SAHA INSTITUTE OF NUCLEAR PHYSICS

ANNUAL REPORT 1964

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PREFACE

THE Annual Report for 1964 has been prepared in a somewhat different form than those of previous years. The report includes the abstracts of papers published during the year 1964 or presented in various conferences or symposia. The report also includes a summary of the various research projects which are in progress. The report of work carried out by our staff in other laboratories have also been included. For convenience of administration the work of the Institute has been divided into broad divisions and groups. The report is presented under each Division with a summary by each Divisional Head. A very short report of the developmental activities and of the growth and administration of the Institute is attempted so as to give a fairly complete picture of the Institute and is activities during the year. It will be our endeavour in future to bring out this report on the basis of the calendar year rather than our budget year.

I am particularly thankful to Prof. S. Chatterjee who has done bulk of the editing of this report. I am also thankful to all my colleagues who co-operated in trying to get the report out as early as possible. The delay in bringing out this report is regretted.

B. D. Nagchaudhuri,
Director.

CONTENTS

NUCLEAR PHYSICS DIVISION

THEORETICAL NUCLEAR PHYSICS DIVISION

SUBJECT INDEX

BIOPHYSICS

THE ORGANISATION

The Institute of Nuclear Physics was founded in 1948 with the dual objective of teaching and research in nuclear and allied sciences. This was possible only through the untiring efforts of Professor Meghnad Saha, the then Palit Professor of Physics of the Calcutta University. Professor Saha had been the life director. In 1951, the Institute was put on an independent organisational status by the Calcutta University. By mutual consent of the University and the Government of India, the Institute has an autonomous Governing Body consisting of representatives of the Government of India and the Calcutta University with the Vice-Chancellor of the Calcutta University as its Chairman. After Professor Saha's death in 1956, the Institute was renamed as Saha Institute of Nuclear Physics.

The laboratories of the Institute are at present housed in three buildings, two within the campus of the Calcutta University Colleges of Science & Technology on Acharyya Prafulla Chandra Road, and one within the premises of the Bengal Veterinary College at Belgachia. The third building, though a very small one is under construction at Pagladanga mainly to house a portion of the workshop and some laboratories. Negotiations for procuring another piece of land of somewhat bigger size at Bon Hooghly are under progress and it is hoped to build the fifth building of the Institute there to house the developmental laboratories.

The research work of the Institute is grouped around the facilities available in the Institute. The broad groups or divisions are (1) Accelerator Division, (2) Biophysics Division, (3) Nuclear Physics Division, (4) Theoretical Nuclear Physics Division, (5) Nuclear Chemistry Division, (6) Instrumentation Division, (7) Director's Research Group and (8) Teaching Division. There are 116 scientific, 70 technical and 34 administrative personnel in the Institute. Nineteen students are undertaking the one year post M.Sc. Associateship Diploma Course and 72 research workers are engaged in doctoral research and 10 of our research workers have obtained doctorate degree in 1964.

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

The Administration of the Institute has its activities sub-divided into four main sections namely, Establishment, Purchase-Stores, Accounts and Medical help. The staff strength of the Institute is above 300 to-day and the annual budget is of the order of Rs. 30.00 lakhs. The scheme of rendering medical help to the employees of the Institute has just been started and it is envisaged to extend the facilities to the members of their family in the course of next few years.

In addition to their normal duties, the employees of the Institute have organised their Recreation Club, Co-operative Credit Society, Canteen and Consumers' Goods Co-operative Society and Housing Co-operative Society.

ACCELERATOR DIVISION

1/0. *Summary of work of the Accelerator Division by Prof. D. N. Kundu*

A. The programmes and projects undertaken during 1964-65 are given below for the three sections. In the Cyclotron Section, the high voltage supply and its associated controls for the deflector and the fabrication of the external supports and cooling units for the deflector shoe have been completed and are being installed. The sub-station transformer (6600 volts to 400 volts) have been removed to a new location to make room for experimental apparatus to be used with the external beam. Relocation of various cyclotron components necessary for laying the external beam plumbing has been taken in hand. The design of beam bending magnets has been completed and the fabrication of one magnet has been entrusted to a commercial firm. A highly stabilised power supply for the deflection magnet has been procured and installed. During 1963-64, the design of the cyclotron septum was completed and the septum and the deflector shoe fabricated and installed. Towards the end of this period Dr. Baliga joined the group and an accelerated programme to develop the external beam facilities was taken up.

In the Mass Spectroscopy section, for increasing the ion output from the machine, a duoplasmatron ion source has been tested and installed after fabricating necessary power supply and controls. The testing of the assembly has been carried out up to an extraction voltage of 10 KV and the performance was found satisfactory with a stable current of about 100 micro-amperes. An ion optical lens arrangement is being installed for concentrating and focussing the beam at the optimum position for the entrance slit. The latter part of 1963-64 was used in the testing of the above mentioned ion source and also in improving the discharge stability of the previously used ion source. This work involved the fabrication of suitable filaments and filaments leads. A surface ionization type ion source has been constructed and the ionization potential of Li has been measured with the instrument.

In the Neutron Physics Section, the Cockroft-Walton Generator was regularly run for making neutron bombardments of target materials. Necessary chemical separations were made. Nuclear measurements on the resulting radio-isotopes lead to important findings. Equipments have been fabricated and electronic circuits lined up for the study of the angular distribution and correlation in (n, α) reactions. Improvements have been effected in a number of components of the neutron generator. Progress was also made in reaction studies with nuclear emulsions. The latter part of 1963-64 was occupied in nuclear studies similar to the above.

B. The plans and programmes to be undertaken during the next financial year 1965-66 are given below for the three sections. In the Cyclotron Section,

the instrumentation required for experiments with external beam will be completed. The external proton beam will be brought and focussed in the experimental room. Preliminary experiments with the external beam will be undertaken. In the Mass Spectroscopy Section, the work of assembly of the ion source will be continued. This machine will be used for the study of atomic collisions. The surface ionization type ion source will be used for the measurement of the ionization potential of rare earth elements. The preliminary phases of the construction of the laboratories for the projected isotope separator are also contemplated. In the Neutron Physics Section, nuclear transmutation work would be continued using 14 — MeV neutrons from the Cockroft-Walton Generator. The angular distribution and the correlation work will be emphasised using solid state detectors. The nuclear emulsion work will be continued using nitrogen as the target material. Necessary steps would be taken for improving the constant low temperature baths and dry chambers in the dark room for more efficient processing of the nuclear emulsions. The expansion of the laboratory at the new site would be pursued consistent with the progress of the building construction.

1/1. *Beam extraction Programme from 37″ Cyclotron*

The design of the cyclotron septum was completed and the septum and the deflector show fabricated and installed. Dr. B. B. Baliga joined the group and an accelerated programme to create the external beam facilities was taken up.

The high voltage supply and its associated controls for the deflector and fabrication of the external supports and cooling units for the deflector shoe have been completed and are being installed. The sub-station transformer (6600 volts to 400 volts) have been removed to a new location to make room for experimental apparatus to be used with external beam. Re-location of various cyclotron components necessary for laying the external beam plumbing have been taken in hand.

The design of beam bending magnets have been completed and fabrication of one magnet has been entrusted to a commercial firm. A highly stabilised power supply for the deflection magnet has been procured and will be put into operation shortly.

A new set of compensating capacitors have been fabricated and installed which will enable us to compensate for the frequency drift of the dee system. It is proposed to complete the instrumentation required for experiments with external beam, to bring the external proton beam and focuss it properly to the experimental room.

(A. P. Patro, B. Basu & B. B. Baliga)

1/2. *(p. γ) Reactions in the Giant Resonance Energy Region*

The 90° differential cross-sections have been measured for the four reactions Li^7 (p, γ) Be^8, B^{11} (p, γ) C^{12}, Na^{23} (p, γ) Mg^{24} and K^{39} (p, γ) Ca^{40}, using proton energies from 10.4 Mev to 14.5 Mev from the Columbia variable energy cyclotron. For the reactions Li^7 (p, γ) Be^8 and Na^{23} (p, γ) Mg^{24} the yields due to transitions to first excited state of the residual nuclei are reported as the number of transitions to the ground state is very small. For B^{11} (p, γ) C^{12} both the yields to the first excited state and the ground state are presented and in the case of K^{39} (p, γ) Ca^{40} only the ground state transitions are observed. Very little fine structure has been observed in the yield curve for Li^7 (p, γ) Be^8 whereas eight peaks are observed in the yield curve for Na^{23} (p, γ) Mg^{24}. The fine structure in B^{11} (p, γ) C^{12} from the transitions to the first excited state of C^{12} is observed at four excitation energies; while three peaks appear in the curve for the transitions to ground state. The yield curve for K^{39} (p, γ) Ca^{40} peaks at six excitation energies. A comparison with other experimental results show many more peaks than have previously been observed. In the region of overlap published results are consistent with our results.

Comparison with the theoretically predicted positions of the levels in C^{12} and Ca^{40} on the basis of the model of Brown et al., has been made.

(B. B. Baliga, L. Feldman and M. Nessin: Proceedings of the Nuclear Physics and Solid State Physics Symposium, DAE, Chandigarh, 147, 1964).

1/3. *Low Pressure Cloud Chamber and its Application*

a) Construction of a Stereo-reprojection equipment :

This equipment is needed for the spatial reconstruction of tracks obtained in the cloud chamber under stereo setup. The unit comprises of (i) a tilting screen and (ii) a strong illuminating light source. Two 250 watts lamps and a pair of compound lenses for condensing the light, form the illuminating system. The lenses are cooled by an air circulator. Entire assembly is housed in an aluminium box and made easy to handle.

b) Construction of an electromagnetically operated shutter :

A Po^{210}—source is permanently installed inside the cloud chamber which serves as a calibrating standard and also for checking the constancy of pressure. When relatively less intense alpha radiations are being photographed, it is desirable to cut off the polonium alphas to prevent jamming the pictures. This is achieved by an electromagnetically operated shutter arrangement which is remotely controlled. This device is installed and is operating satisfactorily.

c) Construction of a continuously variable, automatic pressure control device for cloud chamber :

After every expansion the pressure in the back chamber is to be readjusted to a present value. With the existing arrangement it is possible to set the pressure at certain discrete but close intervals. It has, however, been found that for obtaining good tracks the pressure setting has to be adjusted to value lying in between these discrete values. In order to achieve this smooth variation of pressure, a variable contact probe using sylphon bellows has been designed and constructed.

d) Studies on alpha-decay of Am^{241} :

The excitation levels of Np^{237} have been studied by a large number of workers using different experimental techniques. Relatively, much less is known about the excitation levels of Np^{237} derived through studies based on direct measurements of alpha decay of Am^{241}. Recently our knowledge in this aspect is enhanced by more information available through experiments performed with the help of high resolution magnetic-spectrographs. It is hence found desirable to undertake such a study in some detail. This is being done with the help of the existing low pressure cloud chamber. So far, about 50,000 tracks have been photographed under stereo setup. A preliminary analysis of the data shows that there exists several groups of alphas. Systematic analysis is continuing.

(M. Rama Rao)

1/4. *Shell Effects in 14 MeV (n, p) Reactions*

The available experimental data on the 14 MeV total (n, p) reaction cross-section have been brought up to date for the most abundant elements and re-analysed. Marked proton shell and subshell effects and pairing effects are shown to be present.

A convenient shell-dependent form of the statistical level density has been developed by using the simple Bloch-Rosenzweig model of combinatorial nuclear structure. This form has been used to estimate quantitatively the observed shell and subshell effects.

(Aparesh Chatterjee : Nuclear Physics, *60*, 273, 1964)

1/5. *Compound Nuclear Shell Effects in 14-MeV* (n, α) *Reactions*

Smoothed curves drawn with suitable selection of 14-MeV reaction cross-section data reveal distinct shell effects. The cross section dips down at the proton shell and subshell closure positions throughout the mass region. Within a shell, the odd-even nucleon effects tend to disappear and the cross section is seen to be a very slowly decreasing function of the mass number. Across the

shells, in addition to abrupt discontinuities, there is a gradual decrease of the cross sections from smaller to larger shells. These effects can be compared with various recent statements of the statistical level density. In the present work, the simple Bloch-Rosenzweig model of the shell-dependent form of the level density has been used and developed to study the effects. Results of computation reproduce the observed shapes faithfully up to Z = 50; with plausible estimates about the combinatorial degeneracy in a major shell, good agreement with the assumption of the validity of the compound nuclear reaction at high excitation is obtained.

(Aparesh Chatterjee : Phys Rev, *134B*, 374, 1964)

1/6. *Alpha Reaction Cross Sections for 14-MeV Neutrons*

The table presented here is a comprehensive compilation of the data available through December, 1963, on the total n, α cross sections at 14 MeV.

In the first column at the left of the table, the target nuclei are arranged in order of increasing charge numbers and isotopes; known isomeric cross sections are listed below those of the ground-state cross sections of the respective isotopes. In the second column, the neutron energy E_n in the laboratory system is noted. The experimental techniques used are indicated by the following abbreviations: direct α—counting during irradiation with telescopic systems or with scintillation or solid-state detectors; transmission experiments; activation method and emulsion-track measurements.

