Annual Report

1966

SAHA INSTITUTE OF NUCLEAR PHYSICS
92, ACHARYA PRAFULLA CHANDRA ROAD
CALCUTTA-9

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PREFACE

This report presents a brief résumé of the activities of the Institute in its sixteenth year. This is the third annual report since publication according to the calendar year rather than the financial year as previously.

The presentation, in general, follows the pattern set up in the reports of the last two years. The research, technical and teaching programmes that have been carried out are covered under the broad divisions and groups existing in the Institute. In addition, the activities of the library and the workshop are listed, followed by a short survey on the general administration.

The activities reported pertain to all the workers of the Institute, including those supported by other organisations such as the Calcutta University, Department of Atomic Energy and Council of Scientific & Industrial Research.

We are indebted to Prof. B. D. Nagchaudhuri, our Director, for his valuable advice and helpful suggestions. Sincere thanks are due to all our colleagues for their kind co-operation in compiling and editing this annual report.

Calcutta,
January, 1967.

J. Basu D. K. Ghosh
Editors.

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Cover : Proton beam (3.8 MeV) emerging in air from the 37″ Cyclotron

INTRODUCTION

We have endeavoured in the Saha Institute, during the fifteen years of our existence, to keep in touch with certain areas of research in physics and related subjects. We have also tried to keep abreast of modern developments in our teaching in the rapidly growing fields of nuclear and allied sciences.

The annual reports of the various groups show that there has been, by and large, a satisfactory progress over the last one year. The major achievements are summarized in the reports by the Divisional Heads.

Five research workers of our Institute have been awarded the D. Phil. degree of the Calcutta University in 1966, while twelve more have submitted their theses for the doctorate degree. Fifteen students are attending the one year post-M.Sc. Associateship Diploma Course of the Institute. Apart from running the course, a few members of the staff also participate in the teaching programme of the Calcutta University. Five of our members have been abroad for short periods during the year as visiting scientists, and about twenty five have participated in national and international conferences and symposia.

It is evident from the reports that scarcity of foreign exchange is a serious problem of ours, which limits our research activities and ambitions. This difficulty, however, has given us an impetus to try to generate, as far as practicable, some technical bias in our experimental activities. A technical physics group has recently been formed for developing technical know-how and research equipments.

An obstacle to our growth is the lack of working space. Financial sanction has been received, and as soon as land is available and plans are completed, it is proposed to build extensions of our laboratories at a new site.

I am thankful to Dr. J. Basu and Prof. D. K. Ghosh for the time and energy they have devoted in bringing out the annual report this year.

B. D. Nagchaudhuri
Director

1. ACCELERATOR DIVISION

1.0 *Introductory Remarks*

From the reports of the activity of the different groups and workers in the Accelerator Division, it would appear that the Division has made satisfactory progress in its two-fold programme of development and research.

The extraction of the proton beam of the Cyclotron followed by its transportation to the experimental room through appropriate vacuum piping and quadrupole magnet installations is a significant land-mark for the Cyclotron group and brings credit to their sound understanding and experimental skill in accelerator techniques. In the hands of such capable workers, one feels highly optimistic about the development of the 20-inch model magnet study facilities at the Pagladanga site of the Institute. Another note-worthy development has been the setting up of an isotope separator and its operation. With lead isotopes, it has been possible to obtain an isotope separation factor of $\triangle M/M \sim 1/150$ with a peak current of $\sim 640\ \mu A$ at mass number 208. When supplies of necessary spare parts and materials become available, it would be possible to use the machine for research problems. Improvement of measuring equipments and their precision have been the continual care of the neutron physics group with solid state detectors gradually coming into wider use. The Division lent the services of Sri D. N. Basu Mallik to the Technical Physics Group and is pleased to note that he has been making praise-worthy contribution in several programmes there.

It is particularly gratifying to note that in spite of scarcity of funds for equipments and staff, the research activities are spread over wide areas of interest. Valuable original contributions have been made in several papers. The neutron research group has been pushing ahead with their studies of nuclear energy levels and neutron reaction mechanism and their findings have received wide appreciation from workers in other countries as well. The studies on the life-times and formation mechanism of positronium with high time-resolution equipments constructed in the laboratories have already proved highly rewarding. Measurements of the sputtering yields of radioactive silver single crystal by noble gas ions under appropriate conditions of crystal face and ion beam geometry may show correlations between ion channelling and sputtering phenomenon. It has been possible to obtain stereo photograph of ternary fission with the low pressure automatic cloud chamber and data would now be accumulated to critically study features of such a fission process. The surface ionization method has been used to measure the first ionization potentials of five rare earth elements, for some of which no spectroscopic data for this quantity were in the literature.

Gradually dwindling foreign exchanges have faced research workers with a challenge. It is hoped that with resources developed internally, research programmes would be put on a firmer base in spite of temporary set-backs.

D. N. Kundu
Head, Accelerator Division

1.1 *Report on Cyclotron*

External beam of protons from the cyclotron was successfully extracted and led to the experimental room. As predicted by our calculations the fringing field was affecting the extracted beam and much time was spent in reducing the fringing field. Several different types of iron shields were tried and the one which deflected the beam the least was selected. A quadrupole magnet which was fabricated a few years back was tested and introduced in the beam pipe system for focussing the beam. Careful alignment of the beam through the pipe necessitated certain alterations of the cyclotron magnet coil support and it was completed in a short period.

The beam immediately at the exit gate of the cyclotron is $\sim$ 90 mμA. At the entrance of the quadrupole magnet ($\sim$ 4 ft. away from the exit gate) it is 40-48 mμA. The focussed beam at the end of the beam pipe in the experimental room is 6-9 mμA without collimator. With a collimator ($\sim$ 1 cm diam) this reduces to 1-2 mμA. So far the rf oscillator is running with ac power (i.e. effective power is applied only for about 1/10 of the cycle). Within a few weeks it will be run with dc power for which arrangements are all ready. When this and other improvements are done it is expected that the beam current will increase by 10-100 times.

About the end of May 1966 we had a break-down in magnet power supply unit which forced a shut down for over three months as certain components had to be imported. When the situation became normal, the absorber wheel and Faraday cup assembly, which was fabricated last year, was introduced into the beam pipe terminus and the beam energy measured; the energy so measured is 3.8 MeV. Measurement with a solid state detector gave an energy spread of $\pm$ 100 keV.

Chamber fabricated as beam viewing opening is presently used as a scattering chamber with slight modifications. A new larger scattering chamber is being made in the workshop. Proton scattering from mylar, aluminium, teflon and nickel have been observed. Solid state detectors were used for detecting scattered particles. In case of mylar elastic peaks were clearly observed from carbon and hydrogen and the shifting of the peak with angle. Attempt to observe the alpha-group from (p, α) reaction did not succeed fully. Most of the pick-up problems have been successfully solved.

A scintillation counter with NaI is being used to study the gamma rays from proton capture in different nuclei.

The workshop fabrication of 20° focussing deflection magnet is completed. The coils for the magnet are being made and tested individually. The power supply for the magnet is in the last stages of completion.

The vacuum deposition unit built some time back is being set up for preparing targets for scattering experiments.

The building for housing the 20″ diameter Model magnet is nearly complete. Water and power connections will be shortly ready. The 4″ plate necessary for fabricating the chamber has been obtained. The coils for the magnet will be ready within a short period. One coil was tested by sending the full design current, and the cooling system was found to be adequate.

Various shim plates are now being designed, and we expect to begin the study of different magnetic field configurations shortly.

A. P. Patro, B. Basu and B. B. Baliga

1.2 *Development of Fast Coincidence Arrangement and its Application to the Determination of Positronium Life-times*

The determination of positronium life-times in the silicone fluids DC 200 with different viscosity grades and DC 702, 703, 704 and 705 were completed by the middle of the year 1966. Our results show that there is no dependence of the life-time of the longer component, τ_2 or of its intensity, I_2, on the viscosity or molecular weight of the sample under investigation. One paper containing the above mentioned results is ready for publication.

Next the study of the formation mechanism of positronium in some solids (oxides) was taken up. We expect a very low intensity longer component in these oxides. The detection of this low intensity group is not possible by the previous experimental set-up utilising the Eldorado time-to-amplitude converter (T. A. C.), where the minimum 2τ (f.w.h.m.) is 2.0×10^{-9} sec.

The Eldorado T. A. C. has also a limitation on the maximum counting rate that it can handle. This limitation was found to be very important in our work where large counts have to be accumulated to observe weak components. Since the middle of 1966, we started some developmental and construction work on fast T. A. C. By this time (November 1966) we are able to make one tube T. A. C. circuit similar to that of Bell, Tao and Green. Some transistorised T. A. C. circuits were also tried, but the operation was not upto the expectations. The disadvantages of the transistorised T. A. C. are, short linear range and its sensitivity to temperature changes. The tube T. A. C. is quite sensitive to the bias of the 6BN6 (converter tube). Experience has shown that there is a plateau of this bias, where operation of the 6BN6 is desirable.

Leaving aside the high frequency wiring technique, we have realised that the limit of the time resolution is in our photo-multiplier tube. With an electronic pulse generator we have achieved $2\tau = 7.0 \times 10^{-11}$ sec., but when tested with scintillation pulses, we obtained $2\tau = 0.72 \times 10^{-9}$ sec. using two RCA 6810A tubes. This is, in fact, the best 2τ achieved by many workers with RCA 6810A under the similar experimental conditions, i.e. plastic phosphors, its dimensions, the counting rate, etc. Bell, Tao and Green also get $2\tau \sim 0.72 \times 10^{-9}$ sec. with RCA 6810A tubes.

Recently people have achieved very low $2\tau \sim 0.2 \times 10^{-9}$ sec. only by replacing the RCA 6810A tubes with the superior tubes, i.e., XP 1020 (Philips) and RCA C70045. We also hope and expect to improve our 2τ by at least a factor of 2 just by replacing the RCA 6810A tubes by either of the above mentioned superior tubes. By doing this we shall be able to read the first life-time, ($\sim 2.0 \times 10^{-10}$ sec.) directly from the time distribution spectrum. This, in fact, will reveal the insight of the positronium life-times in metals and other solids (oxides) and some systematic understanding can be achieved.

P. Sen and A. P. Patro

1.3 *Studies of Thermal Neutron Fission of U-235*

Studies of thermal neutron fission of U-235 with the help of a counter controlled low pressure cloud chamber have been taken up. Targets of natural uranium on Al-backing foils prepared by the familiar painting technique were used in the initial stages. Photographs of fission events obtained with such targets have revealed tracks of only one fission fragment. The absence of the other fragment in the case of binary fission is accounted for by the self absorption of the source and the thickness of the supporting backing material. It was, therefore, found necessary to develop the technique of preparing thin targets. It was incidentally found also necessary to bring about changes in the existing counter assembly for increased efficiency of detecting the fission events. These investigations were persued.

a) *Preparation of Thin Targets of Uranium*

Thin films of celluloid which serve as backing material for deposition of uranium coatings have been prepared by "film drawing technique". The thin film of celluloid drawn on the surface of water has been transferred on to a thin copper coil with a number of perforations punched on it. The foil is gently rested on the floating celluloid film, which then adheres to it under the action of surface tension. It is then disentangled from the bulk of the film by cutting the edges with a knife edge and finally taken out of water and kept for drying.

Uranium in the form of uranyl nitrate is dissolved in absolute alcohol and solution of the desired concentration is prepared. This solution is slowly spread on the film of celluloid prepared earlier. The film is initially wetted with a drop of insulin to ensure uniform dispersal of the uranium salt on the supporting film. The thickness of celluloid film and uranium coating prepared by the above processes have been estimated to be 40 $\mu g/cm^2$ and 20 $\mu g/cm^2$ respectively.

b) *Construction of the Counter Assembly*

A rectangular metallic frame mounted across the diameter of the chamber and maintained at earth potential serves as the cathode of the counter assembly and also as a source holder. Two tungsten wires, 6 mil in diameter, are stretched parallel to the cathode at a distance of 4 cm on either side of it. These wires maintained at suitable operating voltages (+500 V) serve as collector electrodes of the counter. The two wires are aligned to be in the median plane of the cathode.

With this new set-up fission photographs are being obtained. Besides, the more common binary fission process, a ternary fission event, in which the uranium atom splits into two heavy fragments accompanied by the emission of a charged particle identified to be an alpha particle, has also been photographed. The energy of the α-particle has been estimated to be roughly around 10 MeV. More data is needed to assess the frequency of such ternary events. Work is in progress.

M. Rama Rao

1.4 *Sputtering of Single Crystal by Energetic Ions*

In continuation of the studies on sputtering phenomena, done earlier, we are measuring the sputtering yields of a silver single crystal by ions of Kr, Xe, Ho, etc. The silver single crystal is made radioactive by bombardment with neutrons in Harwell reactor for facilities of measuring the sputtering yield by tracer method as reported earlier.

A magnetic oscillation type ion source suitable for gases and solids is used for producing energetic ions. Some results with Kr and Xe ions from this ion source accelerated to 0–10 KV and the silver single crystal, having its 110 face flat surface and the ions being normal to this surface, are obtained. The work is in progress. More data will be helpful in finding the correlation between the channelling of ions and the sputtering phenomena.

S. D. Dey and S. B. Karmohapatro

1.5 *Studies on Negative Ions and Ions Produced as a Rare Phenomenon*

The magnetic spectrometer has been modified for receiving an analysed beam of higher current. Negative ions of oxygen have been studied. The work will be pursued and extended for a variety of negative ions of gases and solids.

Ions produced as a rare phenomenon, i.e., negative ions of elements not generally found or molecular ions of noble gases will be studied systematically.

Ion spectrum originated in the atoms in course of radioactive emission will also be studied. For this purpose, a highly sensitive mass spectrometer is partly completed and described below.

The mass spectrometer is under development. The 60° magnetic analyser with $r_0 = 15$ cm with its power supply and vacuum chamber has been completed, Electron multiplier system and the photomultiplier system are being developed for single particle counting. The vacuum system for maintaining a pressure $\sim 10^{-7}$ mm Hg with full load is being developed.

S. D. Dey and S. B. Karmohapatro

1.6 *Measurement of I.P. of Rare Earth Elements by Surface Ionisation Method*

The following values of the I.P. of the rare earth elements Gd, Ho, Dy, Pr, Er by the surface ionisation method have been determined.

Gd	—	6.73 ± 0.09 eV
Ho	—	6.08 ± 0.09 eV
Dy	—	5.72 ± 0.10 eV
Pr	—	5.61 ± 0.12 eV
Er	—	6.36 ± 0.10 eV

(S. D. Dey and S. B. Karmohapatro, 'First Atomic I. P. of Dy and Pr', to be published in J. Phys. Soc., Japan).

(S. D. Dey and S. B. Karmohapatro, 'Measurement of the ionisation potential of the rare-earth elements by surface ionisation method', to be presented at the International Symposium on Spectroscopy, Bombay, January 1967)

Publication :

S. D. Dey and S. B. Karmohapatro, Ind. J. Phys., *40*, 151, 1966.

S. D. Dey and S. B. Karmohapatro

1.7 *Electromagnetic Separation of Isotope*

An electromagnetic isotope separator was installed in the Institute in the early part of this year. Since the French technicians associated with the instru-

ment left, quite a few modifications have been made in the laboratory. A new cooling system was installed and underground polythene pipeline laid down. During test operations we have come across several mechanical and electrical weak points in the high voltage supply, arc supply, furnace, ion source, various valves, etc. These have been remedied and in some cases certain parts have been replaced. A collector has been designed and fabricated for some preliminary experiments. After the completion of the test operations the instrument will be put to research uses.

D. Basu

1.8 *Decay Scheme of Nb-92*

A study of the activities produced by 14.8 MeV neutron bombardment of Niobium was made. Evidence was found to support an assignment of 10.1 days activity to Nb-92 and of levels in Zr-92 at 0.932, 1.38, 1.49, 1.83, 2.05 and 2.16 MeV. Previously reported half-lives of 13 hrs. and 3.1 hrs. also assigned to Nb-92 were looked for and not found. Cross sections for the (n, 2n), (n, α) and (n, γ) reactions on Nb were measured.

Publication :

D. Basu, B. Sethi and H. Bakhru, Proc. Nucl. Phys. & Solid State Phys. Symp., Bombay, 1966, p. 209 (Nucl. Phys.).

D. Basu

1.9 *Decay of ^{176}Tm and Levels of ^{176}Yb*

The ^{176}Tm nucleus is produced through (n, p) reaction with 14.8 – MeV neutrons on enriched (97.5%) ^{176}Yb. A half-life of 1.4 ± 0.2 min is assigned to ^{176}Tm. The beta and gamma measurements show three beta groups of end-point energies 3050 ± 100 (20%), 2000 ± 100 (40%) and 1150 ± 100 (40%) keV and eight gamma rays of energies 50 (Yb K x-ray), 91, 190, 285, 390, 870, 1050 and 1816 keV decaying with a 1.4-min activity of ^{176}Tm. Coincidence and sum spectrum studies indicate that the 1150-keV beta group is in coincidence with a gamma ray energy cascade 870-1816-1950 keV; the 2000-keV beta group is in coincidence with the 1050-keV gamma ray and a gamma ray energy cascade 1816-190-50 keV; and the 3050-keV beta group is in coincidence with none. The 91, 390, 285, 190 and 50-keV gamma rays form a cascade. A decay

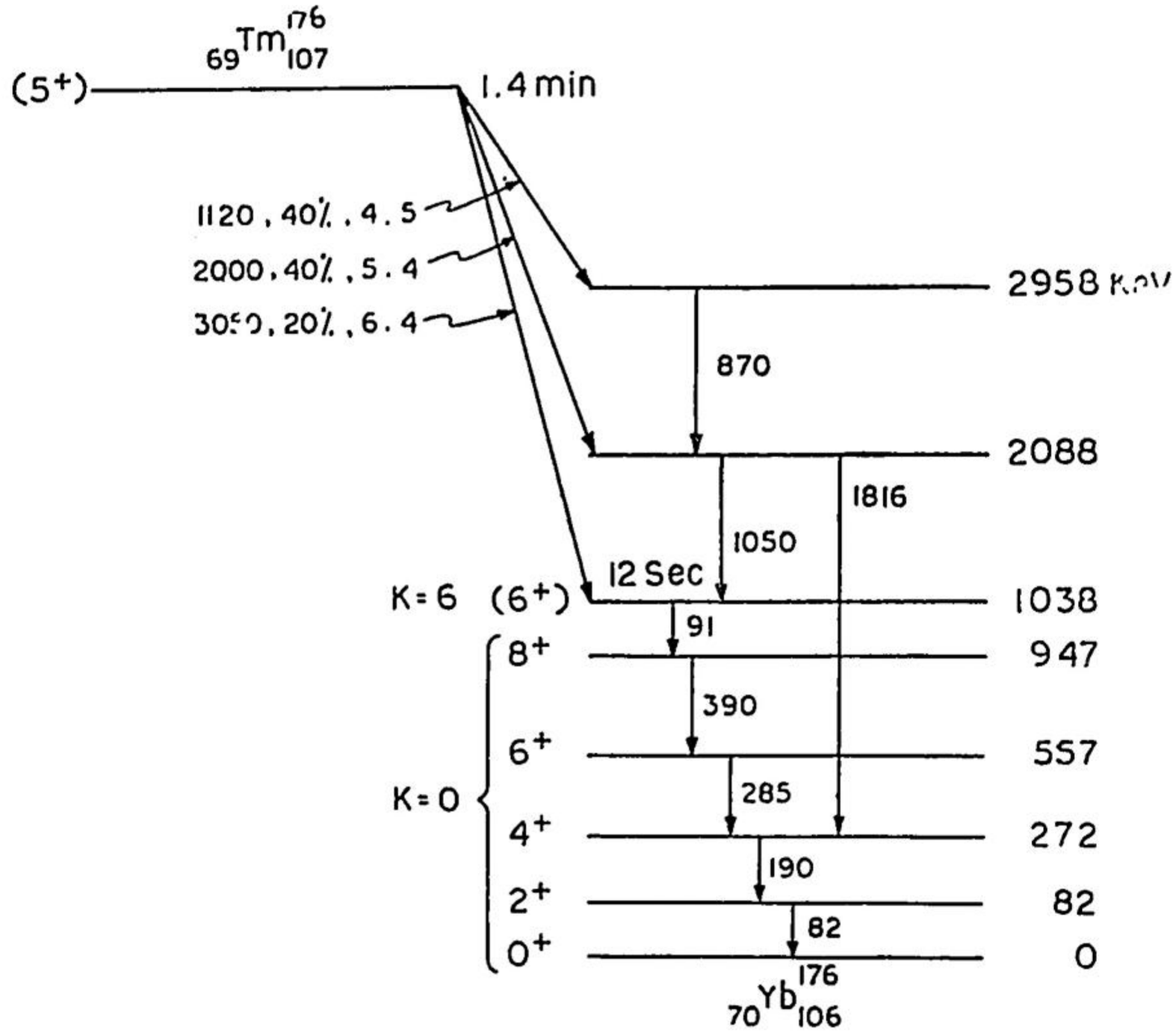

Fig. 1.9

scheme of ^{176}Tm is proposed and the results are discussed in the light of the unified model. The θ_β for the ^{176}Tm-^{176}Yb transition is 4088 ± 100 keV. The (n, p) cross-section for ^{176}Yb is found to be 1.5 ± 0.5mb.

Publication :

S. C. Gujrathi and S. K. Mukherjee, Proc. Nucl. Phys. & Solid State Phys. Symp., Bombay, 1966.

S. C. Gujrathi and S. K. Mukherjee

1.10. *Excited Levels in ^{61}Co from the Decay of ^{61}Fe*

Irradiation of enriched ^{64}Ni samples with 14.8-MeV neutrons was found to produce an activity of 5.8 min half-life, which was assigned to ^{61}Fe. The assignment was confirmed by following the decay of iron activity separated from the irradiated samples of spec-pure nickel. The scintillation spectrometer studies showed that the gamma rays of energies 130, 170, 230, 295, 400, 1010 and 1180 keV and the beta groups of maximum energies 2800 ± 100 (31%), 2630 ± 100 (54%) and 2500 ± 100 (13%) keV were decaying with a half-life of 5.8 min. The gamma-gamma and the beta-gamma coincidence studies were performed, which showed the existence of the excited levels at 1010, 1180, 1305

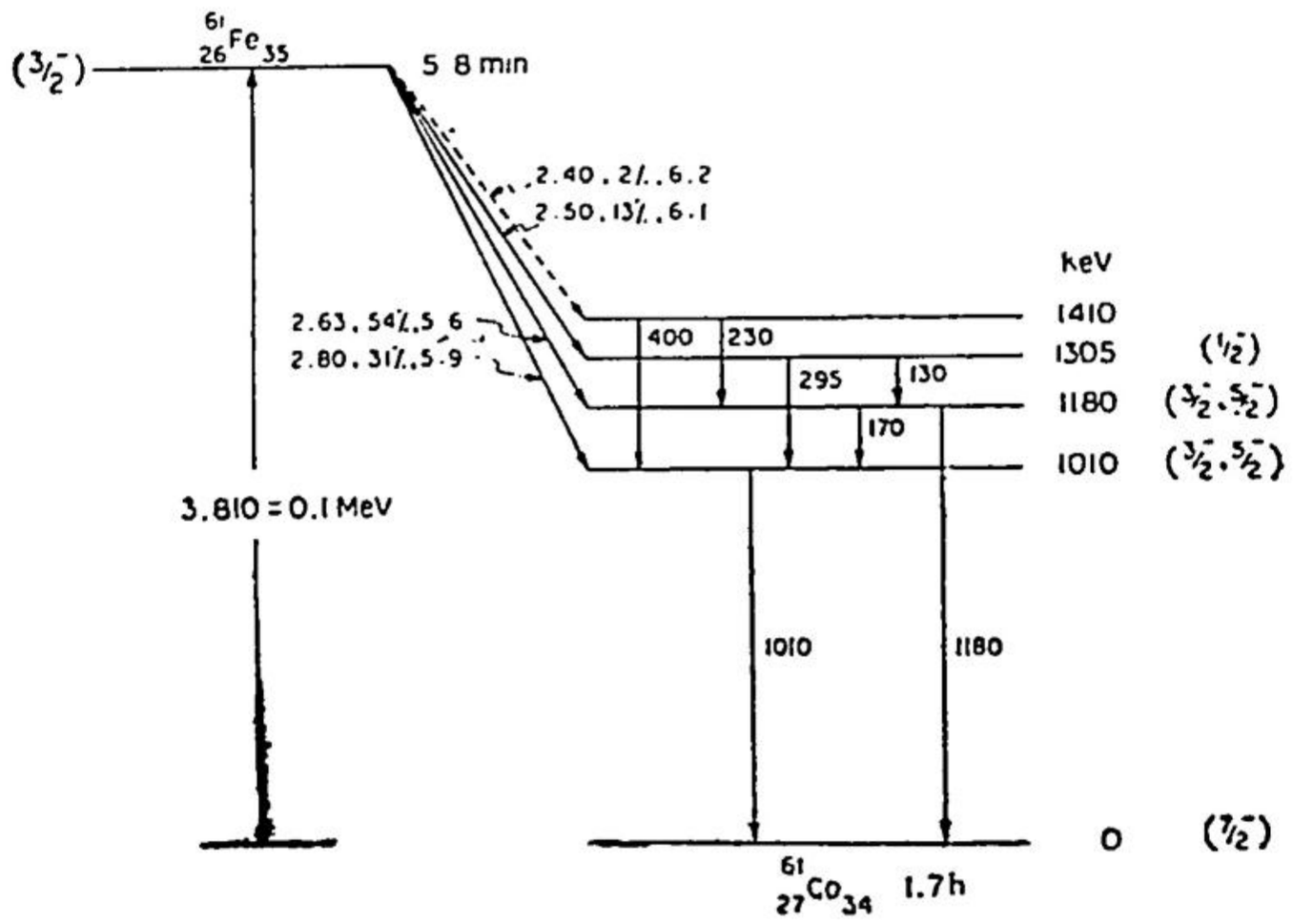

Fig. 1.10

and 1410 keV in ^{61}Co. A decay scheme of ^{61}Fe is proposed and the results are discussed in the light of single-particle shell model.

S. C. Gujrathi and S. K. Mukherjee

1.11 *Decay of ^{76}Ga*

^{76}Ga is produced by (n, p) reaction with 14-MeV neutrons on ^{76}Ga (enriched) as well as on spec-pure natural germanium. The half-time of ^{76}Ga is

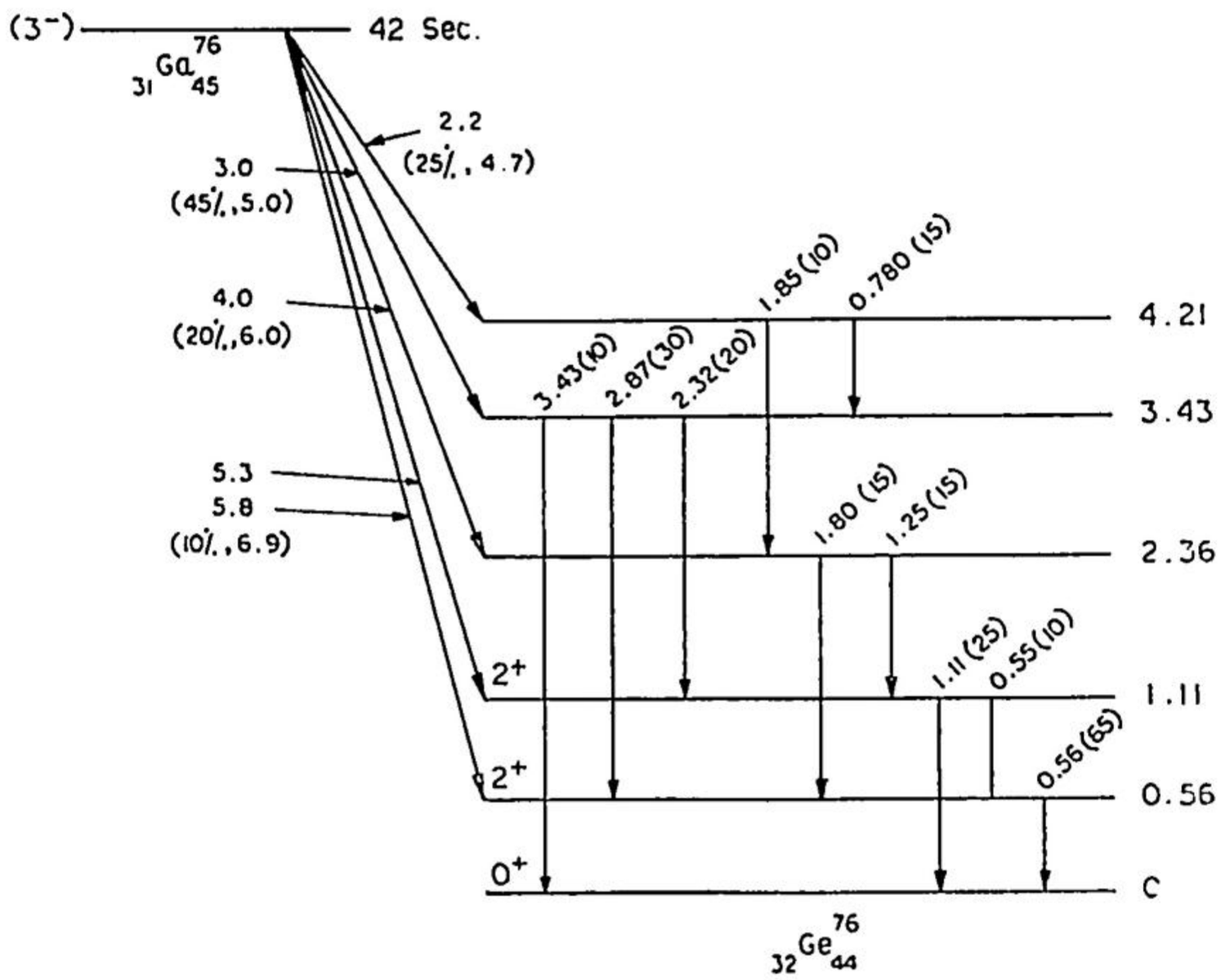

Fig. 1.11

found to be 45 sec. Its decay is investigated with standard scintillation techniques. Beta groups with end point energies at 2.2, 3.0, 4.0, 5.3 and 5.8 MeV were found to decay with a half-life of 45 sec. The gamma spectrum showed gamma rays of energies 0.560, 0.780, 1.110, 1.250, 1.80, 2.32, 2.87 and 3.43 MeV. β–γ and γ–γ coincidence experiments are performed and based on these a decay scheme of ^{76}Ga is proposed.

Publication :

B. Sethi and S. K. Mukherjee, Proc. Nucl. Phys. & Solid State Phys. Symp., Bombay, 1966.

B. Sethi and S. K. Mukherjee

1.12 *Study of (n, p) and (n, α) Reactions*

For improved angular and energy distribution studies in (n, α), (n, p) etc. reactions an emulsion multiplate camera has been designed and is under construction. Suitable collimations for the incident neutron and the emitted particles have been provided. In such a camera the angular distribution for eight angular positions at equal intervals of 10 degrees in the angular range 15° to 165° can be studied. The pure forward and backward directions have been purposefully eliminated to avoid the direct irradiation of the plates by the incident neutrons. Necessity of introducing proper shielding and of maintaining good vacuum inside the chamber has been taken into consideration.

B. Pathak and M. L. Chatterjee

2. BIOPHYSICS DIVISION

2.0 *Introductory Remarks*

The Biophysics Division has been shifted to its new building at Belgachia. A large part of the year has been spent in installing the instruments shifted from the main building of Saha Institute of Nuclear Physics to the Biophysics Laboratory at Belgachia. Some of the instruments e.g. the Electron Microscope of our own make is still in the process of installation at the new site.

Scarcity of funds, particularly foreign exchange, has compelled the Division to curtail its activities in a number of projects. A serious difficulty has been the remoteness of the library, administration and workshop facilities, all of which are located in the main building of Saha Institute of Nuclear Physics, about 3 miles away from Biophysics Laboratory. A transport for the use of Biophysics Division would have helped in solving the communication problem.

The theses submitted by two workers from this Division have been accepted for the award of D.Phil. (Sc.) degree of Calcutta University.

Theoretical and practical teaching in Biophysics Special paper of the M.Sc. courses of Calcutta University is being continued and 10 students have got their M.Sc. degree in 1966 with Biophysics as a special subject of study.

A summary of the research activities of the Biophysics Division is given below :

In the *Electron Microscope* section, researches have been continued on the normal and diseased erythrocytes, on the organization of chromosomal fibres of amphibian erythrocytes and on nuclear organization of ciliated protozoa. DNA from bacteria and other higher organisms have been isolated and electron micrographed both in native and denatured conditions. With a view to develop quantitative electron microscopy of biological objects, mass scattering cross-section of thin films and the response of photographic emulsions to electrons of different energies have been studied in details.

Radiation Biology section was concerned with the elucidation of the mechanism of radiation inactivation of cells. With this object, the effect of thymineless incubation on the sensitivity of the cells to subsequent incorporated P-32 decay (and *vice versa*) was studied. Experiments were also initiated on the synergism of X-rays with ultra-violet radiation in the inhibition of colony formation by cells. Simultaneously with these investigations on the cellular level, comparative studies have been made on the effect of heat, U.V. and X-irradiation on the DNA molecule *in vitro*.

In the *Physical Biology* section, ultracentrifugal, U.V. absorption and autoradiographic studies have been carried out on DNA with particular reference to the changes brought about by denaturation. Interaction of protein molecules with different electron strains has been analysed. The physical changes

brought about by heat and X-irradiation on the ribosomal distribution from yeast cells was the subject matter of another investigation.

