B. Sen ..	Lecturer
II.	Dr. N. N. Das Gupta ..	Professor and Head, Biophysics Division
	Shri M. L. Dey ..	Reader
	Dr. R. K. Poddar ..	Reader
	Dr. S. B. Bhattacharyya ..	Lecturer
	Dr. P. Sadhukhan ..	Lecturer
	Shri P. K. Ganguly ..	Senior Research Assistant
	Mrs. Amala Chatterjee ..	Research Assistant
	Shri D. N. Mishra ..	Research Assistant
III.	Dr. D. N. Kundu ..	Professor and Head, Accelerator Division
	Dr. A. P. Patro ..	Associate Professor
	Dr. S. K. Mukherjee ..	Associate Professor
	Dr. S. B. Karmohapatro ..	Reader
	Dr. B. Basu ..	Reader
	Dr. A. Chatterjee ..	Reader
	Dr. B. B. Baliga ..	Reader
	Shri M. Rama Rao ..	Senior Research Assistant
	Shri H. Bakhru ..	Senior Research Assistant
	Shri B. Sethi ..	Research Assistant
	Shri S. C. Gujrathi ..	Research Assistant
	Shri M. L. Chatterjee ..	Research Assistant
	Shri S. D. Dey ..	Research Assistant
	Shri D. Basu ..	Research Assistant
	Shri T. K. Dey ..	Research Assistant
	Shri P. Sen ..	Research Fellow
	Shri D. N. Basu Mallick ..	Technical Associate
IV.	Dr. A. K. Saha ..	Professor and Head, Nuclear Physics Division
	Dr. N. N. Saha ..	Associate Professor

	Dr. R. N. Roy	.. Associate Professor
	Dr. (Mrs.) M. Bose	.. Associate Professor
	Dr. D. K. Ray	.. Associate Professor
	Dr. P. N. Mukherjee	.. Reader
	Dr. D. K. Ghosh	.. Reader
	Dr. (Mrs.) Ila Mukherjee	.. Reader
	Dr. R. L. Bhattacharyya	.. Reader
	Dr. A. Mukherjee	.. Reader
	Dr. (Mrs.) Tuhina Ray	.. Reader
	Dr. S. K. Ghosh Roy	.. Lecturer
	Dr. S. K. Sinha	... ...
	Shri S. Das	.. Lecturer
	Dr. S. D. Bhattacharyya	.. Lecturer
	Shri A. K. Roychowdhury	.. Senior Research Assistant
	Shri S. Sen Gupta	.. Research Assistant
	Shri P. N. Roy	.. Research Assistant
	Shri S. Shastri	.. Research Assistant
	Shri A. K. Roy	.. Research Assistant
	Shri N. Chatterjee	.. Research Assistant
	Shri P. K. Rudra	.. Research Assistant
	Shri A. K. Nigam	.. Research Assistant
	Shri M. N. Ghatikar	.. Research Assistant
	Shri Anutosh Chatterjee	.. Research Assistant
	Mrs. Jayanti Lahiri	.. Research Assistant
	Shri S. C. Bhattacharyya	.. Research Assistant
	Shri N. C. Das	.. Research Assistant
	Shri P. Bhattacharyya	.. Research Fellow
	Shri S. K. Gupta	.. Research Fellow
V.	Dr. M. K. Banerjee	.. Professor and Head, Theoretical Nuclear Physics Division.
	Dr. T. Pradhan	.. Associate Professor
	Dr. M. K. Pal	.. Associate Professor
	Dr. S. Mukherjee	.. Reader
	Dr. B. Datta Roy	.. Reader
	Shri S. R. Roy	.. Research Assistant
	Shri L. Satpathy	.. Research Fellow
	Shri Harish Chandra	.. Research Fellow
	Miss. Mamata Patnayak	.. Research Fellow
	Miss. Rajagopal Shanta	.. Research Fellow
	Shri S. Dutta	.. Research Fellow
	Shri R. K. Satpathy	.. Research Fellow

VI.	Shri B. C. Purkayastha ..	Professor and Head, Nuclear Chemistry Division
	Dr. S. N. Bhattacharyya ..	Lecturer
	Shri N. R. Das ..	Research Assistant
	Shri K. N. Dutta ..	Research Assistant
	Shri D. K. Bhattacharyya	Research Assistant
	Miss Shyamali Sen ..	Research Assistant
	Shri Samir Sarkar ..	Research Assistant
	Miss Anita Chatterjee ..	Research Assistant
	Mrs. Sunanda Aditya ..	Research Assistant
VII.	Shri B. M. Banerjee ..	Head, Instrumentation Division
	Dr. S. C. Nath ..	Reader
	Dr. (Miss) Sneha Chowdhury	Lecturer
	Shri K. S. Patel ..	Senior Research Assistant
	Shri P. K. Gupta ..	Research Fellow
VIII.	Dr. S. Chatterjee ..	Associate Professor and Head, Teaching Division
	Dr. R. K. Das ..	Lecturer
	Dr. (Mrs.) Dipti Pal ..	Lecturer
XII.	Shri Anand Kuamr ..	Senior D. A. E. Fellow
	Shri P. Das Gupta ..	Senior D. A. E. Fellow
	Shri S. N. Tewari ..	Senior D. A. E. Fellow
	Shri D. N. Tripathy ..	Senior D. A. E. Fellow
	Shri B. Das Gupta ..	Senior D. A. E. Fellow
	Shri Y. K. Gambhir ..	Senior D. A. E. Fellow
	Shri K. B. Uduppa ..	Senior D. A. E. Fellow
XIII.	Shri S. N. Mallik ..	Junior D. A. E. Fellow
	Shri Ram Raj ..	Junior D. A. E. Fellow
	Shri J. N. Passi ..	Junior D. A. E. Fellow
	Shri C. S. Shastri ..	Junior D. A. E. Fellow
	Shri M. V. Moorthy ..	Junior D. A. E. Fellow
	Shri K. C. Das ..	Junior D. A. E. Fellow
	Shri M. Bhattacharyya ..	Junior D. A. E. Fellow
	Miss Madhuri Sarkar ..	Junior D. A. E. Fellow
	Shri A. B. Sanyal ..	Research Training Scholar
	Shri P. Ganguly ..	Research Training Scholar
	Shri S. K. Sarkar ..	C.S.I.R. Senior Research Scholar
	Shri S. R. Pal Chowdhury	C.S.I.R. Junior Research Scholar
	Miss Bani Dutta ..	C.S.I.R. Junior Research Scholar
	Shri B. H. Bye ..	Government of India Reciprocal Scholar

