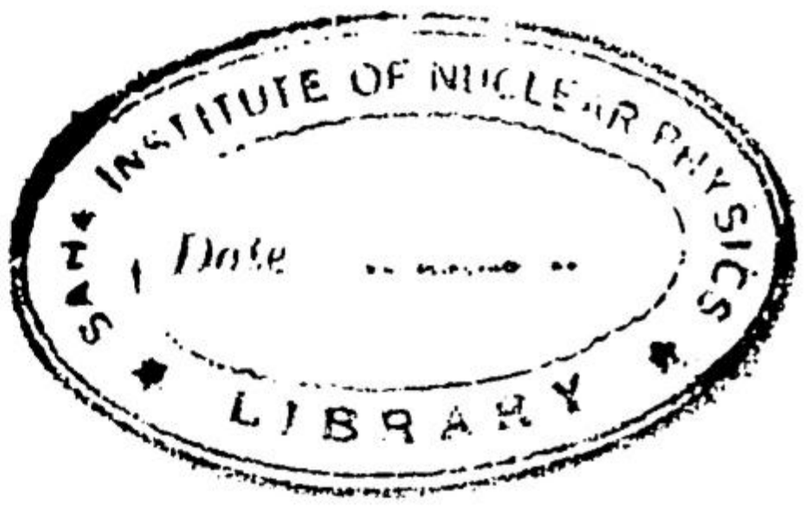
INP/Ann.Rep./1968

Annual Report

1968





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

Cover :
Stark-modulated microwave spectrometer
built at the Institute.

Published by Shri H. K. Basu, Registrar, Saha Institute of Nuclear Physics, 92 Acharya Prafulla Chandra Road, Calcutta-9. Printed by M. K. Mukerjee at Temple Press, 2 Nayaratna Lane, Calcutta-4.

PREFACE

This annual report presents a brief résumé of the activities of the Saha Institute of Nuclear Physics during the calendar year 1968.

The report with an introduction by the Director follows, in general, the pattern set up in the last year. The teaching, research and technical programmes which were carried out during the year under review, are arranged group- and division-wise. A short introduction to the activities of each division is provided by the respective Heads. The sections, figures and tables belonging to a group or division are numbered serially and they, therefore, do not necessarily correspond to one another.

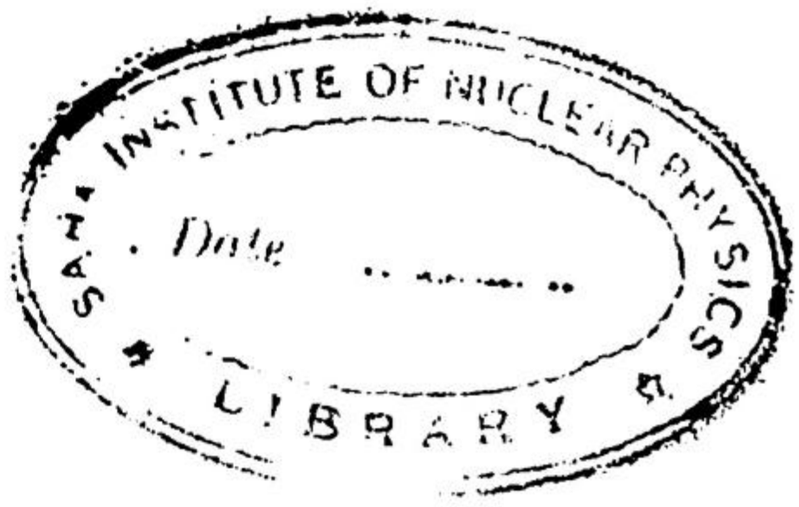
General information covering workshop, library, administration and medical unit is also incorporated. The author index and the list of publications in the year 1968 are arranged alphabetically. A list of the staff of the Institute is included at the end of this volume.

The activities reported herein pertain to all workers of the Institute, including those supported by other organisations, particularly, Calcutta University, the Department of Atomic Energy, Ministry of Education—Government of India and Council of Scientific and Industrial Research.

We take this opportunity to express our thanks to all our colleagues for their co-operation in compiling and editing this report.

Calcutta,
January, 1969.

S. N. Bhattacharyya
R. Bhattacharyya
Editors



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INTRODUCTION

It gives me great pleasure to place the fourth Annual Report of the Saha Institute of Nuclear Physics in the hands of our colleagues and friends. Looking over the pages, it would appear that the Institute has steadily maintained a high level of activity both in researches and in developments. The report has considerably increased in size incorporating two hundred and twenty one short articles describing the activity of the different groups and divisions.

In the Cyclic Accelerator Division, improvements of beam qualities, both internal and external have led to interesting studies of short-lived radioisotopes and also of nuclear reactions. Wide use of germanium detectors have made possible high precision measurements in nuclear spectroscopic work. This has been true in the Electrostatic Accelerator Division also where several studies of the life-times of excited states of nuclei together with high resolution nuclear spectroscopy are reported. On the developmental side, very fast coincidence units employing tunnel diodes, high voltage cascade rectifier using silicon rectifiers and other instruments may be mentioned. In the Nuclear Chemistry Division, work is continuing on analytical, radiation and separation chemistry together with studies of uptake through mixed crystal formation and its application. In mass spectroscopy, further studies on sputtering phenomena in crystals and theoretical studies on atomic collision have been made together with the use of the high intensity mass spectrometer for the study of the characteristics of a duoplasmatron ion-source. The isotope separator has given good performance in different mass regions from zinc to lead.

The Nuclear Physics Division is characterised by a diversity of problems under study. Only a few illustrative topics may be cited. The experimental work consists mainly of measurements of g-factors of nuclear levels using PAC techniques, estimation of the frequency range of the Stark-modulated microwave spectrometer, microwave spectral measurements of molecules and rotational constants and studies on spin-lattice relaxation times. Interesting theoretical work is reported on spin-phonon interaction, crystal field parameters, energy-band calculations, irreducible representation on non-symmorphic groups, paramagnetic susceptibility, covalency and vibronic interaction, atomic polarizabilities and Van der Waals' force constant.

Developmental work has been carried out on proton lock-cum-frequency device for NMR spectrometer, superheterodyne ESR unit in the X-band and UHF ESR spectrometer.

In the Structural Crystallography and Molecular Biology Division, the studies have been made in solid state physics on the one hand and biomolucles on the other. Structure of Cu-sarcosine, further study of collagen, the structure of amino acid derivatives and metal complexes and investigations on the conformation of biomolucules have also yielded interesting results.

The Bio-Physics Division also exhibits a proliferation of interests, incorporating studies on molecular genetics, ultrastructure research and physical biology among other topics. Techniques using electron microscope, ultracentrifuge and other biophysical research equipments have led to valuable find-

ings on the damage produced by UV-irradiation in a single stranded DNA, thymineless death in bacteria, ultrastructure of nucleohistone complexes, electron micrograph of bacteriophages and plant viruses and conformation of DNA.

The Theoretical Nuclear Physics Division has continued to contribute a large output of research notes and papers in the fields of elementary particles and high energy physics and in low energy nuclear physics. Interest is also developing in the classical and quantum theory of electron gas.

In the Instrumentation Division, in addition to certain important review work on wide-band amplification and also on UHF and microwave amplifiers, interesting developments of stable sources for UHF and microwaves, studies on the performances of varactor and frequency multipliers and several types of transistorised circuits including pulse height-to-time converter of the analog-to-digital type have been effected.

Researches in the field of plasma physics, under the guidance of Dr. B. D. Nagchaudhuri, report interesting studies of gas discharges and solid semi-conductors, investigating plasma behaviour of the condensed and of the dispersed state. Determination of the electron density, collision frequency and conductivity of plasma using RF methods and also the construction of electromagnetic shock-tubes and the study of shock-wave are proving to be of considerable interest. Progress has been made in the studies on problems connected with power generation and distribution of ion-source assembly, ion-beam exit from ion-source and other constructional aspects of Van de Graff type electrostatic accelerator.

The Technical Physics Division has continued its efforts in developing and constructing apparatus like, Root's pump, induction furnace, high intensity X-ray machine and other devices.

The Teaching Division had introduced certain innovations in the teaching programme for the Post-M.Sc. students and the results are being eagerly awaited.

The Institute has obtained possession of about seven acres of land at the Salt Lake Development site contiguous to the site for the Variable Energy Cyclotron Project of B.A.R.C. A programme for construction and development is being planned for the Institute in that area and considerable collaboration is envisaged between the Institute and B.A.R.C. in respect of the large development programmes already underway.