In the *Molecular Genetics* section, methods for isolation and characterisation of RNA fractions from *E. coli* extracts have been developed, and are being used to study the messenger RNA turnover, in cells infected with bacteriophage $\phi X-174$. The replicative form (RF) DNA of $\phi X-174$ has been labelled specifically in its either strand, with Bromo-uracil and radioactive phosphorus. The effect of inducing various types of lesions with the help of U.V., X-rays, visible light and P-32 decay, in either strand of such a DNA has been studied. It is suggested that a damaged parental strand is more effective in destroying the biological activity of this DNA. Some success has been achieved in isolating single and double stranded ϕX DNA in pure form and measuring their biological activity.

N. N. Das Gupta
Head, Biophysics Division

2.1 *Electron Microscopy of E. coli DNA*

Native DNA was extracted from *E. coli* B according to Marmur's method. The native DNA showed 40% hyperchromicity on heating, which proved that DNA was in a highly polymerised form. The average length measured from electron micrographs of 100 molecules was $8\,\mu$ which correspondent with a molecular weight of about 16 million.

When the native DNA was stored in low molarity solvent for a number of days, it showed a number of characteristic changes. These were (a) degradation, (b) local separation of the component strands over parts of the DNA molecule, (c) complete separation of the two strands over the whole length of the molecule, and (d) formation of inter- and intramolecular links resulting in net work of DNA.

Publication :

N. N. Das Gupta, M. Sarkar and D. N. Misra, J. Mol. Biol., *15*, 619, 1966.

D. N. Misra, N. N. Das Gupta, S. Bose and P. Sadhukhan, Proc. 6th Int. Cong. Elec. Micr., Kyoto, *II*, 117, 1966.

N. N. Das Gupta and D. N. Misra

2.2 *Electron Microscopic Studies on Normal and Diseased Erythrocytes*

Electron microscopic studies have been made on erythrocytes from normal subjects and from persons suffering from hereditary spherocytosis and thalas-

saemia minor disorders. The ultrathin sections of the thalassaemic cells showed some abnormal features, but those of the spherocytic cells were found normal. The ghosts of the spherocytes were found to be more flexible and thinner than those of the normal cells, whereas those of the thalassaemic cells appeared coarser. Mass-thickness values of the ghosts have been calculated from the measured contrast of their electron micrographs. The total weight of the spherocytic ghost, calculated from the mass-thickness data, was found to be abnormally low, whereas the weight of the thalassaemic ghost was the same as that of the normal ones.

Ultrastructure of erythrocytes from a patient suffering from Hb-E disease (homozygous) is being investigated by electron microscopy. Also the haemoglobin pigment (Hb-E) from these cells has been electron micrographed after metal shadowing (by Hall's pre-shadowed replica technique) to determine its size, shape and ultrastructure.

Publication :

D. N. Misra, J. Chakraborty, N. H. Sarkar and J. B. Chatterjea, J. Roy. Micros. Soc., *85*, 485, 1966.

D. N. Misra

2.3 *Anaphase Structure in Mitotic Cells Typified by Spindle Elongation*

Cells that are typified by anaphase spindle elongation have been chosen from five species (*Ostrinia nubilalis, Periplaneta americana, Tradescantia paludosa, Raphanus Sp.* and *Pelomyxa carolinensis*) and examined by electron microscopy. Filament morphology including diameter of individual filaments is constant throughout metaphase and anaphase within the limitation of the method employed. Filaments have been observed in the interzone in numerous anaphase mitotic figure, although the number of filaments there is less than on the poleward side of the chromosome plates. During late anaphase in these cells, filaments disappear poleward first and then progressively toward the cleavage plane and a disarrangement of filaments may be observed near their ends. Filaments are characteristically in parallel arrays, but definite perpendicular orientations have been observed in several cases. Golgi bodies and mitochondria may persist with largely unaltered morphology throughout division.

This work was carried out in the Department of Biochemistry and Biophysics, Iowa State University, Ames, Iowa, U.S.A., while the author (J. C.) was a post-doctoral Research Associate in the above Department.

Publication :

L. E. Roth, H. J. Wilson and J. Chakraborty, J. Ultra. Res. *14*, 460, 1966.

J. Chakraborty

2.4 *Electron Microscopic Studies on the Macro- and Micro-Nuclei of the Ciliated Protozoa.*

Electron microscopic studies have been made on the macro- and micro-nuclei of *Oxytricha platystoma* and also on their divisional stages.

There are two macro- and two micro-nuclei. The macro-nuclei are very large bodies 18 μ long and 12 μ wide, whereas the micro-nuclei are small, only about 2 μ in diameter. During division, the two macro-nuclei fuse into one elongated mass, which divides into two and each of these again subdivides into two, thus giving rise to four macro-nuclei in one cell. The micro-nuclei divide mitotically. Each micro-nucleus divides only once forming four small bodies inside a single cell. After the cytoplasmic division two macro- and two micro-nuclei go to each daughter cell and give rise to two cells containing two macro- and two micro-nuclei.

Publication :

J. Chakraborty, Proc. 6th Int. Cong. Elec. Micr., Kyoto, *II*, 355, 1966.

J. Chakraborty

2.5 *Organisation of Basic Chromosome Fibrils in Blood Cells of Vertebrates*

A broad project has been undertaken to study the basic chromosome fibrils from blood cells (both R. B. C. and W. B. C.) of different groups of vertebrates from amphibian erythrocytes to human leukocytes. The investigation, so far been done, is the isolation of nucleo-histone fibrils from amphibian erythrocytes. These isolated fibrils have been studied under the Siemens Elmiskop-I at 60 kV.

The thickness of the fiber occurring most frequently ranges from 300 to 400 Å in diameter. Occasionally, however, fibers having a diameter of 50 to 250 Å are also seen. When blood is stored at 10°C for 2 days before electron microscopy, the most frequently occurring fibers have a diameter of 100 Å with a few 40 Å thick ones. The maximum length of the fibers observed in this study is 13 μ. The most interesting observation in this study is that the storage and haemolysis time have an effect on the separation of fibrils at the molecular level.

D. K. Chattoraj, P. Sadhukhan and J. Chakraborty

2.6 *Response of Photographic Emulsions to Electrons for Quantitative Electron Microscopy*

Further work is being continued on the interaction of medium energy

electrons to different photographic films and plates normally used for high resolution electron microscopic pictures.

For the accurate counting of developed grains two more methods were developed. Grain suspensions were mixed with suspensions of known concentration of polystyrene latex spheres, having a mean diameter of 0.783 μ, spread onto formvar or collodion films and counted on enlarged prints of electron micrographs (Siemens Elmiskop-I, magnification $\sim 5000\times$), according to the procedure of Backus and Williams. Grains were also counted in situ using oil immersion and an objective with a numerical aperture of 1.32 at a magnification of 1,875×. A small square in the reticle of the ocular corresponded to 25 μ^2 emulsion area. Grains were counted by slowly focussing through the thickness of the emulsion at randomly chosen fields of view. This method was employed to minimize the effects of clumping which could not be avoided otherwise. Grain counts from these independent approaches agreed to within 20%. The average values were taken for subsequent analysis. The following observations have been made :

1. Yield of grains per electron for different films and plates,
2. Speed and sensitivity of emulsions, and,
3. Minimum magnification required for high resolution electron micrographs.

With these data so far obtained the nature of films and plates most suitable for high resolution electron microscopy could be inferred.

Publication :

P. Sadhukhan and J. Chakraborty, Proc. 6th Int. Cong. Elec. Micr., Kyoto, *I*, 277, 1966.

P. Sadhukhan

2.7 *An Analytical Expression for the Mass-Scattering Cross-Section of Carbon*

The mass-scattering cross-section S_t of Carbon has been represented by an analytical expression of the form $S_t = -(m \log_{10}\theta + C)$, where θ is the scattering angle and m and C are constants that depend on the electron energy. The expression is valid for the angles of 10^{-3} to 10^{-2} rad and 40 to 100 kV.

Publication :

N. H. Sarkar, J. Appl. Phys., Aug., 1966.

N. H. Sarkar

2.8 *Mass-Scattering Cross-Section of Thin Carbon Films*

Mass-scattering cross-sections of thin carbon films have been determined experimentally for 60 and 80 kV electrons at the scattering angles of 2.23×10^{-3},

4.25×10^{-3}, 9.76×10^{-3} and 1.86×10^{-2} rad. This was done by densitometric determination of the contrast in the electron microscope negatives of thin carbon films of known mass thickness, on the basis of a rigorous contrast-density relationship. These experimental results and those due to Leisegang, Lippert and Komoda have been compared with the values calculated from the theories of Lenz, of Burge and Smith, and of Sarkar. The experimental results are found to agree quite well with the theory of Sarkar.

Publication :

N. H. Sarkar, J. Appl. Phys., Nov., 1966.

N. H. Sarkar

2.9 *Installation of the Electron Microscope in the New Laboratory at Belgachia*

After the shifting of the Biophysics Division from 92 Acharya Prafulla Chandra Road to the new building at Belgachia, most of the instruments which were originally installed and functioning at the former address had to be reinstalled at the new site. Out of these only the installation of Ultracentrifuge and Siemens Electron Microscope could be completed during the last year. Work of the reinstallation of the other electron microscope of our own make, which also had to be dismantled and shifted to the new buildings, is still continuing.

M. L. De

2.10. *Radiation Sensitivity of E. coli during Thymineless Death*

Complementation in the death caused by thymineless incubation and that by X-irradiation in case of *E. coli* 15 $T^-A^-U^-$ has been reported earlier (Annual Report 1965). These investigations have been extended to study the influences of incorporation of P-32 decay on the thymineless death of the cells and *vice versa*. *E. coli* 15 $T^-A^-U^-$ were labelled by growing them in the presence of P-32. They were washed free of radio activity and nutrients, and allowed to undergo thymineless incubation and stored in cold to study their susceptibility to incorporated P-32 decay.

Fig. 2.10.1 shows the survival of the cells due to the incorporated P-32 decay. It may be seen that the sensitivity of the cells to incorporated P-32 decay increased with increasing amount of thymineless incubation. The increase is

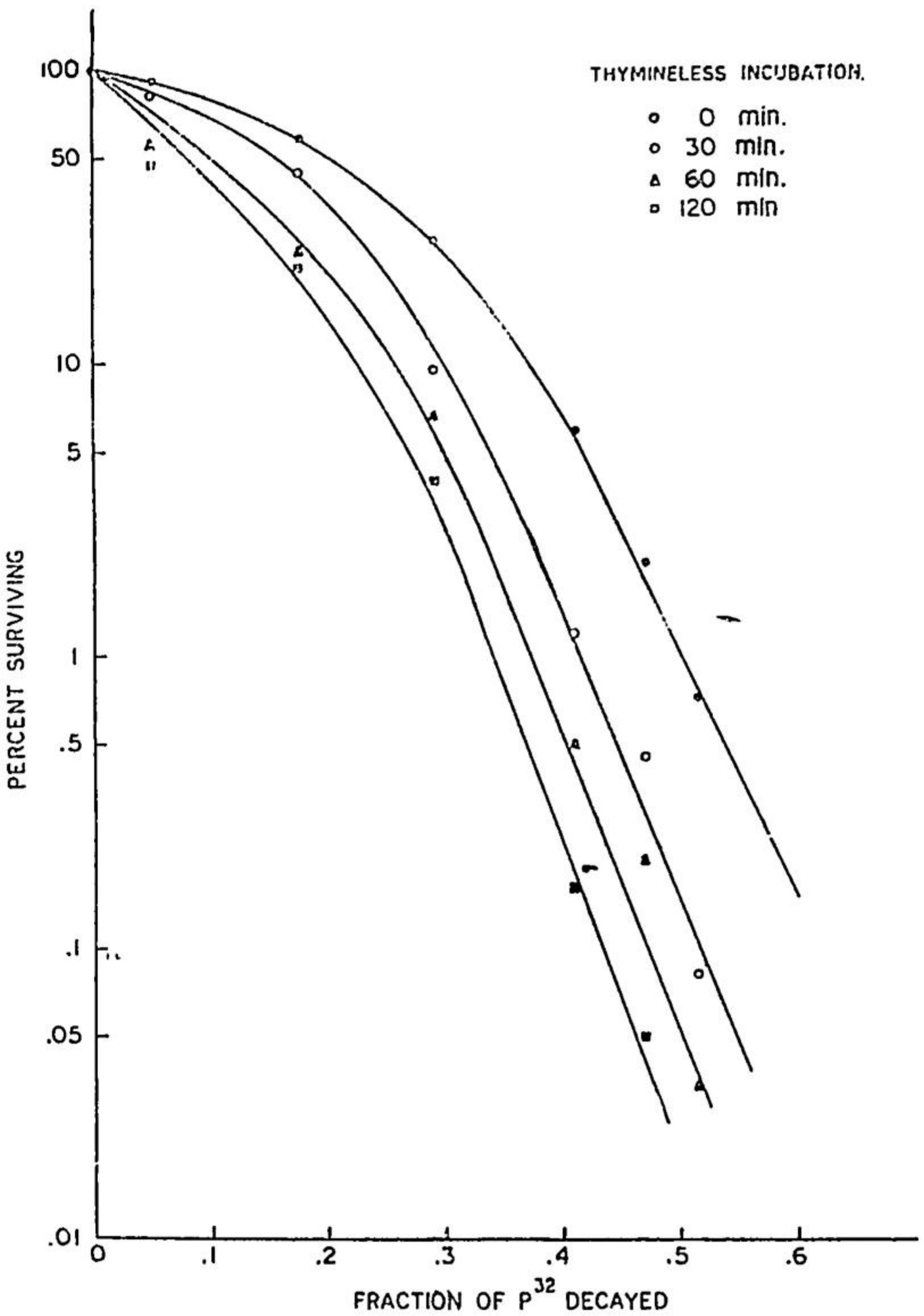

Fig. 2.10.1

faster during the first 60 minutes of thymineless incubation than that during the later period, indicating a variation of the radiation sensitivity at the different stages of thymineless death.

Fig. 2.10.2 shows the results of the reverse study, *viz.*, the influence of incorporated P-32 decay on the susceptibility of the cells to thymineless incubation. The graphs show that with the increasing amount of incorporated P-32 decay, the lag period in the thymineless survival curve gradually vanishes and also the slope increases.

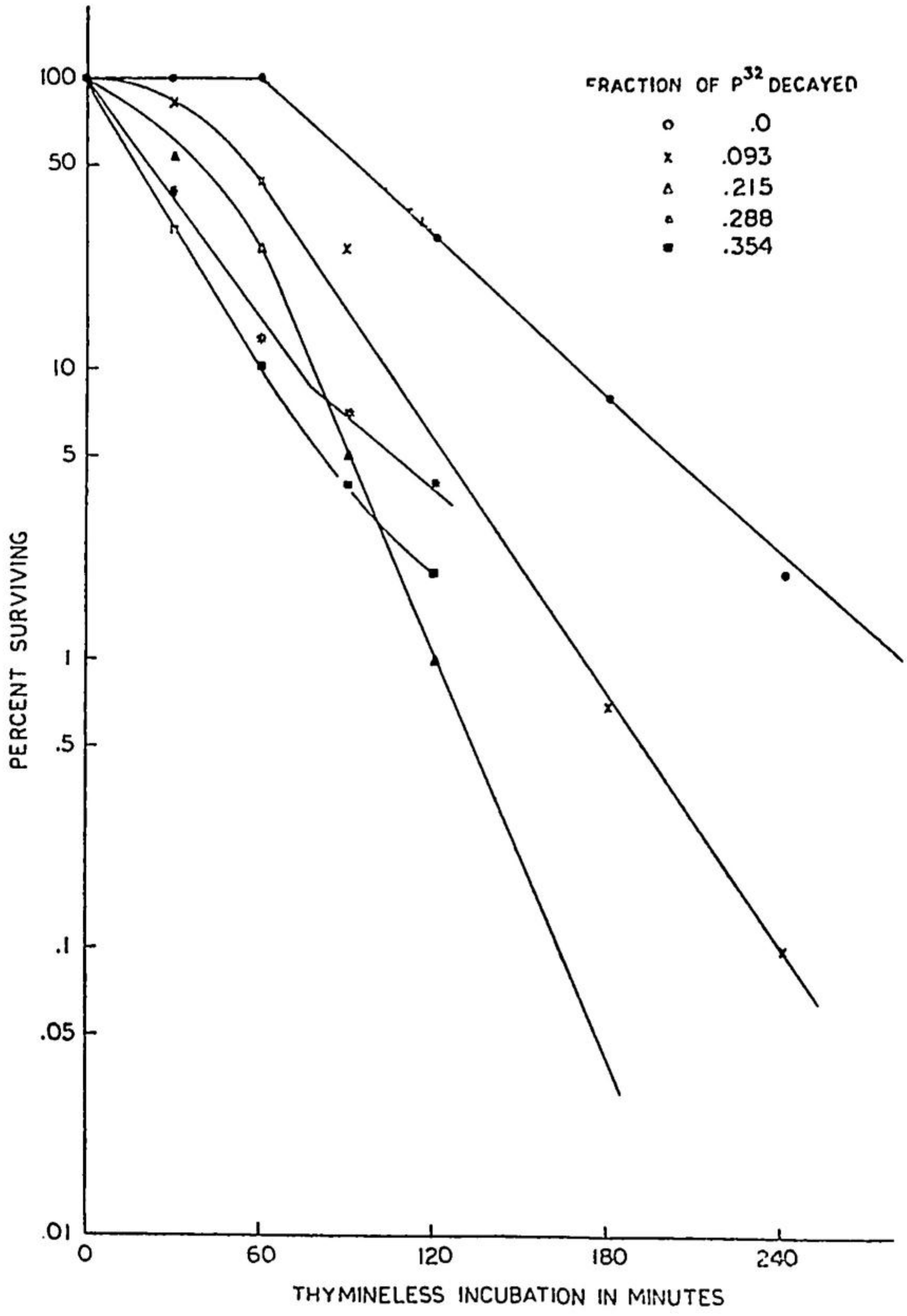

Fig. 2.10.2

These studies indicate a complementation between the effect of incorporated P-32 decay and the thymineless incubation. Hence it can be concluded that the death caused by thymineless incubation, X-rays, or incorporated P-32 decay must have a common site of action. Since death due to incorporated P-32 decay is due to the action on DNA, DNA may be that common site of action.

Publication :

1. N. Ganguli and S. B. Bhattacharjee, Radiation Research, *29*, 445, 1966.

2. S. B. Bhattacharjee and N. Ganguli, Second International Biophysics Congress, Vienna, 1966.

S. B. Bhattacharjee and Nati Ganguli

2.11 *Interaction of X-rays and Ultraviolet Rays in Cell Killing*

Both X-rays and Ultraviolet rays are independently capable of killing cells; but the mechanism of such inactivation is not known. It is possible that the radiations kill the cells by interfering with the cellular DNA, the genetic material. If the sites of action for X-rays and U.V. rays on cells overlap even partially, then synergism between these agents in causing cell death is expected. We have observed such synergism between X-rays and U.V. rays in causing the inactivation of *E. Coli B*.

Fig. 2.11.1 shows the X-ray survival curves for the bacteria, previously exposed to various doses of ultraviolet radiation. It may be observed that with increasing doses of pre-irradiation, cells become more sensitive to X-rays. How-

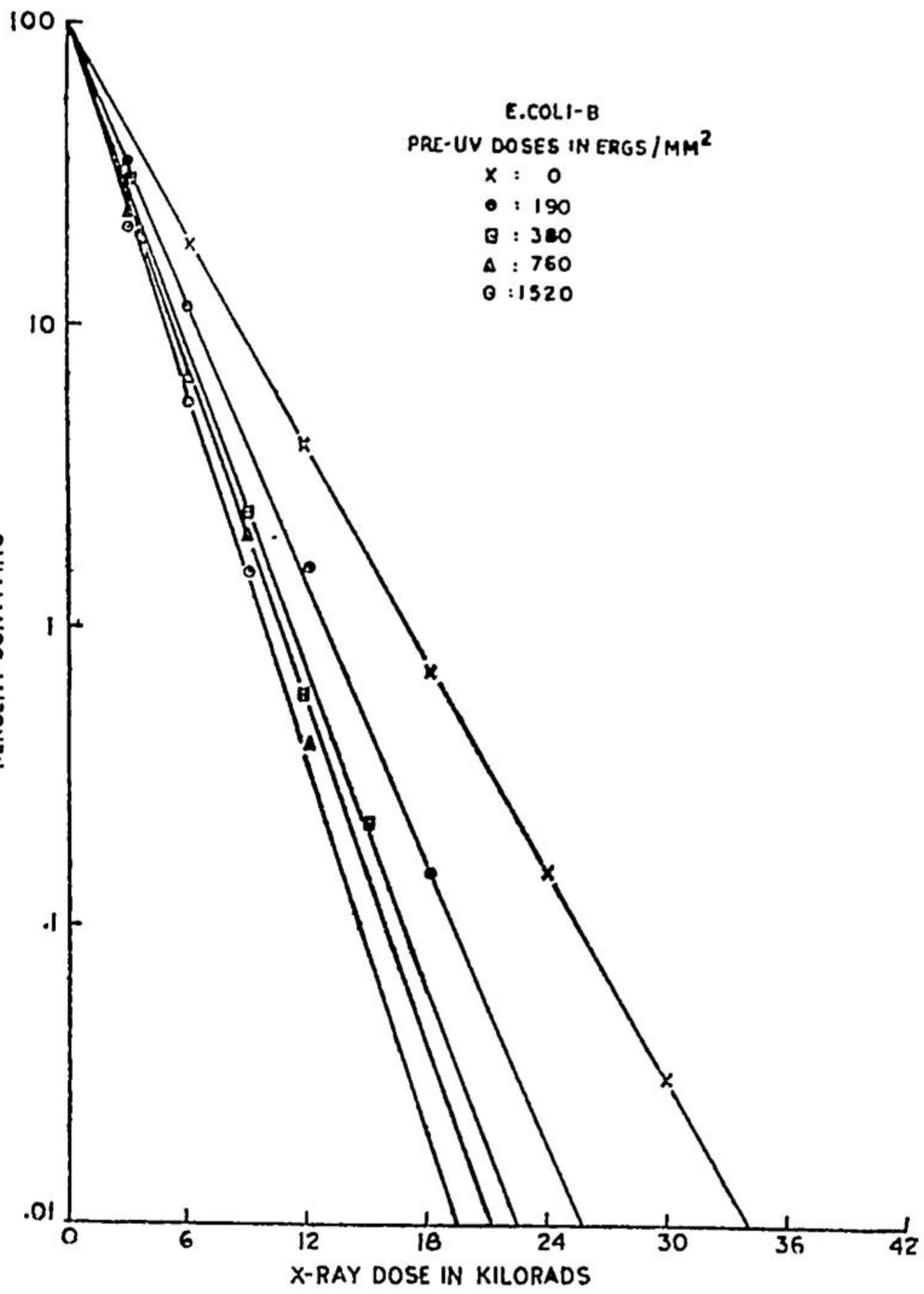

Fig. 2.11.1

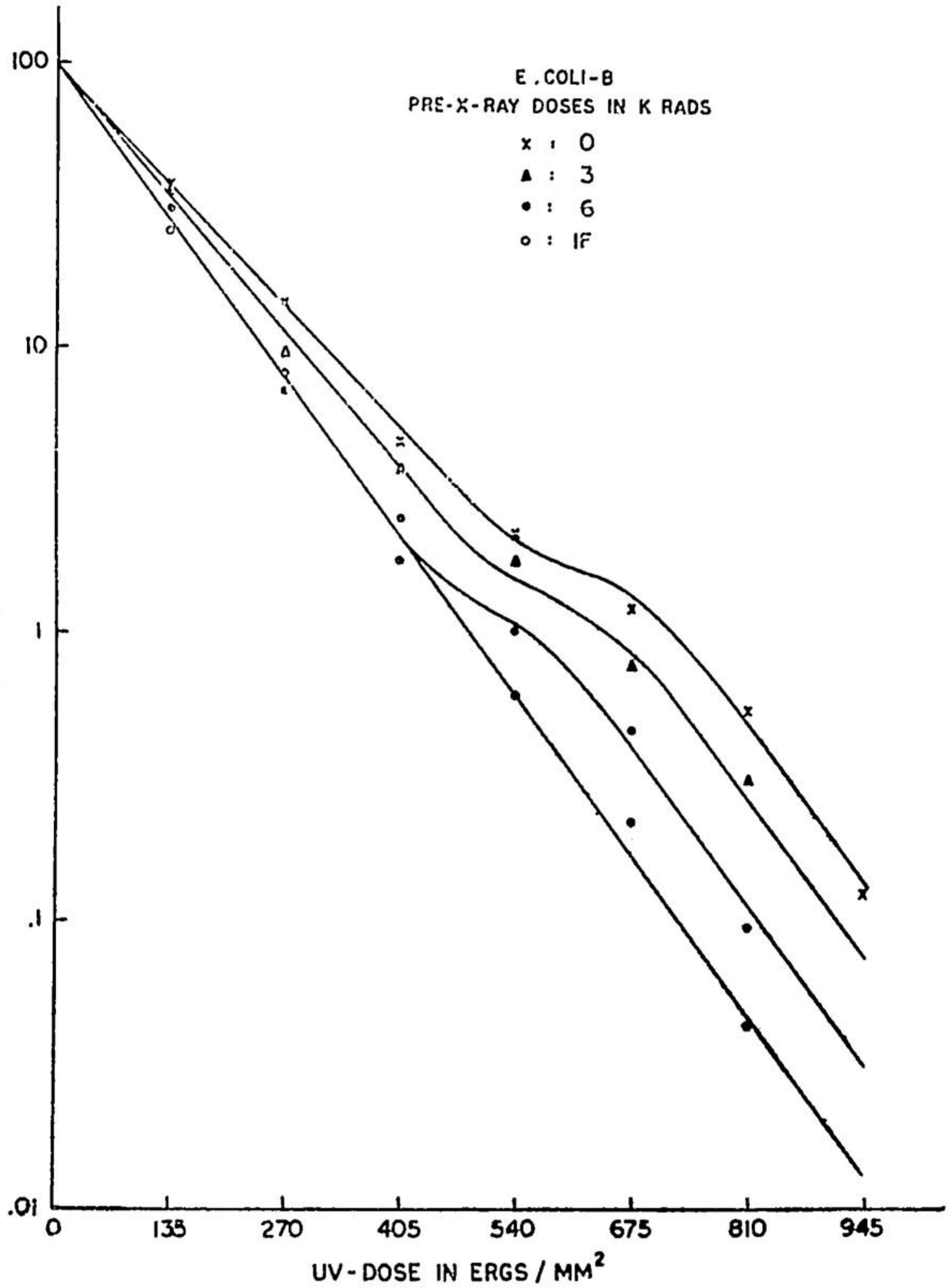

Fig. 2.11.2

ever, the sensitivity reaches a maximum value and thereafter there is no change in sensitivity due to the increase in the previous U.V. exposure.

Fig. 2.11.2 shows the influence of previously exposing the cells to different doses of X-rays on the sensitivity to ultraviolet irradiation. Ultraviolet survival curve of the untreated cells has a bend in the survival range of 2 to 1%. Pre-X-ray exposures help in removing this bend and also in increasing the slope of the survival curve above the 2% survival region. But the slope after 1% survival region remains the same for treated and untreated cells. Ultimately when the bend has vanished due to pre-X-ray exposure, the slope reaches a maximum limiting value and is equal to the slope of the survival region below 1%. There-

after, no increase in the slope of the survival curve is observed, due to increase in pre-X-ray exposure dose. The pre-U.V. dose at which maximum X-ray sensitivity is reached, corresponds to the survival, at which the bend in the U.V. survival curve disappears.

Further experiments are in progress, but these results indicate that in the inactivation caused by X-rays and U.V. rays there are other sites of action besides DNA of the cell.

Publication :

S. B. Bhattacharjee and G. Bhaumik, Molecular Biology Session, Benaras, 1966.

S. B. Bhattacharjee and G. Bhaumik.

2.12 *Comparative Studies on the Effect of Heat and X-radiation on DNA*

Investigations have been carried out on the changes in the conformation of the DNA molecules from *E. coli,* when subjected to heat and X-rays. Electron micrographs of such DNA showed that there was a characteristic difference in the mode of denaturation of the molecule caused by heat and X-radiation. Heating DNA at 100°C produced degradation of longer molecules into smaller lengths, and aggregation of neighbouring polynucleotide chains leading to branched structures. X-irradiation, on the other hand, produced local breaks cross-linking and extensive net-works.

Madhuri Das

2.13 *Conformational Changes in Denatured DNA*

DNA from *E. coli* B was denatured by heat and storage in low molarity solvents. It was observed that heating of DNA at Tm and subsequent cooling either rapidly or slowly, without the presence of blocking agents (e.g. HCHO), produced little change in the optical absorbance and a small decrease in the sedimentation coefficient. Heating in the presence of 1% formaldehyde gave 40% hyperchromicity but the change in S-value gave evidence in favour of aggregation. Heating of DNA well above Tm ($\sim$ 100°C) resulted in degradation, hyperchromicity was 40% and the S-value was reduced.

On storage, it was found that appreciable rise in the optical density took place at 37°C, 14°C and even at 0°C. The effect is more pronounced at low concentration of the solvent or solute or both. The change in $S_{20,w}$ was undetectable for the first few days, then it had a tendency to decrease in low molarity

solvent. It appeared that in the initial stage, though the hydrogen bonds were progressively rupted as was evidenced by the continuous increase in O.D., the twin-strands did not separate from each other. As a result, no great change in conformation, as can be detected by sedimentation analysis, occurred.

In course of these investigations on absorption peak for DNA at 206 mμ was obtained. This peak was more sensitive than the conventional peak at 258 mμ for denaturation studies. This 206 mμ peak was obtained at the same position for DNA's from a variety of sources at different concentrations of DNA dissolved in different molarities of Na^+.

Samarendra Basu and Buddhadeb Bagchi.

2.14 *Grain Yield of Tritium in Kodak AR-10 Emulsion*

The study of *E. coli* DNA molecules with the technique of autoradiography with H^3-thymidine has been continued. An estimate of the grain yield of tritium has been made.

In autoradiography with tritiated biochemicals, absolute quantitation is difficult owing to the very low energy of the tritium β-rays (mean energy = 5.6 keV.). Only a few of the emitted β-particles can hit the emulsion, the geometric efficiency is low and variable. Hughes, Bond, Brecher, Cronkite, Painter, Quastler & Sherman (1958) claimed a geometric efficiency of 2% for sections, 5% for smears and 20% for micro-organisms. Apart from geometric efficiency, the number of tritium β-particles that must hit the emulsion in order to produce a photographic grain must also be known. As a labelled locus of known geometric efficiency and known number of incorporated tritium atoms, we have chosen *E. coli* DNA molecules, labelled with thymidine-methyl-H^3. In this case, the amount of incorporated tritium can be calculated and the efficiency may be taken as 50% since the molecules are in intimate contact with the photographic emulsion and half of the emitted β-rays will be absorbed by the millipore filter paper on which the DNA is collected.

A thymineless strain, *E. coli* 15 T^-, having requirements of several amino-acids and nucleotides besides thymine, was used. For labelling a small inoculum of bacteria, taken from a logphase broth culture was diluted 100 fold in M-9 medium, supplemented with 2 μg/ml of thymidine-methyl-H^3 (specific activity-3C/mM) and other requirements in the non-labelled form. After 18 hrs. of growth at 37°C, the bacteria were centrifuged and washed thrice in PO_4 buffer. The DNA was isolated and autoradiographed according to the method of Cairns (1963). The exposure was 75 days at 4°C in an atmosphere of dry CO_2.

The grain intensity, i.e., the number of grains/micron of DNA was 0.83. The total number of grains counted was 1080 over a length of 1300 μ of DNA.

If N* be the number of tritium atoms per mM of thymidine, whose activity is A C/mM, then it can be shown that

$$N^* = 2 \times 10^{19} \text{ A.}$$

Under the assumption that there is only one tritium atom per active thymidine molecule, the number of radioactive thymidine molecules is also N*. Since one mM of thymidine contains 6×10^{20} molecules of thymidine, the ratio of non-radioactive molecules to active molecules, is 30/A.

Number of base pair per μ of DNA is $10^4/3.46$ or 2.9×10^3. If for any DNA A-T/C-G = 1, the number of thymine molecules per μ is 1.45×10^3. Out of these, the number of labelled thymidine molecules is 48 A per μ.

Tritium decays at the rate of 0.016% per day. Let T_d be the number of days of exposure which results in a grain intensity of $\overline{g}$ per μ. If x beta particles must hit the emulsion to produce a grain, then

$$\overline{g} = 3.84 \times 10^{-3} \text{ A } T_d/x$$

assuming that only 50% of the emitted beta rays have a chance of hitting the emulsion. If $\overline{g}$ is measured and A, T_d are known, x may be calculated from the relation $x = 3.8 \times 10^{-3}$ A $T_d/\overline{g}$.

In Table 2.14 the values of x calculated from the results of Cairns (1963) and the present experiments are compared.

TABLE—2.14

Author	$\overline{g}$ (gr/μ)	T_d (Days)	A (C/mM)	$(T_d A/\overline{g})$ 10^{-3}	x
Cairns	1.80	60	10	0.33	1.25
Present	0.83	75	3	0.27	1.03

The values of x agree and the results show that one tritium β-particle is sufficient to produce a photographic grain in AR-10 emulsion. Therefore the labelled molecules with a grain density of 0.83 gr/micron represent a DNA which is fully labelled in both strands.

Samir Kumar Sarkar.

2.15 *Negative staining of Protein Molecules*

The interaction of solutions of phosphotungstate of different pH values with bovine plasma albumin, egg albumin and γ-globulin has been investigated. With decreasing pH, this interaction has been found to cause a progressive increase in the sedimentation coefficient of each of these proteins. With bovine

plasma albumin the sedimentation coefficient is higher in the entire pH range 4.0-9.0, while for egg albumin and γ-globulin the sedimentation coefficients increase below pH 6.5 and 7.5, respectively. It has been concluded that interaction with phosphotungstic acid leads to aggregation of the protein molecules. This interaction has been observed to be less at high concentration of the protein and at a low concentration of the proteins and at a low concentration of phosphotungstate.