Dr. A. K. Ghosh	..	C.S.I.R. Pool Officer
Shri S. G. Biswas	..	—do—
Miss Anjali Choudhury	..	—do—
Dr. A. S. Chakraborty	..	—do—
Dr. (Mrs.) J. Chakraborty	..	—do—
Dr. (Miss) S. Guha	..	—do—

List of Receipients of D.Phil (Science) Degree : 1961-1964

1. B. B. Baliga
2. B. Basu
3. R. L. Bhattacherjee
4. S. B. Bhattacherjee
5. S. N. Bhattacherjee
6. (Mrs.) J. Chakravarty
7. (Miss) S. Choudhuri
8. (Miss) I. Dutta
9. B. Dutta Roy
10. P. K. Ganguly
11. S. K. Ghosh Roy
12. D. C. Jain
13. S. B. Karmahapatro
14. O. N. Kaul
15. P. K. Lala
16. N. K. Majumder
17. S. K. Majumder
18. Miss. D. Mitra
19. A. Mukherjee
20. (Mrs.) A. Mukherjee
21. P. N. Mukherjee
22. S. Mukherjee
23. (Mrs) S. Mukherjee
24. S. K. Mukherjee
25. M. A. Nagarajan
26. A. P. Patro
27. C. K. Pyne
28. (Mrs) T. Roy
29. A. M. Sayied
30. P. Sadhukhan
31. A. K. Sen Gupta
32. S. K. Sinha

List of Receipients of Premchand Roychand Studentship 1961-1964

1. R. L. Bhattacharyya
2. A. Mukherjee
3. P. N. Mukherjee
4. S. K. Sinha

List of Post M. Sc. Associates

1962

1. M. K. Agarwal
2. B. B. Barman Roy
3. B. Das Gupta
4. M. N. Ghatikar
5. S. C. Gujrathi
6. A. K. Nigam
7. B. D. Mungurwadi
8. Salil Ranjan Roy
9. Bhisam Sethi
15. L. M. Sehgal
16. Prasanta Sen
17. C. S. Shastry
18. Bedanta Kr. Sinha
19. Sat Pal Singhal

1963

1. A. K. Agarwal
2. Debashis Basu
3. Miss C. Dutta
4. Y. K. Gambhir
5. C. S. Khrishna
6. S. N. Mallik
7. K. Haridas
8. Ranadhir Mitra
9. C. S. Mukherjee
10. M. V. Murthy
11. P. S. Nair
12. J. N. Passi
13. Ram Raj
14. P. K. Rudra

1963–'64

1. Debdas Bandopadhyay
2. Rajendra Prasad Bajpai
3. Manoranjan Bhattacharyya
4. Pranab Kumar Bhattacharyya
5. Harish Chandra
6. Kartick Chandra Das
7. Triptesh Kumar Dey
8. Subrata Dutta
9. S. K. Dutta
10. Alakh Niranjan Mantri
11. Miss Mamata Patnaik
12. Balabir Singh Reehal
13. Lakshidhar Satpathy
14. Raj Kishore Satpathy
15. K. Joseph Sebastian
16. Miss Rajagopal Shanta
17. Jagadish Sharan Vaishya

LIST OF PUBLICATIONS FROM THE INSTITUTE FOR THE PERIOD 1961–1964.

—1961—

1. Bardhan, U.C. : The concept of zero in the mathematics of ancient India, (*Science & Culture*, vol. **27**, p. 282, 1961.)
2. Basu, S. R. & Hosain, F. : Capillary tube technique for small liquid biological samples. (*Journal of Applied Radiation & Isotopes*, Vol. **12**, p. 67, 1961.)
3. Bhattacharjee, S. B. : Action of X-irradiation on E. Coli. (*Radiation Research*, **14**, p. 50, 1961.)
4. Bhattacharjee, S. B. & Das Gupta, N. N. : The shape of the target molecule and the diffusion distance of radicals formed by ionizing radiation. (*Ind. Jour. of Phys.*, vol. **35**, p. 604, 1961.)
5. Bhattacharjee, S. B. & Das Gupta, N. N. : Radiation sensitivity of escherich -ia coli to B-rays in dry and wet condition, (*Nature*, vol. **191**, p. 1015, 1961.)
6. Chatterjee, S. N. & Sadhukhan, P. : Electron microscopic and ultraviolet absorption studies on DNA molecules. (*Journal of Electronmicroscopy*, vol. **10**, p. 43, 1961.)
7. Chatterjee, S. N., Sadhukhan, P. & Chatterjee, J. B. : Electron microscopic studies on the Haemoglobin molecules. (*Jour. of Biophys. Biochem. Cytol.*, vol. **10**, p. 113, 1961.)
8. Chatterjee, Sheela, Sadhukhan, P., Ganguli, P. K. and Das Gupta, N. N. : Ribonucleoprotein particles from Dry Yeast Granule. (*Proc. Int. Biophys. Cong., Stockholm*, p. 218, 1961.)
9. De, M. L. : Estimation of mass thickness of biological samples from their electron micrographs. (*Nature*, vol. **192**, p. 547, 1961.)
10. De, M. L., Sadhukhan, P., & Das Gupta, N. N. : Some considerations on quantitative estimation of mass thickness of biological samples from their electron micrographs. (*Proc. Int. Biophys. Cong., Stockholm*, p. 327, 1961.)
11. Dutt, P. K. : Theory of "Ion-bunching" in relation to the development of an electrostatic time-of-flight mass spectrometer. (*Nucl. Inst. & Methods*, vol. **10**, p. 37, 1961)