D. N. Kundu

1. ACCELERATOR GROUP

1A. CYCLIC ACCELERATOR DIVISION

1A.0 *Introductory Remarks*

The improvements in the internal beam and the external beam resulted in the utilisation of the cyclotron for producing some short-lived activities and in the study of (p, nγ) reactions. The investigations of gamma spectrum with the germanium detector whose resolution was further improved is yielding good results and in the near future some of the studies will be completed. Some of the results included in this report are indicative of the future plan of the division. The machine operation time has increased and further increase will be possible if a pulse height analyser is available continuously.

The model magnet studies are still in progress and results are expected in the coming year.

The time measuring system developed to perfection last year has been very successfully used for positron life-time studies and the results have been sent for publication.

In addition to the solid state detector development, the division has already started constructing transistor circuits on printed boards for replacing some of the equipments.

On the whole, the progress is very satisfactory and further utilisation of facilities will be possible if certain equipments like a large pulse height analyser and a larger Ge-detector are available which will cut down the time needed for completing some of the studies by a factor of four at least.

As in past years, Dr. B. B. Baliga continues giving a course of 40-45 lectures on nuclear physics to the M.Sc. students of the Calcutta University.

Sri P. Sen submitted his thesis for D.Phil.

A. P. Patro

1A.1 *Cyclotron*

The cyclotron was utilised throughout this year for the study of nuclear reactions and nuclear spectroscopy. After modifications and improvements carried out in 1967, the cyclotron regularly delivers 30-40μA of internal proton beam and extracted current of 2-3μA inside the chamber. Some studies were made in the middle of the year to improve the extracted current and to increase the fraction of the extracted current that goes to the experimental room. To

obtain the required increase, the quadrupole lenses have to be accurately positioned and for this purpose an adjustable table is being fabricated in the workshop. Afterwards, we expect to get substantial improvements in the current available in the experimental room over the value obtained last year (i.e., 90 mμA).

The cyclotron was run for nearly 500 hours for research, divided between internal and external bombardments. Gamma spectrum of radioactive nuclei produced by internal bombardments were studied by the Ge(Li) detector and the results are presented in later sections.

The preliminary studies indicated that the external beam can be profitably utilised for studying the gamma spectrum in (p, nγ) reaction. The results of such studies in the case of Ga(p, nγ) ^{71}Ge and ^{75}As (p, nγ) ^{75}Se are presented in a later section.

The 20° deflection magnet with its adjustable table is ready and will be installed as soon as fabrication of the power supply is completed.

The engineers have taken over the running and maintenance of the cyclotron and it is hoped that during the next year the utilisation of the machine will be at least double.

The design studies of the model AVF machine have been continued and spiral shimes have been installed. An aluminium chamber has been constructed and tested. The measurement of the magnetic field is expected to begin early next year.

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

1A.2 *The (p, nγ) Reactions on Arsenic-75 and Gallium-71*

At the beginning of the year the gamma spectrum from the reaction ^{75}As (p, nγ) ^{75}Se was studied with the Ge(Li) detector at 6 keV resolution upto 1,500 keV. Later in the year, resolution of the detector was improved to 3 keV with the installation of an FET preamplifier and the gamma spectrum was reinvestigated with the improved resolution upto 900 keV. The gamma rays observed and assigned to ^{75}Se are given in the Table 1A.1. To enable assignment of the gamma rays originating from (p, nγ) reaction, the gamma spectrum was investigated by degrading the proton energy by nearly 300 keV steps by interposing thin mylar films. The problem of calibration to get accurate energies is being studied and pending a reliable method, the energies have been quoted with large errors. During the coming year it is proposed to determine the intensities and the energies accurately in order to construct the level-scheme of ^{75}Se. Fig. 1A.1 gives the gamma rays observed in the reaction ^{75}As (p, nγ) ^{75}Se.

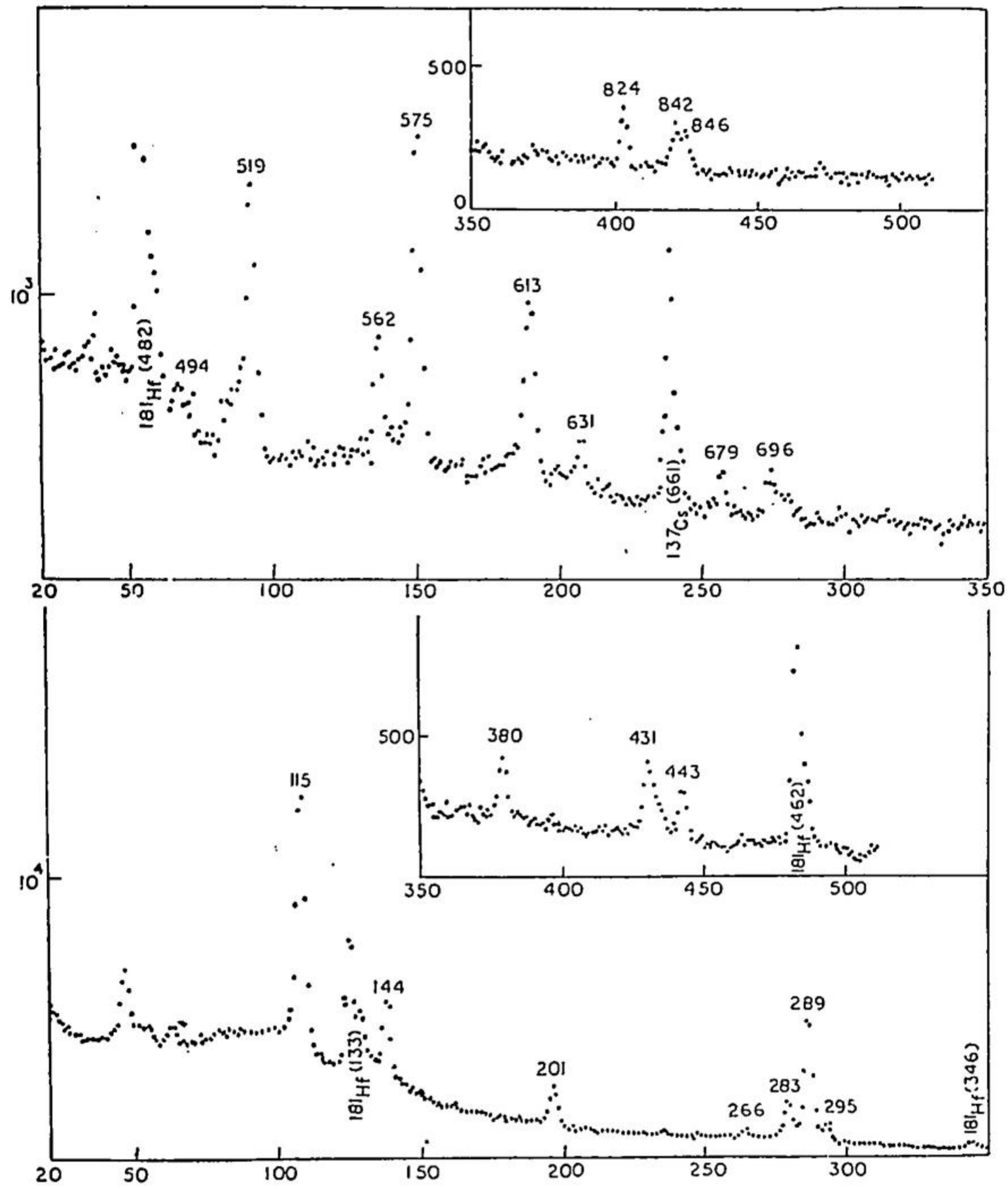


Fig. 1A.1. Gamma spectrum of $^{75}As + p$ with Ge(Li) detector.

Similar studies were also made with natural sample of Ga_2O_3. In this case the cross section for ^{69}Ga (p, nγ) ^{69}Ge is expected to be low and hence the gamma rays observed have been ascribed to ^{71}Ge. Fig. 1A.2 gives the gamma spectrum observed at 3 keV resolution and Fig. 1A.3 gives the spectrum observed with different absorbers placed before the target to lower the proton energies. The gamma rays are listed in Table 1A.2.

TABLE 1A.1

Gamma rays from proton bombardment on ^{75}As

Energy (keV)	Comments	Energy (keV)	Comments
115 ± 3	^{75}Se	519	^{75}Se
144	„	562	„

TABLE 1A.1 (Contd.)