A correlation between the amino-acid composition of the proteins and the characteristics of their interaction with phosphotungstate has been suggested.

Publiction :

P. Ganguli, Biochim. Biophys. Acta, *112*, 565, 1966.

P. Ganguli.

2.16 *Influence of Heat on the Stability of the Ribosomes in Yeast Extract*

In this work, the crude extract containing ribosomes prepared from yeast was heated to different degrees of temperature. The changes induced by heating were studied with the help of the ultraviolet absorption spectrophotometry and the sedimentation analysis.

The U.V. absorption curve of the ribosomes in the crude extract at room temperature (30°C) had an absorption maximum at 259 mμ and the minimum at 240 mμ. The ratio of the optical densities at 259 and 240 mμ was 1.38. It was found that the optical density of the extract at 259 mμ increased with the increase of temperature. The change was small up to 50°C, then a rapid change occurred between 50 and 80°C. The maximum increase in the optical density at 259 mμ was about 35% over the value at room temperature.

Up to a heating temperature of 50°C, there was no change in the sedimentation pattern of the extract; but there was a slight fall in the concentration of all the components as judged from the areas under the different peaks. When the extract was heated to 55°C-60°C, the clear solution immediately became turbid and a white precipitate appeared. The ultracentrifugal pattern of the supernatant showed only the 6 and 20S components, while the components from 40 to 80S had disappeared. Heating to 80°C and run made with the supernatant showed the absence of all sedimentable peaks from the pattern.

These experiments showed that the crude extract was much more stable in comparison with the purified ribosomes, where dissociation occurred even after heating at 37°C. This stability was due to the presence of cofactors in the crude extract which were heat stable.

Sheela Mukherji

2.17 *Effect of X-radiation on Ribosomes of Yeast Cells*

The effects of X-radiation on the various cytoplasmic components of yeast cells have been studied.

Three sets of experiments were done. In all cases about 2×10^8 log-phase cells, contained in 5 c.c. normal saline, were irradiated in cold with the desired dose of X-rays. Parallel control experiments were made with about the same number of cells kept in ice. The irradiation and the subsequent treatment of the cells were made according to the details given in the columns 2 and 3 of the following table.

TABLE—2.17

Experiment	Dose of irradiation in kilorads	Treatment of the cells after irradiation and before preparation of the extract.
(a)	0	
(b)	176	Cells collected immediately after irradiation.
(c)	0	Cells suspended in phosphate buffer 0.002 M $KH_2PO_4 - K_2HPO_4$ (1 : 4) + 0.001 M $MgSO_4$ for 5 hrs at room temperature.
(d)	176	
(e)	0	
(f)	4.4	Cells allowed to grow in the nutrient medium for 5 hrs. at room temperature.
(g)	8.8	
(h)	17.6	
(i)	52.8	
(j)	79.2	

After the treatment, the cells were collected, washed and crushed with the buffer 0.002 M $KH_2PO_4 - K_2HPO_4$ (1:4) + 0.001 M $MgSO_4$. The crude extract freed from all unbroken cell, cell debris etc. was examined in the Spinco model E Analytical Ultracentrifuge at room temperature.

In the extract made from log-phase yeast cells, the amount of the 80-S component was always greater than that of the 6-S component. The other intermediate size groups were present in small quantities (Expt. a).

No significant change was observed in the ultracentrifugal pattern when the extract was made from the cells immediately after radiation (Expt. b) or after incubation in phosphate buffer for 5 hours following radiation (Expts. c, d).

With the increase of the X-ray dose there was a gradual decrease in the

amount of the 80 – S component compared with that of the 6 – S component provided the cells were allowed to grow for another 5 hours after radiation (Expts. e – j). With this decrease, however, the amount of 40 – S and 60 – S components did not increase, hence there was no dissociation of the 80 – S group.

The diminution of the 80 – S content in the experiments (e – j), therefore, indicated hampering of the protein synthesizing capacity of the cells due to the action of X-radiation. The radiated cells replicated for two or three times, after which the division stopped. This inhibition in cell division may be partly due to the fall in the power of the cells to synthesize protein.

Nandini Ghosh.

2.18 *Isolation and Characterisation of RNA Fractions*

Methods have been developed to extract RNA from *E. coli* cells and to fractionate total RNA into ribosomal (23 s and 16 s) and transfer (4 – 6 s) RNA moieties by means of chromatography on Methylated Albumin-coated Kieselguhr (MAK) and sedimentation in sucrose density gradient with the help of preparative ultracentrifuge. Total RNA was isolated by treating the crude extract of alumina ground cells with freshly distilled phenol and precipitated with alcohol. Separated ribosomal and transfer RNA fractions were placed individually on three MAK columns and were found to be eluted at the expected NaCl molarities. Similarly when the different RNA fractions were contrifuged individually, they were located at their expected positions in the density gradient

Methods for the determination of base composition of various RNA fractions after alkali hydrolysis, by means of ion exchange chromatography in Dowex columns are being developed.

S. Pal Chaudhury and R. K. Poddar

2.19 *Messenger-RNA Turnover in Cells Infected with Bacteriophage ϕX-174*

Log-phase *E. coli* C cells were given a 2 minute pulse of ^{32}P at 30°C in a synthetic medium. Pulse was terminated by adding 50 times more non-radioactive phosphorus to the medium and the radioactivity "chased" during subsequent growth of the cells by measuring ^{32}P counts in the various RNA fractions obtained from the MAK column and sucrose density sedimentation analysis. The time of transfer of radioactivity from the unstable RNA to stable RNA moieties is a measure of the rate of messenger RNA turnover. For uninfected cells this time has been found to be about 15 min at 30°C. Experiments in progress indicate

that infection of the cells with ϕX-174 brings about significant changes in the time of such transfer.

R. K. Poddar and S. Pal Chaudhury

2.20 *Nucleic Acid Synthesis in ϕX-infected E. coli Cells*

Nucleic acid synthesis in ϕX-infected cells was compared with that in uninfected ones by measuring the TCA-insoluble ^{32}P counts in the two cases at various stages of growth period. It was found that chloramphenicol depressed ^{32}P-incorporation to a greater extent in the infected complexes. When the complexes were formed by infecting normal cells with UV-irradiated ϕX there was no difference in ^{32}P incorporation in the infected and in the uninfected cells if the cells were kept in visible light. If kept in dark, depressed nucleic acid synthesis in the infected cells was observed as before. Causes of this peculiar behaviour are under investigation.

S. Pal Chaudhury and R. K. Poddar

2.21 *Labeling of Specific Strands of a DNA Double Helix*

The DNA of bacteriophage ϕX-174 exists as a single polynucleotide strand in its cell-free state but assumes the usual double stranded form, usually called RF DNA, when it enters the host cell. This fact has been utilised to specifically label the two strands of this RF DNA with ^{32}P and Bromouracil (BU).

Method of labeling with ^{32}P was described in the last year's report. BU-labeled ϕX-174 was prepared using *E. coli* CR (a thymine-requiring strain of *E. coli* C, a gift from Prof. R. L. Sinsheimer) as host bacteria and adding bromodeoxyuridine (BudR) instead of thymidine in the growth medium. Normal phages were obtained by infecting and growing CR cells in presence of thymidine. Average burst size of BU-labeled phage was about ten times less than that of normal, thymine-containing phages, although the latent period was not very much affected.

BU-labeled phages were more sensitive towards irradiation with UV, X-rays and visible light (2×40 fluorescent lamps)—two times in the case of UV-light and three times in the case of X-rays. Normal phages were practically resistant to visible light while only 37% of BU-labeled phages survived 2 hours' exposure.

When ^{32}P or BU-labeled phages were allowed to infect normal cells growing in normal medium (in presence of chloramphenicol to prevent formation of

mature phage), complexes containing RF DNA with labeled parental strand were obtained. Infection of cells growing in ^{32}P or BU-medium under identical conditions for several generations with normal phages provided complexes containing RF DNA with labeled complimentary strand.

B. Datta and R. K. Poddar

2.22 *Relative Biological Importance of Two Strands of a DNA Molecule*

ϕX-infected *E. coli* cells described in the previous sections offered a means of testing the effect of inducing various types of lesions specifically in either strand of the RF DNA. When the labeling was done with Bromouracil (BU), it was found from UV-and X-irradiation experiments on the above complexes that the RF was rendered more sensitive when the susceptible label (BU) was in the parental strand, irrespective of the fact whether the complimentary strand contained the label or not. Suicide experiments on the complexes containing ^{32}P on either strand of RF DNA also suggested that the beta decay occuring on the parental strand of the RF was more effective in inactivating their plaque forming ability.

R. K. Poddar and B. Datta

2.23 *Isolation of Single and Double Stranded Forms of ϕX-DNA and their Biological Assay*

High-titer ϕX lysate was prepared by ammonium sulphate precipitation and subsequent recovery with borate buffer. Experiments are being done to concentrate ϕX in the lysate with the help of mangesium pyrophosphate gel. Single stranded ϕX DNA was obtained by treating the ϕX suspension with freshly distilled phenol.

To obtain double-stranded RF DNA, cells were infected at high multiplicity with ϕX-174 and allowed to grow for 30 min in CM. Complexes were then lysed with EDTA-lysozyme. RF DNA was isolated from the lysate on MAK and on Hydroxy apatite columns. Attempts are in progress to purify RF DNA by removing the contamination of host DNA.

Bacterial protoplasts have been made by EDTA-lysozyme treatment in presence of sucrose. Such protoplasts have been successfully infected with single and double stranded DNA so as to produce regular phage plaques on agar plates. Technical improvements are being made to use this method as a quantitative biological assay of DNA of bacteriophage ϕX-174.

U. Choudhury and R. K. Poddar

3. DIRECTOR'S RESEARCH GROUP

3.0 *Introductory Remarks*

The aim of this group is to introduce and develop techniques and branches of research in the Institute and to integrate them with the general research programme of the Institute at an appropriate stage. The activities are, at present, confined to radiation biology and plasma physics.

The low level tracer work which was initiated several years ago has been applied to a number of bio-medical cases. A development programme on 4π counter has been undertaken. The effects of internal irradiation by I^{131} and P^{32} have been studied in rats. The work in radiation biology appears to be sufficiently mature, so as to consider its integration with that of the molecular biology and crystallography section.

The work in plasma physics has been developing into various channels, viz., study of plasma ion sources, plasma diagnostics, investigations on plasma instability, development of semiconductors for the study of plasma in solids, etc. Although the work is advancing, the projects, mostly in their initial stages, still need a considerable amount of attention, encouragement and effort.

In addition, a small beginning has been made to study some of the problems of electrostatic high voltage generation.

B. D. Nagchaudhuri
Director.

A. Radiation Biology

3.1 *Low Dose Tracer Investigation in Biomedical Tracer Problems*

The problems currently in progress are those with radioisotopes like DFP^{32}, I^{131} and Fe^{59} in medical problems with the collaboration of a couple of Medical Institutions. Recently DFP^{32} has been obtained and measurements on the red cell life span is in progress on the thalassaemia patients at the Calcutta School of Propical Medicine.

Publication :

1. P. Hosain, F. Hosain and C. L. Mukherjee, J. Obst. Gynec. India, *16*, 1, 1966.
2. F. Hosain and C. A. Finch, Acta Medica Scand. Suppl. *445*, 256, 1966.
3. F. Hosain, Proc. 2nd. Int. Biophys. Cong., Vienna, Sept. 1966.

F. Hosain

3.2 *A Study on the Low Background 4π Counter*

In an attempt to have high efficiency counting equipment with low background, a windowless 4π counter has been constructed out of perspex. Its threshold potential is 975 volts and it has a plateau of 125 volts with a slope of 2.5% per 100 volts. Its background is comparable to that of a conventional counter. A well-type scintillation counter has been set up to operate along with a single channel pulse height analyser. This would be very useful in tracer work with gamma emitting isotopes. A photographic-type polarograph has also been set up.

K. B. Udupa

3.3 *Preparation of Thin Conducting Sample Holders for 4π Counter*

A test 4π counter was constructed and various preliminary tests were carried out. Attention was focused to have extremely thin sample holders for the 4π measurements of radioactive specimens. These are normally achieved by preparing stretched collodion films. To make it conducting, impregnation with carbon, silver, etc. were attempted. This system will be utilized in tracer work on the fibril system of paramecium.

K. B. Ududa and S. Mukherjee *

* Now at IIT, Kanpur.

3.4 *A Set-up of Low Level 4π Counter and its Use as 2×2π Counter for Low Dose Double Tracer Work*

The development of a low level 4π counter is under progress. This would be compared with the few existing designs to ascertain the suitability of its efficient conversion into two 2π counters. This would, then, enable to solve problems not only where a 4π counter is required to commission but also in double tracer work. It would be convenient to carry out tracer work in various physical, chemical and biological problems, using simultaneously two isotopes at reduced doses.

K. B. Udupa, F. Hosain and B. D. Nag

3.5 *A Study on Multiple Tracer Technique with Special Reference to Hematological Problems*

Multiple tracer technique has got a great deal of advantages over the simple tracer work, particularly in diagnostic and investigative problems in human subjects. The technique becomes complicated but it is gaining importance as it can provide better information in a shorter time. If the investigations are carried out one after another, it would cause unnecessary delay for the patient to undergo proper treatment. Several investigations have already been carried out with conventional and also with low level counters with double tracers in blood volume determinations. A similar work on red cell life span is in progress.

P. Hosain, F. Hosain and B. D. Nag

3.6 *Studies on the Riboflavin Deficiency in Rats*

Radioactive tracer studies were started on riboflavin deficiency rats using P^{32} and Fe^{59}. The riboflavin deficient rats has a tendency to accumulate more P^{32} in the body, and in case of Fe^{59} the depositions were more in liver and spleen. A study was completed on the protein metabolism in muscle of riboflavin deficient rat with the help of $2-{}^{14}C$--glycine. This indicated a low rate of protein synthesis in muscle.

Publication :

S. C. Jamdar, K. B. Udupa and A. Chatterji, Naturwiss, *53*, 408, 1966.

S. C. Jamdar, and K. B. Udupa.

3.7 *Effect of P^{32} Radiation on the Hematopoiesis of Rats*

The investigation was started a few years ago to study the effect of internal irradiation by varying doses of P^{32} on the hematopoietic tissues of rats. Studies covered the aspects of hemogram, bone marrow analysis and DNA-RNA fractionization. Some of the aspects of the study have been completed and at present the experimental activities in this line have been slowed down.

Publication :

S. K. Lahiri, K. B. Udupa, S. C. Jamdar and D. N. Banerji, Ind. J. Exp. Biol. *4*, 95, 1966.

S. K. Lahiri, K. B. Udupa, S. C. Jamdar and D. N. Banerji

3.8 *Studies on Cockroaches with Radioisotopes on Hemolymph*

The study was undertaken on the hemolymphs of the insects. It has been found that the hemolymph inside and outside the heart carries different concentrations of inorganic ions like sodium, chloride, phosphate, iodine and iron. The difference in anionic concentration was more pronounced. The study has also been extended on the protein composition of the fluids. The use of paper electrophoretic technique has indicated that the protein composition of the two fluids is actually different.

S. K. Lahiri and S. R. Basu

3.9 *Studies on the Different Doses of Radioiodine on the Thyroid by Serum Electrophoresis*

The effect of varying doses of iodine-131 on the thyroid function was carried out on rats earlier. Further studies were undertaken with chromatographic and electrophoretic techniques to understand the changes that underwent in thyroid function with different doses of iodine-131. An extensive electrophoretic work has been carried out on the rat serum following I^{131} administration, and the data are under processing.

S. R. Basu and S. K. Lahiri

3.10. *A Study on the Gastro-Intestinal Absorption of I^{131}-Labelled Albumin in Rats*

This study was initially carried out a few years ago. However, the data were not thought statistically significant enough to publish. At present the study is being repeated. The method is based on the determination of the initial blood isotope level following the oral administration of I^{131}-albumin. The results indicate that the absorption of protein by rats is very much low compared to human subjects.

S. R. Basu, R. Bhattacharya and F. Hosain

B. Plasma Physics

3.11 *Extraction of Electrons and Ions Simultaneously from a Duoplasmatron*

In Ion Engines used as thrust devices, it is required that the source of the propellant must work under charge neutralised condition. In general practice, only ions are extracted from the ion source and electrons produced separately are injected into the ion beam in an equal amount.

However, the requirement may be met by an arrangement in which electrons and ions are extracted simultaneously from a common plasma source.

Taking a duoplasmatron as the plasma source, different types of emitter-extractor system are under investigation for the latter type of operation. In one particular case ion and electrons have been drawn at an angle of about 45° from the axis from an expanded plasma having two emission openings (1 cm diameter). One set of typical double extraction data is : 3mA of argon ion-current by −6 kV, together with about 50 mA of electron-current by about +500 V from a 2 amp arc. The value of T_e of plasma measured by probe is about 3×10^5°K. This arrangement has the advantage that the extracted electrons may be re-injected into the ion beam for neutralisation purpose, and no separate electron gun is, therefore, required.

In a second type of system, arrangements are being made for extraction directly along the axis with the field configuration so changed that a higher ion current may be expected.

Publication:

1. D. K. Bose, N. K. Majumdar and S. N. Sengupta, Ind. J. Phys., *XL*, 147, 1966.

2. D. K. Bose, B. D. Nag, N. K. Majumdar, S. N. Sengupta and S. K. Majumdar, Proc. Nucl. Phys. & Solid State Phys. Symp., Bombay, 1966, 372 (Nucl. Phys.)

D. K. Bose and S. N. Sengupta

3.12 *Hollow PIG Plasma Generator*

A PIG discharge has been operated for producing a hollow cylindrical plasma. This type of plasma configuration appears to be suitable for producing ion beams and also for studying a number of plasma properties.

The experimental arrangement is shown in Fig. 3.12 (K—cathode; A, B-outer

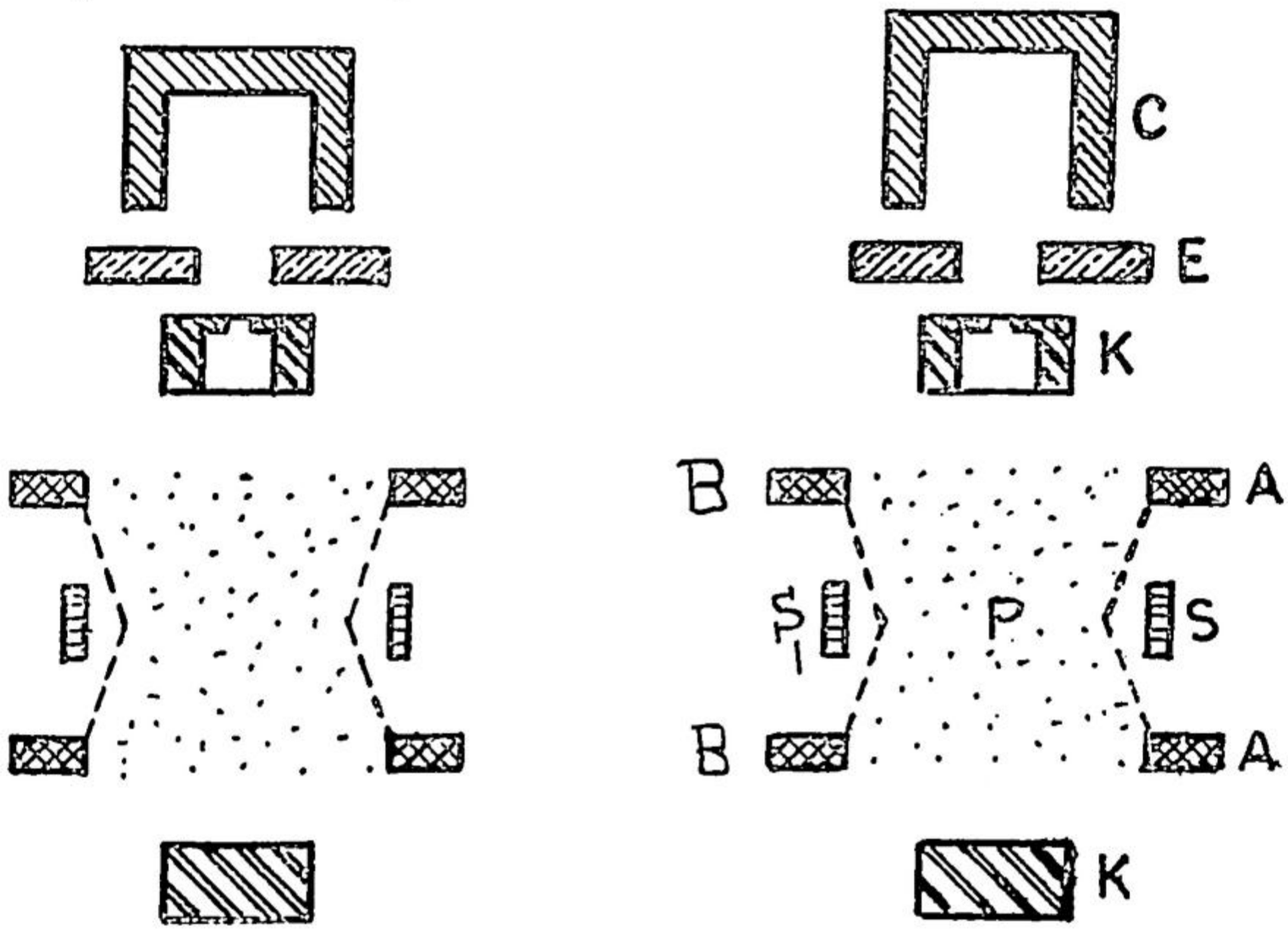

Fig. 3.12

and inner ring anodes; E—extractor; C—collector; S, S_1—outer and inner electrodes for measuring Hall emf; P—plasma column). After a preliminary run of about an hour a circular impression was produced on the central portion of the ring cathodes. This indicates that ions at the cathodes are concentrated on a narrow ring. Fig. 1 also shows the extraction arrangement. Two coaxial electrodes are at present being inserted to measure the Hall emf generated by the large current circulating perpendicular to the magnetic field.

D. K. Bose, J. N. Maiti, S. N. Sengupta and J. Basu

3.13 *Time Varying Phenomena in a Cold Cathode PIG Discharge*

During the dc probe measurements of the PIG plasma using cathode ray oscilloscope, the probe, while recording the 'i-V' characteristic, was found to pick up ac signals from the plasma. In order to determine the nature and origin of these electrical signals a small area Langmuir probe (diam: 5 mil; length: 2 mm) placed 2-3 mm within the discharge was kept at the floating potential and the picked-up signals were fed either directly or through a receiver to the C.R.O. From the oscillograms recorded we were able to detect the following types of signals:

(i) Broad band noise associated with the random fluctuations of density and potential of the plasma (PIG hash).

(ii) Discrete frequency component due to some collective phenomena in the plasma.

The observed broad band noise has the frequency range roughly from several Kc/s to several Mc/s. The noise amplitude showed strong dependence on the magnetic field. Below about 500 gauss the noise signals were absent. Above this value of the field the noise signals appeared on the oscilloscope with their amplitudes increasing with the increase of the magnetic field. This observation suggests that the Penning discharge becomes more noisy as one increases the magnetic field. The amplitude of the noise signals was found to be affected less prominently by the change of gas pressure in the discharge tube.

The discrete frequency component of the probe signals, on the other hand, showed strong dependence on gas pressure. At a pressure of 1×10^{-3} mm Hg this frequency was found to be 10 Kc/s and at 1×10^{-5} mm Hg it was about 15 Mc/s. This increase of signal frequency with the decrease of gas pressure indicates that the signals are associated with the collective rotation resulting from the $\vec{E} \times \vec{B}$ drift of the plasma.

It will be possible for us to make a thorough analysis of the frequency spectrum of the signals from the PIG discharge plasma by a spectrum analyser, which we are trying to procure.

D. K. Bose, J. N. Maiti and S. N. Sengupta

3.14 *RF Study of Penning Plasma*

The non-linear property of a Langmuir probe in a Penning plasma has been studied by noting the change in the probe dc current due to the introduction of an rf voltage to the probe. The experiment has been carried out with the probe biased at the floating potential as well as above and below it and with the frequency varied from 0.5 Mc to 30 Mc. It is observed that the change in the dc current has peaks at certain discrete frequencies and that it is reversed in sign at certain other frequencies.

The results which cannot be explained by earlier theories may be attributed to velocity modulation, owing to the rf electric field, of oscillatory or rotating electrons passing through or near the dc sheath at the probe. Further investigations are contemplated.

Publication :

Proc. Nucl. Phys. & Solid State Phys. Symp., Bombay, 1966, p. 376, (Nucl. Phys.)

J. Basu, C. Dutta and S. N. Sengupta

3.15 *Discharge Characteristics of a Low-Pressure PIG Discharge*

The discharge characteristics of a cold cathode PIG discharge have been invested at the low pressure region of 10^{-4} - 10^{-5} torr. The discharge current is found to have a maximum at a critical magnetic field, the effect being much more pronounced when an argon leak is introduced to the discharge system. A typical set of experimental data under the critical condition together with the calculated values of the ionization and total collision frequencies are given below:

	Magnetic field (Gauss)	Discharge voltage (V)	Discharge current (μA)	Ionization frequency (sec^{-1})	Collision frequency (sec^{-1})
(a) Without argon leak	540	1600	255	2.3×10^5	2.2×10^6
(b) With argon leak	550	1600	885	7.8×10^5	7.9×10^6

Further study is in progress in an attempt to correlate discharge parameters, such as the electron density and electron temperature, to the critical magnetic field.

C. Dutta, S. N. Sengupta and J. Basu

3.16 *Coaxial Probe for Plasma Diagnostics*

The performance of a double-probe system in the form of a coaxial probe is under study in connection with dc and ac measurements of plasma parameters.

As a part of the programme, a coaxial probe, 4 mm in length, has been built. A wire, 20 mil in diameter, acts as the inner conductor. The external surface of the outer conductor which has an inside diameter of 4 mm is coated with glass so as to be electrically insulating. A wide-band amplfier (10 Kc - 5 Mc) is also being constructed in cooperation with the Instrumentation Division.

J. Basu, S. N. Sengupta and C. Dutta

3.17 *Design and Construction of a Microwave Cavity Resonator*

A microwave cylindrical cavity resonator has been designed and constructed for making measurements on a semi-conductor plasma or a gaseous plasma column. The specimen is to be placed coaxially in the cavity which operates in the TM_{012} mode at a resonant frequency of 3.2 Gc.

The resonator, made of brass, is 15 cm in length and has an internal diameter of 9.2 cm. The input and output are coupled to the cavity through a pair of loops, the position of which can be adjusted to vary the amount of coupling.

J. Basu and J. N. Maiti

3.18 *RF Heating of Plasma*

Theoretical and experimental work on induction and dielectric heating of plasma at radio frequencies has been undertaken. An expression has been derived, relating the power absorbed from an rf coil to various plasma parameters. In connection with the experimental work a 4-band rf oscillator operating in the frequency range, 1 Mc to 60 Mc, is under construction.

J. N. Maiti and J. Basu

3.19 *Dispersion Properties of High Temperature Plasma*

Investigation on the dispersion properties of high temperature plasma has been made. The asymptotic expansion of the function

$$S_{\nu}(z) = \int_{0}^{\infty} e^{i\nu t + z\cos t}\, dt,$$

which completely describes the plasma dispersion law and which was introduced by Majumdar last year (vide Ind. J. Phys., *39*, 511, 1965) has been carried out for very high temperature and low magnetic field.

Saroj K. Majumdar

3.20 *Plasma Instabilities in an External Electric Field*

A detailed study of the gaseous plasma regarding instabilities in an external electric field has been undertaken. Calculation indicates that for a plasma obeying Maxwellian distribution a minimum strength of the electric field is necessary in order to produce the instabilities.

Saroj K. Majumdar

3.21 *Semiconducting Behaviour of Thallium Selenide*

The compounds formed from group III-VI are of great interest because of their possible photoconductive applications. The semiconducting thallium selenide (TISe) of this group exhibits very interesting electrical properties and hence a detailed study of its electrical properties has been undertaken.

(a) *Growth of Crystals*

Bridgman technique is very suitable for growth of compound semiconductors from melt. Several samples of T1Se were prepared using the above technique. Crystals of about 8 mm diameter and up to 7 cm in length have been produced. All samples grown by Bridgman technique had a resistivity of about 1 ohm-cm at room temperature. High resistivity samples are obtained by subsequent zone refining of the above samples. High resistivity samples can also be obtained by proper heat treatment of the samples grown by Bridgman technique.

(b) *Experimental Results*

Thermoelectric probe test showed the samples to be p-type, measurement of electrical conductivity and Hall coefficient are carried out by the conventional dc potentiometric method. Measurements are made on parallelepiped single crystal specimens. All measurements are made in temperature range between 100°K and 540°K conductivity. The Hall probes are molybdenum wires welded to the specimen by condenser discharge technique. End contacts are made with aquadag and silver paste for high and low temperature respectively. From the

variation of conductivity with temperature in the intrinsic range, the intrinsic activation emergy has been estimated to be 0.574 eV. The carrier concentration in the samples, as estimated from Hall effect measurements, ranged from 1.4×10^{17} cm^{-3} to 2×10^{15} cm^{-3}. The ratio of electron to hole mobility calculated comes out to be 0.398. The variation of Hall mobility at high temperature is found to obey $T^{-3/2}$ law, indicating the presence of lattice scattering. A strong dependence of mobility on purity is also observed both at high and low temperatures. At low temperature, the region of phonon scattering becomes broad as purity increases.

(c) *Preparation of Thin Films of T1Se*

A small vacuum deposition unit, about 6 cm in diameter, has been constructed for making evaporated thin fiims of semiconductors and for making contacts on small semiconductor samples. Electrical measurements may be made in vacuum without taking the sample out of the system. Thin films of T1Se have been prepared. Preliminary measurements are in progress.

P. S. Nayar and J. K. D. Verma

3.22 *Electrical Properties of Naphthalene*

A lot of work has been done on inorganic elemental and compound semiconductors because of their practical applications. A large number of organic compounds also show semiconducting behaviour. The semiconducting properties of organic compounds are specially interesting because most of them are molecular crystals. Amongst the organic molecular crystals, napthalene is the first compound in the series of fused ring hydrocarbons. Therefore, a complete understanding of its semiconducting properties might give a deeper insight into the so-called organic semiconductors. The semiconducting properties of naphthalene have been studied by a number of workers but their results are very much conflicting. The value of activation energy reported ranges from 0.71 eV to 1.85 eV. Considering all this, an extensive study of the semiconducting properties of naphthalene has been undertaken.

(a) *Purification of Naphthalene*

It is expected that these widely different results are primarily due to impurity in the material. Therefore, it was decided to use ultrapure naphthalene for these studies. The chemical grade naphthalene has been purified by two vacuum sublimations and then submitted to normal freezing. This purified naphthalene is repeatedly zone refined (upto 50 passes). The impurity concen-

tration is estimated to be less than 0.001 ppm. A critical survey of the literature concerned with zone refining and allied techniques was also made in view of their importance in the purification of semiconductors. The review deals with purity and ultrapurity, the determination of purity, zone refining and various considerations in the design of zone refining apparatus.

Publication :

S. C. Datt, J. K. D. Verma and B. D. Nag, J. Scient. ind. Res., 25, 455, 1966.

(b) *Growth of Single Crystals of Naphthalene*

A furnace for the growth of single crystals of naphthalene (m.p. 80°C) from the melt by Bridgman-Stockbarger technique has been constructed. The crystal container is lowered through the furnace by an electric clock mechanism. The rate of descent is adjusted to 0.033 inch per hour. A study of the effect of various temperature gradients on the growth of single crystals has revealed that only a particular temperature gradient which is different from that suggested by Stockbarger yields good quality naphthalene single crystals. It has also been found that the chances of obtaining a good single crystal in any given run with this particular gradient are more than 80% for a container having a spiral tip. Crystals of 1″ diameter and upto 6″ in length have been obtained with this arrangement.

(S. C. Datt, J. K. D. Verma and B. D. Nag, 'On the Growth of Single Crystals of Naphthalene,' to be published in Ind. J. Phys.)

(c) *Electrical Conductivity*

Apart from purity, other factors such as aggregate forms of specimen, cell design, electrode materials, pressure and ambients are also found to affect electrical conductivity. For developing the correct experimental technique, a comprehensive study of the literature on electrical conductivity, both dark and photo, in organic semiconductors has been made.

A special sample holder for these very high resistivity (upto 10^{18} ohm-cm) crystals has been constructed. Special precautions have been taken to avoid errors due to leakage current. The measurements are being made with an electrometer, using guarded electrode technique, in vacuum as well as in other ambients.

(S. C. Datt, J. K. D. Verma and B. D. Nag, 'Electrical Conductivity in Organic Semiconductors', to be published in J. Scient. ind. Res.)

S. C. Datt and J. K. D. Verma

3.23 *Preparation of Thin Films*

A vacuum coating unit with a 12″ diameter belljar has been installed for preparation of thin films and targets by evaporation and sputtering. Trial runs

have been given and very thin films of aluminium on glass substrates have been deposited. Certain modifications, such as incorporating liquid air trap for improving the vacuum and the quality of films, rearranging vacuum lines for lowering the pumping time, etc., are in progress.

J. K. D. Verma and B. D. Nag

C. Electrostatic Generator

3.24 *Design Studies of a Small Electrostatic Generator*

The following projects and studies have been carried out :

(a) Existing designs of the electrostatic generator systems have been analyzed and a tentative design to build a 1.5 - 2.0 MeV generator has been finalized.

(b) A model charging unit with a spark gap for the measurement of high voltages has been set up and is being tested. A charging current of 25 μA has so far been achieved.

(c) A 100 Mc oscillator, its power supply and an 8 kV, 10 mA dc extraction voltage supply have been completed to be used with an rf ion source.