The fourth column gives measured values (with errors when available); relative measurements with respect to particular target or residual nuclei are also included. The fifth column lists the sources from which the experimental information was obtained. The column of residual nuclei distinguishes between the ground and metastable states. The Q-values in the last column are taken from the 1960 Nuclear Data Tables with the exception of the values in parenthesses, which are estimated from the known energy-level schmes of nuclei.

An interesting use of this table has been made in showing the presence of proton shell and subsell effects in 14-MeV n, α reactions.

(Aparesh Chatterjee : Nucleonics, *22*, Aug 1964)

1/7. *Modes of Oscillation of a Grounded Grid Cyclotron Oscillator*

A linear analysis of a grounded-grid cyclotron oscillator considering the effect of all the important circuit elements is presented. It is shown that the oscillator may execute oscillations at one of the cyclotron-dee resonant frequencies

and/or at one of the coupling transmission line frequencies. The conditions of excitation of these oscillations are derived. Experimental evidence obtained from a model oscillator verifying the above results are also given.

(D. N. Basu Mallik and B. R. Nag : Radio Elec Engr, *27*, 27, 1964)

1/8. *Decay of* Cu^{63}

The decay of Cu^{63} was studied after bombarding Zn and Ga with 14 MeV neutrons, using standard scintillation counter techniques. The beta and gamma measurements showed the presence of four gamma rays of energies 810 ± 8 keV (18), 1080 ± 3 kev (100), 1240 ± 10 kev (3) and 1880 ± 10 kev (5) and three beta groups of maximum energies 3.5 ± 0.06 MeV (75%), 2.7 ± 0.08 Mev (22%) and 2.25 ± 0.08 Mev (3%) decaying with a half-life of 30 ± 1 sec. Coincidence and some spectrum studies showed that the 1080 keV gamma ray was in cascade with 800 keV and 1240 keV gamma rays, and that the 1080 keV gamma ray was in coincidence with 3.5 MeV, 2.7 MeV and 2.25 MeV beta particles. A decay scheme is proposed, and a Cu^{63} — Zn^{63} mass difference of 4.58 MeV is obtained.

(H. Bakhru and S. K. Mukherjee: Nuclear Physics, *52*, 125, 1964)

1/9. *Radioactive Decay of* Lu^{178}

The decay of Lu^{173} is studied after bombarding Ta^{181} with 14 MeV neutrons, separating the Lu fraction by means of radiochemistry and using standard scintillation counter techniques. A quick method for radiochemical separation of Lu, has been worked out. The beta and gamma measurements show four gamma rays of energies 90, 215, 325 and 430 keV, each decaying with half lives of 30 ± 1 min and 5 ± 1 min and three beta groups of maximum energies 2.25 ± 0.05 MeV (88%), 0.770 ± 0.06 MeV (12%) and 1.50 ± 0.05 Mev (98%); the first two groups decaying with a half life of 5 ± 1 min and the last one with a half life of 30 ± 1 min. A metastable state of Lu^{178m} decaying with a half life 30 ± 1 min is suggested; the ground state of Lu^{173} is found to decay with a half life of 5 ± 1 min. A conversion electron peak of 340 keV energy and a 60 keV gamma ray, later identified as the K x-ray of Lu^{178m} are found to decay with a half life of 30 ± 1 min only. Coincidence studies show that the above gamma rays are in cascade and that none of the three beta groups is in coincidence with any of those above four gamma rays. Only the 0.770 MeV beta group is found to be in coincidence with the 332 keV gamma rays. A decay scheme based on the above observations is proposed and the results are discussed in the light of the unified model.

(H. Bakhru and S. K. Mukherjee: Nuclear Physics, *55*, 161, 1964)

1/10. *Radioactive Decay of Sr^{93}*

Sr^{93} is produced by the Zr^{96} (n, α) Sr^{93} reaction with 14 MeV neutrons, and is studied by means of standard scintillation counter techniques. A quick and efficient method for radio-chemical separation of Sr from Zr and Y, has been developed. The beta and gamma measurements show three beta groups of maximum energies 2.9 + 0.05 MeV (65%), 2.6 + 0.05 MeV (25% and 2.2 + 0.05 MeV (10%) and eight gamma rays of energies 0.300, 0.400, 0.600, 0.800, 1.10, 1.50, 1.70, and 2.1 MeV. Coincidence studies show that 0.600 MeV gamma ray is in coincidence with 0.300, 0.400, 0.800, 1.1 and 1.5 MeV gamma rays; 0.800 MeV gamma rays with 0.300, 0.400 and 0.600 MeV gamma rays, and 1.7 MeV gamma with 0.400 and 0.600 MeV only. Also with 0.600 and 0.800 MeV gamma rays in gate, all the three beta groups are observed; with 1.7 MeV gamma ray, two beta groups of maximum energies 2.6 and 2.2 MeV, are observed; and with 2.1 MeV gamma ray only the beta group of energy 2.2 MeV appears. Based on the above observations, a decay scheme of Sr^{93} is proposed.

(S. K. Mukherjee and H. Bakhru : Proc. of the Nuclear Physics and Solid State Physics Symposium, DAE, Chandigarh, 266, 1964)

1/11. *The (n, α) Reaction on C^{12} at 14 MeV*

The C^{12} (n, α) Be^{9} reaction leading to the ground state of Be^{9}, has been studied using nuclear emulsions. The angular distribution of the emitted group of alphas is found to be asymmetric about 90° c.m. and indicates the presence of direct interaction. The distribution shows a prominent forward peak at about 30° and a comparatively slow rise in the backward direction. The total cross-section for the ground state transition is 69 ± 13 mb. The theoretical fits to the experimental angular distribution have been discussed in terms of direct and exchange effects.

(M. L. Chatterjee and B. Sen : Nucl Phys, *51*, 583, 1964).

1/12. *Ion Source and the Mass Analyser*

The Duoplasmatron ion source was tested with an ionoptical lens arrangement for Argon ions. The ions source is being installed with the magnetic analyser for mass analysed beam of heavier ions. The circuits for the filament, Arc and the ion source magnet with proper control system have been completed. A current stabiliser with high stability has been installed with the magnet coils.

(S. B. Karmohapatro and S. D. Dey)

1/13. *Surface Ionisation*

A three filament ion source has been developed for solid substances. The ion generated with this source are governed by the Saha-Langmuir equation and with its help an absolute method for determination of ionisation potential of Lithium has been devised. The results will be reported in the Low Energy Nuclear Physics Symposium to be held in Calcutta, 1965.

The results promised the utility of the method to be applied to other elements. Rare earth elements are chosen for this purpose, since there are difficulties to establish their ionisation potential by optical spectroscopy. Of course, spectroscopic data of some of them are available. But it is worthwhile to find them and others having no data. An attempt has been made to determine the ionisation potential of Gd. The results are comparable with the results of other laboratories experimentally derived by a similar method. But the discrepency with the spectroscopic data is yet to be explained. The work in this line is being continued.

(S. B. Karmohapatro and S. D. Dey)

1|14. *Atomic Collisions and Negative Ions*

Atomic collision processes are studied with reference to the negative ions. For quantitative estimation of the loss of the negative ions in gases, the impact parameter method with two state approximation has been applied.

With this method, the solution of the time dependent Schrodinger equation with expansion of the atomic eigen function gives the probabality of the loss of the negative ions by charge exchange. Some results will be reported in the Low Energy Nuclear Physics Symposium to be held in Calcutta, 1965.

(S. B. Karmohapatro)

BIOPHYSICS DIVISION

2/0. *Summary of work of the Biophysics Division by Prof. N. N. Das Gupta*

The following is a brief account of the activities of the Biophysics Division during the year 1964.

In the molecular genetics section, researches have been carried out on the analysis of the nature of genetic information transfer during growth of the bacteriophage ϕX-174. In the free state these phages contain single-stranded DNA as their genetic material. But soon after infection, this DNA assumes the usual double-stranded form (called RF) within the host cell. The present studies indicate that the integrity of both the strands of the RF-DNA is necessary for the transcription of genetic message leading to the intracellular maturation of these phages. This result has later been corroborated by the Prof. Sinsheimer and his associates at California Institute of Technology. Our studies have also shown for the first time, a method of decoupling the phage induced and the normal host controlled metabolic processes in the X-infected cells. A comparison of ϕX-irradiation sensitivities of double-and single-stranded DNA containing phages has been made and the results show that damage in the DNA due to ingested P-32 decay increases the radiation sensitivity of the former but not of the latter.

In the radiation biology section, X-ray sensitivity of the bacterial cells has been measured after different pretreatments e.g. heat, P-32 incorporation, etc. These pre-treatments have been found to increase the sensitivity of the cells to later X-irradiation. The increased sensitivity in such cases indicates that these different agents have a common inactivating site. This common locus of radiation action is probably the DNA inside the cell. The reactivation of X-ray irradiated cells has also received attention. RNAse has been found to enhance the survival of irradiated cells and evidence has been collected that prove that RNAse acts as a reactivator and not as a protector. The researches in this Division led to the award of a D. Phil. (Science) degree of the Calcutta University.

Electron microscopic study of the human haemoglobin variants A, F and E, has shown for the first time that the molecules are asymmetric with a hole in the middle and seem to be divided into unequal halves by lines radiating from the centre. The optimum conditions for successful electron staining of these molecules with PTA have been established. The ultrastructures of the normal and some diseased erythrocytes (thalassaemic-triat disorder and hereditary spherocytosis) have also been investigated. From the appearance of the ghost cells and ultrastructures of the membranes, the thalassaemic cells are seen to have marked abnormalities compared to the normal red blood cells.

Electron microscopic studies of the chromosomes of Euglena show that these resemble those of higher cells. Macro-and micro-nuclei of ciliates have been studied with optical microscops using different stains and fixatives. The characteristics of the division stages of the micro-and macro-nuclei have been established.

Most of the previous diffusion studies on macro-molecules have been carried out using either Gouy or Raleigh interference optics. In this laboratory Jamin interference technique has been used for the measurement of the diffusion coefficient of bovine serum albumin and the variation of the diffusion coefficient with concentration has been estimated.

2|1. *Transmission of Genetic Message by φX174*

It is known that genetic information in living matter reside in the DNA molecules and that one of the strands DNA carried all the necessary genetic information. Our problem was to study how φX174, which is a single-stranded DNA bacteriophage, carries the genetic information. It has been found that immediately after the infection of the host bacteria *E. coli* by φX174, the complement to the infecting DNA results and this has been called the replicating form (RF) of φXDNA. In order to find which of the two strands of the RF is responsible for the transmission of genetic message, the complexes of (i) P-32 labelled *E. coli* C and P-32 labeled φX174, (ii) P-32 labeled *E. coli* C and nonlabeled φ174, (iii) nonlabeled *E. coli* C and P-32 labeled φX174 were stored at 4°C after 4 min' growth at 37°C. It was known that during this time of growth RF was formed. The study of survival of the phage-bacteria complexes with time of storage at 4°C due to the decay of radio-active phosphorus should, therefore, identify the strand, integrity of which is essential for the transmission of the genetic message. Experiments are still in progress, but preliminar results indicate that the integrity of the infecting DNA strand of φX174 is necessary for the transcription of genetic message.

(B. Dutta and R. K. Poddar)

2|2. *Changes in Sensitivity towards X-irradiation of ΦX174 and T2 Bacteriophage after Survival of Ingested P-32 Decay*

The efficiency of killing of bacteriophage T2 due to ingest P-32 decay was 0.1 and that of φX174 was 1.0 indicating that about one out of ten disintegration kills the T2 phage particle, whereas every disintegration is lethal in the case of φX174. So it may be expected that a population of labeled phages, surviving a given number of ingested P-32 decay, should exhibit unchanged sensitivity towards X-rays in the case of ΦX174, but an altered sensitivity in the case of T2. It was observed that the slopes of the survival curves due to X-irradiation of non-labeled φX174 and that of labeled φX174, 99.8% of which have been inactivated due to ingested P-32 decay were same. But from the slope of the survival curves due

to X-irradiation of labeled and non-labeled T2 it was observed that, under identical conditions, labeled T2 surviving P-32 decay was more sensitive to X-rays than non-labeled T2.

(B. Dutta and R. K. Poddar)

2|3. *Investigations on the Macromolecular Synthesis in Normal and X-irradiated Cells due to Infection with ϕX174*

On irradiation with 40 kilorads of X-rays, only 0.1% of the cells were able to form colonies but 20% of the cells still sustained the growth of bacteriophage ϕX174. This indicated the synthetic machineries responsible for bacterial growth and divisions were seriously damaged but the machanisms for phage used to study macromolecular synthesis induced by ϕX infection.