200	Coulomb ex ^{75}As	575	Coulomb ex ^{75}As
267	,,	613	^{75}Se
283	,,	631	,,
289	^{75}Se	679	,,
295	Coulomb ex ^{75}As	696	,,
380	^{75}Se	702	,,
431	,,	824	,,
443	^{75}Se Background	842	Coulomb ex ^{75}As
494	^{75}Se	846	Background

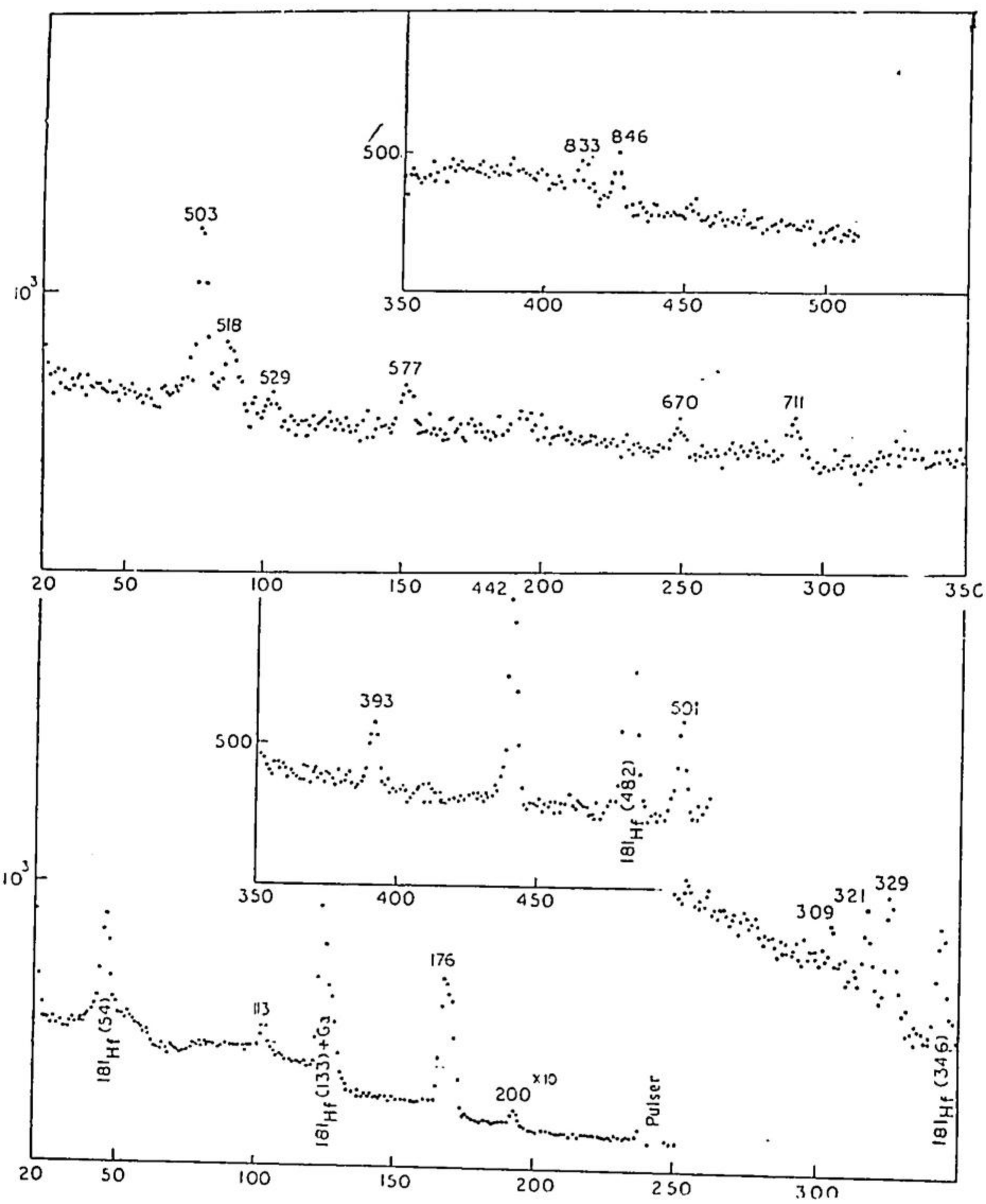


Fig. 1A.2. Gamma spectrum of $Ga_2O_3 + p$ with Ge(Li) detector.

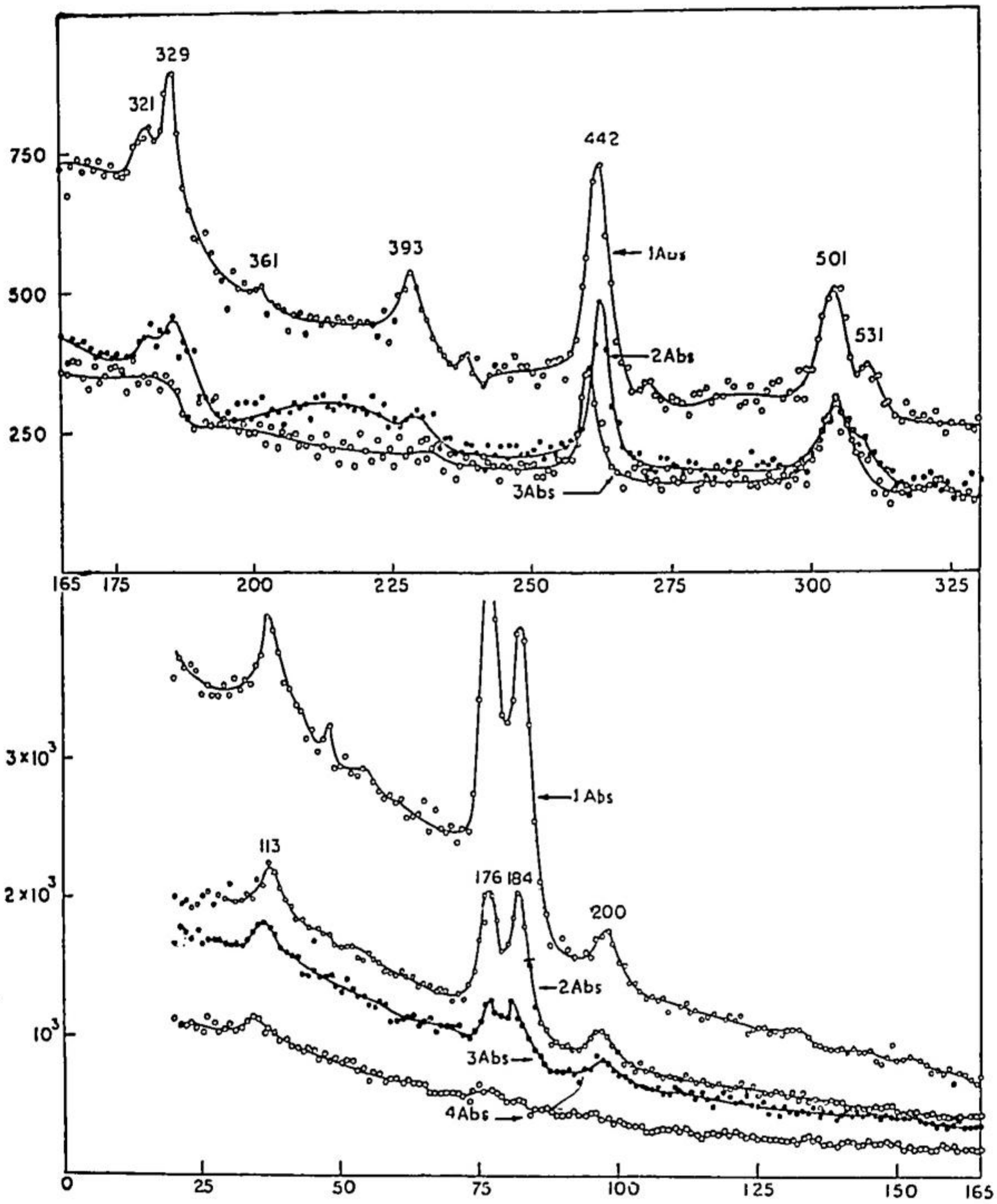


Fig. 1A.3. Gamma spectrum of $Ga_2O_3 + p$ with different absorbers

TABLE 1A.2

Gamma rays from proton bombardment of gallium oxide.

Energy (keV)	Comments	Energy (keV)	Comments
113 ± 3	^{71}Ge	501	Coulomb ex ^{71}Ga
176	,,	513	Coulomb ex ^{71}Ga
200	,,	529	^{71}Ge
309	,,	577	Coulomb ex ^{69}Ga
321	Coulomb ex ^{69}Ga	670	^{71}Ge
329	^{71}Ge	711	,,
393	Coulomb ex ^{71}Ga	833	,,
442	Coulomb ex or Background	846	Background

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

1A.3 *Gamma Spectroscopy*

A new FET preamplifier was added to the Ge(Li) detector system to improve the energy resolution. An energy resolution of 2.5 keV was obtained for the ^{137}Cs line. The system was further found to be very stable for a considerably long time. Reinvestigation of some isotopes produced with the internal beam was undertaken and the results are given below.

Level Studies on Mo-isotopes

Two isotopes, viz., ^{96}Tc and ^{95}Tc were studied. Both of them were simultaneously produced through (p, γ) and (p, n) reactions, respectively, by bombarding enriched (96.8%) $^{95}MoO_3$ (gold-backed) with 3.8 MeV protons from the cyclotron of the Institute. No chemical separation was done for these investigations.