(d) An accelerating column with externally ridged glass discs and variable metal ring aperture electrode system has been decided upon.

(e) Plot of equipotential lines with the simulated design of the above acceleration column system has been made; ion focussing properties of this system have been particularly studied.

(f) Two 4″ diffusion pump vacuum units have been set up for experimental studies of the rf and dc type ion sources.

(g) An rf power supply has been redesigned to deliver 0.5 mA at 8 kV dc.

(h) A 2 kV, 3 mA power supply has been constructed; design of a 3 kV pulsed rf power supply has been undertaken; a 40 kV voltage spray unit is under construction; the accelerating column glass discs are expected to be delivered soon; an electrolytic gas generator has been completed.

(i) A low power ion source has been constructed and tested in the vacuum system. With a voltage supply of 0 to 2 kV dc or ac, it has been operated

at a pressure between 10^{-1} mm and 10^{-2} mm Hg at source currents between 5 mA and 0.5 mA; use of a suitable magnetic field is contemplated.

With an extraction voltage of -8 kV, 100 μA of ion current has been drawn on a target 12 cm away from the ion source exit canal at a source current of 1 mA. Extraction electrode geometry is currently being optimized.

A gas flow inlet regulation system will shortly be used in conjunction with the electrolytic generator.

An rf ion source will soon be bench tested.

A. Chatterjee, N. K. Majumdar, Ashim K. Ganguly,
Sudip K. Ghosh and Ratna Sarkar

4. INSTRUMENTATION DIVISION

4.0 *Introductory Remarks*

The microwave frequency standard completed last year was thoroughly tested. Spurious frequencies were found to be generated besides the desired frequencies of 50 Mc/s and 500 Mc/s. These could not be reduced sufficiently in amplitude till additional filter circuits were introduced. The unit that has now been installed in the Microwave Spectroscopy laboratory gives essentially pure 50 Mc/s and 500 Mc/s output in satisfactory amplitude.

Work on a second unit, that follows an altered plan and will deliver additional outputs at 1 Mc/s, 10 Mc/s and 100 Mc/s besides the regular output at 50 Mc/s and 1000 Mc/s, has been taken in hand.

A 500 Mc/s stable frequency V.H.F. generator, of about one watt output, has been constructed. It is driven at 25 Mc/s, through a quintupler (125 Mc/s), two doublers (250 Mc/s, 500 Mc/s) and an amplifier (500 Mc/s). It is being used as the source of power for varactor multiplier systems.

Attempts for development of varactor multiplier systems have not yet borne fruit. Absence of an indicator type absorption frequency meter (1000-3000 Mc/s) is withholding progress. Construction of a receiver for this range (1000-3000 Mc/s) was therefore undertaken and the 100 Mc/s I.F. amplifier completed. The receiver could not be completed because the mixer rectifier and other accessories were not received.

Work on transistor classification resulted in the publication of a data book.

Help was also given to the Indian Explosives Ltd. at Gomia in Bihar in connection with the electronic systems for their testing.

The progress of the Division is not very satisfactory.

B. M. Banerjee
Head, Instrumentation Division

4.1 *Harmonic Generator for Microwave Frequency Standard*

Many spurious frequencies were observed in the unit completed in November 1965. These had to be removed by additional filters in every stage of harmonic generation. However, by May 1966, a satisfactory unit took shape, and was delivered to the Microwave Spectroscopy laboratory of the Nuclear Physics Division. Some time and effort had to be spent here also before the different units "meshed in teeth" to give satisfactory operation. The harmonic generator, as installed now in the above-mentioned laboratory, delivers adequate

output at 50 Mc/s and 500 Mc/s to cause crystal burnouts. However, with suitably reduced outputs applied to the lN26 crystal, measurable standard frequency signals are obtained in the 22-26 kMc band. The system has proved to be stable and has been in regular operation since then.

A second unit is under construction. This follows a changed plan and will deliver outputs at 50 Mc/s and 1000 Mc/s. Additional outputs at frequencies of 1 Mc/s, 10 Mc/s and 100 Mc|s will also be available.

B. M. Banerjee, K. S. Patel, S. Chowdhury, P. K. Gupta and C. Chatterjee

4.2 500 *Mc/s Generator*

A stable frequency generator, delivering about one watt at 500 Mc/s, has been completed. This is being used as the source of power for varactor multi-

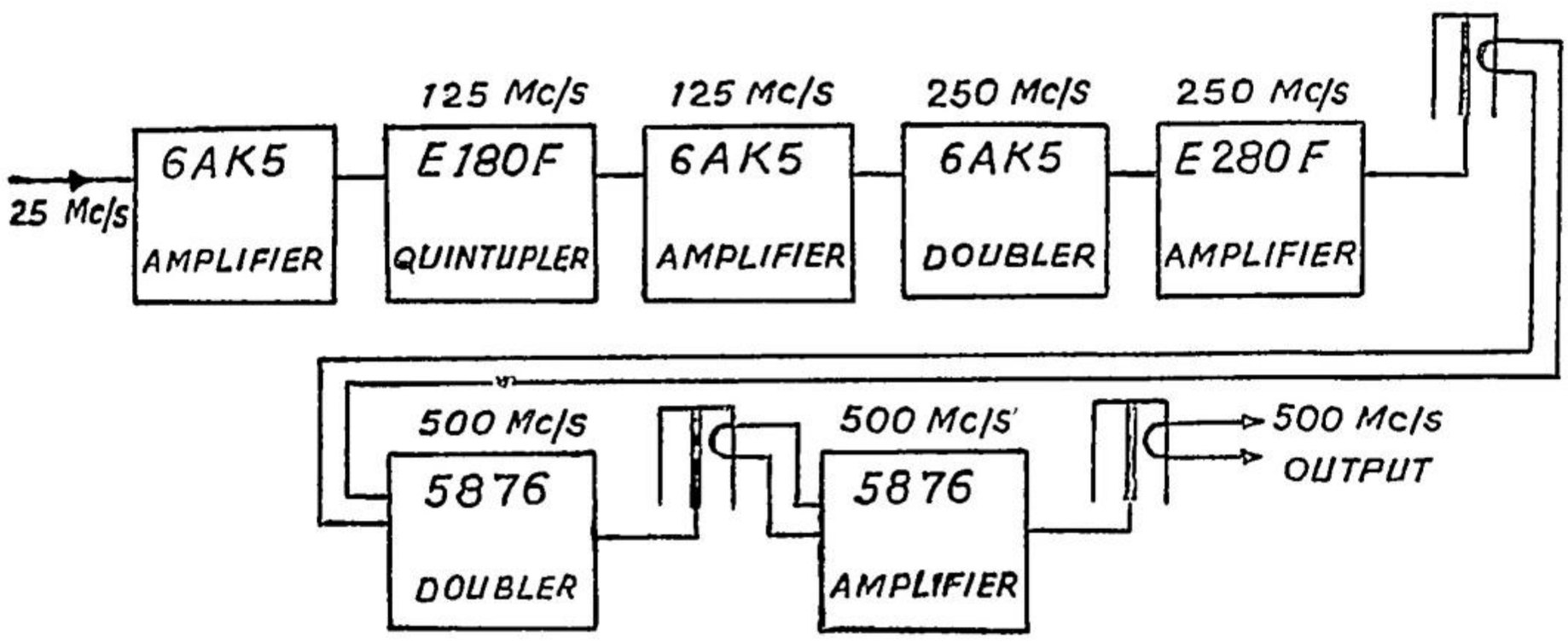

Fig. 4.2

plier systems. The block diagram of the present unit is given in Fig. 4.2. It will ultimately be driven by a quartz crystal.

B. M. Banerjee, K. S. Patel, P. K. Gupta and C. Chatterjee

4.3 *Varactor Multiplier Systems*

Two varactor multiplier systems have been fabricated. The resonant systems in them could not be adjusted properly because there was no device available that could indicate resonance adjustments at individual frequencies. This could have been easy, if we had an indicator type absorption frequency meter in the range of 1000 Mc/s to 3000 Mc/s.

B. M. Banerjee, P. K. Gupta and C. Chatterjee

4.4 *Receiver for 1000 Mc/s to 3000 Mc/s*

Construction of a receiver tunable over the range of 1000 Mc/s to 3000

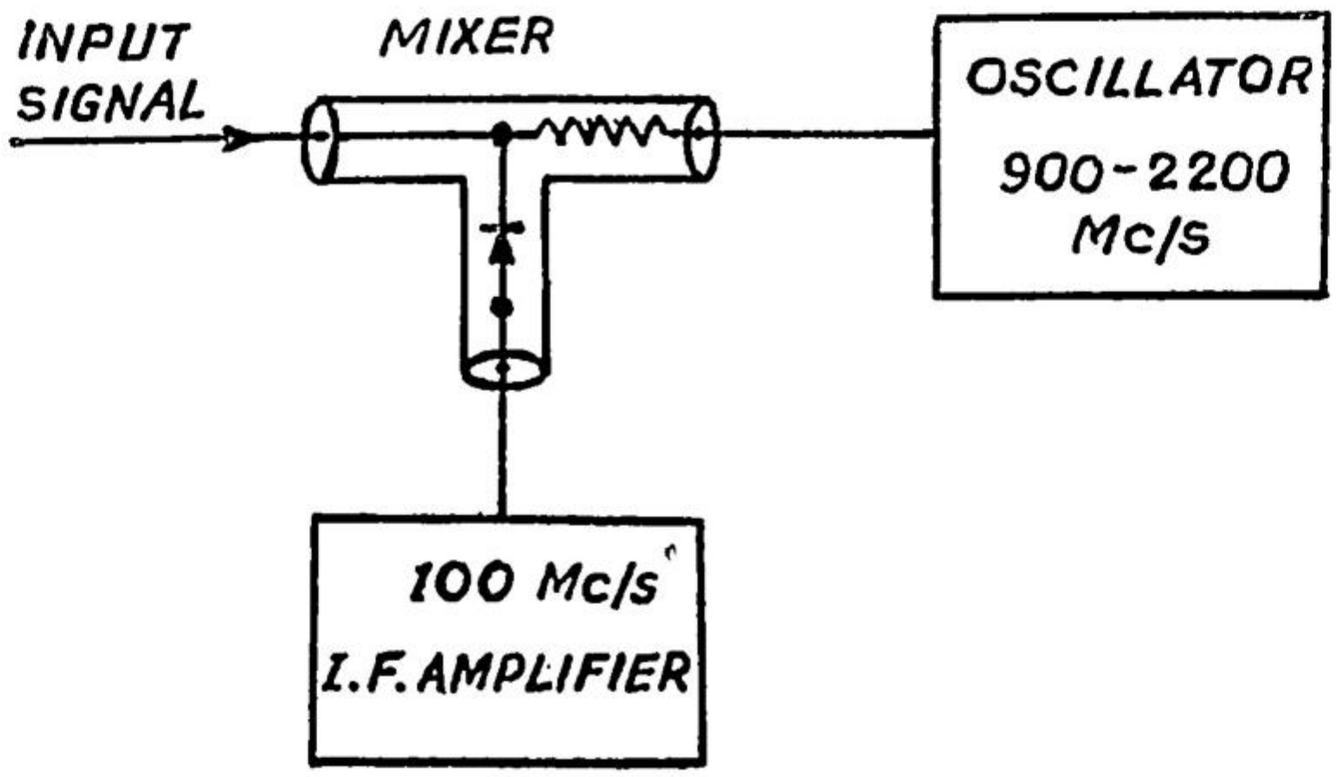

Fig 4.4

Mc/s is under way. It will follow the plan given in Fig. 4.4. The I.F. amplifier unit has been constructed.

B. M. Banerjee, C. Chatterjee and P. K. Gupta

4.5 *Transistor Classification*

A data-book, containing complete data of 320 types of R. C. A. transistors in tabular form, has been published.

Publication :

B. M. Banerjee, 'Transistor Data in Tabular Form', Saha Institute of Nuclear Physics, Sept. 1966.

B. M. Banerjee

5. NUCLEAR CHEMISTRY DIVISION

5.0 *Introductory Remarks*

Research activity in this Division is mainly concentrated on the application of radioactive nuclei to solution of problems relating to analytical, inorganic and physical chemistry and development of radiochemical technology. Only those chemical problems which cannot be solved by conventional ways and where a radioactive isotope is an indispensable tool have all along been chosen. The work has been broadly classified under four heads : (1) Analytical chemistry, (2) Study of uptake through mixed crystal formation and its applications, (3) Study of separation chemistry in the laboratory scale, and (4) Radiation chemistry.

For the last two years we have been trying to take up the following lines of approach and it is a pleasure to note that considerable progress has been made during the year. These are: (a) Necessary arrangements and preparations for measuring low level radioactivity with reference to products of spontaneous fission, (b) Simplified procedures in some interesting systems for working out chemical analysis through neutron activation, (c) Developing radiation chemistry, and (d) To construct, fabricate and assemble simple apparatus which are used in the laboratory.

We are thankful to Atomic Energy Establishment, Trombay and Biophysics Division of our Institute for giving us the facilities of irradiation for studies in radiation chemistry.

B. C. Purkayastha
Head, Nuclear Chemistry Division

A. Analytical Chemistry

5.1 *Estimation of Palladium as Iodide with the help of I^{131}*

Estimation of trace amount of an element by radiometric procedure has been pursued here for the last few years. During 1966, a thorough study in the microdetermination of palladium and iodide by radiometric procedure in presence of interfering ions with I^{131} has been done. The principle employed in such estimation is to add an excess of iodine (2-4 times the theoretical equivalent amount of the metal in question) as KI containing I^{131} to the unknown metal in question and the trace of the metal iodide is carried along with zirconium phosphate. From the loss in activity of I^{131} in the solution, the amount

of the metal in question can be estimated. If palladium is known, the amount of unknown iodide can be computed.

Palladium ranging from 4×10^{-3} to 2×10^{-7} gm has thus far been estimated. Error always lies within statistical fluctuations in activity measurement. Effect of the presence of some of the foreign ions has also been included in the study.

Uptake of the metal iodide in question by zirconium phosphate has been found to be selective in nature. The method is simple and can be completed within 30 minutes.

(Mrs.) Usha Purkayastha and H. P. Maity, 'A Radiometric Procedure for the Micro Determination of Palladium and Iodide with Iodine-131', to be published in "The Analyst").

(Mrs.) Usha Purkayastha and H. P. Maity

5.2 *Estimation of Hafnium as Pyrophosphate with the help of P^{32}*

Microestimation of zirconium with lebelled pyrophosphate by the use of thallous iodide as a carrier for trace amount of zirconium phosphate was communicated in the last report. Our efforts during 1966 were concentrated in the estimation of hafnium in presence of a large number of foreign ions. It has been observed that up to 32×10^{-6} gm of hafnium can be estimated in presence of 1(N) nitric acid whereas in case of zirconium we could not go beyond 92×10^{-6} gm under identical conditions. Importance of this observation is being thoroughly studied. It should be pointed out that at pH 2 upto 2×10^{-6} gm of hafnium can be estimated with a fair degree of accuracy. Lower limit of zirconium and hafnium are near about the same. Certain typical data at the lowest concentration are given below.

TABLE—5.2

Estimation of Hafnium with the help of $Na_4\overset{*}{P}_2O_7$ using thallous iodide as a carrier for the pyrophosphate in question

Hafnium taken in mg.	Hafnium found in mg.	Error (%)
0.01018	0.009804	−3.7
0.00509	0.004897	−3.8
0.002024	0.002015	−0.5
0.002024	0.002062	+1.9

A glance at the table will indicate that the method is very efficient and quick. The procedure does not require more than 30 minutes and can be claimed

to be very useful in routine analytical work. The error is always within the limits of standard deviation in activity measurements.

(Mrs.) Usha Purkayastha and H. P. Maity

5.3 *Estimation of Scandium by Radiometric Procedure*

In continuation of the study on the estimation of scandium by radiometric procedure it has been found that as low as 0.3 mg of scandium can be estimated as pyrophosphate using Sc^{46} of high specific activity. In a previous communication only upto 1 mg of scandium with P^{32} was estimated. Much lower limit ($\sim 55\,\gamma$) has been reached by raising the pH to ~ 5 and carrying $\overset{*}{Sc}HP_2O_7$ with T11. It has been observed that tervalent ions like Fe^{+3}, Al^{+3} interfere in the estimation of scandium with Sc^{46}. Tervalent rare earths and divalent ions like Cd^{+2}, Be^{+2}, Fe^{+2} do not interfere in slightly acid solution. In course of such estimation it has also been found that scandium pyrophosphate assumes the compositions $ScHP_2O_7$ in excess of Pyrophosphate and $Sc_4(P_2O_7)_3$ in excess of scandium. Some of the typical data are given below :

TABLE—5.3.1

Estimation of scandium by Sc^{46} as $Sc_4(P_2O_7)_3$.

Scandium taken (mg).	$Na_4P_2O_7$ added (mg).	Scandium found (mg).	$Na_4P_2O_7$ found (mg).	Error (%)
7.640	16.46	7.74	16.658	1.2
1.112	2.244	1.110	2.241	0.2
0.513	1.112	0.529	1.157	3.0
0.278	0.659	0.272	0.647	2.0

TABLE—5.3.2

Estimation of scandium by P^{32} as $ScHP_2O_7$

Scandium taken (mg).	Scandium found (mg).	Error (%)
0.112	0.110	1.8
0.112	0.113	0.9
0.056	0.0536	5.0
0.0112	0.0075	33.0
0.056	0.0533	5.0

B. C. Purkayastha and K. N. Dutta

5.4 *Spectrophotometric Determination of Periodate in the Presence of Iodate using Aluminium Hydroxide*

A simple method has been developed for spectrophotometric determination of periodate in the presence of a large excess of iodate by separating out the former by using $Al(OH)_3$ as a scavenger. The periodate was carried out with $Al(OH)_3$ which was then washed with water and dissolved in 2.4N H_2SO_4. Absorbance was measured against the blank at 210 mμ. The system obeys Beer's law in the range of concentration of periodate, 1×10^{-5} to 18×10^{-5} M. The method is simple, reproducible and easily adoptable. It gives accurate results for mixtures ranging from a molar ratio of 1 : 1 to 1: 500 for periodate and iodate.

(S. N. Bhattacharyya and P. K. Chetia, 'Spectrophotometric Determination of Periodate in the Presence of Iodate using Aluminium Hydroxide', to be published in "Analytical Chemistry").

S. N. Bhattacharyya and P. K. Chetia

B. Study of Uptake Through Mixed Crystal Formation and its Various Applications

5.5 *A New Method for Determining Transition Temperature through Mixed Crystal Formation*

It is stated in the previous report (1965) that a new method has been developed in determining the transition temperature with a radioactive isotope where the component whose transition temperature is determined does not manifest its existence as such but gives evidence of its existence through mixed crystal formation. Study of distribution coefficient of a morphologically analogous host having a greater range of stability with a guest at tracer level at different temperatures gives a prominent break at the transition point of the guest component. This new mode of approach in known and unknown systems has been the subject matter of study during the year and a paper relating to it has been published (vide J. Inorg. Nucl. Chem., *28*, pp-347 to 354, 1966).

It is well known that vitriols are dimorphous. They exist in monoclinic and orthorhombic forms. One variety is metastable with respect to the other. Monoclinic variety of $CoSO_4.7H_2O$ is stable from O°C to 47°C. An attempt has been made to find out the transition temperature of the orthorhombic variety by the new method. Orthorhombic $MgSO_4.7H_2O$ was taken as the host component and Co^{60} in H_2SO_4 medium at tracer level was chosen as guest. Constancy of the distribution factors at any particular temperature gives a clear evidence that orthorhombic variety of $CoSO_4.7H_2O$ does exist. By measuring

the distribution factors of the system at different temperatures, transition temperature of the guest component ($CoSO_4.7H_2O$ - $6H_2O$) was found to be 18°C ± O.5°C.

Fig. 5.5 will show the simplicity of the procedure and its superiority over classical methods in such complex systems. Other unknown systems of similar in nature are under investigations.

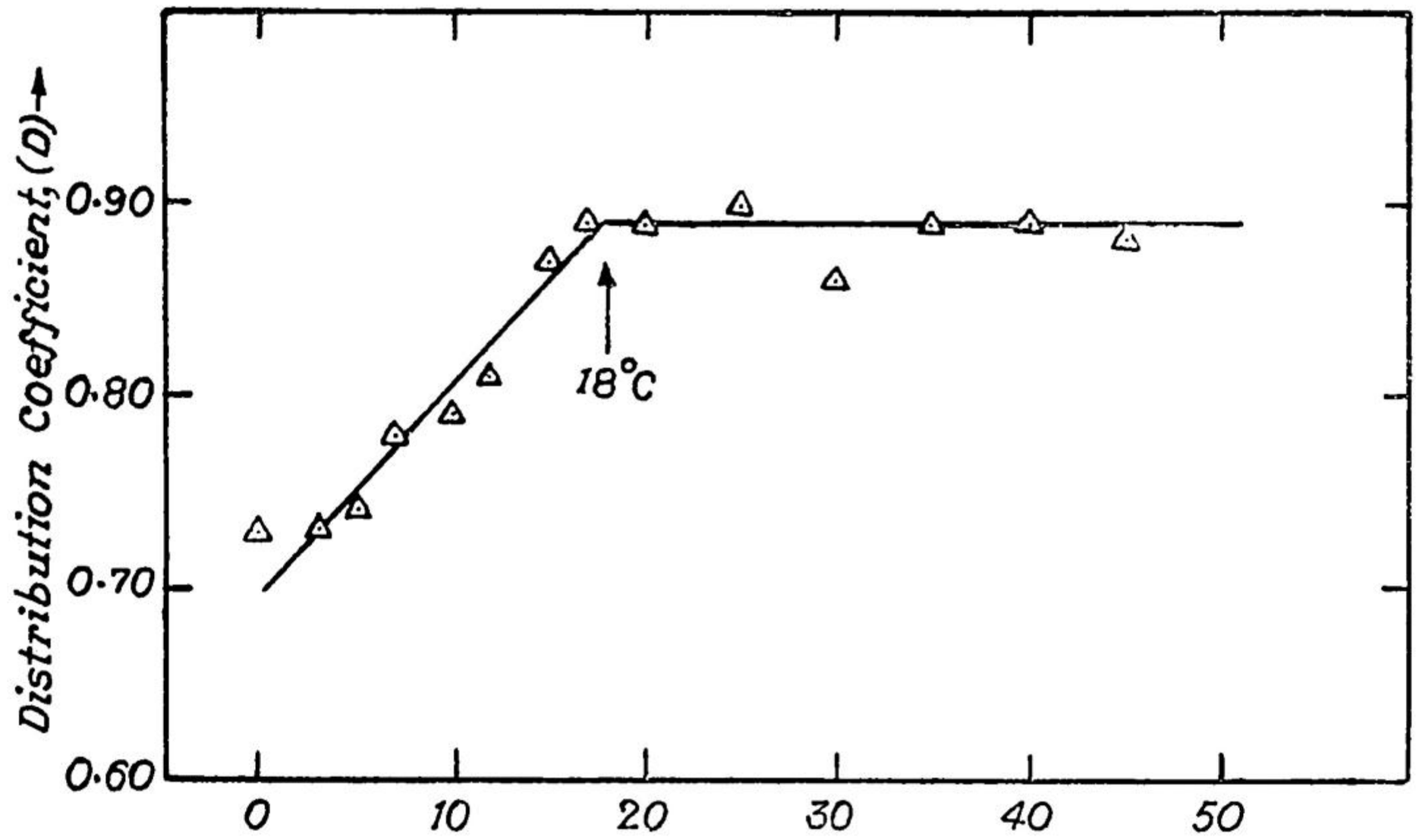

Fig. 5.5

(B. C. Purkayastha and Samir Sarkar, 'Application of Radioactive Isotopes in the Study of Transition Temperature—II', to be published in J. Inorg. Nucl. Chem.)

Publication :

B. C. Purkayastha and Samir Sarkar, J. Inorg. Nucl. Chem., *28*, 347-354, 1966.

B. C. Purkayastha and Samir Sarkar

5.6 *On the Study of Tetrahydrated Double Sulphate of Tervalent Elements with Radioactive Indicators*

Distribution study with $(NH_4)Tl(SO_4)_2.4H_2O$ as host and Sc^{46} as guest showed that scandium is taken up by the host component through mixed crystal

formation both at tracer and finite concentrations of the guest component. Values of the homogeneous distribution factors (D) have been determined from O°C to 15°C and it was found that the values undergo a prominent change above 5°C. The conclusion has been arrived at that the transition temperature of the tetrahydrated double sulphate of scandium lies in the neighbourhood of 5°C. As a matter of fact, $(NH_4)Tl(SO_4)_2.4H_2O$ containing $\sim$ 14 mol % of scandium with corresponding composition has been isolated at 3°C, whereas any attempt to isolate the tetrahydrated double sulphate of scandium with the same concentration of the guest component as mentioned, above 5°C, resulted in the formation of a mixture of $(NH_4)Sc(SO_4)_2$ and $(NH_4)Tl(SO_4)_2.4H_2O$. The anhydrous double sulphate of scandium is found to be stable at 3°C and is much less soluble than the corresponding tetrahydrate. It was anticipated that $(NH_4)Sc(SO_4)_2.4H_2O$ is metastable with respect to $(NH_4)Sc(SO_4)_2$.

Distribution with $(NH_4)Ce(SO_4)_2.4H_2O$ and $(NH_4)Tl(SO_4)_2.4H_2O$ as hosts and $Eu^{152,154}$, Tb^{160}, Tm^{170}, Y^{90}, Bi^{210}, In^{114} and $Fe^{55,59}$ as guests have been studied in considerable details. It has been observed that the former host takes up rare earths, yttrium and bismuth activities through mixed crystal formation and in case of In^{114} and $Fe^{55,59}$ as guests the partition values are negligibly small. In case of $(NH_4)Tl(SO_4)_2.4H_2O$ as host, rare earth activities and yttrium and bismuth tracers are taken up by adsorption and indium and iron activities through mixed crystal formation. Findings derived from a series of study give a clear evidence that 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 indium, ferric iron, thallic thallium, scandium and aluminium belong to the other group.

B. C. Purkayastha and D. K. Bhattacharyya

5.7 *On the Behaviour of Bismuth Fluoride as a Guest Component in the Study of Uptake by Calcium and Rare-earth Fluorides*

Distribution study with calcium fluoride and cerous fluoride as hosts and RaE as guest, reveals that both the hosts take up bismuth tracer through mixed crystal formation. Study has been extended from the tracer level to the finite scale of the guest component. It has been argued that some of the compounds of bismuth shows some morphological analogy with those of the rare-earths, and presence of bismuth in calcium fluoride lattice can be expected from such study.

B. C. Purkayastha and Shyamoli Sen

5.8 *On the Study of the Uptake of Calcium Tracer by Strontium Oxalate*

In the present investigation analogy amongst the oxalates of strontium and calcium has been mainly the subject matter of study. Fluorides have also

been included with a comparative outlook. Distribution study with different forms of calcium and strontium oxalates as hosts and Ca^{45} and $Sr^{89,90}$ as guests have been thoroughly investigated.

It has been found that just like SrC_2O_4, $2.5H_2O$ calcium has got a corresponding compound. Calcium oxalate monohydrate is mixed crystal forming with corresponding hydrate of strontium. Trace amount of strontium can be removed from the system by carrying with calcium fluoride in presence of excess of fluoride.

B. C. Purkayastha and Anita Dutta (née Chatterjee)

5.9 *On the Study of the Uptake of Strontium Tracer by Different Forms of Calcium Sulphate*

Uptake of strontium tracer by different forms of calcium sulphate and its geological importance was included in the previous report. It was assumed from the evidences derived from physical studies that any phase precipitated above 45°C is anhydrite. An apparatus has been devised for isolating the solid phase and to wash it and get it dried at the temperature of precipitation to verify chemically the composition of the solid phase.

Publication :

B. C. Purkayastha and Anita Chatterjee, J. Ind. Chem. Soc., *43*, No. 11, 1966

B. C. Purkayastha and Anita Dutta (née Chatterjee)

C. Separation Chemistry

5.10 *Coseparation of Tetravalent Actinides by Bismuth Iodate*

During the previous year the use of bismuth iodate as a carrier of tetravalent actinides was investigated. Selectivity of the carrier was studied in details with special reference to the fission products. It has been found that tetravalent actinides can be carried avoiding contaminations from any fission products save and except zirconium and niobium activities. It was also observed that bismuth iodate is precipitated as a simple compound whereas zirconium iodate which has all along been used in separation chemistry has the composition of a double salt.

Publication :

B. C. Purkayastha and Shyamoli Sen, J. Ind. Chem. Soc., *43*, 404-410, 1966.

B. C. Purkayastha and Shyamoli Sen

5.11 *On the Study of the Methods of Concentrating Rare Elements from Natural Sources or from Bulk of Materials*

Separation of scandium from complex minerals like beryl, monazite etc. : A simple separation procedure for concentrating scandium from complex minerals like beryl, monazite, etc has been developed. Final purification is made through coprecipitation with ceric pyrophosphate. Ceric cerium was reduced to the cerous state by addition of H_2O_2 in an acedic medium. It was boiled with HNO_3 to convert pyrophosphate to phosphate. The medium was then made ammoniacal. The precipitate carrying scandium was washed to free from nitrate. It was then dissolved in HCl and scandium was extracted by T.B.P. The product was found to be pure scandium. The object of such procedure is to get quantitative recovery for analysis through neutron activation.

B. C. Purkayastha and N. R. Das

5.12 *A Study on the Attempts of Separating Cesium from Bulk of Potassium Salts*

With an object to study the concentration of cesium in potassium minerals, a method has been developed to concentrate cent per cent cesium from bulk of potassium compounds. Ammonium salts of heteropoly acids like ammonium phosphomolybdate were used as a carrier. Effect of concentration on potassium was studied in considerable details both in internally formed and externally formed systems. Ammonium phosphomolybdate containing cesium tracer (Cs^{137}) was made ammoniacal and the solution was passed through a Dowex resin anion exchanging column. Phosphate and molybdate remained adsorbed in the column, cesium and ammonium were washed out. Cesium thus recovered will, on subsequent treatment, serve as a source for estimating cesium through neutron activation : Cs^{133} (n,γ) Cs^{134}.

B. C. Purkayastha and (Mrs.) S. Aditya

5.13 *Separation of Scandium through Ether Extraction*

It is well known that the ammonium thiocyanate complex of scandium is extracted by ether. The data, however, refers to finite concentration. The partition coefficient in this interesting system has been studied from finite to tracer concentration using Sc^{46} as the measuring indicator. The temperature, acidity and thiocyanate concentration remained the same throughout the study. It is of interest to note that at a molar concentration of 10^{-4} there is a characteristic break

(Fig. 5.13) and the same characteristic break also occurs in case of potassium

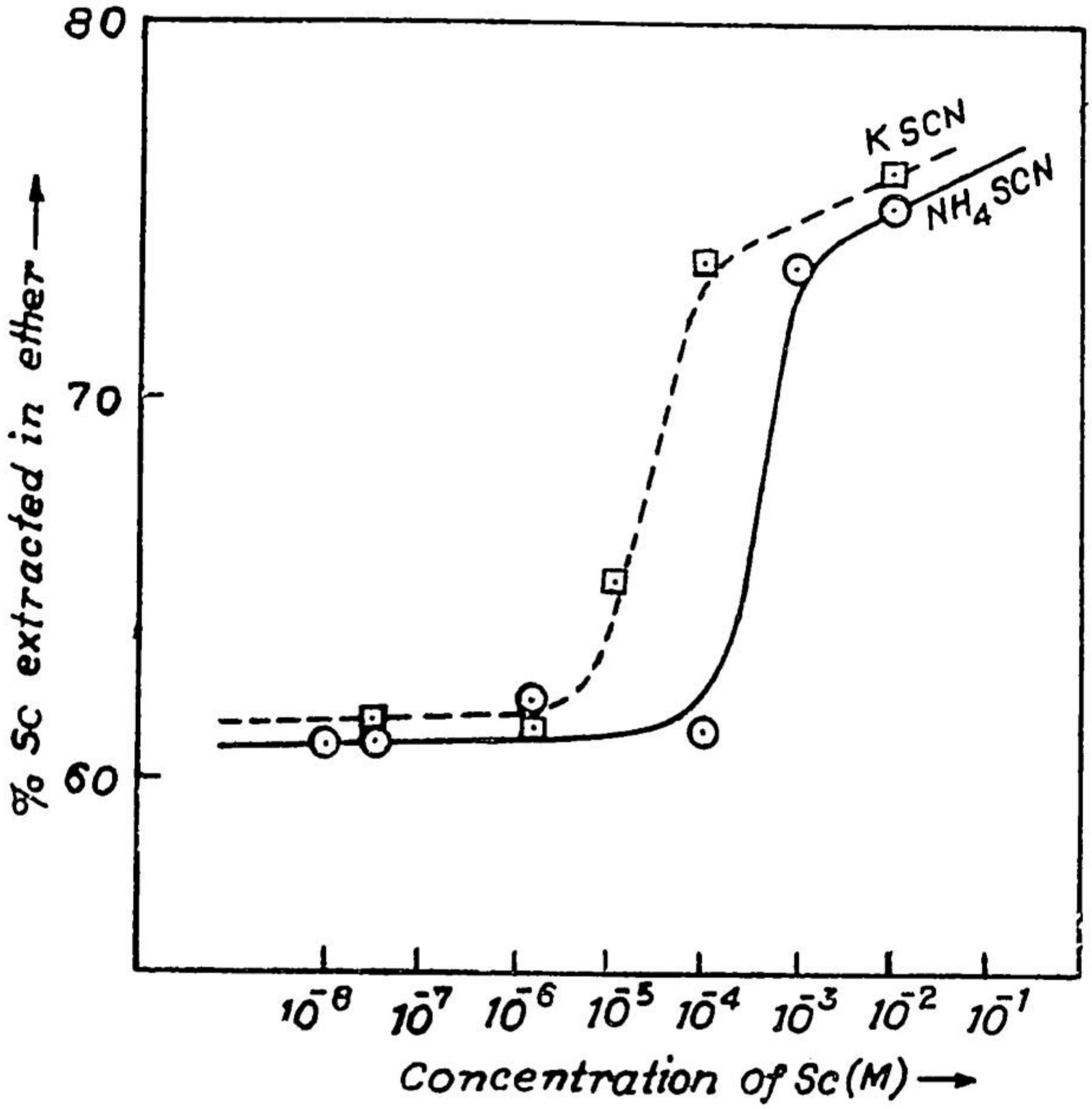

Fig. 5.13

thiocyanate though there is some small shift in the concentration range. Our study on analytical determination of scandium by radiometric procedure also gives indication that thallous iodate does not carry cent per cent scandium pyrophosphate below this concentration. The behaviour from these two sources of independent measurements gives an indication that solution complexities in multivalent systems may play an important role when we go from finite to tracer level and this observation was also mentioned in different systems by Alimarin (vide Proc. Int. Conf. Peaceful Uses of Atomic Energy, *5*, 60, 1955).