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

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

(S. R. Pal Choudhuri and R. K. Poddar)

multiplication remained unhurt. Such partially radiation damaged cells were

2|4. *X-ray Sensitivity of E. coli under Different Pretreatments*

X-ray sensitivity of *E. coli* has been found to be influenced by the pretreatments of the cell. If radioactive phosphorus was incorporated inside the cell, the sensitivity of the cells to X-rays was found gradually to increase, with progressive damage produced by the incorporated P-32 decay. Pre-heating of the cells at 52°C for various periods also increased their X-ray sensitivity. This increase in sensitivity was found to be a function of the time of heat treatment. Heat killed cells if incubated at 20°C for 96 hrs were found to recover to about 69% of their initial viable fraction population. Such cells, though recovered from heat damage were found to be more sensitive to X-rays compared with the untreated control cells, indicating that the cells still had some damage to make them more suspectible to X-rays.

(Madhuri Das and S. B. Bhattacharjee)

2|5. *Influence of RNA'se on the Reactivation of Irradiated Bacteria*

The idea behind the project was to study if the treatment with RNA'se could increase the survival of the irradiated bacteria and in case of an increase, if it was a protector or a reactivator. It has been observed that as the result of the treatment with RNAse there was 40 fold increase in survival for X-irradiated cells (survival level 0.1%) and two fold increase for the U.V. irradiated cells (survival level 0.1%). Also, RNA'se was predominantly a reactivator and not a protector. The magnitude of the rectivativation depends on the amount of RNA'se and reaches a saturation value at certain concentration of the enzyme (about 40 μg|ml). Thc differential analysis of the influence of RNA'se on X-irradiated and U.V. irradiated cells shows that the mechanisms of the inactivation by X-rays and U.V. rays were different, even though there might be some overlap.

(S. B. Bhattacharya)

2|6. *Interaction of Phosphotungstate with Haemoglobin*

The interaction of phosphotungstate of different pH values with human haemoglobin has been studied by spectrophotometry and ultracentrifugation. In thc pH range 5.0 to 7.0 phosphotungstic acid has been found to interact strongly with haemoglobin as indicated by a rapid increase in the sedimentation coefficient and a sharp fall in absorbance. In the pH range 7.0 to 9.6, this interaction is less, but the molecules show a marked tendency to form clusters.

Comparison with control experiments with buffers of different pH values shows that the observed changes may be either due to a change in the architecture of the haemoglobin molecules themselves leading to aggregation or due to selective binding of the phesphotungstate macro-ions.

(A. B. Sanyal, P. Ganguly and N. N. Das Gupta:
J Mol Biol, *8*, 325, 1964).

2|7. *Electron Microscopic Observations on Human Haemoglobins*

Molecules of human haemoglobins E and F have been micrographed after nagative staining with phosphotungstic acid. Many of the molecules seem to have a hole at their centres. While some of the molecules have an ellipsoidal appearance, in many cases, the shape is very asymmetrical and pointed towards one end. Many other molecules appear to be pear-shaped and divided into unequal halves by depressions radiating from their centres. The average dimensions of the stained molecules appear to be 76Å × 63Å. Human Hb-A mole-

cules have also been micrographed after metal shadowing. Some of these shadowed molecules also show the typical hole and the substructures similar to those observed in the case of stained preparations.

(D. N. Misra, N. N. Das Gupta, A. B. Sanyal and J. B. Chatterjea; Expt. Cell. Res, 34, 325, 1964)

2/8. *Electron Microscopic Studies on Normal and Diseased Erythrocytes*

Ultrathin sections as well as plasma membranes of erythrocytes from normal adults, from a strongly anaemic patient suffering from hereditary spherocytosis and from two patients with thalassaemic trait disorder have been studied by electron microscopy. The membranes of the three kinds of cells were prepared identically by gradual haemolysis method. The ultrastructures of the membranes were studied by shadowing them with metal vapour. Thin sections of the hereditary spherocytes occasionally showed small vacuoles and sometimes inclusions in them. Some of the sections of the thalassaemic cells showed a big central vacuole with a characteristic inclusion. Ghosts of the spherocytes were found to be more flexible and thinner than the normal ones, whereas those of thalassaemic cells appeared coarser. The results indicated prominent stromal abnormality of the spherocytes. The ghosts of the thalassaemic cells were also found abnormal in some respects. The ultrathin sections of the thalassaemic cells showed some abnormal features, but those of the spherocytes were considered normal.

(D. N. Misra and J. Chakraborty)

2/9. *Investigations on the Physical Character of DNA Molecules in Native and Denatured Condition*

This study is an attempt to observe under the electron microscope the characteristic produced in the DNA molecule by exposure to low ionic strength solvents, by heat and by X-irradiation. It has been shown that although hyperchromicity is produced in every case as a result of denaturation, there are characteristic differences in the nature of DNA denatured by different methods.

Exposure to low ionic strength solvents brings about disintegration to single polynucleotide chains over long regions of DNA with the possibility of renaturation at a later state. Heating at 100°C for 10 minutes may also lead to the formation of single chains but the more characteristic feature in this case, is the production of diffuse patches along the length of the DNA thread. Under this condition a single DNA may be partially denatured in an irreversible manner over a part of its length and may also retain its normal double stranded form in

another part. Characteristics of X-ray denaturation were occasional breaks in the DNA and the formation of DNA net work.

(N. N. Das Gupta, M. Das and D. N. Misra)

2/10. *Diffusion Studies on Bovine Plasma Albumin at* 25°C *with the Help of Jamin Interference Optics*

Diffusion coefficients of Bovine albumin in acetate buffer were measured at 25°C at different values of mean protein concentration ($\bar{c}$) with the help of Jamin interference optics using a micro-diffusion cell. $D(\bar{c})$ was found to be linearly dependent on $\bar{c}$ with a small negative slope of 0.08737×10^{7}, $\bar{c}$ being in gm/100 ml. The extrapolated value of the diffusion coefficient was obtained as $D_0^{25,\,w} = 6.73 \times 10^{-7}$ cm²/sec. The probable theoretical basis of the present observations has been discussed.

(Amala Chatterjee: J Amer Chem Soc, *86*, 3640, 1964)

2/11. *Measurement of the Diffusion Coefficient of Sucrose in very Dilute Aqueous Solutions using Jamin Interference Optics at* 25°C.

Diffusion coefficients of sucrose in very dilute solutions have been measured at 25°C as a function of concentration with the help of the Jamin interference optics and a micro-diffusion cell. The details of the method have been described and the results compared with those obtained by Gosting and Morris with the help of the Gouy method at 25°C. A very satisfactory agreement has been obtained.

(Amala Chatterjee: J Amer Chem Soc, *86*, 793-795, 1964)

2/12. *Electron Microscopic Studies on the Mitotic Cycle of Euglena*

A number of investigators have reported on the ultrastructure of *Euglena*. But our problem was to confirm the earlier optical microscopic observations, with the help of electron microscopy, and ultrathin sectioning technique. The earlier authors described that the interphase nucleus of *Euglena* contains fine Feulgen positive threads or the chromososome, and Grell (1963) compared these chromosomes with those of Dinoflagellates. Our micrographs show that these resemble that of higher cells and the chromosomes during mitotic division have typical ultrastructures like higher cells. Some granules are also present inside the nucleus.

(C. K. Pyne and J. Chakravorty)

2/13. *Optical Microscopic Investigations on the Ciliate Macro- and Micronucleus*

Ciliate of *oxytricha* group was cultured in the laboratory. The problem was to study the entire dividing stages of macro- and micro-nucleus with the help of optical microscope. For this purpose the cells were fixed with (a) chromic anid fixative, (b) susa fixative, (c) osmic acid vapour, (4) Zenker, (e) Carnoy-Lebrun and (f) Flemings' fluid. The fixed cells were stained with feulegen nuclear stain and micrographed. The following observations were made.

There are two macro- and two micronuclei in each cell. The division of macronucleus starts with the fusion of two macronuclei, which form one big elongated feulgen positive mass. This long nucleus then becomes constricted at the middle and separated into two parts, thus giving rise to two nuclei, which again divide and ultimately four macronuclei are formed. The micronuclei divide mitotically. In this case also four nuclei are formed. During this time the cytoplasmic division starts. Each daughter cell containing two of these macro- and micronuclei are ultimately separated.

(J. Chakraborty)

2/14. *Physical Studies on ϕ X-174 DNA*

Large quantities of the bacterial virus φX-174 were grown which were purified by selective precipitation and centriguration. From the purified virus, DNA was studied by ultracentrifugation and electron microscopy in an attempt to gain direct confirmation of the current hypothesis that the DNA in this case is a closed loop. The preliminary results obtained was consistent with such a view. A part of this work was carried out in the laboratory of Prof. M. Beer in the Department of Biophysics at the Johns Hopkins University in Baltimore, USA where the author enjoyed a Research Associateship.

(P. Sadhukhan)

2/15. *Interaction of Electrons with Photographic Emulsions in Electron Microscopy*

For the quantitative electron microscopy of the biological macromolecules, it is essential to know the characteristics of the interaction of electrons with photographic emulsions used. With this object in view, the silver grains developed in the emulsions counted under a variety of electron microscopic techniques. The results of the preliminary measurements of the yield of grains per electron have been published under the title "Characteristics of Photographic Emulsions for Electron Microscopy" in the Journal of the Optical Society of America, Vol. 52, p. 204, 1965.

This work was done during the period from April, 1964 through August, 1964 when the author was a Visiting Scientist in the Laboratory of Dr. G. F. Bahr in the Biophysics Branch of the Armed Forces Institute of Pathology in Washington, U. S. A.

(P. Sadhukhan)

2/16. *Nomogramic Method for the Estimation of Mass-thickness of Biological Samples*

Electron microscopy is now being much utilised in quantitative estimation of mass-thickness of biological materials, from the measurement of image contrast in electron micrographs. The degree of scattering of electrons in a specimen properly mounted in an electron microscope determines the contrast in the image. In the previous attempts to determine the mass-thickness, Sadhukhan and De (1960), only the elastic scattering cross-section was taken into consideration. In the present communication, both elastic and inelastic scattering cross-sections and their variation with aperture angles have been considered.

A graphical chart has been constricted with sets of straight lines connected $\triangle$ D, ϕ, θ, γ, and ρt i.e. photographic density difference, electron energy in kV, objective aperture angle in radians, the slope of the H-D curve and mass-thickness in gm|cm^2, respectively. Knowing the operating condition of the microscope, the mass density can be found out from the chart. A method has been suggested for avoiding the γ -value of photographic plate in the measurement of contrast.

(N. H. Sarkar : Exptl Cell Res, *36*, 487, 1964)

NUCLEAR PHYSICS DIVISION

3/0. *Summary of work of the Nuclear Physics Division by Prof. A. K. Saha*

The division has its programme divided in three broad sections viz. :

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

Under nuclear spectroscopy we carry out conventional β and γ spectroscopy work and analysis of nuclear reaction data. Solid state and molecular physics research can be divided into: (a) Theoretical studies which is mainly concerned with application of group theory of lattice vibration problems and studies of crystalline electric fields; (b) Microwave gas absorption studies with spectrometer which has just been constructed, (c) EPR studies with a 3 cm spectrometer, the construction of which has just been completed; (d) EQR studies with a 28-36 Mc spectrometer constructed in our laboratory; (e) NMR studies of N^{14}; and (f) X-diffraction studies for which the laboratory has has just been completed. The work on molecular biology was mainly concerned with a study programme of collagens from different sources. Among the equipments added to our group mention may be made of a 100 Mc HR Varian NMR spectrometer which has just been installed. A beginning has been made of of setting up of crystal growing equipments.

3/1. *Decay of Y^{88} to the 3.22 and 3.52 MeV Levels of Sr^{88}*

Decay of Y^{88} has been studied in a 10 cm diam + 10 cm thick Na I (Tl) phosphor. Two levels of Sr^{88} at 3.22 and 3.52 MeV have been identified in the capture decay of Y^{88}. The 3.22 MeV level proceeds through a direct as well as a parallel branch of decay by a 1.36 and 1.86 MeV cascade. Gamma-gamma angular correlation measurements were made and the spin-parity of various levels has been assigned.

(S. Shastry & R. Bhattacharyya : Nucl Phys, *55*, 397, 1964)

3/2. *Decay of Tc^{96}*

The multipolarities of the different gamma rays of Mo^{96} following the decay of the 4.3 day Tc^{96} were measured from internal conversion coefficients using the Sieghahn-Slätis beta-ray spectrometer. The 317.2 keV and 1115 keV gamma-rays have been found to be of M1 and E2 characters respectively. The gamma-gamma angular correlation measurements were made employing the summing technique of Hoogenboom for the 317-1115 and 1115-841 keV cascades.

(S. Shastry, B. B. Burman Roy & R. Bhattacharyya : Nucl Phys, *56*, 491, 1964)

3/3. *Spin of the 3.22 MeV State of Sr^{88}*

The spin of the 3.22 MeV state of Sr^{88} has been measured by gamma-gamma angular correlation method. A spin parity 2^+ is assigned to it from this result and from the log ft. value of the capture transition to this level.