12. Ghosh, S. K. , Lahiri, J. & Sinha, S. K. : F^{19} nuclear magnetic resonance in polycrystalline MgF_2.
(*Ind. Jour. of Phys.*, vol. **35**, p. 236, 1961)

13. Karmahapatra, S. B : Charge exchange between Krypton ions and atoms.
(*Jour. of Chem. Phys.* vol. **35**, p. 1524, 1961)

14. Kaul, O. N. : A study of development defects and track structures in nuclear emulsions using amidol developers.
(*Ind. Jour of Phys.*, vol. **35**, p. 183, 1961)

15. Kaul, O. N. : On the processing of nuclear emulsions.
(*Ind. Jour. Phys.*, vol. **35**, p. 459, 1961)

16. Kaul, O. N. : Role played by ammonium salts in the clearing of nuclear emulsions.
(*Ind. Jour. of Phys.*, vol. **35**, p. 562, 1961.)

17. Majumdar, S. K. : Radiation by charged particle passing through an external magnetic field. (*Proc. of Phys. Soc.*, vol. **77**, p. 1109, 1961)

18. Mukherjee, P. & Dutta, I. : Nuclear octupole deformation. (*Phys. Rev.*, vol. **124**, p. 888, 1961.)

19. Mukherjee, S. K. , Ganguly, A. K. and Majumder, N. K. : Activation cross sections with 14 new neutrons. (*Proc. of the Phys. Soc.*, vol. **77**, p. 508, 1961.)

20. Rama Rao, M. : A Low pressure expansion cloud chamber. (*Ind. Jour. of Phys.* vol. **35**, p. 92, 1961.)

21. Rama Rao, M. : An internal counter controlled low pressure cloud chamber. (*Ind. Jour. of Phys.*, vol. **35**, p. 361, 1961)

22. Rama Rao, M. & Verma, J. K. D. : A note on portable battery operated high voltage supply. (*Electro-Technology* vol. **5**, p. 453, 1961.)

23. Ray, D. K. : On the electron paramagnetic resonance line corresponding to a transition Δ Ms = +2 for ions with effective spin S=1, (*Physica*, vol. **27**, p. 872, 1961.)

24. Ray, D. K. : On the electron paramagnetic resonance spectra of V_3+ in corundum (AL_2 0_3) (*Nuovo Cimento, Sr. X*,vol. **20**, p. 1148, 1961.)

25. Ray, D. K. : Second-order effect of spin-orbit interaction on the paramagnetic resonance spectra of ions with a single 3d electron. (*Nuovo Cimento, Sr. X*, vol. **21**, p. 1, 1961.)

26. Swarup, S., Chatterjee, J. B. Hosain, P. and Hosain, F. : A comparative study on ion turnovers with special reference to Hb. E–Thalassaemis using small doses of Fe^{59}. (*Ind. Jour. Med. Resh.*, vol. **49**, p. 256, 1961.)

27. Swarup, S., Chatterjee, J. B. , Ghosh, S. K., Hosain, P. and Hosain, F. Observations on erythropisis in Hb. Ethalassaemia diseases—a study with Cr^{51} and Fe^{59}. (*Ind. Jour. of Pathology and Bacteriology*, vol. **4**, no. 1, 1961.)

—1962—

1. Basu, B. & Patro, A. P. : Disintegration of Rhodium 97. (*Nuclear Physics*, Vol. **33**, p. 347, 1962).

2. Basu, B. & Patro, A. P. : Gamma Spectrum and Coincidence studies of Ru^{100}. (*Nuclear Physics* Vol. **29**, p. 672, 1962.)

3. Basu, S. R. : A Comparative Study of Hemogram of Heart and Tail Blood in both Irradiated and Non-Irradiated Rates. (*Naturwissenschaften*, Vol. **49**, p. 234, 1962).

4. Basu, S. R., Lahiri, S. K. & Chaudhuri, S. : Variation in Thyroid Function with the Variation in Tracer dose of ^{131}I in the Rat: Selection of Optimum Tracer Dose. (Jour. of Radiation Biology, Vol. 5, p. 265, 1962).

5. Bhattacharjee, R. : Decay of 105 Ag. (Nuovo Cimento, Sr. X, Vol. 24, p.1000, 1962)

6. Bhattacharjee, S. B. & Das Gupta, N. N. : Diffusion Distance of the Radicals Produced by Ionizing Radiations in Cells. (*Radiation Research*, Vol. **16**, p. 773, 1962.)

7. Chakraborty, J., & Sanyal, A. B. : Some Observations of the Nucleus and the Kinetoplast of Leishmania Donovani—The Kala-Azar-parasite. (*Fifth Int. Congress for Electron Microscopy* 1962).

8. Chakraborty, J. & Das Gupta, N. N. : Mitotic Cycle of the Kala-Azar Parasite, Leishmania Donovani. (*Jour. of General Microbiology*, Vol. **28**, p. 541, 1962).

9. Chakraborty, J., Guha, A. & Das Gupta, N. N. : Cytology of the Flagellate form of Leishmania Donovani with Consideration of the Evidence for Abnormal Nuclear Division. (*Jour. of Parasitology*, Vol. **48**, p. 131, 1962.)

10. Chatterjee, A : Diffusion Studies of Bovine Serum Albumin with Jamin Interference Opties and Micro-Diffusion Cell. (*Nature*, Vol. **194**, p. 1053, 1962.)

11. Chatterjee, S. & Das Gupta, N. N : Studies on the Ribonucleoprotein particles from dry yeast granules. (Proc. of National Institute of Sciences of India, Vol. 28, p. 439, 1962).

12. Chatterjee, S., Ganguli P. K. & Sadhukhan, P. : Ribonucleoprotein Particles from yeast Granules. (*Naturwissenschaften*, Vol. **49**, p. 69, 1962).

13. Das Gupta, P. : Regge Trajectory and Resonant : Partial Wave Amplitude (*Physics Letters*, Vol. **2**, p. 273, 1962).