B. C. Purkayastha and K. N. Dutta

5.14 *Separation of Scandium (Sc^{46}) from Titanium*

In order to separate Sc^{46} from titanium target titanium was dissolved in $H_2SO_4 - HNO_3$ mixture. It was then treated with H_2O_2, the acidity was neutra-

lized and the pH was raised to about 8. The solution was passed through a column of glass powder. Scandium was adsorbed on the glass surface and the titanium in solution passed through the column. By several washing with ammoniacal H_2O_2 the glass column was made free from titanium Carrier free Sc^{46} was recovered from the glass surface by washing with (1 : 1) HCl. The recovery was almost quantitative and the product was free from titanium. It has been observed that instead of glass powder the column may be filled up with cellulose powder.

B. C. Purkayastha and M. N. Chandra

D. Radiation Chemistry

5.15. *Radiation Induced Oxidation of Ethylenediaminetetraacetic Acid in Aqueous Solution*

Photooxidation of tertiary nitrogen compounds by dyes has been widely studied. But no thorough study has yet been made as regards the behaviour when the tertiary nitrogen compounds are irradiated with ionising radiation. Among such tertiary nitrogenous compounds we have chosen ethylenediaminetetraacetic acid (EDTA). Aerated aqueous solution of EDTA in 0.1 N H_2SO_4 was irradiated with 80 kV unfiltered X-rays (at the Biophysics Division of the Institute) and the radiation induced decomposition of EDTA was measured. Formaldehyde and hydrogen peroxide in irradiated solutions were determined quantitatively and the radiolytic yields G(–EDTA), G(CH_2O) and G(H_2O_2) were evaluated. The concentration of EDTA has been varied over wide limits. The pH and scavenger effects are being studied to gain an insight into the mechanism of radiation induced decomposition of EDTA.

S. N. Bhattacharyya and A. K. Datta

5.16 *Radiolysis of Aqueous Solution of Fe^{111} – EDTA*

The study of radiolysis of Fe^{111} – EDTA forms an interesting aspect in gaining knowledge as regards the radiolytic mechanism of chelated compounds. Aerated aqueous solution of Fe^{111} – EDTA in 0.1 N H_2SO_4 was irradiated with 80 kV unfiltered X-rays (at the Biophysics Division of the Institute). It is observed that Fe^{111} – EDTA on radiolysis is reduced and that the reduced product is neither a simple Fe (11) aqua ion nor Fe^{11} — EDTA but a complex of ferrous

ion where Fe^{2+} is probably chelated with some undetermined dehydrogenated EDTA. Further work in the system is being continued.

S. N. Bhattacharyya and A. K. Datta

5.17 *Radiation Induced Reduction of Potassium Iodate in Aqueous Solution*

That aqueous solutions of oxidising agents are reduced under the influence of high energy radiation is well known from the study of aqueous systems containing a variety of oxidising agents. But no generalised correlation can, however, be made for all the systems studied. Moreover, there are systems which are yet to be investigated. Iodate and periodate represent two interesting species amongst the classically well known oxidising agents. But no detailed study has yet been made as regards their behaviour when they are irradiated with ionising radiation both in aqueous solution and in the solid state. Aerated aqueous solution of potassium iodate in neutral medium was irradiated with Co^{60} gamma rays (at the Atomic Energy Establishment, Trombay, Bombay). Iodide and elemental iodine have been identified amongst the radiation induced decomposition products. The radiolytic yields, $G(-IO_3^-)$, $G(I_2)$ and $G(I^-)$ were determined. Effects of varying the solute concentration are under investigation. The effects of pH and suitable radical scavengers will be studied to have a thorough understanding of the mechanism of radiolysis.

S. N. Bhattacharyya and D. K. Bardhan

6. NUCLEAR PHYSICS DIVISION

6.0 *Introductory Remarks*

As a result of severe foreign exchange shortage, fabrication of new instruments or improvement of existing equipment could be taken up only on a limited scale. All our experimental plans were strictly restricted to available facilities. In Nuclear Spectroscopy, nuclear g factors have been measured for a number of nuclei with the instrument fabricated last year. The construction of the e-e pair spectrometer has been completed and the instrument is now being tested. Theoretical calculations have been completed for Sr^{88} with finite range interactions. Calculations for W^{187} and Yb^{169} are also complete. Shell structure calculations with a residual surface interaction has been carried out for P^{30}, Si^{30} and Ca^{48} and validity of the wave functions obtained from such interaction has been tested by a systematic study of (t,p) reactions. An extensive recalculations of Nilsson's orbitals for deformed nuclei has also been carried out and the involved parameters have been obtained. In the field of theoretical Solid State and Molecular Physics emphasis has been on investigation of the origin of the crystalline electric field in rare earth metals and rare earth compounds. A systematic investigation has been made of the phonon processes in paramagnetic crystals and zero field splitting and quadrupolar interaction of S state ions. Electric quadrupole transitions of octahedral complexes of transition have also been investigated. A systematic study has been made of the intensities of optical absorption spectra of octahedral complexes of transition metal ions by postulating a vibronic interaction. Calculations of electrostatic polarisability and nuclear shielding factors have been continued. Self consistent calculations of dynamic polarisability of H and He have been completed. A method has been suggested of gauge variation calculation of diamagnetic susceptibility and nuclear magnetic shielding in H_2 molecule. In our microwave laboratory the electric field used for the Stark cell has been calibrated against spectra of OCS. Instrumentation for accurate frequency determination was developed by Prof. B. M. Banerjee and his group. A detailed study has been made of the microwave spectra of ethylamine molecule in the K band and a preliminary theoretical investigation has been made to explain the spectra. Study is being made of 2-Chloropyridine and Sulphur dichloride molecules. Plans have been formulated to extend the range of investigation into the J, Q and X bands. In the field of EPR studies, improvement of instrumentation had to be continued. Study of g tensor components from line shape studies from polycrystalline samples of $CuCl_2.2H_2O$ and $CuSO_4,5H_2O$ is in progress. The NQR programme was concerned with the design and fabrication of a goniometer for determination of orientation parameters of the nuclei with quadrupole moments. This is now complete and is being tested with studies of $NaC10_3$ single crystals. The high resolution NMR investigations were concerned with studies of solvent

effects on NMR spectra of Aza-aromatics. The ambiguity of spin-spin coupling constants in the complicated high resolution spectra of pyridine was removed by a study on spin decoupling technique based on double resonance methods. This technique was also employed to determine the sign of gem coupling constants in a AMX system. Effects of substituents on Spin-Spin coupling constants was also investigated. NMR studies on solids were concerned with improvement of techniques for study of line shifts and improvements of NMR signals by use of pellets. NMR studies of P^{31} resonance in compounds containing P were systematically undertaken both in regard to relaxation processes and hyperfine interactions. A developmental programme was undertaken for construction of a heater-sensor assembly and a dewar for NMR studies at variable temperatures. In molecular biology, investigations were continued for determination of structures of biomolecules and derivatives and metal complexes of amino acids and peptides. The structure of Sarcosine hydrochloride has been completely determined. Those of ornithine hydrochloride, glycocyamine hydrobromide and copper lysine are nearing completion. Work has started with Sarcosine hydrobromide, glycocyamine hydrochloride, pure sarcosine, glutamyl glycine hydrobromide and copper ornithine. In the field of non-biomolecular crystals, structure determination of Ca-EDTA is at the stage of final refinement with 3-dimensional data. Two more crystals Sr-EDTA, Y-EDTA are being investigated. All the metal complexes and heavy ion replacements have been made in the laboratory. Electron microscopic studies of collagen from various sources are being continued and interesting results have been obtained. Physico-chemical and enzymatic studies of biomolecules are also being continued.

A. K. Saha
Head, Nuclear Physics Division

6.1 *The Electric Dipole and Octupole Transitions in Sr^{88}*

Exact zero-range force calculations have been performed to explain the collective nature of the 2.76 MeV 3^- State of Sr^{88}. The results show that the El transition is in good agreement with experiment while the E3 transition falls short by a factor of 10.

Publication :

A. K. Saha and S. Shastry, Nucl. Phys., *85*, 393, 1966.

A. K. Saha and S. Shastry

6.2 *On the Collective Octupole State in Sr^{88}*

A finite-range force calculation has been performed to explain the collec-

tive character of 2.76 MeV 3^- octupole state of Sr^{88}. The ratio of experimental to theoretical transition probability is 1.96.

S. Shastry and A. K. Saha

6.3 *Study of Odd-A Isotope of Sb*

Detailed comparison of the experimental level systematics of odd-A isotope of Sb with recent theoretical calculations has been done. It has been found that the theoretical calculations of Kisslinger and Sorensen using two basic excitations —(a) a quasi-particle excitation and (b) a phonon excitation—can explain the qualitative features of the experimental systematics to some reasonable extent. As regards quantitative comparison, in some cases of E2 and M1 transitions, disagreement between theoretical and experimental results is quite marked. Attempts are being made to fit the experimental data by suitably adjusting the phonon mixing parameter in the wave-function of the states concerned.

In order to extend hole-particle model to Sb^{117} a hole-particle excitation model calculation on Sn^{116} has been taken up. An exact zero-range force calculation is being performed to explain the collective nature of the first excited 2^+ and 3^- level of Sn^{116}. Taking strength of the δ-force to be 80 MeV, the first excited 2^+ state is found to be at 1.3 MeV and corresponding E2 transition ($2^+ \rightarrow 0^+$ ground state) rate 1.05×10^{12} sec^{-1}. The experimental values are 1.29 MeV and 1.4×10^{12} sec^{-1} respectively.

S. Sen and R. Bhattacharyya

6.4 *Levels of Re^{187}*

Re^{185} and Re^{187} have been found to have the smallest deformation amongst the nuclei in the region $150 \leqslant A \leqslant 190$. Calculations have been done by Galloghar et al. using Nilsson wave function on the levels of Re^{187}. On comparison with experimental results some differences were pointed out by them. In our experiments, the levels of Re^{187} decaying from W^{187}, were studied using total absorption gamma-spectroscopy, internal conversion measurements, various gamma-gamma coincidence and gamma-gamma angular correlation techniques. A level at 1.17 MeV was found to exist, suggesting that it is probably excited by a low energy weak beta-decay of W^{187}. With the help of the coincidence experiments and the correlation experiments on the 72-134 keV and 552-134 keV cascades a level scheme was worked out.

A. K. Nigam

6.5 *Measurements on Nuclear g-factor*

By measuring the angular correlation with the source placed in a magnetic field, the g-factor has been determined for a few nuclei. The field can be raised up to 18 K.G. for a pole gap of 3 mm. The stabiliser used for energising the magnet was built in the laboratory at a current stability of better than five in ten thousand. The 122 keV level of Sm-152 has been measured by the IRF method where the 1411-122 keV and 1112-122 keV cascades are taken into account. g is found to be 0.28. In the case of Hf-181, the DDRF method is utilised for the 482 keV level taking 133-482 keV cascade into account, yielding a value of 1.28 for g. The 379 keV level of Tm-169 has also been investigated according to DDRF method using the 93-63 keV cascade. In this case g is found to be 1.38. Further work on this nuclide is in progress. Investigation on the 35 keV level of Te-125 following the IRF method has been taken up recently.

A. K. Nigam and R. Bhattacharyya

6.6 *Monopole Transition in Au-197*

It has been reported previously that the 268 keV level of Au-197 has a spin parity $3/2^+$. This is also supported by de-Shalit's calculation. An analysis of the experimental data on internal conversion coefficient of the 191 keV-gamma ray from the 268 keV level indicates the necessity of assumption of an EO component in this transition in presence of M1. This explanation, however, needs the 268 keV level to be $\frac{1}{2}^+$. In absence of any other confirmatory experiment, a lifetime measurement on the 268 keV state has been undertaken to find whether or not an E2 component is present in the 191 keV transition and hence support a $3/2^+$ spin of the 268 keV level.

In Au-197, which contains 3 protons in the $d_{3/2}$ shell, de-Shalit has made a calculation by coupling the odd $d_{3/2}$ proton with the 2^+ state of Pt-196 core. His calculation indicates that the 268 keV level is $3/2^+$ and not $\frac{1}{2}^+$ as demanded experimentally. Work is in progress to explain the possibility of a $\frac{1}{2}^+$ 268 keV level by considering it to be composed of (a) $d_{3/2}$ proton excited to $S_{1/2}$ state and (b) a $d_{3/2}$ proton coupled with the 2^+ state of the core. Implications of this assumption on the various transition rates are being studied.

B. K. Sinha and R. Bhattacharyya

6.7 *Curves for Mixing Ratios*

In order to find out the multipole mixing ratio δ from gamma-gamma angular correlation experiments, a series of curves have been drawn in the form

of parametric graphs of dependence of correlation expansion coefficients on spin and multipole mixtures for all likely combinations of cascades. One set of curves plotted as A_2 vs $\log_{10}\delta$ is meant for cascades having $A_4 = 0$, and another as A_2 vs A_4 where $A_4 \neq 0$. This spin and δ can then be ascertained from inspection.

S. Mahajan

6.8 *Electron-electron Pair Spectrometer*

The electron-electron pair spectrometer has been put in operation. The individual spectrometer fields have been aligned using a Cs-137 beta-source and X-ray plates as detectors. The focussed spots on each plate show a 20% increase in diameter compared to the diameter of the source. The installation of the detectors and the baffle-systems are nearing completion. Transistorised current stabilisers have been developed with a stability of one in ten thousand. Arrangements are also being made for studying e_k-gamma angular correlation in connection with experiments on EO transitions.

R. Bhattacharyya and S. Chatterjee

6.9 *Shell-model calculation on P^{30} and Si^{30}*

Conventional shell-model with residual interaction is expected to give a quantitatively correct description only for nuclei which differ by a few nucleons from closed shell nuclei. The residual interaction for nucleons outside closed shells is contributed to mainly by quadrupole-quadrupole and pairing interactions, but the latter contribute a negligible amount to the pairing energy of nearly 1 to 2 MeV. From these considerations Moszkowski suggested a surface interaction of the delta-function type (SDI),

$$V_{12}(\bar{r}_1 - \bar{r}_2) = \delta(\bar{r}_1 - \bar{R})\ \delta(\bar{r}_2 - \bar{R})\ V_0$$

A major consequence of the surface interaction is that the radial integrals which appears in the Slater expansion are equal, since the one-particle radial wave-functions all have approximately the same amplitude at the surface.

Using the above form of residual interaction, the level schemes of P^{30} and Si^{30} were constructed according to the jj-coupling scheme, and are compared with the available experimental data. This is shown in Fig. 6.9.

K. V. Chelapati Rao and P. Mukherjee

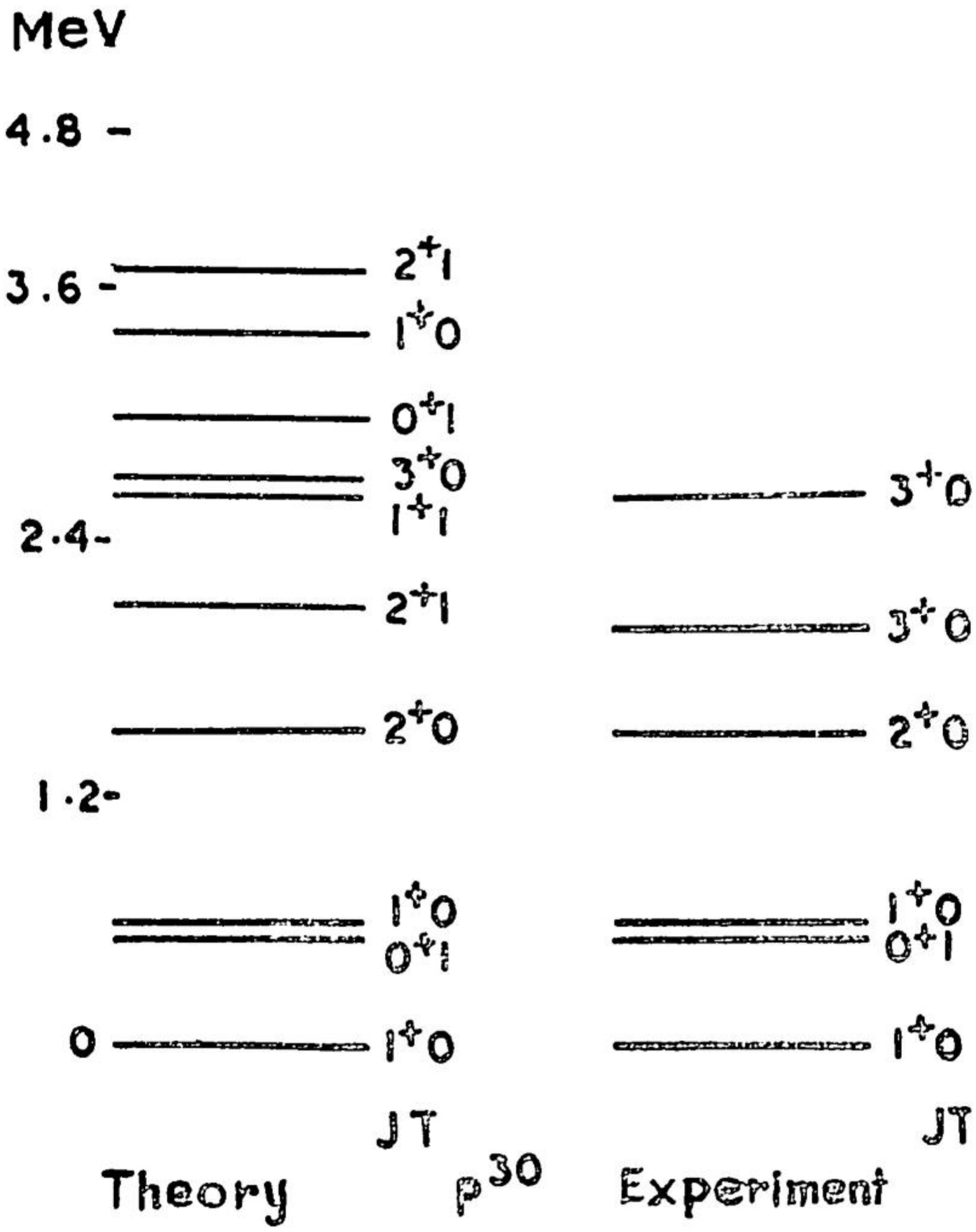

Fig. 6.9

6.10 *Shell-model Calculation on Ca^{50}*

It is generally established that Ca^{48} is a better closed shell than Ca^{40}, as far as the neutron states are concerned. This is apparent from the (d,p) reaction data on these isotopes. Using the SDI as the residual interaction and starting from the single neutron states observed in Ca^{49} the level scheme of Ca^{50} was constructed according to the jj-coupling scheme. The theory predicts one 3^-, three 5^-, one 6^+, one 7^- and one 8^+ states all of which shohld be prominently excited in the (t, p) reaction, A comparison of the theoretical results with the experimental data is shown in Fig. 6.10 .

P. Mukherjee, K. V. Chelapati Rao and I. Mukherjee

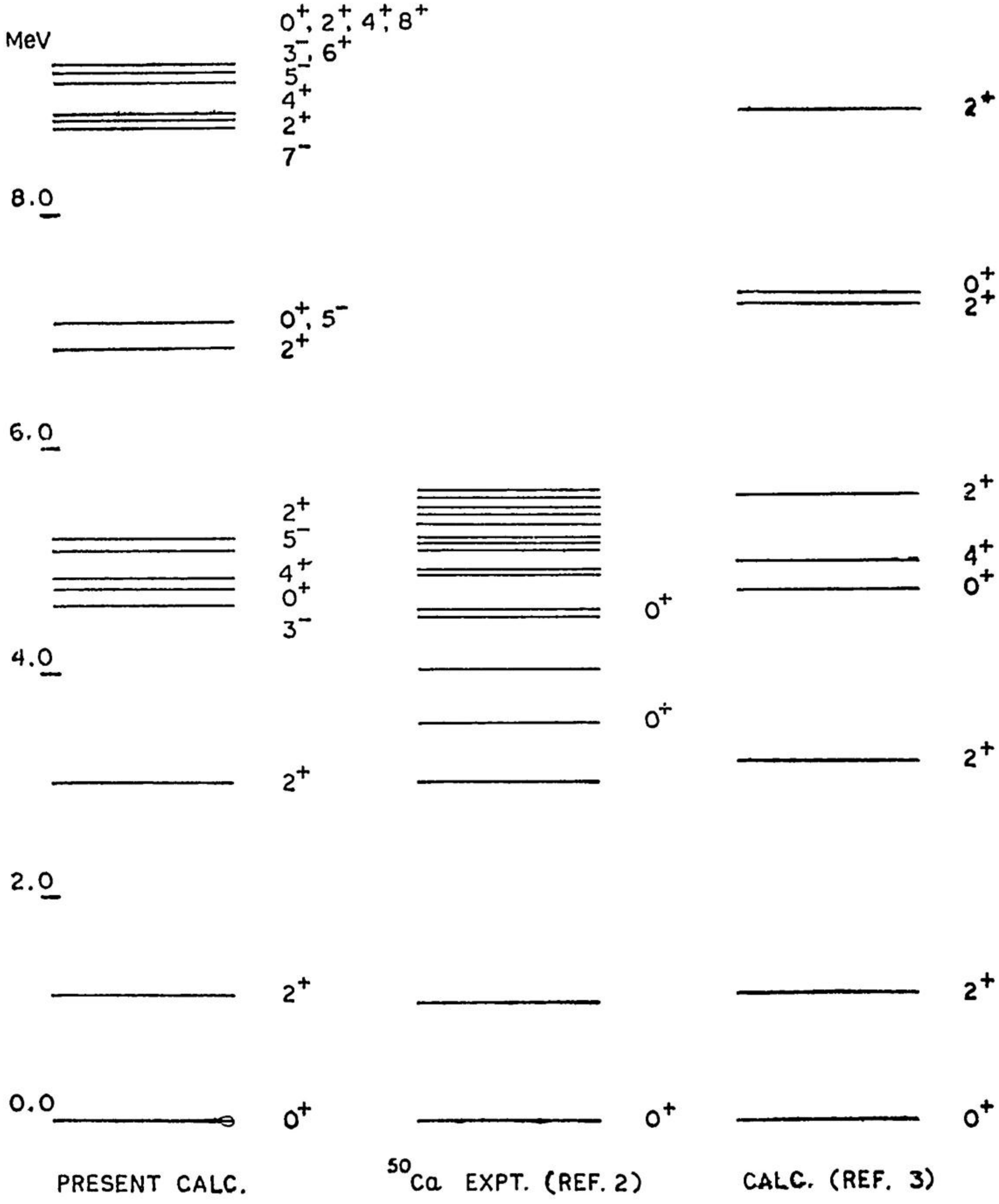

Fig. 6.10

6.11 (*t*, *p*) *Reaction Studies*

To check the validity of the wave-functions obtained from the SDI it was attempted to extract from them the information relevant to double-transfer reac-

tions, specifically the (t, p) reactions. Data on L = O (t, p) reactions in medium heavy nuclei show that when the ratio of excited state intensity to ground state intensity is plotted against the neutron number of the residual even-even nucleus, it shows a sharp fall beyond N = 28. Theoretically, the cross-sections are determined by the structure factors, G given by

$$G_{NLSJT}(J_1,J_2) = g\sum_{\gamma}{}^{\beta}{}_{LSJT}(J^1,J_2)\,\Omega_n\langle n_o, NL; L \mid n_1l_1,n_2l_2\,;\,L\rangle$$

The parentage factors β for configuration mixed wave-function are determined by the wave-functions. Using SDI wave-functions for the nuclei O^{18}, Si^{30}, Ca^{50}

TABLE 6.11(A)

O^{16} (t,p) O^{18} reaction cross-sections estimated from shell model wave-functions

			$(d_{5/2})^2$	$(s_{1/2})^2$	$(d_{3/2})^2$	ΣG	$(\Sigma G)^2$
Ground	0^+	– State	– 0.915	– 0.35335	0.19446		
G_{20001}			0.0526	0.2280	0.0644		
G_{10001}			0.0041	– 0.0035	0.0050	– 0.1192	0.0142
G_{00001}			0.0007	0.0030	0.0009		
Excited	0^+	– State	–0.3691	0.9281	– 0.0497		
G_{20001}			0.0526	0.2280	0.0644		
G_{10001}			0.041	– 0.0035	0.0050	0.1934	0.0374
G_{00001}			0.0007	0.0030	0.0009		

$$\frac{\sigma_{ex}}{\sigma_{ground}} = \frac{(\Sigma G)^2_{ex}}{(\Sigma G)^2_{ground}} = 2.6334$$

TABLE 6.11(B)

Ca^{48} (t,p) Ca^{50} reaction cross-sections estimated from shell model wave-functions

			$(p_{3/2})^2$	$(f_{5/2})^2$	$(p_{1/2})^2$	$(g_{9/2})^2$	ΣG	$(\Sigma G)^2$
Ground	0^+	–State	0.9461	0.1686	0.1707	0.2174		
G_{40001}						0.00878		
G_{30001}			0.41252	0.14431	0.29173	– 0.00502		
G_{20001}			– 0.00858	– 0.06308	– 0.00606	– 0.00109	0.44696	0.19980
G_{10001}			0.00129	0.00949	0.00091	– 0.00011		
G_{00001}			– 0.00149	– 0.00052	– 0.00105	0		

Excited 0^+ –State	– 0.2701	0.8817	0.2409	0.3026		
G_{40001}				0.00878		
G_{30001}	0.41252	0.14431	0.29173	– 0.00502		
G_{20001}	– 0.00858	– 0.06308	– 0.00606	0.00109	0.03567	0.001273
G_{10001}	0.00129	0.00949	0.00091	– 0.00011		
G_{00001}	– 0.00149	– 0.00052	– 0.00105	0		

$$\frac{\sigma_{\text{excited}}}{\sigma_{\text{ground}}} = \frac{0.001273}{0.19980} = 0.006368$$

and Ni^{58}, the values of β for the reactions O^{16} (t, p) O^{18}, Si^{28} (t, p) Si^{30}, Ca^{48} (t, p) Ca^{50} and Ni^{56} (t, p) Ni^{58} were calculated and the values of the cross-section ratios have been computed. These are presented in Table 6.11 (A) and (B). It will be seen that the SDI wave functions give a correct estimate of the cross-section ratios.

K. V. Chelapati Rao and P. Mukherjee

6.12 *Modified Nilsson Orbitals in the N = 5 and 6 Shell*

The usefulness of the Nilsson orbitals in understanding and predicting the properties of the ground and excited states of the deformed nuclei is now universally recognised. Refinements like the pairing effect in the deformed nuclei and the Hartree-Fock calculations are now being attempted where the basic states are those tabulated by Nilsson. Unfortunately, most of the neutron states and almost all the proton states were unlocated at the time of Nilsson's work. Therefore he had to use a rather unrealistic empirical spectrum. Later experimental work, specially those involving single particle transfer reactions have indicated that all the levels in the N = 5 and N = 6 shells are very much different from the level scheme in Nilsson's work. In view of these facts we have undertaken an extensive recalculation of Nilsson's work. We hope to gain new informations about the properties of the deformed nuclei from such an analysis and we expect that our wave functions should be more realistic in the subtler field of Hartree-Fock calculations. We also propose to test our wave-functions in the analysis of the (d, p) reaction data on several even-A deformed nuclei.

As a starting point of these recalculations, we have attempted to get a fit with the experimental level scheme. Through a graphical analysis of the experimental data it is found that χ (the spin-orbit parameter) = 0.033 and μ (the interpolation parameter) = 0.35 would give a close fit for nine of the twelve neutron levels in the N = 5 and N = 6 shells. The reason for the $i^{13/2}$ level not coming into the fit might be understood as due to the fact that it crosses from one major shell to the other with a large spin-orbit splitting. It is also found that with

$\chi = 0.066$ and $\mu = 0.25$ this level also comes into agreement. A typical Nilsson diagram is shown in Fig. 6.12.

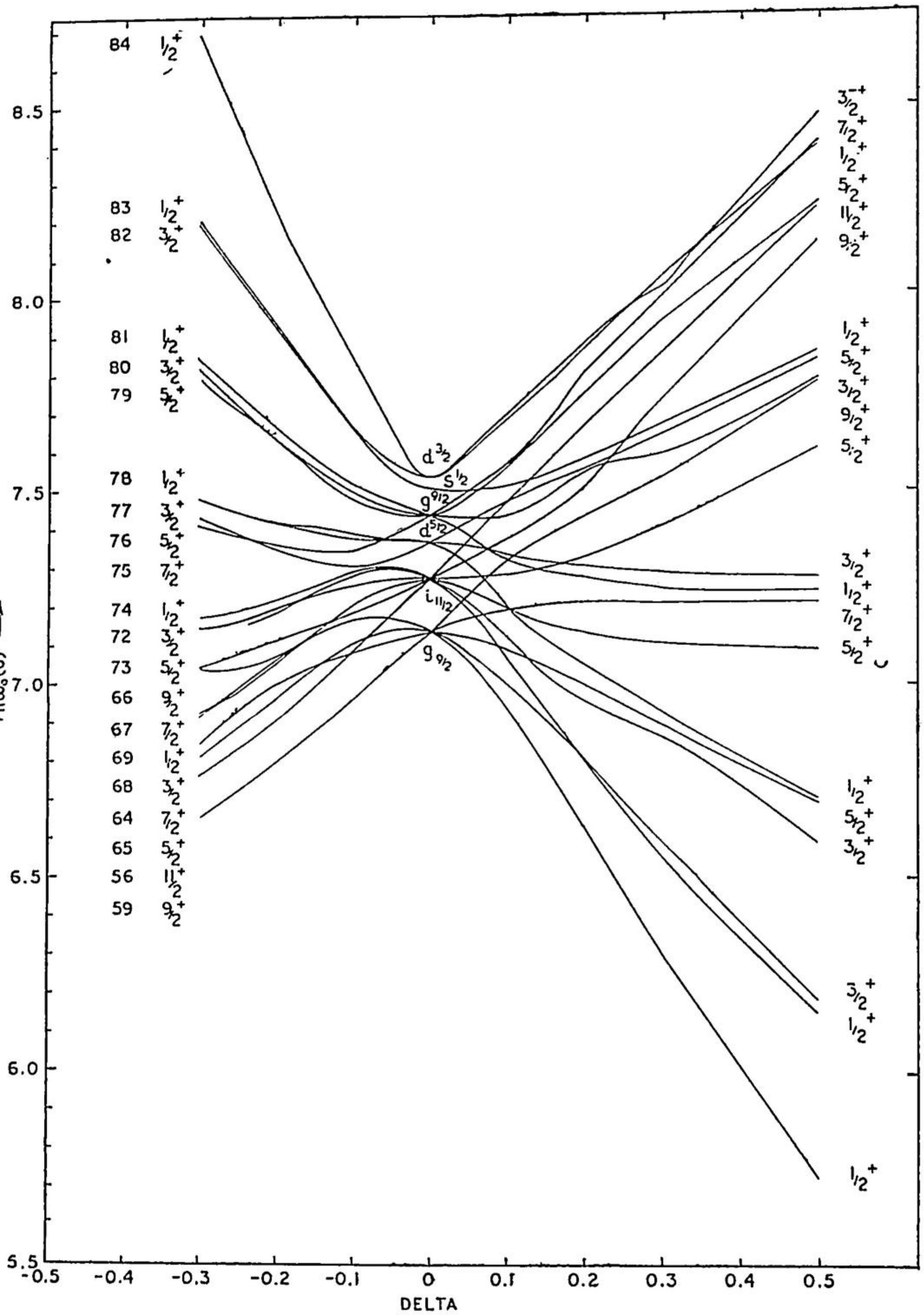

Fig. 6.12

Having thus obtained a better choice of parameters the single particle levels have been calculated in the above mentioned region and a plot is made of the energy ($2\pi E/\hbar w_0(\delta)$) vs. the deformation parameter δ. These so-called modified Nilsson orbitals are found to be very different from the original work of Nilsson. From this graph ground state spins of twelve rare earth nuclei have been determined. These are listed in Table 6.12(A). An estimate of the equilibrium deformation

TABLE 6.12(A)

Ground state spins of rare earth nuclei

Nucleus	I(exp.)	Deformation	I(Present)
$_{64}Gd^{155}$	$3/2^-$	0.31	$3/2^-$
$_{64}Gd^{157}$	$3/2^-$	0.31	$3/2^-$ or $9/2^-$
$_{66}Dy^{161}$	$5/2^+$	0.31	$1/2^-$ or $5/2^-$
$_{66}Dy^{163}$	$5/2^-$	0.30	$5/2^-$ or $7/2^+$
$_{68}Er^{167}$	$7/2^+$	0.29	$5/2^-$ or $7/2^+$
$_{70}Yb^{173}$	$5/2^-$	0.28	$5/2^-$ or $11/2^-$
$_{70}Yb^{175}$	$7/2^-$	0.28	$7/2^-$ or $9/2^+$
$_{72}Hf^{177}$	$7/2^-$	0.27	$7/2^-$ or $9/2^+$
$_{72}Hf^{179}$	$9/2^+$	0.26	$7/2^-$ or $9/2^+$
$_{74}W^{183}$	$1/2^-$	0.21	$1/2^-$ or $3/2^-$
$_{76}OS^{187}$	$1/2^-$	0.18	$1/2^-$ or $3/2^-$
$_{76}OS^{189}$	$3/2^-$	0.15	$3/2^-$ or $7/2^-$

parameter has also been attempted by plotting total energy vs. deformation. In this plot it is assumed that the protons which are completely paired off will not contribute significantly to the variation of total energy. Also it is assumed that the omission of the single particle energies of neutrons upto $N=70$ will not make much difference. As a first test of our wave-functions, decoupling parameters have been calculated for the different $K=1/2$ orbitals. The values are given in Table 6.12(B), which also includes Nilsson's values (in brackets). The table shows a striking variation of the modified decoupling parameter from those of Nilsson. For the (510 $1/2^-$) orbital of W^{183}, though 'a' does not coincide with the experimental value, the variation of the value is certainly to the better side. This difference from Nilsson's values reveals the fact that the involved parameter has quite a bit of importance.