(a) Decay of ^{96}Tc isomers to levels of ^{96}Mo

Both ^{96m}Tc (52m) and ^{96}Tc (4.3d) were studied. It is only known that **^{96m}Tc** decays mainly by isomeric transition ($\sim 99\%$) to the ground state of ^{96}Tc. So the activity of **^{96m}Tc** available to observe the excited levels of ^{96}Mo by direct decay will be small. The following $\gamma-$rays, viz., 185 ± 1 (–), 350 ± 1 (3.6 ± 0.8), 459 ± 1 (–), 480 ± 1 (35.8 ± 8.0), 721 ± 1 (37.2 ± 5.9), 1092 ± 1 (12.5 ± 1.5), 1096 ± 1 (4.8 ± 1.0), 1200 ± 1 (100) and 1499 ± 1 (13.8 ± 1.5) keV, were found to follow 52 min half-life and hence have been assigned to the decay of ^{96m}Tc The bracketted values are the intensities of the lines relative to 1200 keV $\gamma-$ray. No positron decay with 52 min half-life was observed. Thus ^{96m}Tc decays by electron capture to the ^{96}Mo levels at 3075, 1979 (3^+) and 1871 (4^+) keV of which the major part goes to the 1979 keV level. This is in good agreement with the probable 3^+ or 4^+ spin assigned to **^{96m}Tc**

The 4.3d ^{96}Tc yielded $\gamma-$rays of 239 (?), 315, 317, 320, 411 (?), 435 (?), 459, 476, 569, 778.5, 812.5, 850, 982, 1092, 1126, 1764 (?) keV. Evaluation of the intensities of the lines observed and fitting them into a tentative level-scheme is under progress.

(b) Decay of ^{95}Tc isomers to levels in ^{95}Mo

Both ^{95}Tc (20 hr) as well as **^{96m}Tc** (61d) were studied. The following $\gamma-$rays, viz., 744 (?), 765.5 (100), 948.0 (2), 1073.5 (4), 1556 (?) keV were found to follow 20 hr half-life and have been assigned to ^{95}Tc decay.

The 61d – **^{96m}Tc** yielded $\gamma-$rays of 204.5, 253.8, 582.0, 670.0 (?), 786.3, 820.6, 835.3, 967.0 (?), 1038.0, 1063.0 (?), 1115.2 (?) keV. Evalution of the intensities of the lines observed and fitting them into a tentative level-scheme is under progress.

These are the results of some preliminary observations. The decay of

^{96}Tc to the levels of ^{96}Mo will be presented at the Nuclear Physics and Solid State Physics Symposium, to be held at I.I.T., Powai, Bombay.

S. K. Basu and A. P. Patro

1A.4 *Gamma Rays from ^{97}Rh*

With the improved performance of the Ge(Li) detector with the installation of FET preamplifier led to renewed interest in studying the gamma rays from the decay of ^{97}Rh (30 min). The gamma spectrum was taken with 1 keV/channel expansion upto 3 MeV and with 3 keV/channel expansion upto 4 MeV. A new high energy gamma ray of energy 3375 keV was found. In

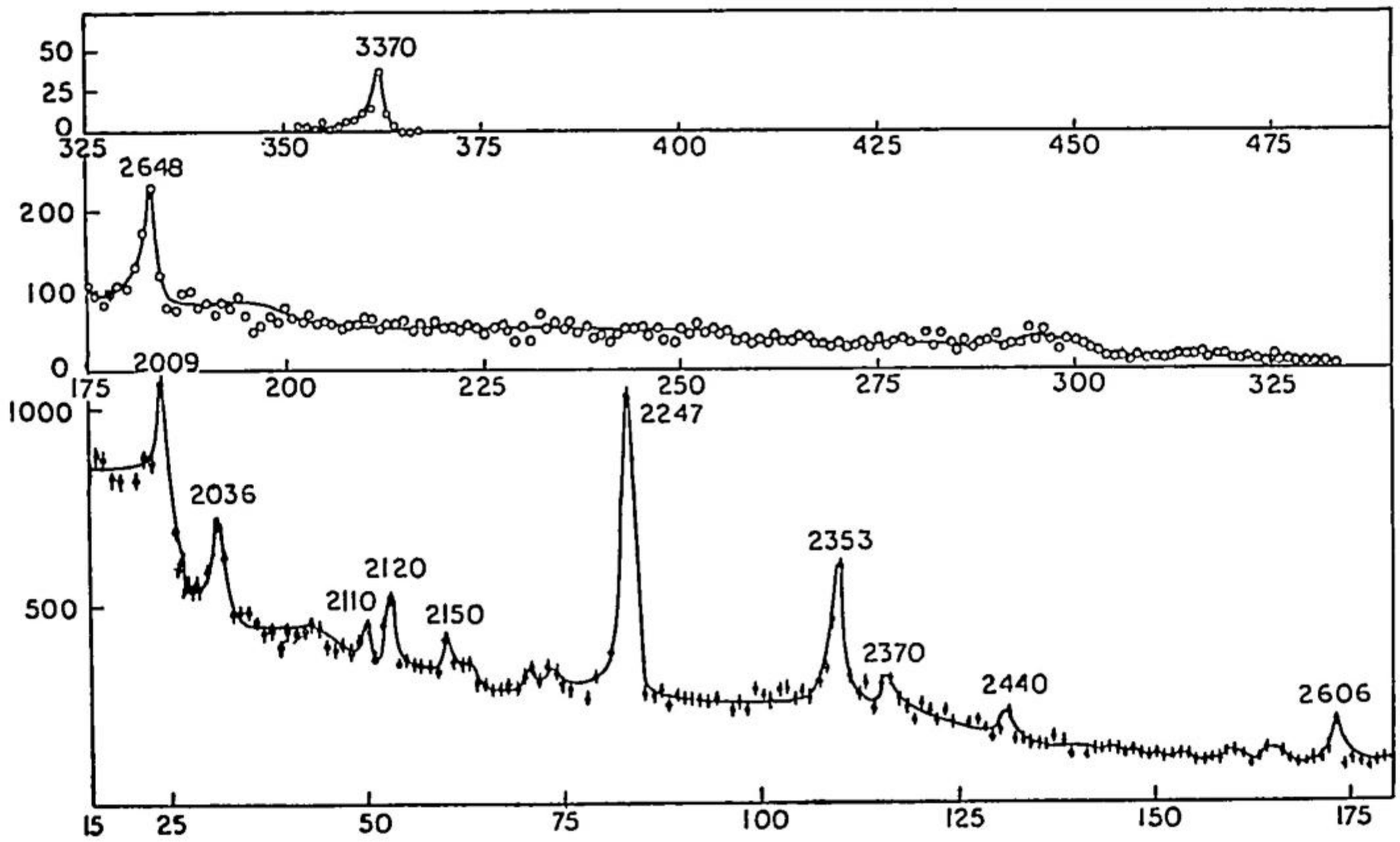


Fig. 1A.4. Gamma spectrum of ^{97}Rh.

addition to this, a number of other gamma rays were found and their energies were determined within ± 3 keV. Fig. 1A.4 shows the part of the gamma spectrum from 2 MeV to 4 MeV. Table 1A.3 gives the gamma rays emitted from ^{97}Rh.

Table 1A.3

Gamma ray energies in keV from ^{97}Rh					
187	719	909	1183	1710	2084
421	771	988	1190	1719	2123
527	778	996	1427	1742	2247

Table 1A.3 (Contd.)

539	840	1014	1586	2009	2606
582	879	1055	1657	2036	2648
					3375

B. Basu

1A.5 *Level-scheme of ^{109}Cd*

The level-scheme of ^{109}Cd was studied by bombarding an enriched sample of ^{108}Cd with the internal beam of the Calcutta cyclotron. ^{109}In produced by (p, γ) reaction decays to ^{109}Cd with a half-life of 4.3 hours. The gamma spectrum of ^{109}Cd upto 2.0 MeV was studied using the Ge(Li) drifted detector. Several new gamma lines were observed. Table 1A.4 lists the observed lines with the possible transitions indicated. These assignments are tentative as the intensity estimation have not yet been completed. It is interesting to note that the level with energy 203 keV has been reported to be 205 keV in the literature. We have determined this conclusively by taking different calibration lines. As many of the workers took this line as a standard to calibrate the others, the level-scheme is in error. We propose to rectify this when further confirmation is obtained from intensity estimation.