(S. Shastry and R. Bhattacharyya : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 289, 1964)

3/4. *On the 2.73 MeV Level of Mo^{96}*

A spin-parity 6^+ has been assigned to the 2.73 McV level of Mo^{96} by internal conversion measurement with a Siegbahn-Slätis beta ray spectrometer.

(B. B. Burman Roy, S. Shastry and R. Bhattacharyya : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, *27*, 1964)

3/5. *On the Levels of Sr^{88}*

A detailed shell model calculation with finite range forces is in progress on the levels of Sr^{88} incorporating hole-particle description of the Nuclear states assuming 38 protons to form a closed shell core.

(S. Shastry)

3/6. *Nuclear g-factor Measurements on some Nuclei*

A magnet has been designed and constructed for the measurements of nuclear g-factor in some nuclei.

(A. K. Nigam & R. Bhattacharyya)

3/7. *On the Levels of W^{187}*

Beta and gamma spectroscopic work, and angular correlation measurements on W^{187} is in progress. Some results have already been obtained but due to its short half-life some more experiments are needed to complete the work on this nucleus.

(A. K. Nigam & R. Bhattacharyya)

3/8. *Interpretation of Pb^{206} (d, p) Pb^{207} Reactions in terms of the Unified Model*

An attempt has been made to determine the level positions of highly excited states in Pb^{207} and to estimate the cross-sections for exciting these levels in (d, p) reactions with Pb^{206} in terms of the unified model. It is assumed that the neutron in the N = 126—184 shell is loosely coupled to the Pb^{206} core and the interaction between the holes in the Pb^{206} core with this extra neutron is replaced by a 2^+ phonon-neutron interaction. Good agreement is obtained for the level positions by a suitable choice of phonon energy and the phonon-particle coupling strength. But the calculated cross-sections deviate widely from the experimental values. Thus two $\frac{1}{2}^+$ and two $3/2^+$ states are predicted to be strongly excited in the (d, p) reaction from the calculation, while one level for each is observed.

(Ila Mukherjee and Paresh Mukherjee : Nucl Phys, *57*, 683, 1964)

3/9. *Nuclear Spectroscopy with (d, p) and (d, t) Reactions on Tl^{205}*

Results of (d, p) and (d, t) reactions on Tl^{205} and Tl^{203} are reported. Informations about the levels of Tl^{206} and Tl^{204} are extracted from the reaction data and compared with the theoretical expectations.

(P. Mukherjee : Phys Lett, *13*, 238, 1964)

3/10. *Nuclear Structure Studies of Tl^{206} with Tl^{205} (d, p) Reactions*

Several energy states of Tl^{206} (up to 5.4 MeV) are located with (d, p) reactions on isotopically enriched (99%) Tl^{205}. From the (d, p) cross sections for exciting the 0^- ground state in Tl^{206}, it is found that the ground state of Tl^{205} is about 74% $(s_{1/2})_p^{-1}(p_{1/2})_n^{-2}$ which agrees well with the theoretical estimate. The $(s_{1/2})_p^{-1}(p_{1/2})_n^{-1}$ splitting in Tl^{206} is found to be 0.29 MeV. The low-energy proton excitation spectra have a close similarly with the Pb^{203} (d, p) proton spectra, so that the $g_{9/2}$, $d_{5/2}$ and $s_{1/2}$ neutron states can be identified in Tl^{206}.

(Paresh Mukherjee: Communicated to Nucl Phys)

3/11. *The Two-nucleon Transfer Reaction Ca^{40} (d, α) K^{38}*

The reaction Ca^{40} (d, α) K^{38} has been studied with 14.8 MeV deuterons. Angular distributions of alpha particles to several levels of K^{38} have been obtained and are compared with two-nucleon pick-up theories.

(P. Mukherjee: Communicated to Nucl Phys)

3/12. *Nuclear Structure Studies with Deuteron induced Reactions*

A survey has been made of the current works with medium energy deuteron. The locations of single particle states with (d, p) and (d, t) reactions are considered and many new features of the shell states are discussed. Of special interests are the spin-orbit splittings over a wide range of nuclei and the possible existence of a new type of neutron-proton interaction. Applications of the (d, p) and (d, t) reactions to study the configuration mixing in nuclei are also considered. The locations of quasi-particle states and estimations of wj^2 and vj^2 from (d, p) and (d, t) reaction studies of single closed shell nuclei are also included. Study of collective states by (d, d′) reactions are summarized and the possible ways to determine the parity of these collective states are discussed. In (d, α) reactions the possibility of studying new types of shell model states is pointed out. But the inherent incompleteness of the current two particle stripping theory is stressed by considering a simple case Ca^{40} (d, α) K^{88}.

(Paresh Mukherjee : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 45, 1964)

3/13. *Nuclear Structure Studies in the Pt region with (d, p), (d, t) and (d, d') Reactions*

A survey has been made of the particle, hole and collective states in seven Pt isotopes (A = 193—199) by (d, p), (d, t) and (d, d′) reaction on Pt^{194} Pt^{195} Pt^{196} and Pt^{198}. The incidet deuteron energy is 15 MeV. The $p_{1/2}$, $p_{3/2}$, $f_{5/2}$, $f_{7/2}$ $i_{13/2}$ quasi-particle states are located in all odd-mass isotopes from an analysis of (d, p) and (d, t) cross sections and (d, p) angular distributions. Several p and f states are found distributed up to an excitation of 1.6 MeV. The $g_{9/2}$ state is located around 1.8 MeV in Pt^{195}, Pt^{197}, and Pt^{199}. About this level several strongly excited states are observed in (d, p) reactions, which are presumably the neutron states in the N = 126—184 shell. In Pt^{195} the 0.210 MeV state (and possibly the 0.240 MeV state also) is found to be strongly excited in (d, p), (d, t) and (d, d′) reactions, indicating particle and phonon admixtures. The excitation spectra of the three even-mass isotopes are very similar to one another. From (d, p) and (d, t) cross sections the pairing theory parameters V_{2j} for Pt^{194} and Pt^{196} are determined for the $p_{1/2}$ state only.

(P. Mukherjee : Communicated to Nucl Phys).

3/14. *Vibrations in Molecules and Crystals*

(a) Group Theoretical Method of Deriving the potential of a vibrating system

Using the rule of tensorial break up in symmetries less than the spherical

one the potential of a vibrating system can be derived. This is of particular use for knowing the cubic anharmonic terms which are of importance for a number of physical phenomenon. All the six terms in the harmonic part and 14 terms in the cubic anharmonic part of XY_3 molecule have been written down as an example. Only under restriction from physical considerations about the nature of the interatomic forces, there may be reduction in the number of terms in the potential.

(D. K. Ray and P. Rudra : Jour Chem Phys, *40*, 2416, 1964)

b) Dynamic Spin Hamiltonian and Spin-lattice relaxation in paramagnetic solids

A general method of deriving the dynamical spin-Hamiltonian valid for any paramagnetic system has been worked out from symmetry principles. This Hamiltonian has been used to the study of anistrophy of spin-lattice relaxation in paramagnetic crystals.

(T. Ray and P. Rudra)

3/15. *Shielding for the Crystalline Electric Field and for the Nuclear Quadrupole Moments in Rare-earth Ions*

In order to determine the nature of the shielding for the crystalline electric field and the nuclear quadrupole moments in rare earth ions, analytical expressions have been derived for these parameters using hydrogenic orbitals with appropriate screening constants. The dependence of the shielding parameters on the atomic screening constants is clearly indicated. The shielding of the crystalline field parameters A_l^m corresponding to different values of l shown to fall of as l increases, and for most of the orbitals the sign of the shielding parameter is such that it acts as a shielding rather than an anti-shielding. Generalized expressions for the shielding of nuclear moment of any order of magnitude have also been derived which show that the radial contributions increase with the increase in the value of l for any particular orbital. There is good agreement with the values of γ_∞ of Sternheimer for the Pr^{3+} ion if Z_{eff} for the outer 5p and 4p orbitals is taken to be about 3 and 11 respectively. In the discussion the inadequacy of the shielding effect in explaining some of the experimentally observed crystalline field parameters has been pointed out.

(M. N. Ghatikar, A. K. Raychaudhuri and D. K. Ray: Proc Phys Soc, *84*, 297, 1964)

3/16. *Generalised Spin Hamiltonian and Nuclear Quadrupole Interactions for Rare Earth Trichlorides*

In view of the possibility of doing ENDOR and Mössbauer experiments for accurate determinations of various terms of the spin Hamiltonian and hyper-

fine parameters of a paramagnetic ion in a crystal, the generalised spin Hamiltonian has been evaluated for D_3 symmetry corresponding to various spin values of rare earth ions in the trichloride structures. Numerical estimate has been made of various important terms of the Hamiltonian for Pr^{3+} in $PrCl_3$. Using the shielding factors evaluated earlier quadrupole splitting for the ground and some of the excited states has been evaluated and the variation of quadrupolar splitting with temperature expected from Mossbauer experiment has been calculated, General conclusions that can made out of these results have been stressed upon.

(M. N. Ghatikar, T. Ray and D. K. Ray : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 336, 1964)

3/17. *Nuclear Quadrupole Interaction for Rare Earth Ions in Crystals*

The exact form of spin Hamiltonian for rare earth ions in crystals has been worked out by T. Ray. This has been applied to the case of rare earth trichlorides in order to estimate the importance of Zeeman field dependent quadrupole terms. Possible effect of Zeeman field on the Mossbauer experiments on rare earth compounds is being investigated.

(M. N. Ghatikar)

3/18. *Nuclear Quadrupole Interaction in Metals*

Studies have been made on the possible contribution to the electric field gradient in metals. The importance of induced moments on the ionic contribution in crystals with h.c.p. structure is under investigation.

(K. C. Das)

3/19. *On the Variational Calculation of the Diamagnetic Susceptibility and Nuclear Magnetic Shielding in Molecules*

A gauge-variation method has been used to formulate expressions for the diamagnetic susceptibility and nuclear magnetic shielding in molecules entirely in terms of the ground state wave-function. The inaccuracy of the total value thus calculated is commented on, together with the equivalence of this method to Hasse-type variational calculations. McConnell's long-range approximation and Rebane's work have been discussed in the light of the present work.

(A. K. Raychaudhuri and S. K. Sinha: Mol Phys, *7*, 473, 1964)

3/20. *Distortions of Atomic or Ionic Wave Functions in a Molecular or Crystalline Environment*

Distortions of hydrogen atom in a molecule like H D were evaluated.

(J. Lahiri and Arunaditya Mukherjee)

3/21. *A Self-consistent Variation-perturbation Method*

In the usual methods of determining the changes in atomic wave functions due to a perturbation the self consistency condition is violated. For more accurate calculation with a self consistent field wave function it may be necessary to include the effect of the changes in the orbitals on themselves. A method has been described where the unperturbed wave function is a determinant of single particle functions and the perturbation of each orbital is chosen in analytic form containing some variation parameters. The energy is calculated which includes upto the second order contribution due to the perturbed orbitals. The set of solutions obtained by minimising this energy will be self-consistent upto the first order in the wave function. The importance of such calculation is discussed.

(Arunaditya Mukherjee: Proc Nucl Phys and Sol State Phys Symp, DAE, Chandigarh, 507, 1964)

3/22. *Effect of electrostatic polarization of atoms on some physical parameters*

In theoretically studying different properties of atoms in solid, approximations are often made in which the atomic wave functions are supposed to be as they are in free state. This is a serious restraint in view of the fact that numerous interactions are present in the solid. In this paper we have considered the effect of an electrostatic field on such an atom. As a simple system perturbation of a hydrogen atom wave function by a point charge is studied. It has been observed that the perturbed states contribute very significantly to the diamagnetic susceptibility, chemical shift and electric field gradient at the proton site. The relative importance of these contributions for various distances between the atom and the point charge is discussed, and application of this result in actual cases of atoms in solids is indicated.

(J. Lahiri, Arunaditya Mukherjee and D. K. Ray : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 427, 1964)

3/23. *Evaluation of Electronic Polarizability of Atom*

(i) A project was undertaken to theoretically evaluate the electronic poparizability of atom. This had been a matter of interest since about 1955, and

many workers have worked in this field. A comprehensive survey is given by Dalgarno in Advances in Physics, Vol. 11, pages 281-315, 1962. However, an accurate calculation of polarizability had been a matter of considerable difficulty and labour, and as such had never been done in cases other than of a few atoms and ions in the early part of the Periodic Table. The major difficulty in a self-consistent perturbation calculation lies in iterative solution of coupled differential equations.

We had developed a variational method for handling the problem, in which the coupling between the various perturbed orbitals have been properly considered and the self-consistency is achieved through iterative diagonalisation of matrices. The dimensions of these matrices depend upon the variation parameters taken for each orbital, and it does not usually go beyond 15.

This way the method worked out has become equally applicable to large or small atomic or ionic systems. The dipole and quadrupole polarizability and shielding factors for He, Li^+, Li and Be have been computed and the results are in excellent agreement with other accurate calculations made by earlier workers in this field.