G. Ramakrishna and P. Mukherjee

TABLE 6.12(B)

Decoupling parameters for different orbitals

$[Nn_z \Lambda \Omega_\pi]$ \ δ	−0.3	−0.2	−0.1	0	0.1	0.2	0.3
[501 1/2⁻]	0.38	0.713	1.166	1.00	1.0323 (−0.96)	0.843 (−0.85)	0.697 (−0.76)
[510 1/2⁻]	−0.179	−0.082	0.119	3.00	0.409 (0.16)	−0.236 (−0.17)	−0.432 (−0.34)
[521 1/2⁻]	0.299	0.723	1.055	−2.00	0.573 (0.78)	0.817 (0.95)	−0.002 (0.89)
[530 1/2⁻]	−0.400	−0.086	2.789	5.00	3.032 (−3.78)	0.152 (−3.01)	−0.760 (−2.08)
[541 1/2⁻]	−0.304	0.139	−1.368	−4.00	−2.425 (2.71)	0.099 (−0.31)	0.517 (−1.04)
[550 1/2⁻]	−2.796	−4.411	−5.625	−6.00	−5.642 (5.89)	−4.699 (5.73)	−3.691 (5.05)

6.13 *Studies on the Magnetic and the Electrical Properties of Rare Earth Metals*

Rare earth metals, in general, indicate a number of phase transitions which are clearly evident from the magnetization vs. temperature curves. The crystalline electric field, in addition to the anisotropic exchange interaction, plays an important role in the magnetic and electrical properties of these metals. Preliminary investigation on the magnetic properties of rare earth metals has been made following the double-time Green function technique. But for numerical estimates, the magnitude of the crystalline field parameters is necessary. Hence a programme of work on the origin of crystalline electric field in rare earth metals is now being carried out. The ionic contribution to these parameters has been estimated. The conduction electrons are expected to contribute significantly. Unfortunately, no band calculations are available for rare earth metals except for Gd metal. Using the spherically symmetric part of the crystal potential, band calculations for the rare earth series have been undertaken and these are now in progress. The effect of the non-spherically symmetric part of the potential on the conduction electrons will be studied next.

K. C. Das and D. K. Ray

6.14 *Origin of the Crystalline Electric Field in Rare Earth Compounds*

Continuing our work in this line, we have investigated in detail the effect of the overlap between the magnetic electron wave function of the central Pr^{3+} ion and the electronic wave function of the nearest Cl^- ions on the crystal field parameters of Pr^{3+} ion in $PrCl^3$ crystal. The Coulomb part of the overlap contribution, which always opposes the point charge contribution, to $A^0_6\langle r^6\rangle$ and $A^6_6\langle r^8\rangle$ is nearly double the point charge contribution, while for $A^0_4\langle r^4\rangle$ and $A^0_2\langle r^2\rangle$ it is 89 percent and 23 percent, respectively, of the point-charge contributions. The calculation emphasises the need for detailed molecular-orbital treatment of crystal field splitting of the energy levels of rare-earth ions in crystals, possibly allowing for the covalency.

(A. K. Raychaudhuri and D. K. Ray, 'Effect of the Ligand Charge Distribution on the Crystalline Electric Fields of the Rare-Earth Ions', to be published in Proc. Phys. Soc. (London).)

A. K. Raychaudhuri and D. K. Ray

6.15 *Phonon Processes in Paramagnetic Crystals*

(i) Phonon processes in Kramer's systems have been studied and the dynamical Hamiltonian has been set up, taking proper account of time reversal

considerations. The result of these studies indicates the importance of a dominant Zeeman-field independent two-phonon process. The effect of this process on the anisotropy of the spin-lattice relaxation in crystals of different symmetries has been worked out.

(ii) The numerical estimation of the spin-lattice relaxation is being completed for paramagnetic ions in cubic crystals viz. Co^{2+} in MgO and Yb^{3+} in CaF_2. The Zeeman field independent relaxation has been shown to be isotropic in cubic crystals whereas the anisotropy is entirely due to the Zeeman relaxation. The absolute magnitude and the anisotropy of the spin lattice relaxation has been calculated under Debye approximation. The effect of the phonon distribution on this is under investigation now.

(iii) The effect of the lattice vibration on g factors of paramagnetic ions has been studied and the work is near completion. Both the temperature independent contribution due to the zero-point vibrations and the temperature dependent contribution due to two-phonon and higher order processes are being calculated for Cu^{2+} in crystals of tetragonal symmetry.

(iv) The spin-lattice relaxation and thermal conductivity in magnetic crystals, particularly near the transition temperature, are being studied. Problems of decoupling in the double time Green function with particular reference to these studies are being investigated. Attempts are being made to set up the appropriate Generating Functions following Matsubara's procedure, from which the Green function of any order can be evolved.

D. K. Ray, T. Ray and S. K. Gupta

6.16 *Zero-field Splitting and Nuclear Quadrupole Interaction for S-state Ions*

The crystal field has no direct influence on the ground S-state of iron and rare earth ions and so the spin degeneracies are not removed in the first approximation. Nevertheless, quite large splittings are observed experimentally and to explain these a number of mechanisms have been suggested. A study has been made to see whether the spin-spin interaction in conjunction with axial crystal field can explain the magnitude of the splitting observed for these ions. The axial field also causes the nuclear quadrupole interaction and so the zero field splitting and the nuclear quadrupole interaction are interrelated. The results so far obtained for Mn^{2+} ion show that the theoretical ratio of zero field splitting and nuclear quadrupole interaction due to this mechanism is in excellent agreement with experimental values. The cases of Eu^{2+} and Gd^{3+} ions are now being studied.

M. N. Ghatikar and D. K. Ray

6.17 *Electric Quadrupole Transitions of the Octahedral Complexes of the Transition Metal Ions*

The algebraic expressions for the oscillator strengths of the electric quadrupole transitions in kd^n ($k = 3, 4, 5$; $n = 1, 2, \ldots, 9$) octahedral complexes have been derived. The oscillator strength of a particular transition has been shown to be dependent on $\langle\bar{r}^2\rangle$ and the energy separation of the two states in which the transition is taking place. A misconception regarding $\langle\bar{r}^2\rangle$ has been pointed out, though fortunately it does not effect too much the magnitude for the oscillator strengths.

(A. S. Chakravarty, 'On the Electric Quadrupole Transitions of the Octahedral Complexes of the Transition Metal Ions', to be published in Ind. J. Phys.)

A. S. Chakravarty

6.18 *Intensities of the Optical Absorption Spectra of the Octahedral Complexes of the Transition Metal Ions*

The origin of the optical absorption spectra of the octahedral complexes of the transition metal ions is not yet completely understood, though it is now generally conceded that the visible absorption bands of such inorganic complexes are vibronically (vibrational-electronic) allowed electric-dipole transitions among the various kd^n electronic configurations ($k = 3, 4, 5$ and $n = 1, 2, \ldots, 9$). In order to get the oscillator strengths of the electric-dipole transitions for the kd^n systems, we have considered the vibronic interaction mechanism by which the kd wave-functions of the transition metal ions get mixed up with some $(k+1)p$ wave-functions and thus the electric-dipole transitions get allowed. Obviously, the odd vibrations of the ligands are responsible for such mixing. We have, however, assumed the point-charge model and the necessary integrals have been calculated using (1) hydrogenic (2) Slater's and (3) Richardson-Watson's wave functions. The oscillator strengths calculated by (1) and (2) have been given against Z_{kd} (effective) and compared with those calculated by (3). We have also calculated the magnetic dipole transitions in such systems. Since the experimental absorption bands are very broad in such complexes it is very difficult to get an accurate value of the oscillator strengths of a particular transition from the experiment. Therefore, we should expect an order of magnitude agreement of the theory with experiments which we indeed do get from our calculations. Lastly, there is a great need for experimentally accurate value for the odd vibrational frequencies (υ_3, υ_4 and υ_6) as well as the oscillator strengths of the

optical absorption spectral transitions of the individual complexes without which an exact estimation of the oscillator strength from the theory would lose much of its importance.

A. S. Chakravarty

6.19 *Electrostatic Polarizability and Nuclear Shielding*

Following the procedure developed in this laboratory (details given in the last year's report) we have calculated the dipole and quadrupole polarizabilities and consequent nuclear shieldings (or anti-shieldings) for 10 and 18 electron closed shell atoms. A self-consistent perturbation approach has been employed maintaining full coupling amongst the perturbed one electron orbitals. The results obtained are the most accurate values for these atoms calculated upto date. Details of the calculation are presented in the following paper :

(J. Lahiri and A. Mukherji, 'Electrostatic Polarizability and Shielding Factors for Ions of Neon Configuration', to be published in Phys. Rev.).

J. Lahiri* and A. Mukherji

*Now at New York University, N. Y.

6.20 *Dynamic Polarizability*

The dynamic polarizability of Hydrogen and Helium have been calculated by considering the effect of an external electromagnetic radiation on an atom through time dependent perturbation procedure. Self-consistent solutions have been obtained in the Harrree-Fock scheme. The coupling of the perturbed functions through the self-consistency procedure markedly alters the relative contribution of the different terms to the total polarizability.

The method developed is quite general and equally applicable to atoms and molecules. Studies of the variation of polarizability with frequency of the radiation reveal certain limitations of the perturbation treatment and also of Koopman's Theorem.

(S. Sengupta and A. Mukherji, 'Self-Consistent Calculation of Dynamic Polarizability', to be presented at the International Conference on Spectroscopy, Bombay, Jan. 1967.)

S. Sengupta and A. Mukherji

6.21 *Guage-variation Calculation of Diamagnetic Susceptibility and Nuclear Magnetic Shielding in Hydrogen Molecule*

To calculate the diamagnetic susceptibility of a molecule, we formulate the energy of the molecular electrons in an external dc magnetic field, retaining only the first-order term in Rayleigh-Schrodinger perturbation scheme. That is, we write

$$\chi_{\lambda\lambda} = [- \alpha^2 a_o] \quad \frac{\delta^2}{\delta H \lambda^2} < A^2 > \qquad \ldots \qquad (1)$$

where α is the spectroscopic fine-structure constant, a_0 the Bohr radius, A is the vector potential describing the external magnetic field H, and λ stands for x, y or z indicating the direction. The symbol, $< >$, stands for averaging over the unperturbed state. Obviously, the magnitude of the above term depends on the choice of the vector potential guage function. The part of the diamagnetic susceptibility left out is the contribution from the second-order perturbation term, whose magnitude is also guage-dependent. But the sum total of these two terms must be guage-invariant. If, now, one varies the form of the guage function such that the second order term remains always positive, it follows that the latter will be minimum for the vector potential that minimises the magnitude of the first-order term. This leads us to the variation method (vide Soviet Phys., JETP, *II*, 694, 1960 and Mol. Phys., *7*, 473, 1964) in which the total diamagnetic susceptibility can be obtained from only the first-order perturbation term, in which the vector potential guage function has been varied to minimise its magnitude.

In actual calculation, the vector potential has been written in the form:

$$\vec{A} = \tfrac{1}{2} \vec{H\lambda} \times \vec{r} + \vec{H\lambda} \nabla f(x,y,z) \qquad \ldots \qquad (2)$$

Here, $\vec{r}$ is measured from the charge-center of the electron system. f(x,y,z) is a polynomial in x, y and z, and two cases have been considered :

1. 'f' is of second degree.
2. 'f' is of fourth degree.

In order that the second-order term remains always positive, the function -al form of f(x,y,z), that contributes to the first-order term should be of the form (when $\lambda \equiv x$) :

Case. 1. $f(x,y,z) = l^{(2)} yz$

Case. 2. $f(x,y,z) = l^{(4)} yz + m^{(4)} yz \ (z^2 - y^2)$ ..... (3)

l and m are variation-parameters, the superscripts denoting the degree of the polynomial 'f'. Using (2) and (3) in (1), l and m have been varied such that χ in (1) becomes minimum, and the expressions for χ_{xx} , χ_{yy} and χ_{zz} have been obtained in this way.

One can show (vide J. Chem. Phys., *36*, 737, 1962) that using a vector potential as given in (2) and (3), one can calculate the total nuclear magnetic shielding from the relevant first-order part only, i.e.

$$\sigma_{\lambda\lambda} = [\,\varkappa^2 a_o\,] \frac{\delta^2}{\delta H_\lambda \delta \mu_\lambda} < \vec{A}_{H_\lambda} - \vec{A}_{\mu_\lambda} > \qquad \ldots \quad (4)$$

With Wang (vide Phys. Rev., *31*, 579, 1928) function for hydrogen molecule ($R = 1.406\ a_0$, $Z = 1.166$), the following results are obtained:

A. Diamagnetic Susceptibility (in units of $\alpha^2 a_0^3$).

	Second degree approx.	Fourth degree approx.
$\chi_{xx} = \chi_{yy}$	–0.9153	–0.9068
χ_{zz}	–0.7670	–0.7670
$\chi = 1/3\,(\chi_{zz} + 2\chi_{xx})$	–0.8659	–0.8602
Experimental χ (Wills & Hector, Phys. Rev., *23*, 209, 1924)	–0.829	

B. Nuclear Magnetic Shielding Constant (in units of 10^{-5}).

	Second degree approx.	Fourth degree approx.
$\sigma_{xx} = \sigma_{yy}$	3.2307	3.0673
σ_{zz}	2.7957	2.7957
$\sigma = 1/3\,(\sigma_{zz} + 2\sigma_{xx})$	3.0857	2.9767
Experimental (Ramsey, Phys. Rev., *78*, 699, 1950).	2.62	

The results for diamagnetic susceptibility show that the improvement in the value of total χ, in fourth degree approximation over the second degree approximation, is very small ($\sim$0.1%). This improvement appears doubtful because of the inaccuracy in the wave-function itself. It is suggested that with a Wang type wave-function it is sufficient to use f(x,y,z) as a second degree polynomial only. The use of f(x,y,z) as a higher degree polynomial (including the fourth) in large molecules may not be very useful unless more accurate wave-functions are available.

S. K. Sinha and S. K. Mondal

6.22 *Irreducible Tensor Operators for Finite Groups*

A method is derived for obtaining the tensor covariants of the finite groups, belonging to any factor system, starting from an arbitrary tensor of rank r in a

N-dimensional vector space. The transformation properties of the irreducible tensor operators for the projective representations of the group have been discussed. The Wigner-Eckart theorem for these representations has also been studied.

Publication:

P. Rudra, J. Math. Phys., *7*, 935, 1966.

P. Rudra

6.23 *Green Functional Analysis of Magnetic Systems*

Green functional analysis is being made for magnetic systems having magnetic symmetry. A lead in this direction is G. Obermair's work in Helv. Phys. Acta, *182*, 5, 1964. He has applied the irreducible representations of the Permutation group to obtain an effective Hamiltonian to describe certain low lying excited states of a ferromagnetic system.

P. Rudra

6.24 *Calibration of the Stark Field and Accurate Frequency Determination of the K-band Gaseous Microwave Spectrometer*

For calibrating the applied stark field of the spectrometer OCS (Carbonyl sulfide) was prepared in our laboratory and a complete field calibration chart was prepared.

Accurate frequency determination of spectral lines was achieved by means of a unit built by the Instrumentation Division of our Institute. The standard frequencies for such measurements are derived from a quartz crystal-controlled 100kc/s oscillator, the crystal itself being mounted in a thermostatic oven for constancy of temperature. A series of frequency-multiplying circuits then steps up this frequency to 500Mc/s. This frequency along with the lower frequency of 50 Mc/s is fed into an IN26 crystal multiplier. This crystal produces harmonics in the region of the klystron frequencies (18-26kMc/s) at intervals of 50 Mc/s. At the same time the crystal serves as a mixer giving beat notes between the harmonics and the klystron frequency. These beat frequencies varying from 0 to 50 Mc/s may be measured accurately by means of a calibrated communications receiver. From this measurement the frequency of the spectral line may be easily but accurately measured (Accuracy 1 in 10^7).

D. K. Ghosh and A. Chatterjee

6.25 *Microwave Spectra of Ethylamine Molecule*

A complete mapping of absorption lines in the range 18.0 kMc/s – 26.0 kMc/s. (barring the region 20.5 kMc/s. – 21.5 kMc/s. in which the klystron presents a dead zone) was made; about 100 lines were observed. Their frequencies were measured accurately as also a complete list drawn up showing their behaviour under the influence of a Stark field. A rough estimate has also been made of the intensities of the ethylamine lines. A detailed Stark-effect study of three or four lines which split favourably has been made and assignments of transitions corresponding to these frequencies are under way.

A theoretical study of the ethylamine molecule is also in progress. A complete programme has been written out and it will enable us to calculate the frequencies corresponding to all types of transitions permissible by selection rules. The effect of internal rotation on overall rotation has been incorporated. This programme will permit calculations for all values of bond lengths, bond angles as well as potential barriers to internal rotation. The idea is to fit a set of theoretical frequencies as close as possible to the experimental values.

(D. K. Ghosh, A. Chatterjee and A. K. Saha, 'Microwave Spectra of Ethylamine Molecule', to be presented at the International Conference on Spectroscopy, Bombay, Jan. 1967.)

D. K. Ghosh, A. Chatterjee and A. K. Saha

6.26 *Microwave Spectra of 2-Chloropyridine and Sulphur dichloride*

The spectra of 2-Chloropyridine has been recorded and the assignment of spectral transitions is in progress. Sulphur dichloride has been prepared in our laboratory and the work is also in progress. Extension of the present programme of work to microwave spectroscopy in J, Q and X bands is contemptated.

A. Chatterjee and D. K. Ghosh

6.27 *ESR Spectroscopy*

Experimental investigations on the line-shapes of ESR signals from samples like $CuCl_2$, $2H_2O$ and $CuSO_4$, $5H_2O$ were started. It was felt that the depth of modulation of the 100 kc/s field at sample site within the thin-walled brass-cavity (a cylindrical resonator operating at TE_{011} mode) was insufficient for delineation of wide resonance lines--as those obtainable from samples mentioned above. One rectangular cavity operating at TE_{012} mode and another cylindrical

cavity at TE_{011} mode, made of perspex but gold-plated inside, were designed and developed. Both had the microwave feed system to the side of the cavity. The cavities proved ideal for studies on polycrystalline or aqueous samples at room temperature or lower temperatures if desired. A small triple-walled Dewar assembly had also been constructed for studies at liquid-air temperatures.

Studies on single crystals of paramagnetic substances need a high Q cavity with its feed system from the top. This then facilitates the rotation of the magnet around the sample—without in any way hampering the tuning of the resonant microwave cavity. For studies on g-anisotropy or hyperfine splitting, the necessary cavity (cylindrical TE_{011} cavity made of perspex—gold-plated inside) with feed through a tapered transition section fitted with Styron 666 is under development.

The derivative line-shapes of signals from polycrystalline $CuCl_2$, $2H_2O$ and $CuSO_4$, $5H_2O$ have been recorded. The data is now being analysed for evaluation of g-tensor components.

The development of 400 c/s modulation system and its detector-amplifer channel—an annexure to the existing ESR spectrometer—and the TE_{104} mode rectangular cavity, have all been set aside as a programme for the next year. The dual modulation system would not only provide the second derivative presentation of the signal, but it would improve upon the S/N ratio of the spectrometer assembly. Further it would provide an easy way for extrapolating the g-values by the method of comparison with the spectra of known samples.

Till now the sensitivity of the spectrometer has been found to be of the order of 10^{14} spins, but another hundred-fold improvement in sensivitity is expected when the dual modulation channel will be introduced. A dual-pen-recorder is needed for such a presentation, but this recorder could not be procured this year for want of fund and the necessary foreign exchange.

R. Roy, S. K. Sinha and A. K. Roy

6.28 *NQR Spectroscopy*

The study on Nuclear Quadrupole Resonance on Cl^{35} nuclei in $NaClO_3$ single crystal was continued. A goniometer sample holder assembly was designed and fabricated. This goniometer device allows rotation of the single crystal around three mutually perpendicular axes—a procedure by which different crystal parameters such as assymmetry parameter η, quadrupole coupling constant eq.Q, for the nucleus in the crystal environment can be easily determined. The diameter of the sample coil had to be enlarged for accommodating the goniometer head-cum-crystal assembly. The low filling-factor obtained thereby calls for an improvement in the S/N ratio. With this object in view, a four-stage twin-tee-amplifier tuned at 400 cps with a gain of 100 db and a bandwidth of 3c/s has been fabri-

cated. The phase-sensitive-detector operates with synchronised gate signals at 400 pps, but the frequency of the modulation signal on the Varicap in the regenerative-detector circuit was kept at 200 cps. The NQR signal from Cl^{35} in the shape of the second derivative pattern, has already been obtained with an appreciable improvement in the S/N ratio. The results of these investigations on Cl^{35} in $NaClO_3$ crystal are being scrutinised at present.

A. K. Saha, R. Roy and S. Sengupta

High Resolution NMR Studies

6.29 *Solvent Effects in the NMR Spectra of Aza-Aromatics*

Solvent effects on proton chemical shifts in a number of substituted pyridine derivatives, viz., 2-methyl pyridine, 3-methyl pyridine and 2,4-dimethyl pyridine have been investigated at 100 Mc. The systems chosen were asymmetric 3 and 4 spin systems which were analysed by the 'Effective Larmor Frequency Method' of Pople and Schaefers. Shifts of ring protons in methyl pyridines were strongly solvent dependent whereas the coupling constants remain fairly constant. 2-Methyl pyridine was chosen as the proto-type compound for studying the solvent effect in further detail. The chemical shifts of this compound were investigated systematically in a number of solvents ranging from the non-polar n-hexane to the highly polar water. The shifts could be qualitatively interpreted on the basis of Buckingham's theory. The rather interesting but anomalous shifts obtained on dilution with water have been explained on the basis of the highly ordered water structure around the solute molecule with a specific hydrogen bond at the 'N' site of the solute. Steric effect of the methyl group is the guiding factor in the interaction of water molecules with the different ring protons. The proton adjacent to the methyl group is always less affected as compared to the other protons. This picture is further corroborated experimentally in cases of interaction of water with 3-methyl pyridine and 2,4-dimethyl pyridine also.

(N. Chatterjee and M. Bose, 'Solvent Effects in Aza-Aromatics', to be published in Mol. Phys.)

N. Chatterjee and M. Bose

6.30 *Double Resonance Study of Pyridine*

The ambiguity in assigning the correct spin-spin coupling constants by analysing the complicated spectrum for the five spin system in pyridine can be overcome by the spin-decoupling technique. The spin state for the pyridine

molecule may be represented as AB_2X_2 type with two unequal B-X couplings. After decoupling the X_2 group, the spectrum obtained is a simple AB_2 type, from which $\nu_0\delta_{AB}$ and J_{AB} can be obtained. Again irradiating strongly on B_2, J_{AX} and $\nu_0\delta_{AX}$ can be obtained. Analysing the symmetrical four spin system B_2X_2 after decoupling the A proton, the two J_{BX} couplings as well as J_{BB} and J_{XX} can be evaluated. The results obtained by applying this technique at 100 Mc are in good agreement with the previous data obtained from conventional analysis.

N. Chatterjee and M. Bose

6.31 *Effect of Substituents on Spin-Spin Coupling*

In our previous report we observed that in all probability spin-spin couplings were dependent on the nature of the substituents. Our more detailed work has upheld this viewpoint. Results are summarised below :

	$J_{3,4}$	$J_{5,6}$	$J_{4,5}$
2-Nitro aniline	8.0 c/s	8.1 c/s	7.4 c/s
2-Amino pyridine	8.0 c/s	4.8 c/s	7.3 c/s
2-Nitro toluene	8.0 c/s	8.1 c/s	8.1 c/s

Strongly perturbing substituents like NO_2 and NH_2 groups are most effective in altering the spin-spin coupling constants. This is in consonance with the prediction of Cohen and Schaefer (Mol. Phys., *10*, 209, 1966). In 2-nitro toluene, however, $J_{4,5}$ does not appear to decrease. This may be due to the weakly perturbing nature of CH_3 substituent. In this compound the Double Resonance method is applied for determining the spin-spin coupling more accurately, by saturating the 'X' proton and thereby reducing the complexity of the spectrum from ABCX to ABC. Resultant spectra can be explained as AB_2 with $J = 8$ c/s.

It was reported earlier by us that the former two compounds can be analysed as ABRX. This simple nature of the spectra can be profitably utilised for studying the solvent-solute interaction also. But as these compounds are all solids and soluble in very few solvents, they cannot be studied in detail. Nevertheless, 2-amino pyridine has been studied in acetone, ether and carbon tetrachloride. In acetone, proton at position 5 is the most shielded. But in ether and carbon tetrachloride, proton at position 3 is most shielded. This may be ascribed to specific solvent-solute interaction.

N. Das and M. Bose

6.32 *Determination of the Sign of the Coupling Constant*

As pointed out by Karplus and others, 'gem' coupling constant can be negative when the dihedral angle exceeds 120°. Vinyl acetate has been analysed

as ABX at 40 mc/s. Here JAX> JBX> JAB. At 100 mc/s, this system becomes AMX. Thus, the partial spin decoupling method can be applied here to determine the relative sign of the coupling constants. This spectral pattern consists of three well separated quartets corresponding to protons A, M and X. The lines due to A proton contains splitting due to JAM and JAX while that of M contains JAM and JMX. Thus by partial decoupling of the multiplets due to JAM in A and observing the nature of the collapsing of M lines, JAX and JMX were found to be of the same sign. Similarly, when the multiplets due to JMX in X were partially decoupled, quartets of A collapsed to two lines of intensity 1 : 3. Thus from the nature of the collapsing of A lines, JAM was observed to be negative with respect to JAX.

N. Das and M. Bose

6.33 *NMR Investigation in Solids*

(I) *Technique of measuring line shifts*

The shift of the resonance lines in solids is generally found to be a small fraction of the line width. Therefore, ordinarily small shifts are not detected, even if they are present. Recently a technique has been advocated where the experimental solid and reference (which is usually a liquid) are placed simultaneously and the resonance line is traced. If the modulation amplitude is selected properly,

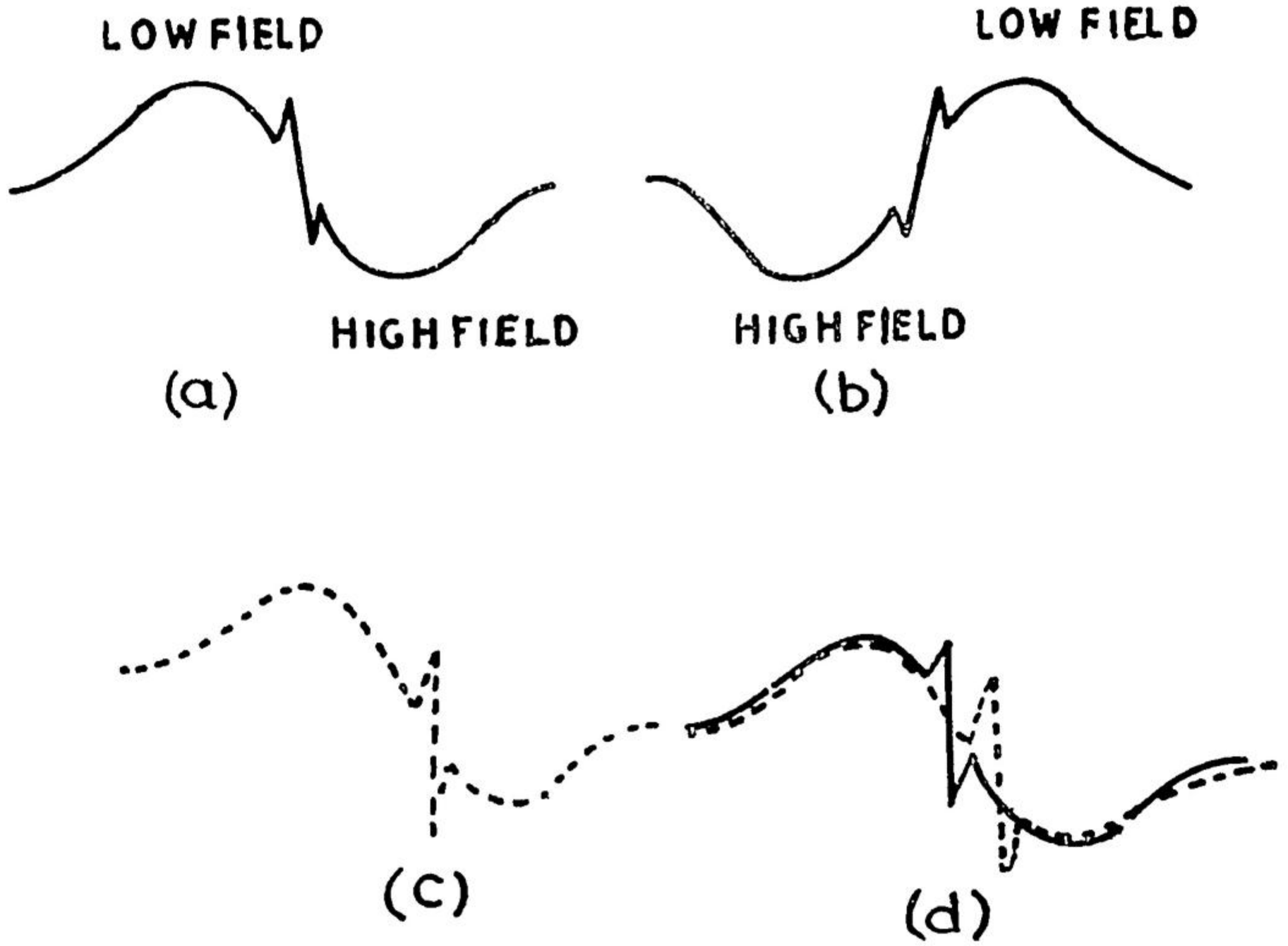

Fig. 6.33

a narrow line should appear over the broad solid line (as in Fig. 6.33(a)). The same line is again traced back in the reverse direction (Fig. 6.33(b)). Now, the two traces are superposed with the help of a tracing paper in such a manner that the low-field-peak of the wide line of one is placed right on the high-field-peak of that of the other. This can be done by inverting one of the traces about the base line (Fig. 6.33(c)) and placing one upon the other. Since the derivative of absorption line is symmetrical, the peaks of the two traces will coincide. If there is a shift between the experimental solid and the reference liquid, the narrow lines will be separated by a distance which equals to twice the amount of shift. By this process, very small shifts can be detected. This method has been utilised to check the F^{19} shifts of BaF_2 and to search for P^{31} shift in sodium phosphate and sodium pyrophosphate. No shift was detected in the phosphate samples.

(II) *Improvement of sensitivity of NMR signals by the use of pellets*

In solids the resonance line becomes wide, so the sensitivity of the signal is lowered very much. The signal can be improved by increasing the number of resonating nuclei, in the specified space within the receiver coil. This number can be increased in the case of powders by pressing the sample into pellets. By using pellets of $Co_3(PO_4)_2$, $8H_2O$ we found that the signal of P^{31} has been increased several times. We propose to use pellets to observe P^{31} resonance in rare-earth phosphate powders. For this purpose a die of tempered steel has been constructed, which can stand a pressure of few tons per square inch.

(III) *P^{31} resonance in phosphorous pentoxide, sodium phosphate, sodium pyrophosphate*

Experimental results on P^{31} resonance in tri-sodium orthophosphate show that the width of resonance line is 3.928 gauss, which is a comparatively low value so far as resonance lines in solids are concerned. The relaxation time in this sample is rather long, so that the signal becomes saturated with low value of rf power. Consequently, the signal to noise ratio could not be improved satisfactorily. As a result, modulation amplitude could not be reduced beyond a limit to avoid line broadening due to large sweep amplitude. So, it is quite likely that the actual line width is less than the measured value.

We then studied the P^{31} resonance in sodium pyrophosphate where there are two bonded phosphorous nuclei in the "pyrophosphate group". The effect of this intra group interaction is revealed by the fact that the P^{31} relaxation process in the pyrophosphate has been promoted considerably. We could use greater power than that in the case of simple phosphate. The line width has become 4.21 gauss and signal to noise ratio increases considerably.

But in phosphorous pentoxide the relaxation time is so long that the steady state signal could not be observed. Indication of the signal appears only when we use the adiabatic rapid passage condition. The relaxation time appears to be of the order of 10 seconds.

In order to have a clear understanding of the relaxation process, line widths and shapes, we are contemplating to investigate single crystals of phosphate where we shall have much improved signals.