Table 1A.4
Observed gamma lines in ^{109}Cd nuclei and their possible transitions

Gamma line (keV)	Transition	Gamma line (keV)	Transition
60	60→0	901	901→0
203	203→0	925	925→0
288	288→0	929	1352→422
348	1273→925	948	1149→203
393	819→427	998	1196→203
422	624→203	1050	1050→0
427	427→0	1149	1352→203
531	819→288	1196	1196→0
614	901→288	1273	1273→0
619	619→0	1346	1768→422
624	1050→427	1352	1352→0
650	650→0	1419	1620→203
720	1620→901	1475	1475→0
793	793→0	1620	1620→0
819	819→0	1768	1768→0

B. B. Baliga and M. B. Chatterjee

1A.6 *Positron Life-time Measurements*

In the report of 1967 we presented the improvements made to achieve the best resolving time and the addition of a pulse height compensator to increase the coincidence counting rate without much loss in time-resolution. The results of these improvements have been published in Nuclear Instruments and Methods. With these improvements a programme was undertaken during this year to measure positron life-times in different substances.

Positron life-times in silicone fluids reported last year were reinvestigated by degassing the samples as dissolved oxygen was found to quench the life-times. The results show a slight decrease in the life-time τ_2 with the length of the chain. No dependence on I_2 was observed. The large variation in τ_2 obtained by Gray *et al.* (P. R. Gray, C. P. Sturm and F. C. Cook, *J. Chem. Phys., 46,* 3487, 1967) for normal aliphatic hydrocarbons having different chain lengths was suggested by us to be mainly due to variation in density. The results of these investigations are published in Nuovo Cimento.

Positron annihilation studies in alkali halides and oxides have been investigated by different workers (A. T. Stewart and L. O. Roellig, Positron Annihilation, Academic Press, 1967). There have been a lot of inconsistencies between the results of different workers. Here the problem of positron annihilation studies in twenty oxides was taken up. The measurements were made by conventional life-time technique, three-photon life-time technique using a three detector assembly and three to two-photon relative yield technique using a Ge(Li) detector. The results show that the presence of air, moisture and absorbed gases affect the life-times and intensities to a great extent. It was observed that the important effect of the presence of air is in quenching and not in formation, at least in powders. One of the typical life-time spectra showing this effect is displayed in Fig. 1A.5 for ZnO sample. The details are contained in a paper recently communicated to Nuovo Cimento.

Different workers (A. T. Stewart and L. O. Roellig, Positron Annihilation, Academic Press, 1967) have tried, unsuccessfully, to draw a correlation between the partial life-time for the three-photon decay and, those extracted from the time spectra. In order to justify the analysis adopted by these authors, it is important to find out if the long life-times (10^{-8} sec.) are two-photon decays or three-photon decays. The present results give the evidence of the two-photon nature of the 10^{-8} sec component. Ortho-positronium life-times were also measured in quite a few cases and found to agree with the theoretical value of 1.4×10^{-7} sec. A paper, containing these results, have been recently published in Physics Letters.

These ortho-positronium life-time data, however, do not contradict the requirement of distorted positronium required in cases where magnetic quenching data do not follow the theoretical predictions, but of course contradicts the analysis used by different workers for the partial life-time of the triplet

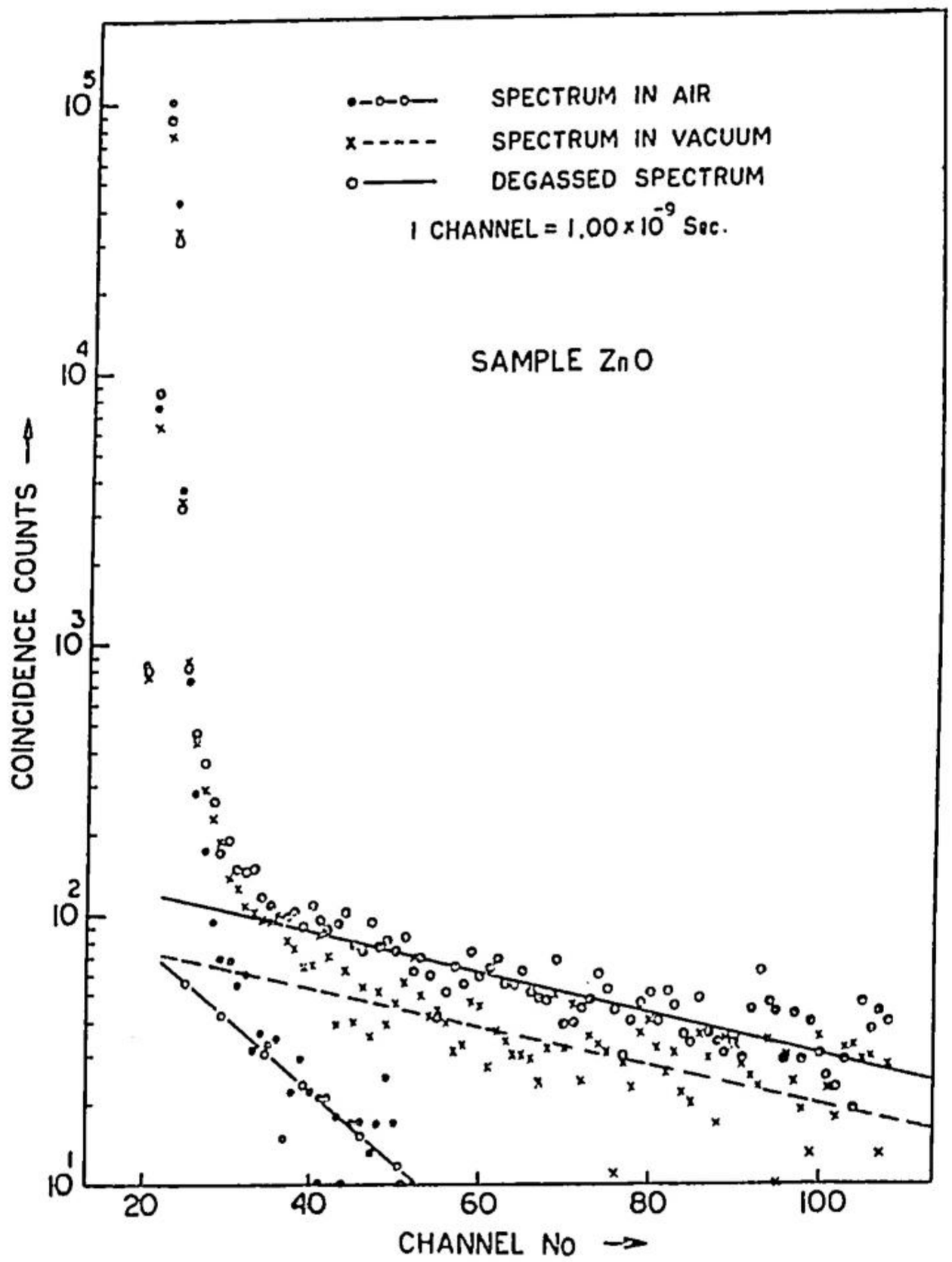


Fig. 1A.5. Time distribution spectra obtained with ZnO in three different conditions, i.e., air, vacuum and degassed.

positronium for three-photon emission, assuming a shorter ortho-positronium life-time.

Experiments in search of the existence of compressed positronium is in progress in the laboratory.

P. Sen and A. P. Patro

1A.7 *Development of Transistorised Circuits*

A programme has been undertaken to replace as much as possible the standard electron tube circuits, e.g., amplifiers, single channel analysers, coincidence and anti-coincidence units, etc., by transistorised circuits on printed boards. The method of making printed board is studied and has been success-

fully applied in making a four-fold coincidence arrangement which has an additional anti-coincidence input. The above circuit, designed after Bertolaccini *et al.* (Bertolaccini *et al., Nuclear Instrm. Meth., 37*, 297, 1965) has been tested and is ready for use. A wide-band linear amplifier has also been studied and further study is under progress.

S. K. Basu and A. P. Patro

1B. ELECTROSTATIC GENERATOR DIVISION

1B.0 *Introductory Remarks*

The reports of the work done by different research and development groups of this division show that satisfactory progress has been made in both the fields of research and development.

The programme of research continued broadly along the lines followed in the previous years. The experimental studies were mainly on spectroscopy and were pursued by three different groups. The availability of Ge(Li) detectors and its increasing use in the field of gamma ray spectroscopy, have given a new impetus to the research groups engaged in the high resolution spectroscopic work. This is amply bourne out by several of the reported work given below. We hope to be able to use in such work bigger and coaxial detectors of the above type with their added advantages. Effort is being made to develop Ge(Li) and Si(Li) detectors in this laboratory. One group continued the spectroscopic studies of the short-lived isotopes produced by means of the neutron generator of this division. Another group was engaged in examining the existing level-schemes with high resolution spectroscopy and succeeded in suggesting a few new level-schemes. Still another group was studying the lifetimes of the excited states of various nuclei in the sub-nanosecond range. The theoretical studies of the (p, p′) and (d, p) reactions in terms of the particle-core model in the heavy mass region, was made. The effect of Nilsson orbital mixing on the level-structure, gamma transition rates, gyromagnetic ratios, RPC calculations, N forbidden β decay F^{τ}– values, and stripping widths were examined. Studies on the properties of the low-lying nuclear energy levels of the odd-mass nuclei on the basis of intermediate coupling approach in the unified nuclear model, was continued with encouraging results. To take full advantages of the high resolution feature of the Ge(Li) detectors, it was found useful to develop a computer code to automatically analyse the gamma ray spectra obtained with their help. A brief report of this attempt is given.