14. De, M. L. : On an Analytical Expression for the axial field of Electromagnetic Lenses. (*Phil. Mag.* Vol. **7**, p. 1065, 1962.)

15. De, M. L. : On the Dependence of Electron Scattering cross section of Atoms on their Atomic Number (*Naturwissenschaften*, vol. **49**, p. 228, 1962).

16. De, M. L. : On the minimum Mass Thickness of Carbonaceous Matter in Electron Microscopy (*Experimental Cell Resh.*, Vol. **27**, p. 181, 1962)

17. De, M. L. : The Optimum Resolving Power of the Electron Microscope (*Naturwissenschaften*, Vol. **49**, p. 296, 1962)

18. De, M. L. : Scattering Cross-Section of Carbon at small-Angle. (*Nature*, Vol. **194**, p. 181, 1962).

19. De, M. L. : Considerations of Image constrast in Electron Microscopy of Objects Composed of Low Atomic Number. (*Zeit. fur Naturforschung*, Vol. **17B**, p. 728, 1962)

20. De, M. L. & Sarkar, N. H. : Optical Density of thin Carbon Films. (*Naturwissenschaften*, Vol. **49**, p. 55, 1962)

21. Dutt, P. K. Patro, A. P., Basu, B. & Chatterjee, A: Characteristics of the Ion-Source of the Calcutta 37-inch Cyclotron. (*Ind. Jour. of Physics* Vol. **36**, p. 169, 1962).

22. Ganguli, P. K. and Bhattacharjee, A. L. : Concentration dependence of sedimentation coefficient of Deoxyribonucleic acid with added sodium chloride. (*Nature*, Vol. **196**, p. 1201, 1962)

23. Ganguli, P. K., Bhattacharya, S. B. & Das Gupta, N. N. : Sedimentation Studies on DNA from Irradiated E. Coli. (*Naturwissenschaften* Vol. **49**, p. 215, 1962)

24. Ganguli, P. K., Sadhukhan, P. & Das Gupta, N. N. : Ultracentrifugal and Electron Microscopic Investigations on Calf Thymus DNA. (*Proc. of the National Inst. of Science of India*, Vol. **28B**, p. 206, 1962.)

25. Ghosh, S. K. & Sinha, S. K. : Calculation of Nuclear Magnetic Shielding in Hydrogen Molecule. (*Jour. of Chemical Physics*, Vol. **36**, p. 737, 1962.)

26. Goswami, A. & Pal, M. K. : On the Collective Quadrupole State of C_{12} (*Nuclear Physics*, Vol. **35**, p. 544, 1962).

27. Hosain, F., Basu, S. R., Sen, B. B., Mukherjee, A. B. & Sarkar, S. : Estimation of Ascitic Fluid Volumes Using Low Doses of I-131-HSA (*Ind. Jour. of Medical Sciences*, Vol. **16**, p. 59, 1962).

28. Hosain, F., Hossain, P., Swarup, S. & Chatterjee, J. B. : Double Exponential Nature in Chromium 51 Red-Blood Cell Survival Curves in Haemoglobin E Thalassaemia and Relation with Reticulocytes. (*Nature*, Vol. 196, p. **76**, 1962).

29. Hosain, F., Basu, S. R., Nag, B. D., Swarup, S. Chatterjee, J. B. & Banerjee, J. C. : A Study on Plasma Protein Turnover by a Low Level Tracer Technique. (*Ind. Jour of Medical Sciences* Vol. **16**, p. 413, 1962).

30. Karmohapatro. S. B. : Report on the Two Directional Focussing High Intensity Massspectrometer. Proc. International Conf. on the Physics of the electromagnetic Isotope Separation held in Paris, July 1962.

31. Kaul, O. N. : Energy and Angular Distribution of Alpha Particles from the Na^{23} (n, α) F^{20} Reaction Induced by 14 MeV Neutrons. (*Nuclear Physics*, Vol. **33**, p. 177, 1962).

32. Kaul, O. N. : Alpha Particles from the Interaction of 14 MeV Neutrons with Arsenic. (*Nuclear Physics*, Vol. **29**, p. 522, 1962).

33. Kaul, O. N. : α Particles Emitted from 14 MeV Neutron Interactions with Light and Medium-Weight Nuclei. (*Nuclear Physics*, Vol. **39**, p. 325, 1962).

34. Lala, P. K., Bhattacharjee, S. B. & Das Gupta, N. N. : Leukocyte Survival in Chronic Leukaemia with the aid of a tracer and a Theraphy Dose of P^{32} (Acta Haemat., Vol. **28**, p. 25, 1962).

35. Lala, P. K. , Das Gupta, N. N. & Bhattacharjee, S. B. : Life-span of Granulocytes in Chronic Leukaemia. (*British Jour. of Haemat* Vol. **8**, p. 232, 1962).

36. Misra, D. N. , Das Gupta, N. N. & Sadhukhan, P. : On the Distortion in Dimensions Produced by Shadowing. (*Fifth Int. Cangress for Electron Microscopy*, 1962)

37. Mukherjee, P. & Dutta, I. : Axial Asymmetry in Even Rare Earth Nuclei. (*Nuclear Physics*, Vol. **29**, p. 623, 1962).

38. Mukherjee, P. & Dutta, I. : Effect of N and N+2 orbital Mixing of Nilsson Energy Levels. (*Bull. Amer. Phys. Soc.* Vol. **7**, p. 18, 1962).

39. Mukherjee, P. & Cohen, B. L. : Nuclear Structure Studies in the Lead Region with Stripping Reactions. (*Phys. Rev.*, Vol. **127**, p. 1284, 1962).

40. Mukherjee P., Cohen B. L. Fulmer, R. H. & McCarthy, A. L, : Spin-Orbit Splittings in Nuclear Shell Model. (*Phys. Rev.*, Vol. **127**, p. 1678, 1962).

41. Mukherjee, P. & Cohen, B. L. : Neutron—Proton Interaction between states of same in Nuclear Shell Model. (*Bull. Amer. Phys., Soc.* Vol. **7**, p. 347, 1962).