M. Bhattacharya, A. Chowdhury and M. Bose

6.34 P^{31} *Resonance of Paramagnetic Phosphates in Orthophosphoric Acid Solution*

(I) *Room temperature studies*

The effect of paramagnetic ions on the NMR of P^{31} in phosphates has been investigated to have a better understanding of the bonding situation. The solution of transition metal phosphates in 89% phosphoric acid has been investigated at 16 Mc/s and at room temperature The relaxation time T_1 was determined by adiabatic rapid passage (a.r.p.) method or with saturation method wherever a.r.p. method failed to be applied because of the insufficiency of the available radio frequency power. Negative shifts are detected in the case of Co^{2+}, Ni^{2+} and Cu^{2+} ions. The results are concentration dependent and indicate strong interaction between the paramagnetic cation and the phosphate group. The effectiveness of broadening the line is in the following order $Mn^{2+} > Cu^{2+} > Ni^{2+} > Fe^{3+} > Co^{2+} > Cr^{3+}$.

The spin-lattice relaxation of P^{31}, clearly shows that the large linewidth is not determined by the short life time of nuclear spin states. So, it has been assumed that the excessive line broadening at room temperature in case of Mn^{2+} and Cu^{2+} ions at least (possibly in case of Ni^{2+} also) are determined by slow chemical exchange.

Shifts arise due to the hyperfine interaction between paramagnetic ion and the phosphate group. The absence of shifts in case of Fe^{3+} and Cr^{3+} possibly indicates that $(PO_4)^{3-}$ ions fail to come close to Fe^{3+} and Cr^{3+} ions, because the aqua shell of the above ions is quite stable at room temperature. Consequently, no hyperfine interaction (A.I.S) between metal ions and the P^{31} nuclei is expected. As a result, the P^{31} relaxation will be promoted by dipolar interaction of the paramagnetic ion alone, and the ratio T_1/T_2 will be of the order of unity. Actually in case of Fe^{3+} and Cr^{3+} ions, we find $T_1/T_2 \sim 1$ at room temperature, while this ratio becomes larger by one to three orders of magnitude in case of other ions investigated.

(M. Bhattacharya, A. Chowdhury and M. Bose, 'Nuclear Magnetic Resonance Studies of Paramagnetic Phosphates', to be presented at the International Symposium on Spectroscopy, Bombay, Jan. 1967).

M. Bhattacharya, A. Chowdhury and M. Bose

(II) *Construction of a heater-sensor assembly and a dewar for temperature variation work*

NMR of P^{31} in H_3PO_4 acid containing paramagnetic ions, mentioned previously, demanded extension of the investigations to high and low temperature regions. This led us to take up a programme for the construction of a heater-sensor assembly for maintaining a constant temperature from 90°K to 573°K. The construction of the delicate sensor proved to be a very big hurdle. The requisite gauge of the fine platinum-wire was not available in the market and special chemical means were adopted to reduce the wire thickness. The technical problem of winding, welding the platinum to the leads, etc., were finally solved after great effort. A pyrex dewar was constructed and the whole assembly worked perfectly in the gas cooled system and attained equilibrium within 10 minutes.

M. Bhattacharya, D. Roy and M. Bose

(III) *Temperature variation studies*

Effect of variation of temperature ranging from 25°C to 105°C, on P^{31} resonance in $Co_3(PO_4)_2$ solutions in phosphoric acid has been investigated. Preliminary results show that there is an abrupt change in the frequency shift of the resonance line near 100°C.

Recent work on O^{17} resonance in aqueous solution containing Co^{2+} ion, shows the evidence for a tetrahedral $Co^{2+}(H_2O)_4$ species in aqueous solution near 100°C. Explanation of our results in the light of the above idea of formation of a new species, demands further investigations, which are being carried out.

M. Bhattacharya, A. Chowdhury and M. Bose

Molecular Biology and Crystallography

The research activities may be grouped under two broad heads :

A. Molecular Biology

(1) Molecular structure of biopolymers, derivatives and metal complexes of peptides, amino acids, etc. by X-ray crystallographic methods.

(2) Ultrastructure of biopolymers by small angle X-ray diffraction and electron microscopic methods.

(3) Properties and functions of biological molecules by physico-chemical and enzymatic methods.

B. Structural Crystallography

(1)(a) Growth of crystals

(b) Study of morphology and other properties of crystals of optical and other methods.

(2) Structure of crystals (nonbiological) by advanced X-ray methods.

6.35 *Structure of Biomolecules by X-ray Method*

(a) The study of structure and properties of collagen from various sources with particular reference to the correlation between structure and function has been made and is being continued. The enzymatically splitted components of SF collagen are being studied with a view to throw more light on this problem. The study has been extended to other types of collagens having peculiar properties. The programme on the study of the correlation between the amino acid composition (if possible, sequence) on the one hand and the structural variation and evolutionary scale of different collagens on the other is in progress.

(b) (i) The study of the relative orientation of the matrices of normal bones has already been made and this study is being continued on a more elaborate scale with many more samples of different biological origin.

(ii) The study on the mechanism of calcification of bone is being continued. In this connection, collagen, Keratin and decalcified bones from different sources are being treated with synthetic hydroxyapatite under different conditions and are being studied by X-ray diffraction methods.

(iii) The study of diseased bone (osteomylelia) from nine cases has been undertaken with an idea of explaining the cause of the diseases (as was done by us in the case of an unusual dysplasia) and is in progress.

N. N. Saha

6.36 *Structure of Amino Acids, Peptides and Their Derivatives*

As already mentioned in our previous report, the determination of the crystal and molecular structure of amino acids, peptides and their derivatives and metal complexes forms a major part of our programme of study of the correlation between structure and function of biological molecules. A study of the amino acids and peptides in the form of their metal complexes establishes the stereochemical relationships of metal-protein interactions which play a vital role in biological systems. We have taken up the structure analysis of eight crystals by the heavy atom method, i.e., the incorporation of heavy metal atoms in the crystals of amino acids and peptides. This is indeed a very tricky technique and it is rather gratifying that we have been successful in our attempts to incorporate heavy atoms in our crystals. Four structures are nearing completion and one has already been completed. It has been possible to do our job in a short time through the kind cooperation of Kharagpur IIT who have allowed us frequent uses of their IBM

1620 computer. The preliminary data of some crystals and their respective stages of progress are being given below. The single crystals of all these compounds were grown in our laboratory.

N. N. Saha

(i) *Sarcosine hydrochloride* ($C_3H_7O_2N.HCl$)

Crystals belong to the monoclinic system with space group $P2_1$ and cell dimension, a = 9.00 Å, b = 5.927 Å, c = 5.408 Å, $\beta = 96°$. The structure has been solved by the heavy atom technique using two dimensional intensity data. The values of agreement factor, $R = \frac{\Sigma \,||Fo| - |Fe||}{\Sigma |Fo|}$, are 0,189 and 0.160 for hOl and Okl reflections respectively. Fig. 6.36(a) shows the final Fourier synthesis of

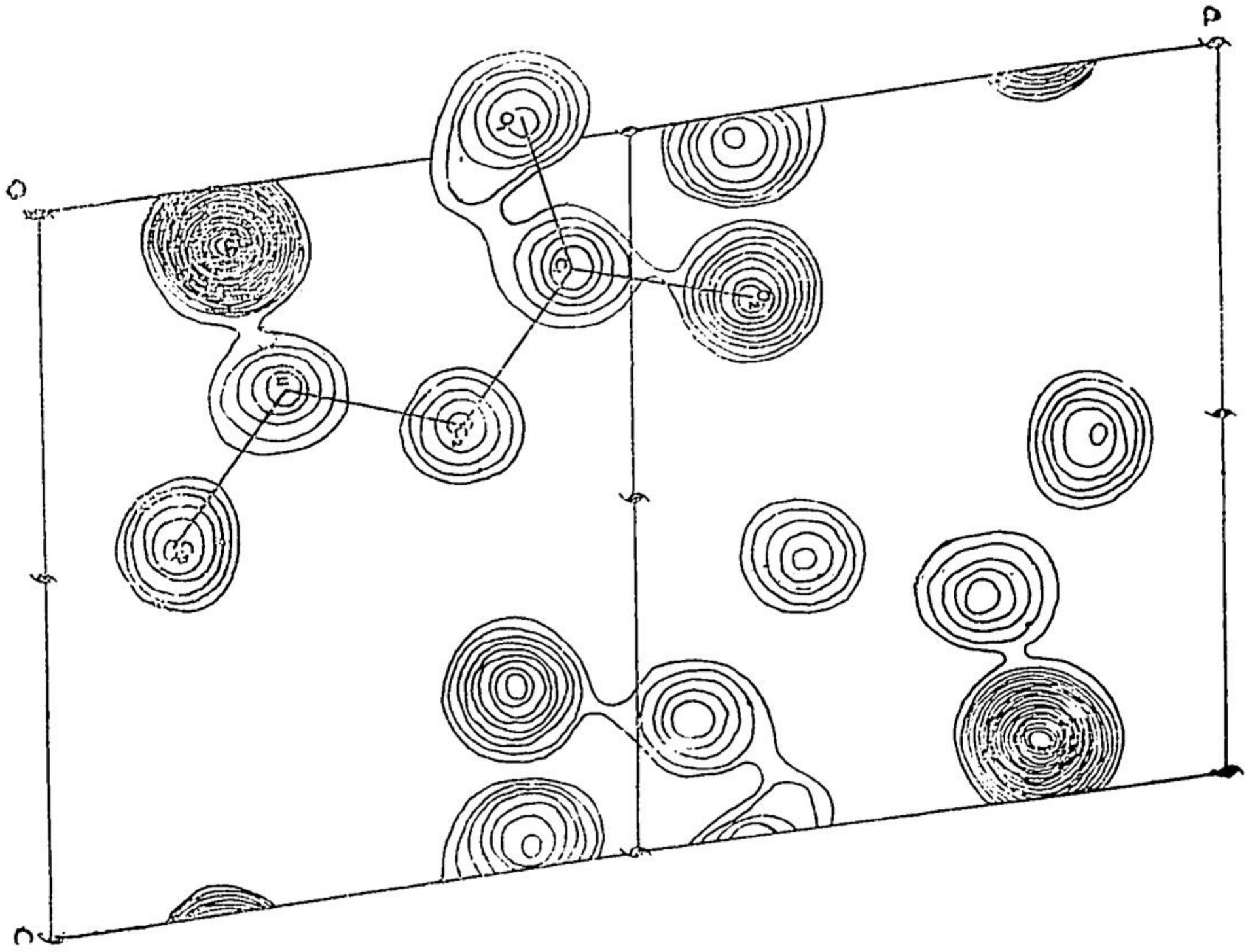

Fig. 6.36(a)

sarcosine hydrochloride projected on (010). The atomic positions are indicated in this figure. The molecular dimensions are shown in Fig. 6.36(b). The molecules are held together by hydrogen bonds inside the crystal. This is shown in Fig. 6.36(c).

Collection of 3—D intensity data about a and b axes has been completed using Cukα radiation. Three dimensional least-squares refinement of the structure is being done in order to obtain more accurate bond angles and bond distances of the molecule.

For the computation of the Fourier synthesis a programme for IBM 1620 was prepared.

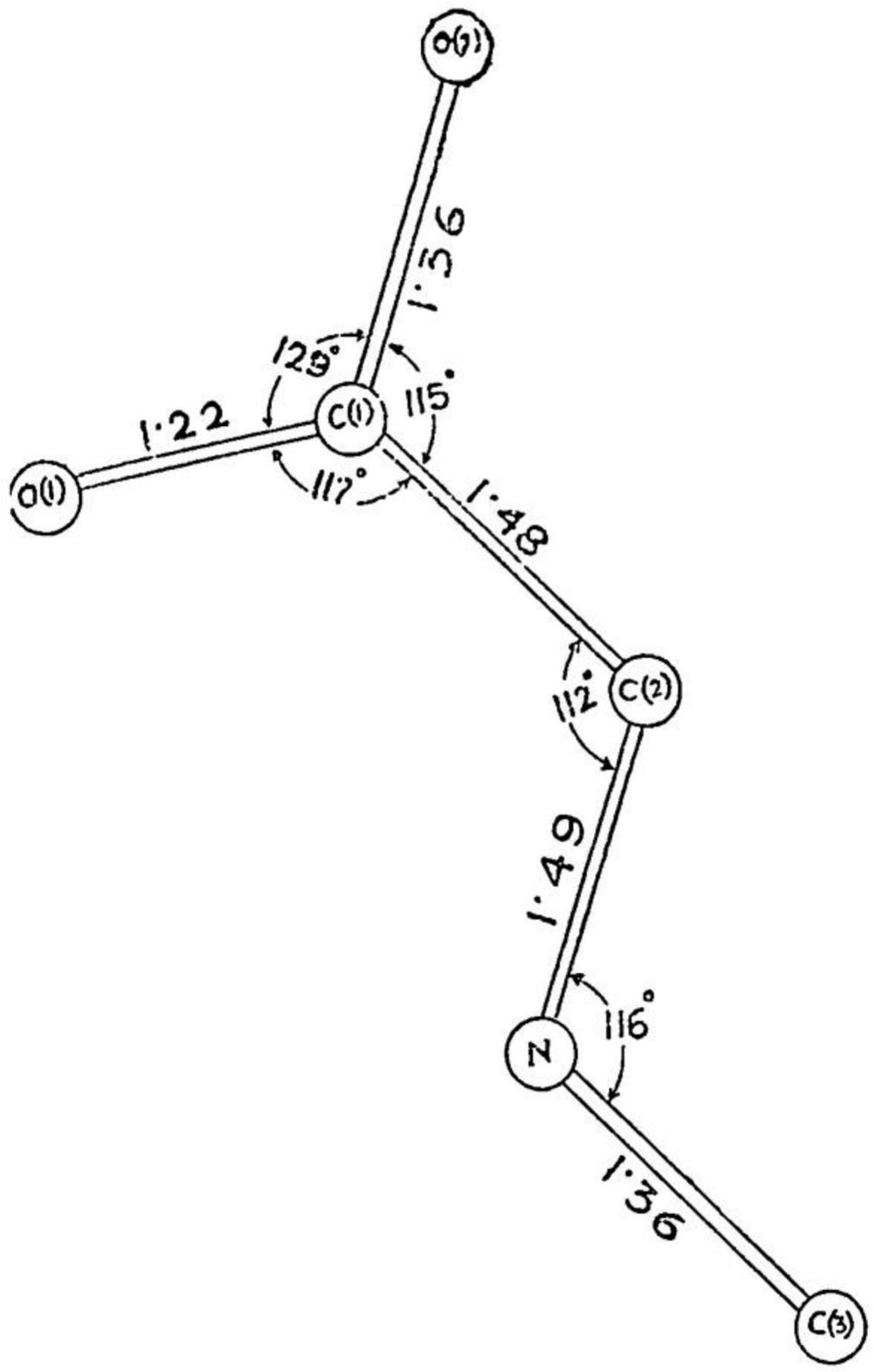

Fig. 6.36(b)

(S. C. Bhattacharyya, S. K. Majumdar and N. N. Saha, 'Crystal Structure of Sarcosine Hydrochloride', presented at the 7th International Conference of Union of Crystallography, Moscow, 1966.)

S. C. Bhattacharyya, S. K. Mazumdar and N. N. Saha

(ii) *Glycocyamine hydrobromide* ($C_3H_7O_2N.HBr$) (Type I)

Single crystals of this compound were obtained by allowing the solution of glycocyamine in 40% of hydrobromic acid to evaporate at room temperature. The crystals belong to the monoclinic system and the space group is $P2_1/c$. The cell dimensions are, a = 5.53Å, b = 13.52Å, c = 9.24Å, β 92°. The complete three-dismensional intensity data were collected about a and c axes using CuK radiation.

The four bromine positions in the unit cell were located from Patterson projections. The minimum functions as obtained from Patterson synthesis gave some clue to the orientation of the molecule. Trial structures derived from minimum functions and bromine phased Fourier synthesis have been tried for a satisfactory fitting. The work for the final solution of the structure is in progress.

P. N. Roy, S. K. Mazumdar and N. N. Saha

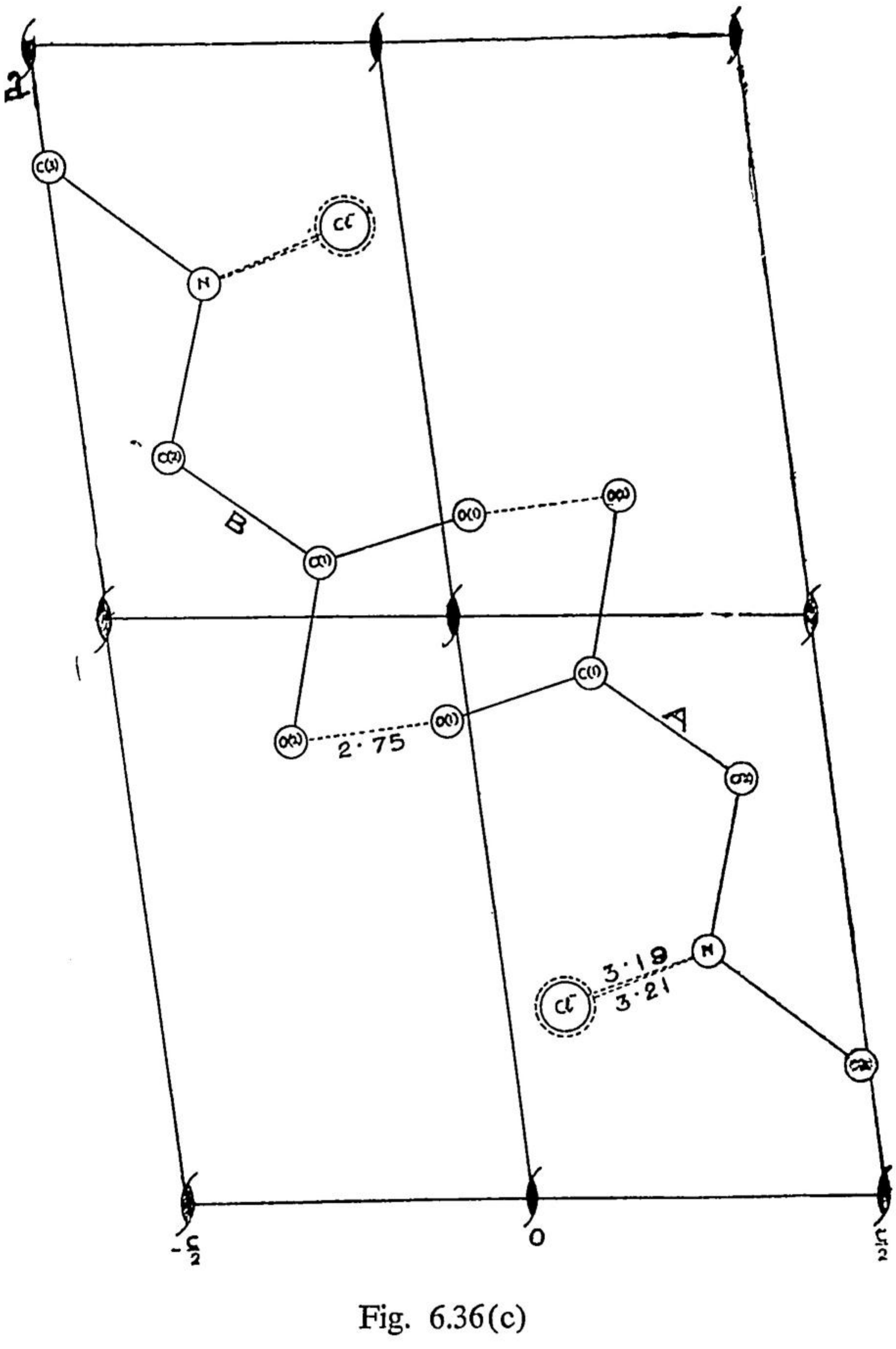

Fig. 6.36(c)

(iii) *Ornithine HCl* ($C_5H_{12}O_2N_2.HCl$)

Needle shaped single crystals of ornithine HCl belong to the monoclinic system. The space is $P2_1$ and the cell dimensions are, a = 5 Å, b = 8 Å, c = 10.16 Å, $\beta = 96°$. Three dimensional intensity measurement was made by the multiple film technique. Patterson syntheses were done with the Okl and hOl data. The sharpened Patterson syntheses revealed the heavy atom (chlorine) position to be x = 36°, y = 90°, z = 150°. A heavy atom phased Fourier synthesis was then made for the Okl and hOl projections. These syntheses together with the minimum

functions drawn from the unsharpened Patterson syntheses helped us to make tentative molecular models conforming to the stereochemistry of the compound. The Okl projection gave a spurious mirror symmetry, putting a great hurdle in solving the problem. All the seven models tried one after another were near enough but not exact.

At this stage three-dimensional work was started. After processing the data by employing a programme for IBM 1620 written by us in our laboratory for shape correction, a three dimensionai heavy atom phased Fourier synthesis has been done. This enables us to ascertain the positions of the atoms and their other parameters exactly. The solution of this structure is nearing completion.

(N. N. Saha, S. K. Majumdar, S. C. Bhattacharyya, P. N. Roy, R. Handa and S. Guha, 'Preliminary Crystal Structure Data of Some Amino-acid Derivatives and Metal Complexes', to be published in Ind. J. Phys.)

S. Guha, S. K. Mazumdar and N. N. Saha

(iv) *Copper Lysine Cu* $(C_6H_{14}O_2N_2)_2Cl_2.2H_2O$

The compound was prepared by refluxing a mixture of lysine HCl and cupric carbonate taken in stoichiometric proportions. The needle shaped crystals have been grown, allowing the solution to evaporate at room temperature. The Weissenberg photographs revealed that the space group is $P2_1$. The cell dimensions are : a = 11.50 Å, b = 16.83 Å, c = 5.10 Å $\beta = 93°$

The structure determination of this crystal is in progress.

S. K. Mazumdar and N. N. Saha

(v) *Sarcosine hydrobromide* $(C_3H_7O_2N.HBr)$

Crystals belong to the monoclinic system and the space group is $P2_1$. Determination of this structure is in progress.

(vi) a) *Glycocyamine hydrochloride* $(C_3H_7O_2N_3.HCl)$

b) *Glycocyamine hydrobromide* (Type II).

Crystals of glycocyamine HCl are isomorphous with those of glycocyamine hydrobromide (Type II). The isomorphous technique is being adopted to solve the structures. The work is in progress.

(vii) *Sarcosine* $(C_3H_7O_2N)$

Single crystals of this compound were grown in this laboratory. The space group determination is in progress.

(viii) *Glutamyl-glycine hydrobromide*

The preparation of this compound and its single crystals is nearing completion in our laboratory.

(ix) *Cu-Ornithine*

The preparation of the copper complex of ornithine is almost complete.

6.37 *Ultrastructure of Biomolecules by Small Angle X-ray Scattering and Electron Microscope.*

(a) In our investigations on the structure of collagens at a higher level of organisation by small angle X-ray diffraction and electron microscopy, a study of the correlation between the long range periodicities obtained from low angle X-ray pattern and band-interband structures from electron micrographs has been made and is being continued with many more specimens of biological origin. Using the small angle X-ray intensity data and the methods of crystal structure analysis such as Patterson and Fourier syntheses and taking the band-interband fine structure of electron micrographs as guide, ultrastructural models of different collagens were proposed by us. Results were obtained on wet shark fin collagen. Small angle X-ray diffraction study of both stained and unstained collagens at different humidities is being made to locate the positions of staining molecules, i.e. in the band or interband region, by difference Patterson method and to build up an ultrastructural model which could account for the change in width of the band and interband regions. The work is in progress.

(N. N. Saha and S. C. Bhattacharyya, 'Ultrastructural Model of Shark-In Collagen', presented at the 6th International Conference on Electron Microscopy, Kyoto, 1966.)

N. N. Saha and S. C. Bhattacharyya

(b) A programme of study of biopolymers of different origin by electron microscope employing small angle scattering technique has been already undertaken. This has been found to be a very powerful technique. The work is in progress with shark fin collagen.

N. N. Saha

(c) A comparative study of collagens from different origins such as rat tail tendon, chicken leg tendon, decalcified human bone and fin collagens (elastoidin) by high resolution electron microscopy has shown that the tropocollagen molecule of fin collagen differs from that of a tendon or bone in the distribution of polar amino acids along its length. The mode of association of fin tropocollagen molecules to generate a native fibril is also different from that of tendon-type tropocollagen.

Electron micrographs of the precipitates formed by the addition of ATP to a solution of fin collagen in dilute acetic acid have indicated the generation of monomeric SLS fragments but they are unstriated. Measured lengths of the SLS fragments were found to be about 2700 Å.

Precipitates from a solution of trypsin digested fin collagen in acetic acid by ATP have shown long polymeric SLS fibrils, but they are also unstriated. Possibilities of observing striated SLS of both kinds, if any, are now being explored by changing the experimental conditions of regeneration process and also of specimen preparation for electron microscopy.

Publication :

S. Das, Electron Microscopy, *2*, 129, 1966.
(Presented at the 6th International Conference on Electron Microscopy, Kyoto, 1966.)

S. Das

6.38 *Development of an Audible Exposure Level Indicator for Electron Microscope*

An audible Exposure Level Indicator for Electron Microscope to overcome the problem of time lapse involved in reading the built-in Visual Exposure Meter is being built in our laboratory. Many biological specimens are susceptible to contamination by prolonged exposure to electron beam. To avoid such contamination photographs of the specimen should be taken as quickly as possible once it is brought to focus. This device will give an audible signal at the optimum range of illumination intensity. It will thus eliminate the necessity for visual observation of the exposure meter and avoid delay in taking micrograph.

The device is a three-transistor circuit comprising an input stage, an ac to dc rectifier, a differential relay, an audio oscillator and a loudspeaker. The loudspeaker is coupled and matched to the oscillator circuit through a transformer. It produces an audible tone only when the operating contacts of the differential relay are closed, completing the loudspeaker circuit. The current in the left hand winding of relay is proportional to the illumination intensity and current through the right hand winding of it is adjustable by a rheostat. The nature of the differential relay is such that when equal and opposite currents flow in its two windings, its operating contacts close. An increase or decrease of current from this balanced condition in either winding will cause the contacts to open again, thus disconnecting the loudspeaker. The current in left hand coil can be varied according to intensity required. The work is in progress.

S. K. Banerjee

6.39 *Physico-chemical and Enzymatic Study*

(a) In order to understand the gross structure of native shark fin collagen, attempts were made to separate the different components of this collagen

and to study their physico-chemical properties. For this purpose collagen has to be made soluble. But, unlike tendon collagens solubilisation of shark fin collagen is extremely difficult. So, a drastic method had to be used for the purpose. Shark fin collagen was treated with 98% formic acid at 30°C for about a week with gentle stirring. The acid extract was centrifuged at high speed. The supernatant and the residue were treated separately.

The supernatant when treated with ether gave a heavy oily layer at the bottom. The oily layer on treatment with water gave a fibrous mass. The fibrous mass was dissolved in veronal buffer (pH 8.6). On paper electrophoresis it shows a single band, thus indicating apparently its homogeneity. The ultraviolet absorption spectrum of this fraction does not show any significant absorption peak at 282mμ. This indicates that the amount of tyrosine and tryptophan present in this fraction is very insignificant.

The residue, on the other hand, was dissolved in alkali (pH 8.5) and was reprecipitated with acid (pH 3.5). Ultracentrifugation of this fraction shows that it contains many components. The components are of high molecular weight ($>$ 10,000), as the dialysis of this fraction did not improve the ultracentrifuge pattern. The detailed physico-chemical study of these two fractions is in progress.

S. K. Ghosh and N. N. Saha

(b) Our previous work on the effect of inositol on the respiration and glycolysis of S. Carlsbergensis resulted in the identification of a 'damped' mitochondrial function in inositol deficient cells. In the presence of substrate and sufficient oxygen, the electron flow across the respiratory chain in the deficient cells was comparatively slow at first but then stopped completely. This is a new biological phenomenon and can be compared to some extent with the Crabtree Effect. The other observation is that the enzyme phosphofructo kinase (PFK) is also somehow inactivated during the respiratory, i.e. electron transport, inhibition.

A detailed programme of study of the cause of the above findings has been undertaken. It may be divided broadly under two headings, (a) Studies on the function of inositol on the electron transport system of the organism, (b) Studies on the function of inositol in PFK activity.

Attempts were made to develop a rapid and efficient method for the preparation of yeast mitochondria and to study the electron transport abilities of both normal and deficient mitochondria. The best method was found to be from the lysate of S. Carlsbergensis protoplasts. Protoplasts were made by treating the cells with enzymes from snail gut juice prepared in our laboratory. The respiratory character of normal yeast mitochondria has been tested by oxygen electrode method. The change of the red-ox state of the mitochondria by following the fluorescence change

during substrate oxidation is now being studied with Eppendorf Fluorimeter. The difference in these characters of the mitochondria of deficient cells will also be studied.

Different methods were followed to extract the enzyme PFK from the yeast for its purification and physico-chemical studies. The extract after lysing the protoplasts of the yeast, made as described above was formed to be the most active source of the enzyme. Salt fractionation and adsorption techniques were used exhaustively and a 20-fold purified enzyme has been made. Attempts are now being made for further purification and crystallisation. Fluorimetric methods are followed to study the enzyme activity. The Kinetic studies will also be made by fluorescence method.

If any significant difference in the electron transport and fluorescence characteristics of the mitochondria from the normal and inositol deficient cells are observed, the actual function of inositol in the process will be studied. PFK being an enzyme of tremendous significance in glycolytic control nucleanism, a rigorous search will be made by Kinetic and other studies, to find out if inositol is in any way connected with enzyne activity. The techniques to be used for this study are (a) U-V spectrophotometry, (b) Polarographic method for oxygen estimation, (c) Fluorimetry and (d) Electron microscopy.

(A. K. Ghosh and S. N. Bhattacharyya, 'Effect of Inositol on the Respiratory and Glycolytic Behaviour of S. Carlsbergensis', to be published in Biochim et. Biophys. Acta.)

S. N. Bhattacharyya and A. K. Ghosh

(c) The DNA's from various sources, e.g. liver tissue, spreen, etc. were isolated by the technique which was developed by us by partially modifying the technique of Marmur for isolation of DNA from micro organisms. The programme on the study of interaction (*in vitro*) of DNA's with chemical carcinogens, e.g. p-dimethylaminoazobenzene, dibenzentherence and benzopynine, is being continued. Electron micrographs and X-ray diffraction photographs of DNA's, both untreated and treated with above chemicals, will be taken in order to see whether this carcinogen has got any effect on DNA or not. This study will enable us to correlate the effect of the carcinogens on DNA and the genetic mutation theory of cancer.

H. S. Singh and N. N. Saha

6.40 *Quantum Biology*

The work on the electronic properties of l-amino acids, e.g., glycine, alanine etc., and related peptides is being continued with an idea of correlating

these data with those of the crystal structure group of our department working on the structure of amino acids and peptides.

The σ-electron densities on different atoms in glycyl-glycine and glycyl-alanine do not alter much when calculated by the approximate LCAOMO method. The calculation has been extended to higher members, e.g. peptides containing 3 or more amino acid molecules. The possibility of application of this method to the long chain molecule will be explored.

A series of benzologues of thiopyrone is being studied from quantum mechanical point of view. The self-consistent field MO method and the Configuration Interaction method are being applied in the case of thiopyrone benzologues and the theoretical findings will be correlated with the physico-chemical data of the compound. The search for appropriate parameters is in progress.

Sephali Guha

6.41 *Growth of Crystals and Study of Their Properties*

(a) A number of crystals were grown from solutions as well as from melt by utilising the techniques developed in our laboratory earlier. The crystals grown from solutions were mostly amino acid derivatives and metal complexes, e.g. sarcosine hydrochloride and hydrobromide, Cu-lysine, Ornithine hydrochloride, Ca-EDTA, etc. The crystals grown from melt were mostly alkali halides.

(b) Morphological study of all these crystals and also of other crystals from other laboratories was made by us by optical goniometric method. Preliminary X-ray study of crystals by back reflection Laue method was made for other laboratories of our Institute and outside. The study of the morphology of crystals which we have to do so frequently both for us and other laboratories can be done more effectively if we can have a two circle goniometer in our laboratory.

An apparatus for pyroelectric measurement is being constructed. Attempt is being made to increase the facilities for studying the crystal properties in a more elaborate way.

R. Handa, P. N. Roy, S. K. Majumdar and N. N. Saha

6.42 *Structure of Crystals by Advanced X-ray Method*

Calcium – EDTA ($CaC_{10}H_{12}O_8N_2.NH_2O$) was prepared in our laboratory by adding ethyl alcohol to a solution containing calcium carbonate and ethylene-dianine-tetra-acetic acid (EDTA) in molar proportions. Crystals were grown by

slow evaporation of aqueous solution of Ca-EDTA. They were plate shaped and colourless. Weissenberg photographs taken about a, b and c crystallographic axes revealed that the crystals belong to triclinic system with space group P_1 or $P\bar{1}$. The cell dimensions were found to be

a = 9.88 Å	α = 131°38′
b = 11.15 Å	β = 114°13′
c = 13.37 Å	γ = 77°2′

In order to determine the space group uniquely, more refined data were needed. For this purpose, correction had to be made for absorption of the X-ray beam by the crystal. As the shape of the crystal taken by us was irregular, it involved a lot of calculation for absorption correction. So, the help of the computer was taken. A general programme for absorption correction for crystals of irregular shapes was written for IBM 1620 computer. Wilson's N(Z) test was made by using the corrected data and it revealed that the space group is $P\bar{1}$.

The positions of the heavy atom (Calcium) were located from the Patterson synthesis projected along (100), (010), and (001). These positions were confirmed from the weighted reciprocal lattice net using the optical diffraction technique. Fitting of models using the Fourier synthesis is in progress.

The preparation of two compounds, viz., Strontium – EDTA and Yttrium – EDTA, and their single crystals is in progress.