On the developmental side, a number of sophisticated electronic instruments had to be designed in order to use them in connection with experimental research. Special mention may be made of (i) a very fast-coincidence unit employing tunnel diodes, (ii) a high voltage cascade rectifier unit employing locally made silicon rectifiers, (iii) an inverter/frequency converter unit using silicon controlled rectifier. Studies and work are in progress to develop a generator in the MeV range. Work on ion-source development has also made satisfactory progress. An ion-source of a simplified duo-plasmatron type has been fabricated and its performance is being tested. It is expected to yield more than 5 mA of proton beam.

The neutron generator was utilised, as before, not only for the work of this division, but also for the work of other divisions of this Institute, as well as for some other sister institutes in and around Calcutta.

S. K. Mukherjee

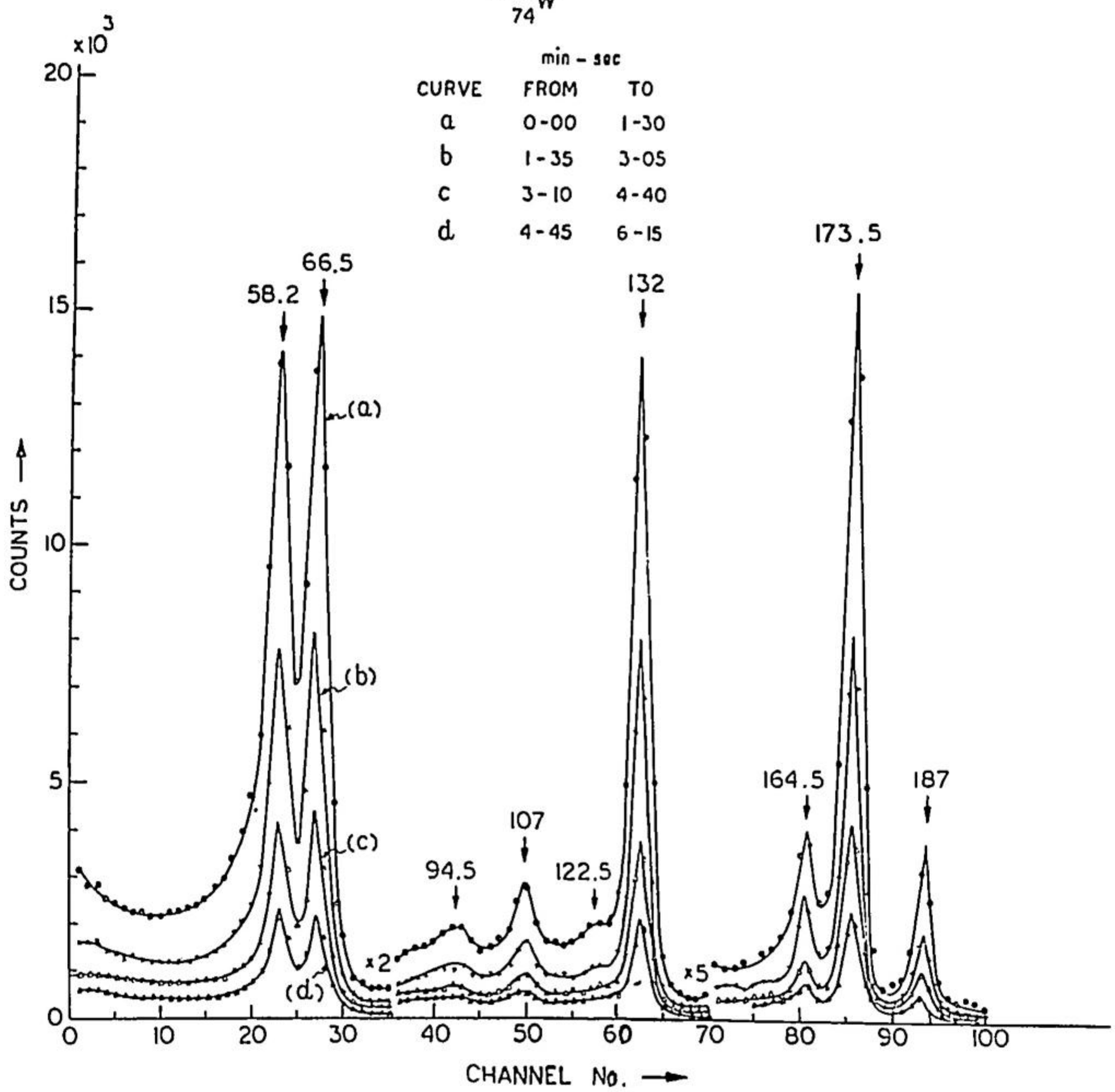
1B.1 *Decay of 1.6 min ^{185m}W and Low Lying Excited States of ^{185}W*

The γ — decay characteristics of 1.6 min ^{185m}W have been studied using Ge(Li) and NaI(Tl) detectors and a 512 channel analyzer. The samples of ^{185m}W were produced by ^{186}W (n, 2n) $^{185\text{ and }g}W$ reaction by bombarding enriched ^{186}W (99.8%). The decay of individual γ–rays has been studied using a Ge (Li) detector. The energies and the relative intensities of the γ–rays decaying with a half-life of 1.6 min (Fig. 1B.1) are given in Table 1B.1. A number of new γ–rays have been observed and a few reported by various authors have been confirmed.

A decay-scheme, based on $\gamma-\gamma$coincidence measurements and relative intensities of the γ–rays, has been proposed. The excited energy states of ^{185}W have been compared with those obtained by Erskin (J. R. Erskin, *Phys. Rev.*, *138*, B66, 1965) (Fig. 1B.2) through ^{184}W (d, p) ^{185}W reaction and also calculated in the light of rotation particle coupling model. A fair agreement has been obtained. The proposed energy states have been substituted in the relation given by Kerman (A. K. Kerman, *Dan. Mat. Fys. Medd.*, *30*, 15, 1956) for the rotational excited states of deformed nuclei and the following values for the parameters are obtained.

$$E_{1/2}^{(1)} = 20.833 \text{ keV}$$
$$E_{3/2}^{(1)} = 13.781 \text{ keV}$$
$$E_{3/2}^{(2)} = 0.0625 \text{ keV}$$
$$a = 0.088 \text{ keV}$$

where $E^{(1)}$ corresponds to $h^2/2g$, $E^{(2)}$ the coefficient of the rotation-vibration term and 'a' the decoupling parameter. The estimated values are in agreement with the systematics of the nuclei in this mass region. All the proposed states are explained in terms of intrinsic states $3/2^-$ (512), $1/2^-$ (510) and $7/2^-$ (503) and the rotational states are built over them. The emission of photon from $7/2^-$ (503) state at 238 keV seems to be delayed. Work is in progress to measure its half-life.



Fib. 1B.1. The energies and relative intensities of the gamma rays from the decay of 1.6 min ^{186m}W.

TABLE 1B.1

Gamma ray energies and their relative intensities

γ–ray energies (keV)	Relative intensities
20	—
58.2 (Kα X–rays and 57 keV γ–rays)	12.3
66.5 (Kβ X–rays and 65 and 68 keV γ–rays)	139
94.5	3.0
107	10.6
132	100
164	12.6
173.5	72
187	14.8

1B.2 *Decay of 18.8 min ^{126m}Sb*

The decay characteristics of 18.8 min ^{126m}Sb and the characteristics of the excited states of ^{126}Te populated by its decay have been studied using NaI(Tl) and Ge(Li) spectrometers. The results of measurements are given in Tables 1B.2 and 1B.3.