42. Nath, S. C. : Design Procedure for very Wide Band Distributed Amplifiers. (*Jour. of the Institute of Engineering* (*India*), Vol. **42**, p. 79, 1962).

43. Patel, K. S. : A comparative Study of the Performance of Class Charmonic Generator with Fractional Sine Wave, Isosceles Triangle and Rectangular Pulse Drives. (*Jour. of the Institute of Telecommunication Engineeaing*, Vol. **8**, p. 298, 1962).

44. Patro, A. P. & Basu, B. : Decay of Ag^{103}, (*Phys. Rev.* Vol. **127**, p. 1258, 1962).

45. Patro, A. P. & Basu, B. : Decay of Yittrium–85. (*Nuclear Physics*, Vol. **37**, p. 272, 1962).

46. Patro, A. P. & Basu, B. : Decay of Antimony–113. (*Nuclear Physics*, Vol. **34**, p. 538, 1962).

47. Purkayastha, B. C. & Saha, S. R. : On the Study of Rare Elements in Minerals from Indian Sources Part I. On the Estimation of submicro amount of Uranium in Indian coal. (*Ind. Jour. of Applied Chemistry*, Vol. **25**, p. 20, 1962).

48. Purkayastha, B. C. & Paivernaker, V. R. : On the Indirect Application of Radioactive Nuclei in Analytical Chemistry. Pt. II. (*Jour. of Ind. Chemical Society*, Vol. **39**, p. 180, 1962).

49. Purkayastha, B. C. & Chandra, M. N. : On the Study of the Indirect Application of Radioactive Nuclei in Analytical Chemistry Part. III. (*Jour. of Ind. Chemical Society*, Vol. **39**, p. 231, 1962).

50. Sadhukhan, P., Das Gupta, N. N., Misra, D. N. & Chatterjee, J. B. : Electron Microscopic Studies on the Molecules of Hemoglobin A and F. (Fifth Int. Congress for Electron Microscopy, 1962).

51. Sarkar, M. : Denaturation of Deoxyribonucleic acid of Escherichia Coli by X-Irradiation in Vitro. (*Nature*, Vol. **196**, P. 269, 1962).

52. Sen, B. : Neutron-Alpha Reaction in Indium with 14 MeV Neutrons. (*Nuclear Physics*, Vol. **38**,p. 601, 1962).

53. Sinha, S. K., Ghose, S. K., Lahiri, J. & Roychoudhuri, A. : F^{19} Free Induction Decay in Polycrystalline, Mg F^2 (*Ind. Jonr. of Phys.* Vol. **36**, p. 513, 1962).

54. Verma, J. K. D. : Fast Neutron Bombardment of Voltage Variable Capacitors. (*Jour. of Physical Society of Japan*, Vol. **17**, p. 242, 1962).

55. Verma, J. K. D. : Neutron Irradiation of Zener Diodes, (*Jour. of the Physical Society of Japan*, Vol. **17**, p. 1203, 1962).

56. Verma, J. K. D. & Majumder, S. C. : The Tunnel Diode—its action and application Part. I. (*Electro Technology*, Vol. **6**, p. 3, 1962).

57. Verma, J. K. D. & Majumder, S. C. : The Tunnel Diode—its action and applications. Part II (Electro Technology Vol. **6**, p. 43, 1962).

—1963—

1. Banerjee, M. K. & Levinson, C. A.: New methods in Nuclear Structure Calculations (*Phys. Rev.* Vol. **130**, p. 1036, 1963).

2. Banerjee, M. K., Levinson, C. A.& Meshkov, S : Calculations of energy Spectra of Nuclei in the 2s, Id shell. (*Phys. Rev.*, Vol. **130**, p. 1064, 1963).

3. Basu, B & Patro, A. P. : Decay of In^{107} and Gamma Spectrum of cd^{107}. (*Nuclear Physics*, Vol. **46**, p. 59, 1963).

4. Basu, S. R., Lahiri, S., Chakraborty, T., & Hosain, F., : A Simultaneous Panaceatic and thyroid function test using small doses of 131 I–HSA. (*British Jour. of Radiology*, Vol. **36**, p. p. 886, 1963).

5. Bhattacharjee, R. : Gamma-gamma Coincidences in Pd^{105}. (*Ind. Jour. Phys.* Vol. **37**, p. 209, 1963).

6. Bhattacharjee, R., Chatterjee, S. and Shastry, S. : Application of Hoogenboom Technic for measurement of angular correlation. (*Proc. of the Low Energy Symposium*, p. 251, 1963).

7. Bhattacherjee, R. & Shastry, S. : Positon-decay of Te^{121} and the excited states of Sb^{121}. (*Nuclear Physics*. Vol. **41**, p. 184, 1963).

8. Bhattarcharjee, R. & Shastry, S. : E_2– MI mixing in the 100 Kev transition in Pr 144. (*Ind. Jour. Physics.*, Vol. **37**, p. 357, 1963).

9. Bhattacharjee, R. & Shastry, S. : An E_3 transition in the decay of Te^{121}. (*Proc. of the Low Energy Symposium, Bombay*, p. 48, 1963).

10. Bhattacharjee, S. B., Sarkar, M., & Das Gupta, N. N. : Influence of radiation on the incorporation of radio activity in different cell constituents. (*Biochem. Biophys. Acta*, Vol. **66**, p. 123, 1963).

11. Chatterjee, A. : Trends in (n, α) Cross-Sections at 14 MeV. (*Nuclear Physics*, Vol. **47**, p. 3, 1963).

12. Chatterjee, A. : Shell effects in (n, α) Cross Section at 14 Mev. (*Nuclear Physics*, Vol. **49**, p. 686, 1963).

13. Das Gupta, N. N. Misra, D. N., Ganguly, P., Sanyal, A. B., & Chatterjee, J. B. : Electron Microscopic and Sedimentation studies on haemoglobins A,F and E. (In "Aspects of Protein Structure, ed by G. N. Ramachandran, Acad. Press, London, 1963).

14. Ganguli, A. K. & Bakhru, H. : Operational Characteristics of a Radio frequency Ion source. (*Nuclear Inst. Methods*, Vol. **21**, p.56, 1963).