R. Handa, S. K. Mazumdar and N. N. Saha

7. THEORETICAL NUCLEAR PHYSICS DIVISION

7.0 *Introductory Remarks*

The research reports of this Division are summarised below. Members of staff continue their strong support to the teaching programme in the post-M.Sc. Associateship Diploma Course. There have been regular divisional seminars where both members of staff and research students have participated.

T. Pradhan
Head, Theoretical Nuclear Physics Division

7.1 *A New Approach to Algebra of Current Operators*

Possible Algebra's of currents formed out of baryon and meson fields are discussed. It is shown that the currents do form algebra without the baryons and mesons having to belong to an irreducible representation of the group.

(Trieste Preprint : IC/66/3)

P. Narayanaswamy, T. Pradhan and T. S. Santhanam

7.2 *Cabibbo Angle as a Renormalisation Effect*

It is shown that the Cabibbo Sinθ factor can be understood as a renormalisation effect if one uses the algebra of currents constructed from phenomenological fields of hadrons to derive some rules for the axial vector coupling constants in their β-decay.

(Trieste Preprint : IC/66/42)

P. Narayanaswamy and T. Pradhan

7.3 *Cabibbo Angle and the Ninth Baryon*

The Cabibbo angle is calculated and found to be such that $\tan^2 \theta = 0.52$ if the integrated time components of axial vector and vector currents are assumed

to form SU(3) × SU(3) × SU(3) × SU(3) algebra and that the Y_0^* (1405) is considered to be the ninth baryon.

(Trieste Preprint : IC/66/59)

T. Pradhan

7.4 *Derivation Delta Function in Current Commutators*

A relation between the pion decay amplitude, axial vector meson-baryon form factor and the coefficient of the derivation delta function in current commutators is obtained.

T. Pradhan

7.5 *Cabibbo Angle and SU(3) Breaking*

Cabibbo angle is being calculated by correcting the SU(3) particle wave-functions to 1st order in symmetry-breaking interaction. The equal time commutation relation for weak vector currents are used to eliminate the unknown matrix elements of the symmetry-breaking interaction between different SU(3) representions.

T. Pradhan and M. Pattnaik

7.6 *Analogue States in Particle Physics*

In particle physics there are many evidences about the violation of SU(3) symmetry. Under such a breaking a physical particle can no longer belong to a particular, but to a mixture of all irreducible representations of SU(3). This complicates the situation as it necessitates the determination of too many parameters. However, some simplification is being made by invoking an assumption similar to the assumption of "analogue states in nuclear physics", where SU(2) is broken. The validity of this assumption will be determined by the accuracy with which "Cabibbo angle" is theoretically obtained. Things are under investigation.

T. Pradhan and Mamata Pattnaik

7.7 *A Study of the Alpha-Alpha Scattering Resonances*

An investigation of the Alpha-Alpha resonance scattering process was carried out using the one-pole Regge representation. The necessary computation was done on CDC 3600. The conclusion that may be drawn from an analysis of these results is that the D and G wave resonances may be represented by a single Regge trajectory. As there is no experimental data in the neighbourhood of the S-wave resonance ($E_r = .094$ Mev) this region could not be investigated. However, the energy dependence of the pole parameters indicates that the S-wave resonance should also lie on the same trajectory.

There is qualitative agreement between the theoretical and experimental angular distribution plots. In the neighbourhood of the D wave resonance the differential scattering cross-sections could be fitted at 14 angles in the 115°-180° range with the one pole Regge formula and in the neighbourhood of the G-wave resonance at 8 angles in the 145°-180° range.

It is now being attempted to find a suitable potential for the Alpha-Alpha interaction which will give a reasonable fit to the experimental phase shifts.

M. K. Pal and R. Shanta

7.8 *Inverse Gap Equation and Effective Interactions*

Calculations based on the Inverse Gap Equation (IGE) method are made first with the phenomenological two body interactions known to give excellent results in the shell model picture for nuclei in the 2p-1f region. Slight departure of the force strength from unity and the smooth variation of the Hartree-Fock spectrum with mass number thus obtained provides the validity of this model in this region. The pairing nature of the conventional two-body potentials and of an approximate reaction matrix obtained from free two nucleon interaction is studied. The Hartree-Fock (HF) spectrum and its variation with mass number are discussed in Ni-and Sn-regions. The results of the Tamm-Dancoff (TD) and Random-Phase approximation (RPA) obtained by using the values of V's (U's) the occupancy (non-occupancy) probabilities obtained by IGE approach are compared with the corresponding ones obtained by (1) the conventional BCS method and (2) the exact shell model calculation.

Y. K. Gambhir

7.9 *Quasi-particle Method and Two-phonon (Nuclear Collective) States*

The modified pairing model, in which n-p interaction was treated by perturbation, has been applied to Pr-and La-isotopes. After detailed numerical cal-

culation it was concluded that no further improvements can be made over the results reported in Low Energy Nuclear Physics Symposium, Calcutta, 1965.

Modified Tamm-Dancoff (TD) approximation was developed for the description of two-phonon (nuclear collective) states of even-even spherical nuclei, which is free from the inherent drawback like redundancy and non-orthonormality of the four quasi-particle basis, present in HRPA theory.

This method has been applied to the calculation of collective states of Ni- and Sn-isotopes, using Q.Q. and realistic forces, and the results for $Ni^{55,(a)}$ have been compared with the results of the exact sheli model calculation.

The calculation for collective states of spherical nuclei with IGE (Inverse Gap Equation) method combined with Modified TD method is in progress.

(M. K. Pal, Y. M. Gambhir and Ram Raj, 'Two-and Four-Quasi-Particle States in Spherical Vibrational Nuclei', to be published in Phys. Rev.)

Ram Raj, Y. K. Gambhir and M. K. Pal

7.10 *Modified Regge Representation*

A new Regge-type representation for the scattering amplitude is proposed, where the partial wave amplitude has the correct threshold behaviour for both its real and imaginary parts and correct asymptotic behaviour in complex angular momentum plane and which, at the same time, has negligibly small background integral.

Suprokash Mukherjee

7.11 *Nuclear Scattering through Pololog*y

Scattering and/or resonance scattering of nucleons from nuclei covering practically the entire mass table and in the energy range of 0.4 MeV. to 40 MeV. are studied by representing the scattering amplitude in terms of its poles in the complex angular momentum plane.

Suprokash Mukherjee and C. S. Shastry

7.12 *A Fast-converging Expansion of Reaction Matrix*

Brueckner-type t-matrix, which is used for saturation calculations and structure studies, is represented by a series very similar to the Modified Born

series of Bethe-Brandow-Petschek. Using the idea of S. Wienberg, this expansion is made in powers of the difference of two effective potentials and its usefulness is being tested by applying it to saturation studies of nuclear matter.

Suprokash Mukherjee and R. K. Satpathy

7.13 *Faddeev Theory Applied to Stripping and Pick-up Reactions*

Faddeev theory of three particle scattering is applied to study stripping and pick-up reactions by allowing the scattering amplitude to be terminated by intermediate bound states and resonances.

Suprokash Mukherjee and S. Samaddar

7.14 *On the Determination of the Phase of High Energy Forward Scattering Amplitude*

The phase of the strong interaction part of the high energy forward scattering amplitudes of hadrons can, in principle, be obtained from Coulomb interference experiments. In the usual theoretical analysis of the results of these experiments one makes an ansatz about the full scattering amplitude which is not correct even in the first order of the Coulomb interaction. In fact, the ansatz is equivalent to the assumption that the electromagnetic and the strong interactions of hadrons do not interfere with each other. This inadequacy can be removed by the methods of final state interaction. In the actual calculation one also needs informations about the scattering state wave functions of the strongly interacting hadrons. We are, therefore, forced to make certain assumptions regarding the structure of this wave function which can presumably be justified in the high energy region.

V. J. Meson and H Banerjee

7.15 *Remarks on Calculation of Mass Shift by the N/D Method*

Validity of the N/D approximation method recently followed by Dashen and Frautschi in calculating mass shifts (response) of bound and resonant states in the direct channel due to variations of the masses of exchanged particles has

been examined. Two models have been considered, which in the usual N/D approximation reproduce the essential features of the dynamical model considered by Dashen and Frautschi, viz., a simple pole in the unphysical region of the complex energy plane, partial wave analyticity and elastic unitarity. In either case the sign of the response obtained by the method of Dashen and Frautschi implies the presence of ghosts in the theory and is opposite to what one gets for the exact result. This discrepancy is attributed to the inadequacy of the approximation (in the N/D method) of the 'potential' singularities of the scattering amplitude by those of the first Born term.

H. Banerjee

7.16 *Electron Capture and Loss by Charged Particles in Dense Electron Gas*

Ratio of the cross-sections for electron capture and loss by positrons passing through metals has been derived on the basis of the Feynman diagrams proposed to represent the two processes. It has been found that there is positronium formation inside a metal if the Fermi energy of the metal exceeds the binding energy of the positronium atom. Since the binding energy of the positronium atom in the ground state is 6.8 eV for metals like Ag and Au where the Fermi energy is of the order 5.5 eV, the positronium atom is likely to be formed in an excited state. It has been seen that for such metals there is positronium formation in the energy range $7.5 < E_i < 25.5$ eV.

T. Pradhan and D. N. Tripathy

7.17 *Regge Behaviour of Physical Particle in Quantum Field Theory*

In conventional field theory, particles can be considered as composite under few restrictions on renormalisation constants. Regge poles occur in the description of manifestly composite systems, both in potential theory and in simple approximations to field theory. To explore the connection between these two languages, we consider a model field theory, viz. Bronzan's version of Lee model with recoil. We find under the restrictions $Z_1 = O$, $Zu = O$ and $Z_1^2/Zu = O$, the elementary particle of conventional field theory lies on Regge trajectory.

T. Pradhan and J. N. Passi

7.18 *T-violation and Second-class Currents*

The breakdown of CP invariance (or T) observed through the two pion decay of the K_2-meson has resulted in a host of speculations. If T-violation

is caused by a part of the weak Hamiltonian and if it is assumed that this is through a phase in the second class currents then an interesting observation can be made. In the β-decay of a polarized parent one studies the correlation $1 + D\vec{p}_e \times \vec{p}_\nu . \langle \vec{J} \rangle$ of the plane of the emitted electron and neutrino $\vec{p}_e \times \vec{p}_\nu$ with the polarization of the parent nucleus $\langle \vec{J} \rangle$. For the neutron and for a number of nuclei such a correlation has been looked for and found to be small, if any. With the assumption that the second-class currents are responsible for T-violation, the correlation function D depends on the electron-energy in such a manner that in certain cases leads to a change of sign of D. With such an effect the correlation tends to disappear unless one discrimates the electron energies. We conclude that the bounds on T-violation obtained from these experiments in nuclear physics must be considerably relaxed if this be the way nature chooses to violate T-invariance. Also it must be borne in mind in planning such experiments on T-violation that such type of effects depends on the model of T-violation.

B. Dutta-Roy and S. Baba Pundari

7.19 *Butler's New Theory of Stripping and an Exactly Soluble Model*

Taking an exactly soluble model of stripping (non-local separable potential model of Mitra and of Amado) we compared the "exact" stripping cross-sections with those of the eminently successful new Butler theory (Nature, 1965). Unfortunately the "exact" stripping cross-sections did not agree with the Butler cross-sections. This discrepancy perhaps gives some insight into the Butler approximation in that in our exactly soluble model stripping can occur "anywhere" whereas in the actual nucleus (where Butler's theory succeeds so weil) stripping perhaps occurs as a surface phenomenon.

B. Dutta-Roy and S. Baba Pundari

7.20 *Calculation of Dielectric Function for a Plasma in a Uniform Magnetic Field*

An expression for the dielectric function is obtained for a plasma in a uniform magnetic field by summing up the series for $\rho_{k,\{n\}}(\{v\} \ldots t)$, the Fourier transform of the distribution function in the 'Short time approximation', keeping only the linear terms and using the Prigogine-Balescu diagram technique developed for classical plasma. An expression for the potential within the plasma

is derived in the 'dressed' particle picture, when the expression for dielectric function enters.

B. Dasgupta and P. Dasgupta

7.21 *Electric Field Correlation within a Plasma by Diagram Technique*

The electric field correlation which occurred in the expression for conductivity of a plasma derived by Pradhan and Dasgupta has been evaluated by the classical diagram technique developed by Prigogine and Balescu. Calculations are done in the cases for (i) a plasma in absence of a magnetic field, (ii) a plasma which is in a uniform homogeneous magnetic field. The calculated results exactly correspond to the standard results obtained by Rostoker.

B. Dasgupta and P. Dasgupta

7.22 *Current-current Correlation within a Plasma*

Current-current correlation or velocity correlation within a plasma, which is related to the conductivity and diffusion coefficient, is directly evaluated by the diagram technique. The results obtained agree with the results obtained by other methods.

Publication :

B. Dasgupta and P. Dasgupta, Physica, *32*, 878, 1966.

B. Dasgupta and P. Dasgupta

7.23 *Study of Excited Bands in s-d Shell Nuclei*

The Hartree-Fock-Bogolyubov wave functions obtained from the ground state studies of the s-d shell nuclei are being applied to the study of excited band by QRPA method.

L. Satpathy

7.24 *Study of Excited Bands by QRPA Method*

Studies of the ground state properties in lp shell were completed. We have undertaken a programme of studying the excited band by QRPA method.

Haris Chandra

7.25 *Nucleon Trajectory in Strip Approximation*

Our investigation in the potential theory showed that instead of unitarization over the entire physical region, N/D equations with partial unitarization lead to much better Regge pole calculation. With proper choice of the strip parameter, one gets reasonably good agreement with the Schrodinger solutions even in the determinantal approximation. We tried the same approximation for isospin 1/2 pion-nucleon amplitude to generate the nucleon Regge pole. The input contained the N*(3.3) resonance in the u-channel which is known to provide enough attraction in the isospin 1/2 amplitude so as to produce a bound state. The effect of adding the ρ-meson in the t-channel was also studied. The slope of the trajectory at the nucleon bound state turned out to be 0.36 per pion mass without ρ and 0.4 per pion mass with ρ, the required strip width being 11 pion mass approximately. These values of the slope are fairly consistent with the experimental mass of $T = 1/2$, $J = 5/2$, pion-nucleon resonance.

Padmanabha Dasgupta

7.26 *Hole-particle Calculations for Nuclear Energy Levels*

New methods in hole-particle calculations for nuclear energy levels have been undertaken. Computations for some nuclei will be completed in the course of the next year.

B. H. Bye

7.27 *Apparent Resonance Structure of Pion Nucleon P_{11} Scattering Amplitude and Bethe-Salpeter Equation in Chew-Low Model*

Recent phase shift analysis by Roper et al shows that the phase shifts for $T = 1/2$ p-wave pion-nucleon scattering becomes very large (or even increases through 90° in some of these analyses) in the neighbourhood of 575 MeV pion laboratory kinetic energy. It has been suggested by Dalitz and Moor-

house that this enhancement in phase shift may not be interpreted as the existence of a resonance at this energy but may be due to the large inelasticity present in this partial wave. It is thus important that this explanation be substantiated quantitatively by calculations taking due account of inelastic channels.

We here study this problem in the framework of Chew-Low Hamiltonian taking into account as much of inelastic singularities as possible. For this purpose the appropriate Bethe-Salpeter integral equation is constructed with the nucleon exchange diagram as the irreducible graph. As is well known, this is a singular type of integral equation, not amenable to ordinary numerical methods of solution. However, this is transformed into a non-singular Fredholm form, thus becoming readily solvable numerically. In the form factors the cut-off mass is determined by requiring the position of the (3.3) resonance in the $T=3/2$, $J=3/2$ channel.

Since the N*(1237) exchange diagram is not included as an irreducible graph in the BS equation, we do not expect the nucleon pole to emerge naturally from the calculation. So we include the direct channel nucleon pole contribution explicitly in the $J=1/2$ $T=1/2$ p-wave amplitude. These questions are now being solved on the computer.

H. Banerjee and S. Mallik

7.28 *Nucleon Electromagnetic Form Factors and Baryon Current*

Assuming partially conserved baryon current and its commutation relation with the meson vector current, we evaluate the off-mass shell matrix element of the electromagnetic vector current between nucleon states. This gives nucleon electromagnetic form factors with the four momenta of one nucleon zero. Within uncertainties of analytic continuations, the results agree qualitatively with experiment.

P. Dasgupta and S. Mallik

7.29 *Structure Effects in Fast Neutron Reactions*

(a) The Rosenzweig model is being applied to compare with the observed dependence of high energy (n, 2n) reaction cross-sections with neutron excess of the target nuclei. Calculations based on the statistical model seem to indicate the presence of such an effect.

A. Chatterjee and S. Chatterjee

(b) Systematics of fission physics is being studied and analyzed in the framework of the statistical model, particularly with respect to the threshold behaviour and the mass yield.

A. Chatterjee and R. Sarkar

8. TEACHING DIVISION

8.0 *Introductory Remarks*

The Institute continued its programme of post-M.Sc. training in nuclear physics and molecular & solid state physics. The fourteenth session started in July 1966. Of the two hundred fifty applications received, eighty candidates were selected for admission test. Twenty three students were offered admission. Fifteen students have joined. The Teachers' Committee reviewed and modified the syllabi. Separate problem sessions and various topics have been introduced.

The students attended a large number of special lectures in various fields of science.

Research and development by the staff of the Division is included in the Report of Nuclear Physics Division.

S. Chatterjee
Head, Teaching Division

8.1 *Teaching Programme for the 13th Session 1965-66*

(January-June)

Advanced Course for Nuclear Physics:

Two Body Problem (22)	B. B. Baliga
Nuclear Structure (14)	Y. K. Gambhir
Quantum Mechanics (25)	S. Mukherjee
Elementary Particle Physics (50)	B. Dutta Roy
Beta-gamma Ray Spectroscopy (16)	R. Bhattacharyya

No formal course was delivered for molecular and solid state physics specialisation. Two students worked on advanced problems under Prof. N. N. Saha and Prof. D. K. Roy.

8.2 *The Special Problems and Reviews Submitted by Students*

Buddhadev Ghosh	H^- ions and other two-electron atoms
Sankarananda Guha	Determination of the space group of sarcosine hydrogen bromide
Lalit Kumar	A short review of beta-gamma angular correlation and design of an automatic apparatus

V. J. Menon	On the solution of the Dirac equation for an atomic electron with finite nuclear size effects included
K. S. N. Murthy	Li-drifted germanium detectors for gamma radiation
K. V. Chalapati Rao	Nuclear resonance fluorescence of gamma radiation
L. Srinivas Rao	Field theoretical models (Scaler & Lee models)
S. K. Samaddar	Analysis of (n, d) pick-up reactions in $1f_{7/2}$ shell for 14 MeV neutrons
Salil Kr. Sarkar	Green function theories of ferromagnetism

8.3 *Teaching Programme for the 14th Session 1966-67 (July-December)*

(a) Basic Course :

1.	Phenomenological Nuclear Physics	(55)	B. B. Baliga
2.	Introductory Solid State Physics	(15)	A. Mukherjee
3.	Basic Mathematics	(30)	H. Banerjee
4.	Classical Electro-dynamics & Plasma Physics	(25)	S. K. Majumdar
5.	Quantum Mechanics	(50)	B. Dutta Roy
6.	Electronics	(24)	S. C. Nath, S. Chaudhury & K. S. Patel
7.	Experimental Techniques :		
	(a) Nuclear Detectors	(10)	R. Bhattacharyya
	(b) Accelerators, Magnetic Spectrometers, etc.	(12)	S. B. Karmahapatro S. Chatterjee B. K. Sinha S. Sen
8.	Laboratory Practice : 40 working days		

8.4 *Special Lecture Courses, Lectures etc. held in 1966*

Date	*Speaker*	*Subject*
January 10, 1966	Prof. A. A. Abrikasov (USSR)	Superconductivity
January 20, 1966	Dr. J. L. Sarrouy (Gamma Industries, France)	Isotope separator and its techniques
Feb. 10, 1966	Prof. A. I. Kitaygorodsky Head, Inst. of Elemento Organic Compds., Moscow	The arrangements of molecules and properties of organic crystals

March 5, 1966	Prof Yash Pal T.I.F.R., Bombay	1. Neutrino interactions 2. Ultra high energy interactions 3. C-p violation in Kaou decay
March 10, 1966	Prof. M. Fetizon Lab. of Steveochemistry of the Faculty of Sciences of Orsay, Paris	Mass spectrometry: the influence of stereo-chemistry on fragmentation
April 11, 1966		Symposium in Biophysics
April 14, 1966	Prof. V. M. Tuckkevich Prof. of Phys. & Maths. and Chief of the Lab. of Semiconductors, Leningrad	p-n junctions of Ga-As and GaP
April 21, 1966	Prof. P. L. Jain Fullbright Visiting Professor, Univ. of Rajasthan	High energy physics
April 26-30, '66	Dr. N. G. Deshpande Matscience, Madras	Elementarity of particles and broken symmetry
May 26, 1966	Dr. P. Mukherjee	The recent studies on nuclear structure by direct nuclear reaction
June 13, 14, '66	Dr. E. C. G. Sudarshan Syracuse University, USA.	Groups as dynamical models in particle physics
July 4, 1966	Prof. A. V. Tulub Leningrad State Univ., USSR	Diagram techniques in density matrix
July 11, 1966	Prof. R. E. Jervis Univ. of Torento, Canada	Applications of activation analysis to crime detection
July 25, 26, '66	Dr. Nityaranjan Nath Clarendon Laboratory, Oxford	Effect of pion production on pion-nucleon scattering
August 6, 1966	Dr. H. Banerjee	Comments on the calcination of n-p mass difference by Dashen & Frautschi
August 8, 1966	Prof. A. M. Sessler Lawrence Radiation Lab., Berkeley, Calif., U.S.A.	Instabilities of beam in accelerators in the relativistic energy range.
Aug. 9, 10, '66	Dr. B. Misra Inst. of Theoretical Physics, Geneva University	Postulates of quantum field theory
Sept. 3, 1966	Dr. Suprokash Mukherjee	Nuclear scattering and reactions by Regge poles

Sept. 5-9, '66	Dr. M. R. Bhagavan Queen Mary College, London	Application of Green-function techniques to the many-body problem
Sept. 15, 27, '66	Shri D. N. Tripathy	Green function approach to electron gas
Sept. 28, 1966	Prof. B. D. Nag	Recent experiences in Japan in the fields of low energy nuclear physics and plasma physics
Oct. 4, 1966	Dr. Ashim Sengupta AERE, Harwell	1. Doppler shift attenuation method for life time measurements of nuclear levels 2. Isobasic analog resonances in inelastic scattering
Dec. 3, 1966	Shri P. Sen	Measurement of short time intervals in positronium life determination
Dec. 17, 1966	Shri P. S. Nair	Growing crystals
Dec. 26, 27, 1966	Prof. A. Von Engel Clarendon Laboratory, Oxford	Influence of excited molecules on the electric breakdown in gases.

9. TECHNICAL PHYSICS GROUP

9.0 *Introductory Remarks*

Many instruments, apparatus and machines needed in the laboratory are unavailable due to lack of foreign exchange. The technical physics group with the help of the other workers in the laboratory, whenever necessary, are trying to develop some of these equipments. A 60 kV, 125 mA rotating target X-ray machine is being built for the radiation chemistry group. An induction heating machine and a getter-ion pump are being developed. X-ray powder cameras are also being built. One of these cameras will be supplied to a CSIR laboratory which has requested it. This is a modest beginning, and it is hoped that the group will take up more ambitious projects in the coming year.

B. D. Nagchaudhuri
Director

9.1 *High Intensity Rotating Target X-ray Tube*

There were initially a few defects in the metal used for housing the seal of the tube. On changing the design of the rotary seal, a good vacuum has been obtained, but the speed has been reduced to 450 r.p.m. from 1000 r.p.m. as the vacuum deteriorated after about an hour's run. One of the causes might be that at this speed, the oil in the cavity of the shaft housing might all have stuck to the walls due to centrifugal forces, leaving sides of the shaft dry. The tube was tested with a filament of 1 mm diameter helix, 1 cm long wound with 12 mil tungsten wire. The split in the cathode cup is 2.5 mm wide and 12 mm long, tapered inside and away from the filament, having a taper angle of 45°. The filament took 8 amperes at 10 volts. The gun was tested with a voltage of 5 kV and gave a current of only 5 mA without any bias on the cathode cup. When a negative bias was applied, no appreciable increase in current was obtained. The reason might be that this arrangement acts as a converging lens and the focal point might be high above the anode. In this case either (1) the cathode cup should be moved from outside while the voltages are on or (2) the bias should be adjusted to bring the focal point on the anode. We intend to use both the arrangements and so the circuit and gun design are being modified. Another difficulty that we are experiencing is that the insulating vacuum seal on the flange carrying the gun, through which the bias voltage is applied, breaks down frequently. The seal is being redesigned. The control panel is now under construction.

G. N. Sarkar and B. D. Nagchaudhuri

9.2 *High Frequency Induction Heating Machine.*

The design and construction of a 3 kW rf induction heating equipment has been undertaken at the beginning of this year. The dc high voltage unit of the equipment has already been constructed along with its control circuits. This unit has three mercury vapour rectifiers connected in a three phase half wave circuit delivering an output of 3000 volts at 2 amps. dc. The dc voltage has been tested at full load and has been quite satisfactory. The control circuits are also working quite well. The construction of the high power radio frequency oscillator at 400 Kc/s is now in progress. The entire equipment is expected to be ready for operation in a few months.

D. N. Basu Mallik

9.3 *Getter-ion Pump*

The construction of the Getter-Ion pump is not yet complete, since the required titanium sheets have been procured very recently. Arrangements for cooling the cathode and the construction of the liquid air traps are now complete. The anode has been fabricated from titanium sheets 1/32″ thick. It has got 45 cells, 1/2″ × 1/2″ × 1/2″ each side, covering an area of 2-1/2″ × 4-1/2″.

G. N. Sarkar

9.4 *Powder Camera for X-ray*

A Debye-Scherer powder camera having a diameter 114.6 mm has been designed. It is under construction and is expected to be completed by March, 1967. A careful consideration has been given in its design so that it is (1) convenient to handle and (2) suitable to all laboratory conditions. The axis of the cylinder is vertical. It consists of two concentric cylinders with a gap of about 12 mm between the two. The film is to be wrapped on the outside surface of the inner cylinder having a diameter of 114.6 mm and is held in position by adjustable fingers. The object in using two cylinders is that very often X-ray laboratories have separate dark rooms. After positioning the camera, the film-cylinder may be loaded in the dark room and may be placed in position in the camera without having removed the whole camera which would be pretty heavy and without disturbing the adjustments. Once the camera is positioned, there would be no disturbance in the setting, which can be used for days. The camera would incorporate the required motions, viz., (1) translational motion at right angles to the axis of the beam, (2) rotational motion along a vertical axis, (3) vertical motion along the camera axis, and (4) translational motion along the beam axis. Fine control of the movements and locking the camera in all positions are provided for. Provision also has been made for rotating the sample, and a precise device for centering the sample from outside would be provided.

G. N. Sarkar

10. WORKSHOP

During the year under review, the workshop completed 362 jobs. The glass blowing shop constructed 225 pieces of glass apparatus for the different laboratories. The electrical shop repaired seventeen motors and made two magnet coils for the N.M.R. Division. It also made about 1200 feet of electrical wiring. The jobs worth mentioning are :—

(1) Completion of 6 pieces of 4″ diffusion pumps.
(2) Several slow motion devices for pulling crystals from melt.
(3) A 60° chamber for a focussing magnet.
(4) Angular correlation table.
(5) Several vacuum valves.
(6) Liquid air traps.
(7) Two feet dia. 4 component goniometer.
(8) A crystal goniometer for quadrupole spectrometer.
(9) Dewar flasks.
(10) Glass metal seals.

The 160 ton hydraulic press is in operation. Several dies were designed for pressing tablets from powder for studying the conductivity and other properties of the pressed materials. Attempts are being made to utilise the press for making graphite bricks from graphite powder. A die has been designed and constructed for this purpose. Preliminary results are encouraging.

Arc welding has been introduced. We are trying to purchase an argon-arc welding set, so that welded steel pipes may be used in vacuum practice. Aluminium brazing has also been introduced. We are in difficulty in procuring aluminium brazing alloys and fluxes that have got to be imported from abroad.

A new high precision and heavy duty lathe has been purchased and installed in the workshop. With this lathe metric, module and inch threads can be cut. The makers claim an accuracy of .05 mm in 100 cm in thread pitch. With this accuracy screws for optical instruments can be cut.

The workshop suffers from lack of space. For this reason a part of it has been shifted to Bon Hooghly where the radiobiological laboratory has been shifted. Another 2000 sq. feet of space and a number of machine tools are the immediate necessity of the workshop.

Due to the fact that several development projects have been undertaken by the Institute the pressure of work on the workshop is very heavy. To cope with this situation, we are now making plans for testing the feasibility of running the workshop in shifts.

G. N. Sarkar
Workshop Superintendent

11. LIBRARY

The present holding of the library is 13,880 books and bound volumes; the reports touched almost the mark of 10,000.

The library subscribes to 206 scientific periodicals. It receives 23 in exchange and 231 as gift from different sources.

The inter-library loan facilities have been extended with a number of libraries. The demand for photo-copying is increasing at a rapid rate. Both microfilms and translations are procured for the departments from different sources whenever they are needed.

We have established a preprint distribution service to different Divisions. We thank Dr. Suprakash Mukherjee for his help in classifying these reports for the distribution.

The library plans to give documentation services from the coming year.

Owing to lack of space, however, the orientation of the stacks has been changed and the reading room space on the main floor of the library has been completely curtailed.

(Mrs.) P. Hosain
Librarian

12. GENERAL

A highlight of the year 1966 was a visit paid to the Institute by Dr. Vikram A. Sarabhai, Chairman, Atomic Energy Commission, Government of India, on 19th August. Dr. Sarabhai went round the laboratories and addressed the members of the staff.

The total strength of the Institute on 31st December, 1966 was 341, consisting of 118 scientific personnel, 15 post-M.Sc. students, 96 technical and 34 administrative personnel, and 78 members of the auxiliary staff.

The following research workers have been awarded the D.Phil. degree of the Calcutta University in 1966.

(1) Shri N. H. Sarkar
(2) Shri P. Ganguli
(3) Shri K. S. Patel
(4) Shri K. N. Dutta
(5) Shri S. Shastry

Twelve workers, in addition, have submitted their theses for the doctorate degree.

Shri N. C. Adhikary (Jr.) has received the 'best worker of the Workshop' award for the year 1966.

Prof. B. D. Nagchaudhuri visited Japan for about three weeks at the invitation of the Tokyo University. Prof. T. Pradhan, Prof. M. K. Pal, Dr. P. Ganguli and Sm. J. Lahiri have also been abroad as visiting scientists. Prof. B. D. Nagchaudhuri, Prof. N. N. Das Gupta, Dr. P. Sadhukhan, Dr. (Mrs.) J. Chakraborty and Shri S. Das participated in the Sixth International Congress for Electron Microscopy at Kyoto in Japan. The Institute was also represented at the Fourth Annual Conference of the Electron Microscopic Society of India in New Delhi, First Summer School on Electron Microscopy in Bangalore, Symposium on Molecular Biology in Varanasi, Nuclear Physics & Solid State Physics Symposium in Bombay and Fifty-third Annual Session of the Indian Science Congress Association in Chandigarh.

Since 1st April, 1966 the Institute has been working on longer hours on all working days excepting the second and fourth Saturdays when the Institute remains closed. During the year 1966 the number of working days of the Institute was 269.

The Contributory Medical Benefit Scheme of the Institute was introduced in the year 1964.The members have to contribute $\frac{1}{2}\%$ of their basic pay as contribution towards the scheme and the balance of the total cost of the scheme is borne by the Institute out of its own resources. Out of 341 members, 222 have enrolled themselves in the scheme. Overall activities of the Medical Unit are summarised as follows.

1.	Medical attendance along with serving of prescriptions ..	3290
2.	Medical advice given to the non-contributor members ..	252
3.	Specialist consultation in different branches of medicine ..	29
4.	Hospital admissions	4
5.	Emergency home visits	19
6.	Vaccination and inoculations :	
	(i) Against cholera, typhoid, etc.	95
	(ii) Against small pox	195
7.	Laboratory investigations	315
8.	Blood check up for persons	90
9.	Courtsey medical advice and aid to the members of University Colleges of Science and Technology	60
10.	Courtsey medical check up and advice to the family members of the employees of the Institute	96
11.	No. of cases of tuberculosis	3
12.	No. of cases of showing minor radiation effects	2

The Institute's expenditure during the year ending 31st March, 1966 amounted to Rs. 32,04,954.53, out of which the Government of India in the Department of Atomic Energy contributed a sum of Rs. 31,73,000.00. The rest came as contribution from the Calcutta University and other miscellaneous sources.

H. K. Basu
Registrar

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9. Bhattacharyya, S. C., Mazumdar, S. K. and Saha, N. N., 'Crystal Structure of Sarcosine Hydrochloride', 7th International Conference of Union of Crystallography, Moscow, 1966.
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16. Datt, S. C., Verma, J. K. D. and Nag, B. D., 'Purification of Organic Semiconductors,' J. Scient. ind. Res., *25*, 465, 1966.
17. Datt, S. C., Verma, J. K. D. and Nag, B. D., 'Organic Semiconductors,' Sci. & Cult., *32*, 57, 1966.

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S. C. Saha

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S. N. Samanta

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R. K. Das

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A. Das

Fitter (Gr. I)

G. M. Mondal

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K. K. Bose
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S. Das Gupta
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B. P. Mukherjee
S. Mukherjee
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J. G. Mondal

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Plumber

P. Singh

Tracer

S. B. Chakravarti

Glass Blower

S. C. Saha

Junior Laboratory Assistants

S. K. Banerjee
K. P. Chaudhuri
P. C. Das
J. Mukherjee

Part-time Chemist

Sudhir Kr. Ghosh

Part-time Photographer

Saral Kr. Dutta

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A. Simpson

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