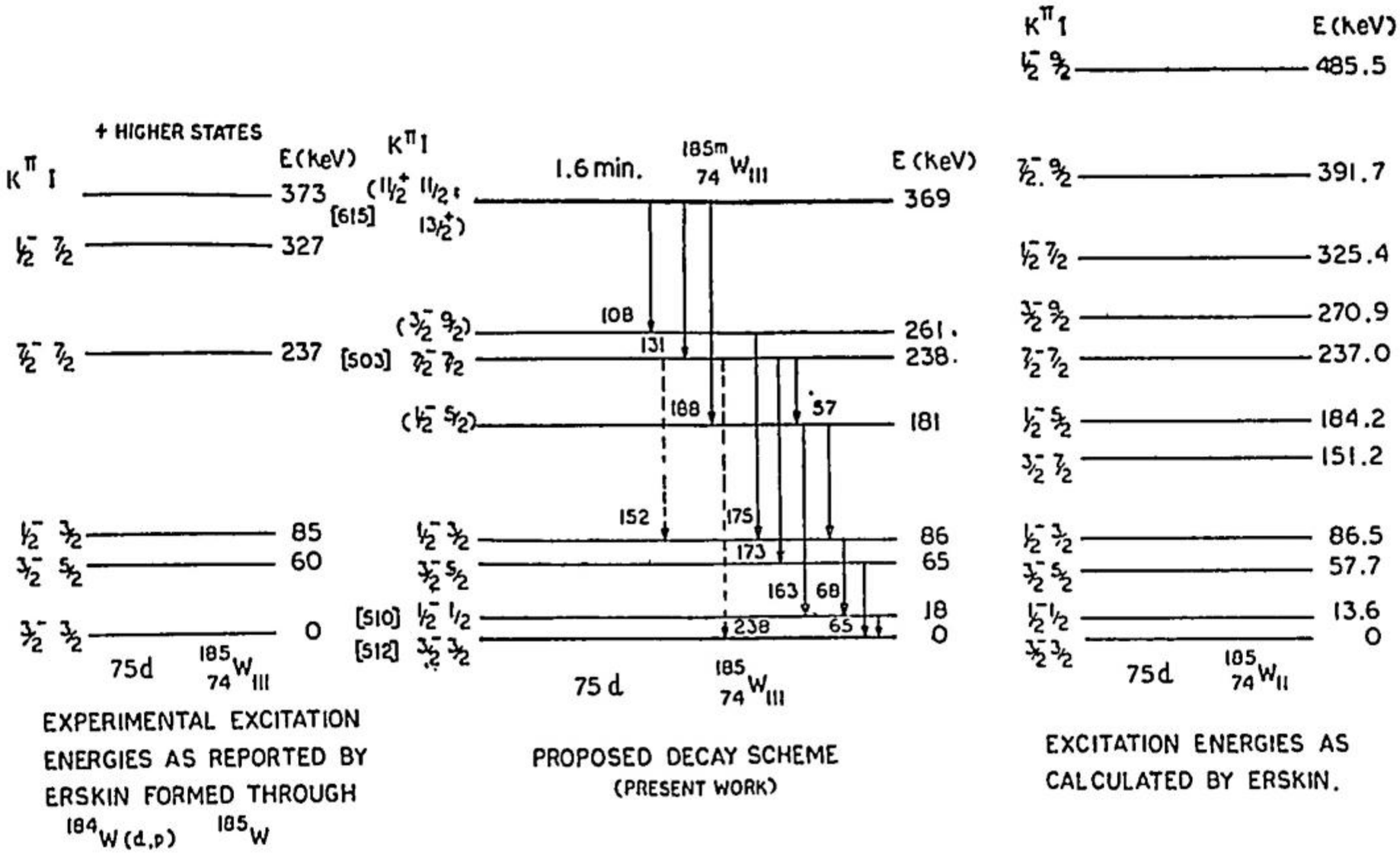


Fig. 1B.2. Calculated and experimentally obtained excited states of ^{185}W.

Table 1B.2

Gamma rays			Beta rays		
Energy (keV)	Relative intensity	Energy measured with Ge(Li) detector (keV)	End-point energy (MeV)	% inten-sity	log ft. value
220 ± 10	0.2%	227 ± 3	(0.57 ± 0.1)§	12%	5.1
315 ± 10	0.6%	292 ± 3	(0.69 ± 0.1)	5%	6.7
410 ± 10	48.4%	414 ± 3	0.925± 0.1	28%	6.1
680 ± 10	100 %	665 ± 5 1088 ± 5	(1.73 ± 0.15)	1%	9.4
1095 ± 15	14 %		2.03 ± 0.15	51%	6.3
		1120 ± 5			
1330 ± 15	2.4%	1340 ± 5	2.44 ± 0.15	3%	9.2
1460 ± 15	6 %	1456 ± 5	———	——	—

§ Parenthesis indicates that these beta rays are not directly observed but their presence is inferred from the proposed decay-scheme.

Table 1B.3

Coincidence measurements

Gamma rays γ–γ coincidence		β–γ coincidence		Beta rays γ–β coincidence	
Energy of gating (keV)	Observed gammas (keV)	Gating beta ray energy	Observed gamma energies (keV)	Energy of gating γ-ray (keV)	Observed beta ray end-point energies (MeV)
410	215, 310, 410, 680, 1080, 1340 and 1445	Integral betas	320, 410, 665, 1090, 1350 and 1430	410	0.93 ± 0.1 1.9 ± 0.15 2.5 ± 0.15
				680	0.96 ± 0.1 1.91 ± 0.15 2.37 ± 0.15
670-690	220, 300, 410, 670, 1040, 1330 and 1450			1050-1470	~ 0.92

On the basis of these measurements a decay-scheme has been proposed for ^{126m}Sb.

Publication :

S. C. Gujrathi, K. S. N. Murty, B. P. Pathak and S. K. Mukherjee, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Madras,* 1968, p. 338.

S. C. Gujrathi, K. S. N. Murty, B. P. Pathak and S. K. Mukherjee

1B.3 *Decay of ^{94}Y*

A detailed study of the decay characteristics of ^{94}Y has been undertaken. The samples of ^{94}Y were produced through ^{94}Zr(n, p)^{94}Y reaction by bombarding enriched and spec. pure samples. Y-fraction from the bombarded sample of spec. pure Zr was separated by radiochemical methods. The results of measurements are summarised in Tables 1B.4 and 1B.5.

Table 1B.4

Energies and intensities of gamma rays of ^{94}Y

Present work		Previous work			
Energy of γ-ray (MeV)	Relative intensity ± 10%	Energy of γ-ray (1) (MeV)	Relative intensity ± 10%	Energy of γ-ray (2) (MeV)	Relative intensity ± 10%
0.395	3.0	—	—	0.382	3.3
0.560	17.0	0.560	13.0	0.552	11.0
0.920	100	0.920	100	0.919	100
1.14	13.9	1.13	11.0	1.139	8.5
1.39	9.3	1.42?	—	—	—
1.66	5.5	1.65	5.7	1.672	2.9
1.184	3.0	—	—	1.831	0.9
—	—	—	—	1.885	0.5
—	—	1.9	3.8	1.896	1.1
2.00	2.1	—	—	1.944	1.1
2.10	0.8	2.13	5.6	2.144	1.0
2.26	0.5	—	—	2.256	4.7
2.38	0.8	—	—	2.30	0.8
2.49	1.0	—	—	—	—
2.62	1.4	2.57 (doublet)	3.4	—	—
2.75	2.5	2.84 (doublet?)	1.6	—	—
3.26	0.9	3.06	3	—	—
3.61	1.2	3.53	2.5	—	—

Table 1B.5

The intensities and log ft values of various beta groups

End-point energy of the beta group (MeV)	Intensity (%)	log ft values
4.90	13.0	9.0
3.94	39.0	8.1
3.24	19.0	7.7
2.84	10.0	8.0
2.59	8.0	8.2

Table 1B.5 (Continued)

1.98	1.5	8.0
1.62	1.0	9.0
1.40	4.0	7.7
1.18	4.5	7.7

A decay-scheme has been proposed for ^{94}Y.

Publication :

S. C. Gujrathi, H. Singh and S. K. Mukherjee, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Madras,* 1968, p. 356.

S. C. Gujrathi, H. Singh and S. K. Mukherjee

1B.4 *Decay of ^{186}Ta*

The decay properties of ^{186}Ta have been studied using NaI(Tl) and Ge(Li) spectrometers. A detailed study of the decay has been reported for the first time. The samples of ^{186}Ta were produced through ^{186}W (n, p) ^{186}Ta reaction by bombarding enriched ^{186}W with 14 MeV neutrons. The results of measurements are summarised in Tables 1B.6 and 1B.7.

Table 1B.6

Gamma ray spectrum taken with 3″ dia. × 3″ long NaI(Tl)			Beta ray spectrum taken with 2″ dia. × ½″ thick anthracene dectector		
γ–ray energy (keV)	Relative intensity	5 cm² area × 5 mm depletion depth Ge(Li) detector, energy (KeV) ξ	End-point energy of the beta-group (MeV)	Percent intensity	log ft
W X–ray	—	59.5,67.0	—	—	—
123±5	21	122.5	3.00±0.15	5	9.1
215±10	87	196,213	—	—	—
275±10	5.5	272.5,286	2.5 ±0.15	32	7.3
300±10	25	306,313	—	—	—
385±10	3.3	379,394	2.1 ±0.15	49	6.5
410±10	26	416,454	—	—	—
510±10	100*	509,537,541	1.5 ±0.15	14	7.1
610±10	21	595,614,635	—	—	—

Table 1B.6 (Continued)

670±10	1.3	652,660	—	—	—
710±10	9.3	708	—	—	—
730±10	51	735,781,798	—	—	—
870±20	10	822,868	—	—	—
930±20	8.8	935,952	—	—	—
1030±20	6.1	—	—	—	—
1140±20	4.5	—	—	—	—
1250±20	3.1	—	—	—	—

§ The possible error in the energies quoted upto 509 keV is ± 2 keV and above that it is less than 5 keV.