15. Ganguli P : Effect & K-rays on Bacterical Ribosomes. (*Biochem. Biophys Acta*, Vol. **75**, p. 59, 1963).

16. Ganguli, P., Dasgupta, N. N. & Chatterjee, J. B. : Sedimentation Characteristics of human haemoglobins A,F and E. (*Nature*, Vol. **199**, p. 919, 1963).

17. Ganguli, P. K. & Bhattacharjee, S. B. : Sedimentation studies on DNA from irradiated Ecoli : (*Arch. Biochem. Biophys.* Vol. **102**, p. 132, 1963).

18. Ganguli P. K. : Concentration effects in measurements & characteristics of deoxyribonucleic acid by transport methods. (*Nature*, Vol. **200**, p. 164, 1963).

19. Goswami, A. & Pal, M. K. : On the Collective States of C^{12} and ground state correlation. (*Nuclear Physics*, Vol. **44**, p. 294, 1963).

20. Hosain, F. & Hosain, P. : Simultaneous estimations of Plasma and red cell volumes by a low level double tracer technique. (*Ind. Jour. of Med. Sci.* Vol. **17**, p. 479, 1963).

21. Hutchins, M. T. & Ray, D. K. : Investigation into the origin of crystalline electric field effects of rare earth ions. I. Contribution from neighbouring induced moments. (*Proc. Phys. Soc.*, Vol. **81**, p. 663, 1963).

22. Jain, D. C. : Franck-Condon factors and r-centroids for the band system of RbH Molecule. (*Proc. Phys.. Soc.* Vol. **81**, p. 171, 1963).

23. Jain, D. C. : Influence of vibration-rotation interaction of the true vibrational waveforms. (*Jour. of Chem. Phys.* Vol. **38**, p. 1300, 1963).

24. Jain, D. C. & Sah, P. : Potential-energy curves of the excited states of Alkali Hydride Molecules. (Jour. Chem. Phys. Vol. 38, p. 1553, 1963).

25. Karmohapatro, S. B., & Narasinham, A. V. : Sputtering yields of Silver and angular distribution of the atoms sputtered by ions of noble gases. (*Proc. of Nat. Acad. of Sci., of India, Sec.* A, Vol. **33**, p 629, 1963).

26. Karmohapatro, S. B. : Inelastic Collision of Ions in gasses. (*Proc. of Nat. Acad of Sci., India, Sec.* A. Vol. **34**, p. 563, 1963)

27. Lahiri, S. K., Choudhuri, S. C., & Nag, B. D. : Leishman Saline techniques for simultaneous total and differential counts of bone-marrow cells. (Naturwissenschaften, Vol. **22**, p. 690, 1963).

28. Majumder, N. K. & Chatterjee, A. : 14.8 MeV Neutron activation Cross-Section measurements of a few tellurium Isotopes. (*Nuclear Physics*, Vol. **41**, p. 192, 1963).

29. Majumder, S. K. : The wave of a charged particle moving through a plasma with magnetic field. (*Proc. Phys. Soc.*, Vol. **82**, p. 669, 1963).

30. Mitra, S. K. : Physics of the outer space (Delivered in 7th Meghnad Saha Memorial Lecture, March 29, 1963). (*Science and Culture*, Vol. **29**, p. 314, 1963).

31. Mukherjee, P. : Nuclear Spectroscopy of Bi^{210} with stripping reaction. (*Phys. Rev.*, Vol. **131**, p. 2162, 1963).

32. Mukherjee, P. : Nuclear Structures Studies in the pt region with (dp) (d,t) and (d,d) reactions. (*Bull. Amer. Phys. Soc.* Vol. **8**, p 47, 1963).

33. Mukherjee, P., Cohen, B. L. Fulmer, R. H. & McCarthy, A. K. :Location of Neutron single particles levels from Stripping Reactions. (*Rev. Mod. Phys.* Vol. **35**, p. 332, 1963).

34. Nagchaudhuri, B. D.: Ultramicrowave generation by Cerenkov interaction with electron beams. (*Jour. of the Inst. of Telecommunication Engineering* Vol. **9**, p. 281, 1963).

35. Narasinham, A. V. & Karmahapatro, S. B. : Sputtering of Silver by Ions of noble gasses. (*Ind. Jour. Phys.* Vol. **37**, p. 394, 1963).

36. Pal, M. K. & Mitra, D. : Pairing model for Pr-Isotopes. (*Nuclear Physics*, Vol. **42**, p. 221, 1963).

37. Pradhan, T. : Exact Solution of a Relativistic Quantum Field theory (*Nuclear Physics*, Vol. **43**, p. 11, 1963).

38. Pradhan, T. & Tripathy, D. N. : Electron capture by Protons passing through hydrogen. (*Phys. Rev.* Vol. 130, p. 2317, 1963).

39. Purkayastha, B. C. & Bhattacharjee, ~~B. C.~~ D. K. : On the study of tetrahydrated double sulphate of tervalent elements with Radioactive indicators. Pt. I. (*Jour. Ind. Chem. Soc.* Vol. **40**, p. 841, 1963).

40. Purkayastha, B. C. & Bhattacharjee, D. K. : On the Study of tetrahydrated double sulphate of tervalent elements with Radio-active indicators. Part II. (*Ind. Jour. Appl. Chem.* Vol. **26**, p. 139, 1963).

41. Purkayastha, B. C. & Bhattacharjee, S. N. : On the study of Co-separation of thorium and rare earths by calcium sulphate on a tracer scale. (*Jour. Ind. Chem., Soc.*, Vol. **40**, p. 759, 1963).

42. Purkayastha, B. C., & Chakraborti, M. C. : On the mechanism of the uptake of tetravalent actinides by bismuth phosphate. (Report of syposium on Nuclear and Radiation Chemistry under the joint auspices of Atomic Energy Establishment, Trombay, Calcutta University and Ind. Chem. Soc. Dec. 9—11, p. 71, 1960).