(ii) It is planned to extend this calculation to a host of other bigger atoms and ions, and to study their effect on crystal field calculations. Then we intend to extend the method so as to make it applicable for molecules. Thirdly, we intend to modify the theory so as to study other properties like hyperfine structure, crystal field parameters, etc.

The present calculations are being done with the collaboration of Mrs. Jayanti Lahiri of this department. The numerical computations were initially done at the IBM 1620 computer at Kanpur, IIT, and lately at the CDC 3600 computer at TIFR, Bombay. Some minor parts are also executed at the IBM 1401 machines at ISI, Calcutta.

(Arunaditya Mukherjee)

3.24. *Nuclear Magnetic Resonance Studies*

a) Wide line NMR investigations of N^{14} resonance in a number of Organic Compounds viz. aza-aromatics as well as substituted aromatics and aliphatics were completed. Effect of conjugation and hyperconjugation as well as charge transfer interaction were evaluated. Attempts to correlate shifts with electronic structure have been made. Further, the effect of relaxation on line-width is discussed from symmetry considerations.

(Paper presented at the Symposium on Spectroscopy at Radio and Microwave Frequencies, National Institute of Science, Bombay 1964.)

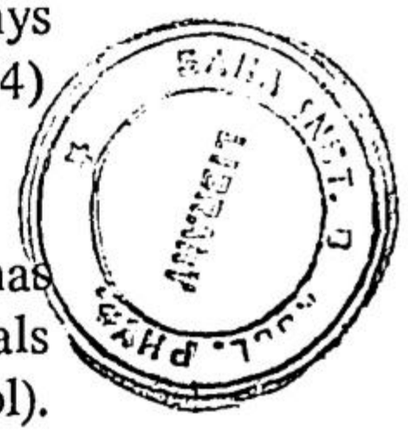
(M. Bose, N. Das and N. Chatterjee)

b) Exchange reactions involving protons have been extensively investigated. In the present work attempts have been made to study the same proton exchange reaction by focussing on the nitrogen nuclei to which the proton becomes attached. The system chosen is familiar pyridine-pyridinium system which enables us to evaluate the feasibility of the NMR method vis-a-vis the conventional spectrophotometric and potentiometric methods.

(M. Bose, N. Das and N. Chatterjee)

c) N^{14} resonances in a number of paramagnetic nitrates with unpaired electrons have been recorded in solution. Attempts to interpret the highly anomalous shifts have been made.

(M. Bose, N. Chatterjee and N. Das : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 432, 1964)



d) For work on solids, a programme of crystal growth from solution has been undertaken. A thermostat has been set up and a few sample crystals grown by slowly lowering the temperature of the thermostat (manual control). At present, working on the mechanical device of automatic lowering of temperature, crystal rotation etc.

(M. Bose and M. Bhattacharya)

e) The laboratory is orienting itself for relaxation time measurements studies. A preliminary report is being prepared.

(M. Bose, M. Bhattacharyya and A. Chowdhury)

f) The laboratory has been busy getting utility requirements completed for the final installation of the 100 mc. High Resolution Spectrometer, which is expected to operate by 1965.

3/25. *Studies on Nuclear Quadrupole Resonance Spectroscopy*

The construction of an NQR spectromeetr arround 28-36 Mc/s with twin-tee amplifier at 200 c/s and the PSD system is nearly complete. The NQR resonance signal from Cl^{35} nuclei in a single crystal of $NaClO_3$ has been obtained. The design of the probe assembly with gonimetric attachment for rotation of crystals, and a crystal arrangement will shortly be taken up.

NQR spectrometers at UHF will be developed for studying resonances of Br and I nuclei. Provision will be made for recording the double derivative line-shapes of such resonance signals.

Work is in progress for the construction of a crystal growing plant from melt for developing single crystals of $NaClO_3$ and p-dichlorobenzene.

(R. N. Roy and S. Sengupta)

3/26. *Studies on Electron Spin Resonance Spectroscopy*

The design and construction of all the component parts of an 100 Kc/s ESR spectrometer including the phase sensitive detection system have been completed. Work is now in progress to construct a modified Pound stabilizer at 29.995 Mc/s for obtaining the electronic interlock between the sample cavity and the Klystron.

The design of dual rectangular cavity—TE104 mode, and a cylindrical cavity—TE011 mode, with provision for flow system, are completed.

This 100 Kc/s ESR spectrometer will be converted into a double modulation system, using an extra modulation at 400 c/s. The development of the 400 c/s oscillator, tuned amplifiers and a PSD system at 400 c/s will be taken up. Cavities with irradiation window and Dewar assemblies will also be constructed.

(R. N. Roy and A. K. Roy)

3/27. *Studies on Microwave Spectroscopy*

By the end of 1963, the K-band (18 to 26 Gc/sec) gaseous microwave spectrometer with 100 Kc/sec square wave stark modulation was set up. The electronic apparatus which were mainly built in our laboratory include stabilized power supply for klystrons, a square wave generator, r.f. amplifier and oscillator, phase sensitive detector, phase shifter, low frequency amplifier, saw tooth generator and stabilized power packs. Microwave transition components, stark coil, wave guide flanges, klystron mount were prepared in our laborary.

The absorption lines of ammonia were observed after proper phase sensitive detection on an oscilloscope. Also the absorption lines of methyl alcohol, hydrogen peroxide and some other samples, which have been previously investigated were examined to callibrate our spectrometer.

The construction of a frequency multiplier for accurate frequency determination was undertaken.

Arrangements to record spectral lines have been made by means of a l r. p. hr. synchronized motor and a varian G-10 recorder.

Theoretical work in some specific directions in connection with analysis of microwave spectra were undertaken.

Complete and up-to-date data comprising of assignments of rotational transitions and structural parameters and other relevant data on gaseous microwave spectroscopy have been compiled.

(D. K. Ghosh, Anutosh Chatterjee and P. K. Bhattacharyya)

3/28. *Structure of Single Crystals by X-ray Method*

(i) Dimension of the unit cell of Tanakha crystals has been determined.

(ii) Indexing of reflections from zero layer line, first layer line normal beam and equi inclination Weissenberg X-ray photographs has been finished.

(N. N. Saha & S. C. Bhattacharyya)

3/29. *Wide and Low-angle X-ray Diffraction Electron Microscopic and Optical Studies of Collagen Fibres from various Sources*

Systematic study of collagens from different phyla e.g., shark fin, rat tail tendon, chicken leg tendon, toad leg tendon and human bone by X-ray, optical and electron microscopic methods has revealed important structural informations. A very important and new finding was the orientation of apetites in our study on human bones.

It has already been planned to extend the above studies to collagens of invertebrate origin with the idea if a correlation could be made between the amino acid composition and the variation in structural features of the vertebrate and invertebrate collagens.

(N. N. Saha, S. Das, S. C. Bhattacharyya & S. G. Biswas)

3/30. *Structure of Carcinogenic Compounds by X-ray Methods*

A project on the determination of structure of a carcinogenic molecule, $C_{16}H_{16}N_2OH$, has already been planned. It is expected that the specific structure determination will assist in developing the direct methods as well as the various types of Patterson functions in the solution of such complex molecules.

(N. N. Saha and S. G. Biswas)

3/31. *Comparative Study of long Spacings in different Collagen Fibres by Electron Microscopy and Low-angle X-ray Diffraction*

Using intensities of the diffraction lines and gross structural patterns revealed by electron micrographs, Patterson and Fourier methods are being applied to find out the structural configuration at higher level.

(N. N. Saha, S. Das and S. G. Biswas)

3/32. *Physico-Chemical Study of Biological Molecules*

A pH-state has been standardized with a standard protein (haemoglobin) for following the enzymatic splitting of protein and its finger printing. A paper-electrophoresis apparatus has also been designed and constructed according to Williams et al with some modification for studying the purity of proteins in solution. Viscometric measurements of protein solution have also been undertaken and necessary experimental set up has been established. Complete amino acid analysis of (i) shark-fin collagen, (ii) normal human bone collagen, (iii) diseased human bone collagen have already been made. Calcium, phosphorous and total inorganic residues of normal and diseased bones have been determined from a number of bone samples.

Studies are now in progress to find out the exact role of inositol on metabolic regulation and electron transport phenomena. In a particular type of yeast it has been established that for normal respiration inositol is necessary and also glucose metabolism is seriously affected due to inositol deficiency. To study the exact point of multi-enzyme sequential reactions, purification of important enzymes like phospho-fructokinase etc. are now being attempted.

Methods have also been developed to isolate mitochordina and electron transport particles from yeast cells to study the substrate oxidation and also the functions of cytochromes in energy trapping reactions.

Studies on the micro-difference of structures of collagen of different origin by enzymological methods are now in progress.

Studies on the reaction kinetics of enzymic hydrolysis of collagen and also of the isolated peptides from collagenese treated collagen will be made to ascertain if there is any structural difference in collagens of different origin.

(N. N. Saha, S. Das, A. K. Ghosh and S. D. Bhattacharyya)

3/33. *Quantum Biology*

Plans have already been made to apply the quantum mechanical methods, e.g., the molecular orbital method to study the electronic aspects of the molecules of biological origin.

The study of the electron donor and the eiectron acceptor properties of a number of amino acids, e.g., aspartic acid, glutamic acid, arginine, lysine, proline, hydroxyproline etc., commonly found in collagen and other protein molecules will be the subject matter of our immediate future research activities in molecular biology.

(N. N. Saha and Sephali Guha)

3/34. *Crystal Growth*

A verneuil furnace was set up during 1964-65. The following components have been tested and found satisfactory viz, (a) the slow motion drive (b) the centring arrangement of the pedestal (c) the flame (oxyhydrogen blow torch) (d) the photocell arrangement. The arrangement for feeding the electromagnetic relay for hammering arrangement at regular interval has worked out satisfactorily.

The arrangement for installing of furnaces for growing tennary semiconductors and to study their structures, electrical and optical properties is in progress.

Some crystals e.g. Bismuth telluride, Indiumantimonide have been grown from melt and attempts are being made to grow single crystals. The electrical, magnetic and thermal properties of these crystals are being measured. The defects and dislocation study by X-ray method will be made.

(N. N. Saha, P. N. Roy and D. N. Kumar)

3/35. *X-ray Study of Electrolytic Copper Powder*

A systematic study of the powder deposited at the cathode when a dilute solution of copper sulphate was electrolysed at a current density of 10 ma/cm^2 using copper as the anode material has been made by X-ray diffraction method. The deposited sample has been found to consist of copper, cuprous and cupric oxides. When the copper anode was replaced by platinum, keeping the bath conditions same as before, no oxide of copper could be detected in the sample and when replaced by nickel the deposit was found to contain copper and nickel but no oxide of copper. Our findings suggest that the formation of oxide etc., at the cathode during electro-deposition is influenced by the nature of the anode material.

(B. C. Banerjee and N. N. Saha : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 496, 1964)

3/36. *Study on the Structure of Collagen of Different Biological Origin*

The present paper comprises in its scope the study of the structure of collagen based on amino acid composition. Amino acid composition of collagens from shark fin, normal and diseased human bone has been determined. A discussion on molecular weight determined from the amino acid composition has also been incorporated in the paper.

(S. D. Bhattacharyya, A. K. Saha, N. N. Saha and S. Das : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 601, 1964)

THEORETICAL NUCLEAR PHYSICS DIVISION

4/0. *Summary of work of the Theoretical Nuclear Physics Division by Prof. M. K. Banerjee*:

Our activities can be broadly grouped under five headings viz. (1) Elementary particles and Field Theory, (2) Nuclear Structure, (3) Nuclear Reaction, (4) Plasma Physics and (5) Many Body Problem.

In elementary particle physics the main interest has been on Unitary symmetries and on Bootstrap calculations. In field theory the question of charge of a massless Dirac particle has been studied. The question of nucleon as a Regge pole is also being studied.

In the field of nuclear structure a very ambitious programme of self-consistent Hartree-Fock-Bogoliubov calculations has been started. Considerable work on Random Phase approximation has been done and is under progress. In the sd shell intermediate coupling shell model calculation has been performed and the results are being used to test the validity of various aspects of cranking model.

In the theory of nuclear reaction two distinct types of work are under progress. The first is the study of analytic properties of multichannel R matrix. The second is the study of exchange effects in direct reaction processes.

In plasma physics the effect of a magnetic field on the conductivity and diffusion coefficient of a plasma has been studied.

In Many body problem investigations have been undertaken on the properties of liquid He III.

4/1. *Can Massless Dirac Particles have Electric Charge?*

By a non-perturbative method which makes use of masslessness (absence of massive particles) and invariance under charge conjugation transformation is shown that a massless Dirac particle cannot acquire charge through minimal interaction, no matter how strongly it is coupled to the electromagnetic field.

(T. Pradhan)

4/2. *Regge Poles in Quantum Electrodynamics*

By a perturbation theoretical calculation we have shown that the electron (mass = 'm') in true quantum electrodynamics is a Regge pole. The method of calculation consists in finding, first the limit of vanishing photon mass 'λ' and then the limit of large momentum transfer. The Regge parameters $\alpha(w)$ has a λ-dependent part which diverges for $\lambda \longrightarrow 0$. The matrix element corresponding

to this part in $\alpha(w)$ is cancelled by the scattering amplitude for the soft photons. So the location of trajectory at $W>m$ will depend upon the experimental arrangement whereas for $W = m$ and in the immediate vicinity of it the trajectory is independent of infrared divergence and is well defined having a definite value zero.