43. Purkayastha, B. C. & Das, A. K. : On the study of indirect application of Radioactive Nuclei in Analytical Chemistry. (*Jour. Ind. Chem. Soc.* Vol. **40**, p. 169, 1963).

44. Purkayastha, B. C. & Das, H. B. : Study of the probable existence of Potassium Indium Alum with Radioactive Nucli Pt. 1. (*Jour. Ind. Chem. Soc.* Vol. **40**, p. 163, 1963)

45. Purkayastha, B. C. & Dutta, K. N. : A Study on the existence of Scandium Alum with Sc^{46}. (*Jour. Ind. Chem. Soc.* Vol. **40**, p. 879, 1963).

46. Purkayastha, B. C. & Dutta, K. N. : On the co-separation study of Acid-insoluble pyrophosphates of rare elements. (*Jour. Ind. Chem. Soc.* Vol. 40, p. 1025, 1963).

47. Purkayastha, B. C. & Dutta, K. N. : Study of the co-separation of Scandium Yttrium and Rare-earths by Calcium Fluoride. (*Ind. Jour. Chem.* Vol. **26**, p. 133, 1963).

48. Purkayastha, B. C. & Dutta, K. N. : Study on the probable existence of Potassium Indium alum with Radioactive Nucli Part II. (*Ind. Jour. Appl. Chem.*. Vol. **26**, p. 19, 1963).

49. Rama Rao, M. : An empirical relation for Alpha disintegration energies for medium heavy elements. (*Ind. Jour. Phys.*, Vol. 37, p. 384, 1963).

50. Roy, D. K. : Investigations into the origin of the crystalline electric field effects on rare earths Ion II. Contributions from the rare earth orbitals. (*Proc. Phys. Soc.* Vol. **82**, p. 47, 1963).

51. Roy T. : Generalized Spin-Hamiltonian for Paramagnetic Ions in crystals : I–General formalism and its applications to cubic crystalline symmetry. (*Proc. Roy. Soc.* Sr. A. Vol. **277**, p. 76, 1963)

52. Sarkar, N. H. : Electron Scattering at small angles by carbon. (*Jour. Appl. Phys.* Vol. **34**. p. 2379, 1963).

53. Sarkar, N. H. & Misra, D. N. : On the measurement of spherical abberation constants of the projector lens of an elctron microscope. (*Ind. Jour. Phys.* Vol. **37**, p. 605, 1963).

54. Sarkar, N. H. & Sadhukhan P : Estimation of Mass-scattering co-efficient Biological samples. (*Nature*, Vol. **197**, p. 1263, 1963).

55. Sen, B. : (n, α) Reactions on light Nuclei at 14 MeV. (*Nuclear Physics*, Vol. **41**, p. 435, 1963).

56. Sen, B. & Chatterjee, M. L. : Fading Phenomena in Nuclear emulsions (*Nuclear Inst. & Methods.* Vol. **22**, p 122, 1963)

57. Verma, J. K. D. : Thermal conductivity of irradiated Semiconductors. (*Jour. of Inst. of Telecommunication Engineering.* Vol **9**, p. 262, 1963).

58. Verma, J. K. D. : (A) Four-point probe for resistivity measurements of Semiconductors. (*Ind. Jour. Phys.* Vol. **37,** p. 241, 1963).

—1964—

1. Bakhru, H. & Mukherjee, S. K. : Decay of Cu^{68} (*Nuclear Physics* Vol. **52,** p. 1, 1964).

2. Bakhru, H. & Mukherjee, S. K. : Radioactive decay of Lu^{178} (*Nuclear Physics,* vol. **55,** p. 161, 1964).

3. Baliga, B. B., Feldman, L. & Nessin, M. : (P γ) Reactions in the Giant Resonance Region. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh,* Pt. **A,** p. 147, 1964).

4. Banerjee, B. C. & Saha, N. N. : X-ray studies of electrolytic copper powder. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh,* Pt. **B,** p. 496, 1964).

5. Banerjee, M. K. : Recent Development in the Theory of Nuclear Reactions. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh,* Pt. **A,** p. 78, 1964).

6. Basu Mallik D. N. & Nag, B. R. : Modes of oscillation of a grounded grid cyclotron oscillator. (*Radio & Electronic Engineer* vol. **27,** p. 27, 1964.)

7. Bhattacherjee, S. D. , Das, S., Saha, N. N. & Saha, A. K. : Study on the structure of collagen of different biological origin. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh,* Pt. **B,** p. 601, 1964).

8. Bose, D. K., Jain, D. C., Nagchaudhuri, B. D. & Sengupta, S. N. : Electrical Conductivity Studies of the Cold Cathode P.T.G. Discharge. (*Proc. of the Nuclear Physics and Solid States Physics Symposium held at Chandigarh,* Pt. **A**, p. 169, 1964).

9. Bose, M., Chatterjee, N. & Das, N. : Nuclear Magnetic Resonance in Paramagnetic Nitrates. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh,* Pt. **B**. p. 432p 1964)

10. Bragg, W. L. : The difference between living and non-living matter from a physical point of view. (Eighth Meghnad Saha Memorial Lecture delivered on 8th Jan., 1964 at the S.I.N.P. Calcutta). (*Science and Culture,* Vol. **30,** p. 161, 1964).

11. Burman Ray, B. B., Shastry, S. & Bhattacharjee, R. : The 2.73 MeV level of Mo^{96}. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, p. 271, 1964).

12. Chatterjee, A. : Alpha Reaction Cross Sections for 14 MeV Neurtons. (*Nucleonics*, vol. **22**, p. 108, 1964).

13. Chatterjee, A. : Compound Nuclear Shell effects in 14–MeV (n, α) Reactions. (*Phys. Rev.*, vol. **134**, p. B374, 1964).

14. Chatterjee, A. : Diffusion studies of Bovine Plasma Albumin at 250 with the help of Jamin Interference optics. (*Jour. Amer. Chem. Soc.*, vol. **86**, p. 3640, 1964).

15. Chatterjee, A. : Measurement of the Diffusion Coefficients of Sucrose in very dilute aqueous solutions using Jamin interference optics at 25° (*Jour. Amer. Chem. Soc.*, vol. **86**, p. 793, 1964).