(T. Pradhan and Mamata Pattnaik)

4/3. *Regge Behaviour of Physical Particles in Field Theory*

To investigate that elementary particles of conventional field theory lie on Regge Trajectories, we have taken Lee Model with recoil and made the source function non spherical. In this modified Lee Model all partial waves are scattered. $H_{int.}$ does not commute with angular momentum. But S-matrix commutes with angular momentum under certain restrictions on the source function. The precise nature of these restrictions are under investigation right now.

In future we plan to draw Regge trajectories in N–O and V–O sectors and wish to see $Z_3 = O$ condition for composite particles V in N–O sector and its effect on the results.

(T. Pradhan and J. N. Passi)

4/4. *A Self Consistent Determination of the Masses and Coupling Constants of Nucleon and Nucleon isobar,* N* (1237)

The speciality was in the treatment of input forces, viz, that it was reggeized before feeding into the N and D integral equations. The Carruther mechanism was extended for the Nucleon and Nucleon isobar trajectories. The integral equations obtained in this way will have to be solved numerically. This should lead to a determination of the Regge parameters of the N and N* trajectories.

A calculation of phase shifts for the $T = \frac{1}{2}$ pion-nucleon system has also been carried out by adding a new Regge trajectory, viz., the trajectory containing the new Roper resonance, to the nucleon trajectory. The nucleon pole term arising from the u-channel contributions was isolated at the outset. The resulting phase shifts fitted much better with the observed phase shifts than the phase shifts obtained by previous workers in the field, who used only the nucleon trajectory and the nucleon pole term.

(S. N. Mallik & P. Das Gupta)

4|5. *Problems of Strong Interaction Physics from the Analyticity Point of View*

Asymptotic behaviour of scattering amplitude was studied by quasi particle method in potential scattering and a proof was given for the theorem that for

finite-range non-singular potentials, the Mandelstam double spectral function is a tempered distribution. Calculation of Regge trajectories for the exponential potential was attempted. The leading trajectory was actually obtained as a solution of an integral equation resulting from the unitarity condition and one pole approximation for a weak exponential potential. The Regge Strip approximation was also studied in potential scattering and a derivation of Chew-Jones representation was obtained for both ordinary and exchange potentials. The partial wave properties resulting from the strip approximation have also been investigated.

Possibility of generating lower Regge trajectories from the leading Regge trajectory using analytic continuation in coupling parameter will be explored. The problem of treating singular potentials will be studied along with several other programmes in pion-nucleon interaction, strong interaction symmetries and axiomatics.

(P. Das Gupta)

4|6. *The Crossing Matrix in Isospin*

We wish to point out the crossing matrix in isospin (in the general case for two-particle scattering), can be obtained in a convenient form, in terms of the well known Racah 6–j coefficients, for which extensive tables are available.

(C. S. Mukherjee and B. Dutta Roy: Nuovo Cimento, Sr. *X*, *34*, 811, 1964)

4/7. *Unitary Symmetry Breaking Interactions and the Decays of Vector Mesons*

Several measurements have been made of the partial widths of ρ. K* and φ corresponding to the decays $\rho \longrightarrow \pi + \pi$, $K^* \longrightarrow K + \pi$ and $\varphi \longrightarrow K + \overline{K}$. The experimetal values seem to deviate much from the values predicted by SU_3. For example the theory predicts $\Gamma(K^* \longrightarrow K\pi)/\Gamma(\varphi \longrightarrow \pi\pi) = 0.29$, whereas experiments give $0.47 \pm 10\%$. This large deviation (about 62% from theoretical values) is explained by introducing symmetry breaking interactions. Comparison with experiment enables us to determine the strength of the symmetry breaking interactions.

(B. Dutta Roy, C. S. Mukherjee and Salil R. Roy: Communicated to Nuc Phys)

4/8. *SU (6) Symmetry*

SU (6) symmetry was applied to study the nucleon-nucleon static potential and it was shown that the expectation of Pais and others that the potential should be of the type obtained phenomenologically (Serber exchange) was not justified.

(B. Dutta Roy and S. R. Roy)

4/9. *Pairing Model for Pr^{144}*

The pairing force calculation for Pr^{144} made by Mitra and Pal has been extended to take into account the quasi-particle configuration mixing effects through the long-range part of the n-p force. The results obtained will be discussed in the context of the experimental findings of Burde, Rakavy and Engler.

(Y. K. Gambhir and Ram Raj: Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 15, 1964)

4/10. *Two Phonon Vibrational States*

Explicit formulas have been derived from the extended Sawada method for the calculation of the two-phonon vibrational states of spherical nuclei. The results obtained have been applied to the calculation of the two phonon states of Ni^{60}.

(Ram Raj and Y. K. Gambhir : Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 17, 1964)

4/11. *Perturbation Treatment in Specific Odd-odd Nuclei in Suitably Chosen Ranges of the Periodic Table*

In this model n-p interaction is treated as a perturbation and the nucleus Pr-144 has yielded encouraging results. Improvements have been made by mixing higher configurations and the theory with some modification has been applied to Pr-isotopes.

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

4/12. *Calculation of Vibrational Spectra*

(a) The TD and RPA treatments have been compared and found to give nearly identical numerical results.

(b) The TD method is, therefore, being applied to the diagonalisation of four quasi-particle states which will yield the two-phonon vibrational states.

(M. K. Pal)

4/13. *Dispersion Theoretic Techniques in Nuclear Physics*

The existing literature on dispersion theory is being reviewed with a view to application in Nuclear Physics.

(M. K. Pal)

4/14. *Dipole Absorption in Pb^{208}*

The wave functions are calculated in Woods-Saxon well with a spin-orbit term; single-particle neutron levels are taken from a recent experimental review by Cohen et al. Zero-range forces are assumed.

(M. K. Pal, J. M. Soper and A. P. Stamp: AERE (Harwell) Rep, T P 148).

4/15. *Treatment of Neutron-proton Correlations*

The possibility of applying a linear quasi-particle transformation to the treatment of neutron-proton correlations in nuclei was investigated by Pal and Goswami. Recently Vogel has published similar results and has demonstrated, for $N=Z$ nuclei, a ground-state wave function containing four-particle groups ("quadruples") over and above the usual pairs. In our work we are able to write down the ground-state in a more general form and examine the genuineness of the quadruples. Our conclusion is that they are not genuine in view of the fact that the ground state can be written in an alternative form where only paired states appear. In fact such a result has always to be expected in a linear theory if one keeps in mind the completely general theorem proved by Bloch and Messiah. The present note is being written to dispel any possible misunderstanding about the so-called quadruples in the ground state that appear in our and Vogel's work. It also presents a straight forward method of obtaining the Bloch-Messiah paired states.

(M. K. Pal and M. K. Banerjee: Phys Lett, *13*, 155, 1964)

4/16. *Exchange Effects in Stripping Reactions*

Attempts are being made to carry out calculation of stripping amplitude including the heavy particle stripping term using DWBA theory and finite range interactions. Preliminary calculations have yielded encouraging results. Plans are being made to use the CDC 3600 computer at TIFR, Bombay for more exhaustive studies.

(Anand Kumar and Manoj K. Banerjee)

4/17. *Recent Developments in the Theory of Nuclear Reactions.*

An invited talk on the above subject was delivered reviewing the following topics : (1) Unification of direct reaction and compound nucleus theories

(2) A certain aspect of Blair model (3) Stripping etc. off a black nucleus; and (4) Dispersion theoretic model of direct reaction using elastic unitarity.

(M. K. Banerjee : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 78, 1964)

4/18. *Shell Model Calculation of Energy Spectrum of Na^{22}*

The shell-model classification scheme based on SU (3) Group along with the operator techniques developed by B & L for the use of SU (3) has been used for the study of the energy spectrum of Na^{22}. The mixing of higher SU (3) states by the central force along with the mixing of near-by partition by spin orbit and spin dependent interaction are taken into account. Except for the one or two states the admixture of higher SU (3) states can be calculated by perturbation theory. The mixing of nearby partitions is caused by spin-orbit alone and is large enough to necessitate the diagonalisation procedure. The results obtained under these conditions will be discussed.

(S. N. Tewari : Proc Nucl Phys & Sol State Phys Symp, DAE, Chandigarh, 32, 1964)

4/19. *Shell Model Studies of Na^{22} and Ne^{22}*

Shell model calculations have been carried out for the low lying states of Na^{22} and Ne^{22} using a Serber exchange and Yukawa potential of 45 MeV depth (triplet) and range of one mesonic unit. The calculation becomes feasible, though still very lengthy, with the use of Elliott's SU 3 representation and the techniques developed by M. K. Banerjee and C. A. Levinson. The main advantage of this representation is that one can tell from the results if there is an intrinsic wave function. When present, it is possible to test the detrimental character of the intrinsic wave function. Actual results have revealed that for Na^{22} one gets very good determinantal wave function, where for Ne^{22} there is considerable two particle correlations.

(S. N. Tewari and M. K. Banerjee)

4/20. *Hartree-Fock and Hartree-Fock-Bogoliubov Studies*

Programmes are being written for Hartree-Fock and Hartree-Fock-Bogoliubov studies in the sd and the pf shells.

(B. H. Bye, Harischandra, Lakshmidhar Satpathy and M. K. Banerjee)

4/21. *Investigation on S.- and R- Matrix*

Analyticity structure of S- and R-matrix in complex angular momentum plane were made. A Mittag-Leffar expansion of R-matrix in complex angular momentum plane is obtained and its analytic continuation in the left-half plane and asymptotic limits are under observation.

(S. Mukherjee, C. S. Shastry and Subrata Dutta)

4/22. *Investigation on Nuclear Reaction and Scattering*

Methods of pology and Reggeisation are being applied to Nuclear Reaction and Scattering.

(S. Mukherjee and C. S. Shastry)

4|23. *Electron Capture and Loss by Charged Particles in Dense Electron Gas*

The mechanism suggested to represent the capture of an electron from the metals by the incident proton, consists of the scattering of the incident proton by the system of electron gas with the excitation of a plasma in the virtual state. The plasma being formed in the virtual state decays into an electron-hole pair. The scattered proton and the excited electron are coupled in the intermediate state to form hydrogen finally.

(T. Pradhan and D. N. Tripathy)

4/24. *Diffusion of Plasma across a Steady Magnetic Field*

We investigated the problem of plasma-diffusion across a magnetic field using Kubo's expression, but employing a joint probability distribution function. The diffusion co-efficient which is equal to the velocity correlation function, is expressed as a electric-field correlation, by first using a hierarchy of equations derived from the Liouville equation. It was observed later that the Liouville equation can be directly used. The magnetic field dependence was found to be $1/B^2$ but the electric field correlation function is to be evaluated at cyclotron frequency. A general Einstein Relation was established between diffusion co-efficient and electrical conductivity. The result is still more rigourously established by using the Green's function for Liouville operator.

We plan to extend this calculation for a two component plasma (i.e. ions and electrons with finite ion mass). Our target is to establish the magnetic field dependence of diffusion co-efficient without ambiguity. We also plan to calculate the plasma conductivity both in presence and in absence of magnetic field. A

rigourous calculation of the dielectric constant of plasma in presence of magnetic field, using fluctuation dissipation theorem will be undertaken very shortly.

(T. Pradhan and B. Dasgupta)

4/25. *Many-Body Problem*

The problem of superfluidity in liquid He^3 is being investigated with the aid of sophisticated Many-Body Theory.

(S. Mukherjee and R. K. Satpathy)

NUCLEAR CHEMISTRY DIVISION

5/0. *Summary of work of the Nuclear Chemistry Division, by Prof. B. C. Purakayastha* :

Research activity in Nuclear Chemistry division is mainly concentrated on 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 classical ways and where radioactive isotope is an indispensable tool has all along been chosen. From the last one year emphasis has also been given to the development of certain aspects of radiation chemistry, study of sponteneous fission and analysis through neutron activation. A short account of the work in our division is given below.

A glance at the short reports given will show that work has been extended to various fields and interesting results have been found in most of the fields mentioned.

5/1. *Analytical Chemistry*

From the very beginning attempts have been made to improve upon radiometric method of analysis. During the last year a new method of estimating scandium with Sc^{46} has been developed. The method for estimating silver, iodine and palladium of γ order of magnitude with I^{31} in presence of interfering ions has been done. P^{32} has been utilised for estimating γ order of zirconium through radiometric precedure. Solubility involved in this type of investigations has been overcome through suitable carriers. In consideration of simplicity and time and various factors involved in classical estimations it has been found that the method developed by us is simple and much more sensitive and dependable. It will also be pursued in other systems to simplify the tidium of classical operations and go beyond the range that is achieved by classical chemists. This type of approach is different from the radiometric procedure practised becaused we have overcome the solubility factor which is a limitation. Study of fluorimetric estimation of uranium in natural substance will also be continued. Besides these we have been able to set up a single channel pulse-height analyser which will be an indispensible tool for chemical analysis through neutron activation.

(B. C. Purakayastha, K. N. Dutta, Mrs. Usha Purakayastha, H. P. Maity, Mrs. S. Aditya, N. R. Das and M. N. Chandra)

5/2. *Study of Mixed Crystal Formation and its Application*

Study of mixed crystal formation with radioactive nuclei has been the subject of study for the last few years. It has thrown some light to clarify the anomaly as pointed out by Hahn and Khlopin. But more study is necessary in

this field. Study of mixed crystal formation has been applied in various fields of chemical investigation.

(a) A new method of determining transition temperature of a guest component at tracer level has been finally established. The method is expected to find extensive application in classical chemistry where the phase in question is metastable with respect to a stable variety. Besides, it will also be useful in the study of solid state chemistry of man made elements. Further study in this line will be taken up during the next year.

(b) Chemistry of rare elements has also been studied through mixed crystal formation. Thus far unknown tetrahydrated double sulphate of scandium has been throughly studied, its transition temperature has been determined by new method. Some success as regards the isolation of the compound in question has been achieved during the year. Morphological analogy amongst the tervalent elements in this group has been studied. This type of interesting work will be a subject of study during the next year. Study of chemistry of rare elements with radioactive indicators which is not possible in a classical way will be done during the next year.

(c) Application of mixed crystal formation in geochemical studies has yielded interesting results. Through the study of coseparation of different morphologies of calcium sulphate with strontium tracer, it has been made possible to have a rational explanation why strontium/calcium ratio is higher in sea than it is in land. Geochemists including Goldschmidt were rather wrong in their speculation. This type of work, which Hahn foresaw and could not do because of limited number of isotopes, will be pursued during the next year.

(d) Mixed crystal formation has also been applied in separation chemistry from the very beginning. The results have been included in various reports, During the last year purification and separation of scandium activity by pyrophosphate carrier has been found to be very successful. Application of ammonium salts of heteropoly acids in the study of uptake of caesium activity has also been studied in considerable details and it has been found that these salts are powerful inorganic ion exchangers. Insoluble salts like bismuth iodate have been found to be good carriers of tetravalent actinide. Tetravalent actinides can be separated from ter- and hexa-valent species through the help of these two carriers. Study in details will be also pursued next year.

Besides separation through coseparation, glass chromatography solvent extraction have also been used in separation chemistry. An easy and quantitative separation of UX_1 from U_1 and of RaE from RaD has been developed through glass chromatography. As regards simplicity the method can be claimed to be the best of all the methods uptil now known. From this background of our study separation chemistry will always be pursued because of its interest and importance in nuclear science.

(B. C. Purakayastha, S. Sarkar, D. K. Bhattacharyya, K. N. Dutta, Miss. A. Chatterjee, Miss. S. Sen and A. S. Rao)

5/3. *Low Level Radioactivity*

Necessary preparation for measurement of low level radioactivity has already been made with a view to study phenomena like spontaneous fission and others dealing with low level radioactivity.

5/4. *Radiation Chemistry*

The work on radiation chemistry could not progress for want of a suitable source for irradiation. Arrangements have now been made to get samples irradiated from the Chittaranjan Cancer Hospital. In view of the handicaps, we have started to study radiation induced behaviour of redox system in presence of organic materials in aqueous solution. In the next year we propose to study the following interesting aspects:

(a) Study of radiation induced oxidation of Butanols.

(b) Attempts will also be made to develop techniques to study synthesis of compounds of considerable importance through radiation. Behaviour of amino acids and interesting aromatic compounds under radiation will also be studied.

(S. N. Bhattacharyya)

INSTRUMENTATION DIVISION

6/0. *Summary of work of the Instrumentation Division by Shri B. M. Banerjee*

The programme and projects included

(a) Development of fast amplifiers using transistors.

(b) Study and development of fast counting circuits.

(c) Redesign of our fast oscilloscope (developed in the period (1956-59) so as to transistorize them as far as practicable. This will make them smaller, more versatile and less costly.

(d) Development of wide band ferrite core transformers used in fast transistor circuitry.

(e) *Construction of two eighteen channel pulse height analysers* asked by other research divisions of this Institute.

(f) Study and development of high order harmonic generators.

(g) Development of circuits for ω and β spectrometers using semiconductor detectors.

Progress has been made in all these fields as will be evident from the individual reports of the workers of this division.

In the year 1965-66, work in all these fields will be continued and completed. The theoretical study on fast scalers using tubes was completed in 1964-65. The theoretical and experimental work on high order harmonic generators is nearing completion.

The new field in which study is being undertaken is data processing by digital computer techniques. Knowledge acquired in this area will be applied to construct transistorized multichannel pulse height analysers, that are very much preferred now-a-days for their reliability. If space and foreign exchange becomes available, design and construction of an induction furnace will be undertaken.

6/1. *A programme to develop (a) wide band amplifiers using transistors as circuit components (b) fast switching circuits and to adapt an existing fast oscilloscope previously developed in the laboratory for recurrent sweep*

Three amplifiers of band width more than 120 MC are working. A switching circuit using transistors has been developed giving a rise time of five millimicroseconds. This with further modification will be used as part of the fast oscilloscope sweep triggering circuit.

Circuit for adapting fast oscilloscope, which now works in pulsed mode only, for recurrent signals have already been designed and are being tested.

During 1965-66 the work on amplifiers and switching circuits will be continued. Parametric amplifiers will be developed. Development work on fast solid state detectors will be undertaken.

(S. C. Nath)

6/2. *Theoretical Analysis of Scaling Circuits*

Theoretical analysis of Resolving Times of Binary Scalers was continued after thesis work and the results included in a paper have already been sent for publication. Meanwhile, a very fast scaling circuit was constructed but testing of the circuit had to be postponed as the fast oscilloscope used for the purpose was not functioning properly for the time being.

Several charge sentitive preamplifier circuits have been made employing fast transistors and also nuvistor tubes type 7586 for use with solid state nuclear particle detectors.

During 1965-66, development of a microwave frequency standard is planned besides constructing multichannel pulse height analyser circuits with their associated scalers.

(S. Chowdhury)

6/3. *Higher-order Harmonic Generation*

Possibilities of generating a harmonic higher than the 5th order in a classic harmonic generator was investigated theoretically, using pulse drive. This work was carried out as a part of the thesis work. The results of this investigation were as follows :

(1) Pulse drive was found practical in generating harmonic higher than the 5th order.

(2) Performance of the generator was found not too critical of the actual shape of the drive waveform.

Later in year 1964-65, a design procedure was formulated for harmonic generators using pulse drive. Two practical units generating harmonics of 2 and 20 Mc/s frequencies from input frequencies of 200 Kc/s and 2 Mc/s respectively were constructed successfully. Performance of these generators was studied in all possible details.

Work is in progress for the design of one more unit for generating harmonic of 100 Mc/s frequency from an input frequency of 10 Mc/s. The design of this unit is likely to help in the development programme undertaken in our section for the design of a 540 Mc/s harmonic generator.

(K. S. Patel)

6/4. *Design of a Harmonic Generator to give the Harmonic of* 540 *Mc/s of the Fundamental Frequency of* 10 *Mc/s.*

A harmonic-generator has been designed consisting of four stages. Each of the first three stages connected in cascade multiplies their respective input

signal frequency. by a factor of three and the fourth stage by a factor of two. The instrument is nearing completion and is being tested now.

It is intended to extend the harmonic generator to give harmonics at microwave frequencies and to design and construct a frequency standard. In connection with the above object we shall study the various operational aspects of Varacter diode as the parametric amplifier and harmonic generator.

(P. K. Gupta)

DIRECTOR'S RESEARCH GROUP

7/0. *Summary of work by Prof. B. D. Nag Chaudhuri*

The work in our Section is divided in two parts. The major part is concerned with Plasma work which incorporates both developments and research work. A small part of the effort is concerned with Solid State Plasma and the rest of the effort is concerned with Gaseous Plasma and Plasma Sources such as various types of Ion Sources. In addition to the report of the various workers in the Section various instrumental devices for measurement of Plasma including Microwave and probe diagnostics have been developed. Some work is also being done on analogue computer construction which will enable us to get the nature of solutions of equations which otherwise would have been difficult to solve.

The second part of our work dates back to many years ago when the measurement of Micro-Micro-Curie quantities of Radio-active matter was developed. We tried different applications and decided to do some tracer biological and chemical problems at very low levels with the aid of this technique. This low level tracer work has continued for sometime and the technique has proved quite valuable to investigate biological phenomena. During the last year Jamadar and Uduppa have worked on haemotological problems dealing with the various stages of red and white blood cells and precursor cells.

7/1. *Studies on Radiation Damage*

Work was continued on systematic study of radiation damage in semiconductors and semiconducting devices. Low resistance thermistors were bombarded with 14—MeV neutrons from Cockkroft-Walton generator of the institute. These results have been communicated in a paper.

(J. K. D. Verma and P. S. Nair)

7/2. *Debye Characteristic Temperature of Cubic Semiconductors*

A knowledge of the Debye temperature of semiconductors is desirable in the study of a large number of problems such as electrical resistivity, thermal conductivity etc. Hence a programme was undertaken to calculate the Debye temperature of cubic semiconductors using VRHG approximation. The method was found simpler and to yield better results as compared to other methods such as that of Betts et al. A paper incorporating these results has been published.

(J. K. D. Verma, B. D. Nag & P. S. Nair: Naturforsch *19A*, 1961, 1964)

7/3. *Growth of Single Crystal of Thallium Selenide (Tl Se)*

The most stable compound of the Tl-Se system and the one of greatest interest as a semiconductor is the stoichiometric Tl Se composition. Hence is was decided to grow single crystal of Tl Se and to study its electrical, thermal and optical properties. A high vacuum system using mercury diffusion pump of glass construction has been set up. The system includes a liquid air trap. A cold cathod Penning gauge, constructed in the laboratory, in conjunction with a RCA Type 1946 thermocouple gauge, form the vacuum measuring system. The ultimate vacuum achieved is 10^{-6} Tor. The system will be used to evacuate capsules containing Tl and Se before melting them into an alloy.

(J. K. D. Verma & P. S. Nair)

7/4. *Impurity Detection in Semiconductors and Insulators by Hall Effect*

A paper on the above subject was presented at the "Symposium on Testing and Evaluations of Materials" held at Government Test House, Calcutta. The abstract is given.

"The detection of impurities in semiconductors and insulators using Hall Effect has been discussed. The chemical and spectroscopic methods are unsuitable for the detection of impurities of less than one part in 10^6. The activation method, though no doubt much superior than either of these two, is nevertheless complicated. The Hall effect method offers unprecedented limit of impurity detection of the order of one part in 10^{10}. This has been illustrated with a numerical example. The Hall effect has also been described in brief."

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

7/5. *Some Electrical Properties of Bismuth Telluride*

A paper on the above subject was presented at the combined 51st and 52nd Indian Science Congress held at Calcutta.

Some preliminary measurements on electrical conductivity and type determination of bismuth telluride crystal grown in the Institute are reported. Electrical conductivity was measured by four point probe method while the type (n - or p -) determination was made by a thermoelectric probe which is suitable for small crystals.

(B. D. Nag & J. K. D. Verma)

7/6. *Studies on the Interaction of Moving Test Particle with Gaseous Plasma*

A thesis on the above mentioned subject has been submitted to the Calcutta University for the Premchand Roychand Studentship. The work reported in this thesis is a study of the plasma model based on kinetic theory. Also an investigation has been made on how a gaseous plasma in a magnetic field reacts with a moving charged particle. This latter study has been based on the hydrodynamic description of plasma. The results are published in Proc. Phys. Soc. (Lond.) *82*, 669, (1963).

(S. K. Majumder)

7/7. *The Nature of Coherent Radiation Emission from Infinite Gaseous Plasma Placed in an External Magnetic Field*

This investigation is based on kinetic model of plasma interacting with a test particle. The method employed is to integrate Boltzmann-Vlasov equation over the entire characteristic trajectory of the test particle. The usual singularity in the solution for zero magnetic field strength renders the calculation very difficult for the emission of cyclotron radiation from plasma. A new method of calculation based on Sommerfeld-Watson transformation is employed to handle the singularity. The calculation is not yet complete. The aim is to analyse the intensity and nature of cyclotron radiation emission from a magnetised plasma.

(S. K. Majumder)

7/8. *Microwave Diagnostics of Plasma*

Theoretical study is under progress on the microwave method of determining the electron density distribution in a cylindrical plasma by placing the plasma in a cavity resonator operating in various modes.

Theoretical investigations are being made on the complex refractive index of a magneto-plasma, plotted conveniently on a Smith chart of transmission line practice.

Attempts are being made to set up an S-band microwave bench for measurements on plasma.