16. Chatterjee, A. : Shell Effects in 14 MeV (n, p) Reactions. (*Nuclear Physics*, vol. **60**, p. 273, 1964).

17. Chatterjee, A. : Shell Effects in the MeV (n,p) and (n, α) Reactions. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, Pt. **A**, p. 112, 1964).

18. Chatterjee, M. L. & Sen B. : Analysis of the Angular Distribution for the C^{12} (n, α) Be^{9} Reaction. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, Pt. **A**, p. 106, 1964).

19. Chatterjee, M. L. & Sen, B. : The (n, α) Reaction on C^{12} at 14 MeV. (*Nuclear Physics*, vol. **51**, p. 583, 1964).

20. Ghatikar, M. N. , Ray, T. & Ray, D. K. : Generalised Spin Hamiltonian and Nuclear Quadrupole Interactions for Rare-Earth Trichlorides. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, Pt. **B**, p. 336, 1964).

21. Ghatikar, M. N., Roychoudhuri, A. K. & Ray, D. K. : Shielding for the Crystalline Electric Field and for the Nuclear Quadrupole Moments in Rare-Earth Ions. (*Proc. Phys. Soc.*, vol. **84**, p. 297, 1964.)

22. Jain, D. C. : Potential Energy Curves of some Electronic States of N_2 Molecule. (*Proc. Phys. Soc.*, vol. **83**, p. 17, 1964).

23. Jain, D. C. : Transition Probability Parameters of the Swan and the Foxherzberg Band Systems of the C_2 Molecule. (*Jour. of Quantitative Spectroscopy & Radiative Transfer*. vol. **4**, p. 427, 1964).

24. Lahiri, J., Mukherjee, A. & Ray, D. K. : Effect of Electrostatic Polarisation of Atoms of some Physical Parameters. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, Pt. **B**, p. 472, 1964).

25. Lahiri, S. K. & Udupa, K. B. : Methylene blue Easinated Saline as a Dispersing Fluid for Bone-Marrow Cell Counting. (*Ind. Jour. of Exp. Biology*, vol. **2**, p. 164, 1964).

26. Misra, D. N. , Das Gupta, N. N., Sanyal A. B. & Chatterjee, J. B. : Electron Microscopic Observations on Human Haemoglobins. (*Expt. Cell. Res.*, vol. **34**, p. 325, 1964).

27. Mukherjee, A. : A Self-consistent Variation Perturbation Method. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, **Pt. B.** p. 507, 1964).

28. Mukherjee, I. : Interpretation of Pb^{206} (d,p) Pb^{207} Reactions in Terms of the Unified Model. *Proc. of the Nuclear Physics and Solid State Physics Symposium, held at Chandigarh*, **Pt, A,** p. 64, 1964).

29. Mukherjee, I. & Mukherjee, P. : Interpretation of Pb^{207} Reactions in Terms of the Unified Model. *Nuclear Physics* vol. **57.** p. 683, 1964).

30. Mukherjee, P. : Nuclear Structures Studies with Deutron induced Reactions. (*Proc. Low Energy Nuclear Physics and Solid State Physics Symposium, held at Chandigarh*, p. 70, 1964).

31. Mukherjee, P. : Nuclear Spectroscopy with (d,p) and (d,t) Reactions on TI^{205}. (*Phys. Letters.*, vol. **13,** p. 238, 1964).

32. Mukherjee, S. K. & Bakhru, H. : Radioactive Decay of Sr^{93}. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh* Pt, **A,** p. 266, 1964).

33. Pal, M .K. & Banerjee, M. K. : Treatment of neutron-Proton Correlations. (*Physics Letters*, vol. **13**, p. 155, 1964).

34. Ray, D. K. : Theoretical Investigations into the Origin of the Crystalline Electric Field for Rare-Earth Ions in Crystals. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh* Pt. **B**, p. 321, 1964).

35. Ray, D. K. & Rudra, P. : Group Theoretical Method of Deriving the Potential of a Vibrating System, (*Jour. of Chem. Phys.*, vol. **40,** p. 2416, 1964).

36. Roychaudhuri, A. K. & Sinha, S. K. : On the Variational Calculation of the Diamagnetic Suspectibility and Nuclear Magnetic Shielding in Molecules. (*Molecular Physics*, vol. **17,** p. 473, 1964).

37. Rudra, P. & Ray, D. K. : A Group Theoretical Method for Obtaining the Exact Form of Potential for Vibrating System. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh* Pt. **B,** p. 594, 1964).

38. Sanyal, A. B., Ganguli, P. & Das Gupta, N. N. : Interaction of Phosphotungslate with Haemoglobin. (*Jour. Molecular Biology* vol. **8**, p. 325, 1964).

39. Sarkar, N. H. : Nomographic method for the estimation of mass-thickness of biological samples (*Exp. Cell Research*, Vol. **36**, p. 487, 1964).

40. Sarkar, N. H. & Misra, D. N. : A Graphical Method for Electron Microscopic Measurement of Thickness of Biological Objects. (*Proc. 3rd Reg. Conf. on Electron Microscopy, Prague*, vol. B p. 25, 1964).

41. Shastry, S. & Bhattacharjee, R. : Decay of y^{88} to the 3.22 and 3.52 MeV Levels of Sr^{88} (*Nuclear Physics* vol. **55**, p. 397, 1964).

42. Shastry, S. & Bhattacharjee, R. : Spin of the 3.22 MeV State of Sr^{88}. (*Proc. of the Nuclear Physics and Solid State Physics Symposium held at Chandigarh*, Pt. A, p. 289, 1964).

43. Shastry, S., Burman Ray, B. B. & Bhattacharjee, R. : Decay of Tc^{96} (*Nuclear Physics*, vol. **56**, p. 491, 1964).

44. Verma, J. K. D., Nag, B. D. & Nair P. S. : Debye Characteristic Temperatures of some Cubic Semi-conductors. (*Zeit fur Naturforschung*, vol. **19a**, p. 1561, 1964).