(J. Basu & C. Dutta)

7/9. *Design Studies of Penning type Ion Sources*

Performance characteristics of an all metal ion source chamber built on the principle of Keller's Source incorporating the field emission devices of Beck

& Brisbane have been obtained. Results show that without magnetic field, a discharge current of 6 ma at 6 x, 10^{-2} mm Hg at an applied potential can be obtained.

(N. K. Majumder)

7/10. *Electron Velocity Distribution in Slightly ionised Argon with Crossed Electric and Magnetic Fields*

A method of solving the Boltzmann equation for the distribution function of the electrons in slightly ionised argon under crossed electric and magnetic fields is outlined using Golants' analytical approximations of the experimental data on the cross-sections for elastic and inelastic collisions. The distribution function is obtained in the presence of an electric field of arbitrary frequency crossed with constant magnetic field as well as in the presnece of crossed d. c. electric and magnetic fields. It has been found from the plots of electron distribution function that (i) for a given E/p, the distribution for crossed d. c. electric and magnetic fields contains more low energy electrons than with only d. c. electric field and (ii) that in a given transverse magnetic field, the electron distribution for a higher E/p is richer in higher energy electrons than that for a lower E/p.

(D. C. Jain, B. D. Nag Chaudhuri, B. Das Gupta, D. K. Bose & S. N. Sen Gupta)

7/11. *Performance of a Duoplasmatron Ion Source*

A duoplasmatron ion source has been operated at an Argon pressure of 1×10^{-2} Tor while the target chamber has been maintained at 10^{-5} Tor. A nominal ion current of about 2.5 ma has been extracted with a nominal extraction voltage of about 8 KV while the arc current has been maintained between 0.5 amp and 2.0 amp with a magnetic field around 250 Gauss to 500 Gauss. We note that 2.5 ma Argon current is equivalent to 15 ma of proton. Studies of the duoplasmatron plasma properties with probes has been taken on hand. Preliminary findings has indicated a value of 1×10^{12} for the ion density.

(D. K. Bose, N. K. Majumder and B. D. Nag Chaudhuri)

7/12. *Electrical Conductivity Studies of the Cold Cathode Penning or PIG discharge*

It is well known that in the case of Penning plasma, the presence of probes well inside the discharge region causes serious disturbance and hence makes

probe measurements unreliable. In the present experiment, however, this difficulty has been removed by adopting the following measures. (1) The single anode in the usual Penning tube has been replaced by a pair of well separated anode rings kept at ground potential so that a nearly field-free plasma region has been achieved in space between the two anodes. (2) Probe measurements have been conducted only in the peripheral region of this field-free plasma so as to cause minimum disturbance to the plasma.

From the probel characteristic curves for single and double probes obtained in the usual manner the electron temperature (Te), electron and ion densities (n_e, n_i) and hence the electrical conductivity (σ_{ij}) of the Penning plasma have been determined. The radial and azimuthal diffusion (Hall diffusion) currents have also been measured by using specially constructed single and double plane probes. These measurements will be reported and the values of the electrical conductivity tensor of the plasma in a magnetic field will be presented.

(D. K. Bose, D. C. Jain, B. D. Nag Chaudhuri and S. Sen Gupta: Proc Nucl Phys. & Sol State Phys Symp, DAE, Chandigarh, 169, 1964)

7/13. *Potential Energy Curves of some Electronic States of the N_2 Molecule*

The approximations made by Singh and Jain in obtaining the expressions for f and g, involved in the Rydberg-Klein-Rees method, have been critically examined. These expressions have been used for obtaining the potential energy curves of the $X^1\Sigma_g^+$, $A^3\Sigma_u^+$, $B^3\Pi_g$ and $C^3\Pi_u$ states of the N_2 molecule by adopting the recent data published by Lofthus.

(D. C. Jain: Proc Phys Soc, *83*, 17, 1964)

7/14. *Transition Probability Parameters of the Swan and The Fox-Herzberg Band Systems of the C_2 Molecule*

The vibrational perturbation between the $A^3\Pi_g$ and $B^3\Pi_g$ states of C_2 molecule has been investigated assuming that the unperturbed potential energy curves can be represented by the Morse potential function and that each one of the levels of the $A^3\Pi_g$ ($B^3\Pi_g$) state is being perturbed by all the levels of the $B^3\Pi_g$ ($A^3\Pi_g$) state.

The Franck-Condon factors and γ-centroids for the Swan and Fox-Herzberg band systems have been computed by using the vibrational wave functions appropriate to the R-K-R (Rydberg-Klein-Rees) potential energy curves. The variation of the electronic transition moment with internuclear separation has been determined for the Swan band system. The relative intensities of the so-called high pressure bands have been calculated and it is found that the

maxima of intensity lie at $v'' = 5$ and 8, as remarked by Herzberg, which supports the view that the high-pressure bands of C_2 molecule belong to the Swan system.

(D. C. Jain : J Quant Spectros Radiat Transfer, *4*, 427, (1964)

7/15. *Methylene Blue-Eosinated Saline as a Dispersing Fluid for Bone Marrow Cell Counting*

A method for the enumeration of bone-marrow cells in which a solution of methylene blue and eosine yellow in normal saline is used as the dispersing fluid is reported. A broad differentiation of the cells has been attempted. The dispersing fluid used is pH-independent and can be prepared easily.

The erythroids show orange hue, and myeloids green, lymphoids look green, but their surface is smoother than myeloids; eosinophils are red.

The total bone marrow count is expressed in millions per milligram.

All the counts can be taken in the rbe chamber of an ordinary hemocytometer, a magnification of 80 being used for total counts and 200 for differential estimation.

(Sunil K. Lahiri and K. Bhaskara Uduppa: Ind Jour Expt Bio, 2, /64, 1964)

7/16. *A Method for Studying the Maturation Time of an Average Bone Marrow Cell in Rat using P^{32} as Tracer*

A method using P^{32} as tracer, for determining the time of maturation of a bone marrow cell has been described, and its mathematical theory given. The method shows that the radioactivity observed in a fixed number of cells bears a constant proportion to the radioactivity in a fixed volume of plasma after an interval, equal to the maturation time, has elapsed from the time of P^{32} incorporation.

(S. K. Lahiri, K. B. Udupa & B. D. Nag)

TEACHING DIVISION

8/0. *Summary of work by Prof. S. Chatterjee*

The teaching programme for the eleventh session of the post M.Sc. Associateship Diploma Course was concluded in June, 1964. The following students successfully completed the course. The subject of the special problem or review work submitted by the students in partial fulfilment for the requirement of the diploma are also given.

Debdas Bandopadhyay	Study of quasi-particle states in nuclei with stripping reactions.
Rajendra Prasad Bajpai	Double stripping (or pick up) reactions as a probe to study the nuclear structure.
Manoranjan Bhattacharya	Application of Mössbauer effect to solid state physics.
Pranab Kr. Bhattacharyya	Crystal field theory.
Harish Chandra	Connection between spin and statistics in elementary particle physics.
Kartick Chandra Das	Physical properties of rare earth & iron group of metals and alloys.
Triptesh Kumar Dey	Reaction mechanism in the intermediate energy range.
Subrata Dutt	Complex angular momentum in high energy physics.
S. K. Gupta	Vibrations in solids.
Alakh Niranjan Mantri	Study of collective states in nuclei with inelastic scattering of protons, alpha particles and deuterons.
Mamata Patnaik	Unitarity symmetry in elementary particle physics.
Balbir Singh Reehal	Dispersion theoretical model of direct nuclear reaction.
Lakshidhar Satpathy	Hartree Fock treatment of Ne^{20} wave function.
Rajkishore Satpathy	Gauge theory of elementary particles.
K. Joseph Sebastian	Treatment of n-p interaction in heavy nuclei.
Rajagopal Shanta	Review on the recent two-nucleon work.

The twelfth session started in July 1964. 20 students were selected from about 350 candidates from various universities. During the period July to December, the following courses were given :

Phenomenological Nuclear Physics -- B. B. Baliga (30)
Phenomenological Solid State Physics — P. Rudra, A. Roychaudhuri } (20)
Classical Mechanics — B. D. Nag (10)
Basic Mathematics — P. Das Gupta (16)
Classical Electrodynamics — S. K. Majumder (10)
Statistical Physics — B. Das Gupta (10)
Elementary Quantum Mechanics — D. Pal (20)
Electronics — B. M. Banerjee (20)
Nuclear Detectors and Laboratory Practice (200 hours) — S. Chatterjee, R. Bhattacharya and B. K. Sinha
Special lecture on Graphics by Dr. B. Karunesh — 10 lectures & 20 hours of drawing work.

For their research work staff members of this division joined the programmes undertaken by the Nuclear Physics Division (S. C., R. L. B., B. K. S.) and Theoretical Nuclear Physics Division (D.P.)

8/1. *Theoretical Study of (t, p) Reactions*

The zero-range distorted wave theory of the (t, p) stripping reaction is formulated and compared with the recent experimental data. Fair agreement is obtained but this is probably because the reaction mechanism is direct rather than due to the validity of the stripping assumption. The finite range theory is investigated in an approximation which reduces to the usual cut-off theory and is found to be important. A qualitative discussion is given of the competing two stage process.

(J. R. Rook, and D. Mitra: Nuc Phys *51*, 96, 1964)

8/2. *Antisymmetrization of the Scattering Wavefunction*

A complete understanding of Nuclear Reaction mechanism requires proper antisymmetrization of the scattering wave function with respect to the incident nucleon and the target particles. The trouble is when one does the antizymmetrization, the structure of the appropriate Schrodinger equation becomes such that the standard approximations subject to which it can be solved seem invalid. We are investigating this point hoping for a positive solution.

It is intended to do numerical calculations to estimate resonance effects in nuclear reactions in different energy regions and to extract information about nuclear structure from the analysis of spectroscopic factor.

(D. Mitra)

8/3. *Apparatus for Low Lifetime Studies in Nuclear Decay*

A transistorised time to pulse height converter was built using 2N 700 transistor which can detect time differences of the order of 10^{-10} sec.

A continuously variable coaxial delay line was designed and built having a total delay of one nano sec. in a length of one metre to callibrate the instrument.

(B. K. Sinha and S. Chatterjee)

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Continued on page 64

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Shri B. K. Sinha

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Shri D. R. Sikdar

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Fitter : (Gd. I)
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Mechanic-cum Welder :
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Shri S. K. Banerjee
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Shri K. K. Bose
Shri M. K. Chakravarti
Sm. Purnima Chaudhuri
Shri Sunil Ch. Das
Shri J. Dasgupta
Shri S. Das Gupta
Shri A. K. Dey
Shri N. M. Ghosh
Shri S. K. Guha
Shri M. K. Darmakar
Shri H. Maity
Shri Asok Mukherjee
Shri B. P. Mukherjee
Shri S. Mukherjee
Shri D. K. Pal
Shri J. N. Roy

Junior Mechanics :

Shri N. C. Adhikary
Shri K. P. Bagh
Shri B. N. Dey
Shri J. G. Mandal

Junior Electrician :
Shri H. L. Saha

Carpenter :
Shri K. M. Dhar

Plumber :
Shri P. Singh

Tracer :
Shri S. B. Chakravarti

Glass Blower :
Shri S. C. Saha

Junior Laboratory Assistants :
Shri S. Banerjee
Shri S. K. Banerjee
Shri K. P. Chaudhuri
Shri S. B. Dutta
Shri J. Mukherjee
Shri R. Sen

Part-time Electrician :
Shri S. N. Samanta

ADMINISTRATIVE PERSONNEL

Accountant :
Shri N. K. Moorthy

Stores-in-Charge :
Shri K. S. Manian

Purchase-in-Charge :
Shri B. K. Chakravarti

Administrative Superintendent :
Shri A. N. Banerjee

P. A. to the Director :
Shri N. K. Sinha

Cashier :
Shri B. M. Roy

Steno-Typist :
Shri S. K. Manna

Assistants :

Shri N. R. Chowdhuri
Shri R. N. Chowdhuri
Shri M. K. Sarkar
Shri B. N. Sinha

Senior Library Assistants :
Sm. Maya Bhattacharyya
Shri S. B. Mukherjee

Junior Assistants :
Shri Jayanta Dutta
Shri G. R. Kahar

Junior Library Assistants :
Shri G. Goswami
Shri S. N. Pal
Shri Babulal Sen
Sm. Manoroma Sen

Typists :
Shri M. K. Basak
Shri A. Chandra
Sm. Maya Chandra
Shri A. T. Das
Shri S. P. Dutta

Despatch Clerk :
Shri D. N. Majumdar

Junior Clerks :
Shri P. K. Banerjee
Shri G. Majumdar

Telephone Operator-cum-Receptionist :
Shri T. D. Ganguly

Telephone Operator-cum-Filing Clerk :
Shri H. N. Mukherjee

Driver : (*Heavy Vehicles*)
Shri A. Simpson

Driver : (*Light Vehicles*)
Shri S. Maity

Clerks :

D. K. Dutta Biswas
N. Choudhury
R. B. Mondal
M. K. Mukherjee
J. C. Saha

AUTHOR INDEX

Continued from page 57

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