* The relative intensity of the 510 keV gamma ray quoted here is expected to be higher than the actual due to the presence of positron annihilation γ-rays.

Table 1B.7

Results of coincidence measurements

Gamma-gamma concidences		Beta-gamma coincidence	
Range of gamma energy selected (keV)	Coincident gamma energies (keV)	Range of gamma energy selected (keV)	Coincident beta-energies (MeV)
150—240	190, 280, 410, 510, 610	460—580	2.53, 1.0
240—360	190, 280, 400, 510, 590, 740, 980	640—800	2.5, 2.0
470—560	130, 200, 300, 515, 730, 860, 980	—	—
550—660	125, 200, 300, 420, 510, 610, 730, 800, 960	—	—
550—660	125, 200, 300, 420, 510, 510, 610, 730, 880	—	—

The decay-scheme (Fig. 1B.3) has been proposed for ^{186}Ta based on the results of above measurements.

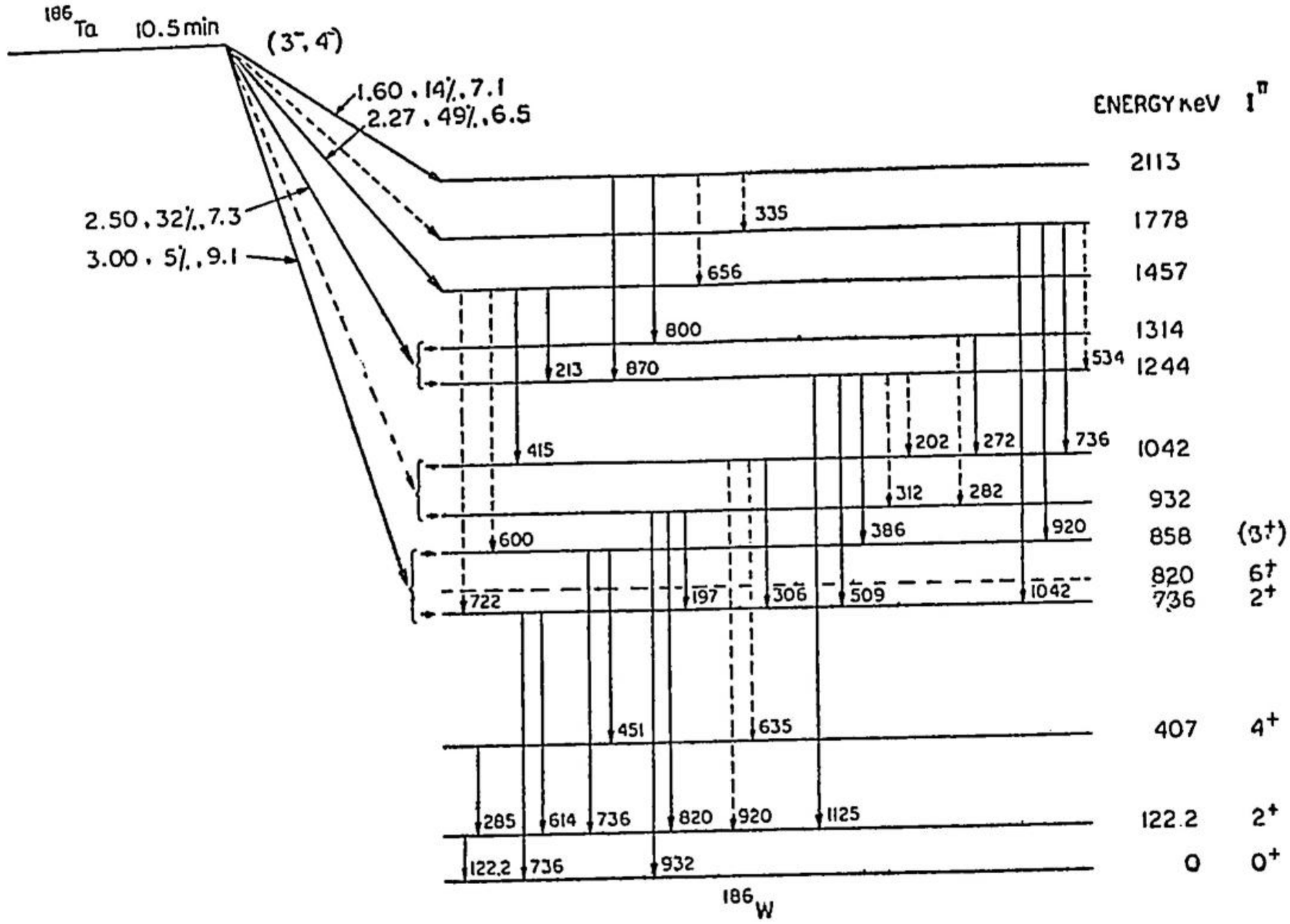


Fig. 1B.3. Proposed decay-scheme of ^{186}Ta.

Publication :

S. C. Gujrathi, B. P. Pathak, K. S. N. Murty and S. K. Mukherjee, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Madras*, 1968, p. 343.

S. C. Gujrathi, B. P. Pathak, K. S. N. Murty and S. K. Mukherjee

1B.5 E0/E2 *Branching in* $I^+ \rightarrow I^+$ *Transitions in* ^{152}*Sm and* ^{152}*Gd from 12.4 yr* ^{152}*Eu Decay*

E0 matrix elements are extremely sensitive to the detailed charge distribution of the nucleus, and also on the nuclear model wave-functions. Uptill now there are very little experimental data for E0 transitions between two non-zero spin states. Moreover, the presence of large M1 admixture will certainly modify this ratio. In the present work six E0/E2 ratios are estimated in ^{152}Sm and ^{152}Gd. The gamma-ray intensities have been measured with a high resolution (2.6 keV) Ge(Li) detector. The results are shown in Table 1B.8. In order to get agreement with the available theoretical predictions, definite M1 admixtures are necessary for the beta-band in ^{152}Sm.

Table 1B.8

EO/E2 transition ratios in ^{152}Sm and ^{152}Gd

Transition	E_γ (keV) ±0.5 keV	I_γ	§ I_{ek}	$\alpha_k \times 10^3$ (Expt.)	α_k (Th) E2	* $\times 10^3$ M1	$\frac{I_{ek}(E0)}{I_{ek}(E2)}$ 20% E2	100% E2
Standard	344.3	26	72	31.1	31.1	—	—	—
^{152}Sm								
Beta band								
$4^+_1 \rightarrow 4^+_0$	656.1	0.15±0.05	0.59±0.11	43.0±17	5.4	9.3	34.2	7.1
$2^+_1 \rightarrow 2^+_0$	688.0	0.80±0.09	2.6 ±0.2	35.1± 4.4	4.9	8.3	29.3	6.4
Gamma band								
$2^+_2 \rightarrow 2^+_0$	964.2	13.8 ±1.4	2.9 ±0.2	2.3± 0.3	2.2	3.6	—	0.06
$4^+_2 \rightarrow 4^+_0$	1006.0	0.54±0.07	0.15±0.05	3.0± 1.0	2.0	3.3	—	0.50
^{152}Gd								
$2^+_1 \rightarrow 2^+_0$	586.4	0.30±0.06	1.1 ±0.2	40 ±10	7.7	14.5	18.5	4.2
$2^+_2 \rightarrow 2^+_0$	764.5**	0.07±0.02	0.09±0.03	14 ± 6	4.1	7.5	9.4	2.5

§ Ref. 2.

* Sliv and Band (Cubic fit in log α_k − log $E\gamma$ space), kindly provided by W. B. Ewbank, ORNL.

** A new level 1109 keV, 2^+ has been identified in ^{152}Gd (P. Mukherjee and B. K. Das Mahapatro, to be published).

(P. Mukherjee and I. Mukherjee, 'EO Transition in ^{152}Sm and ^{152}Gd', to be published in *Physics Letters*).

P. Mukherjee and I. Mukherjee

1B.6 *^{152}Eu (12.4 yr) as a Calibrating Source for Ge (Li) Detector*

The 12.4 yr ^{152}Eu is found to be a very convenient calibrating source for the Ge (Li) detectors. It has eleven strong gamma lines between 121.7 keV to 1408.3 keV. Table 1B.9 lists our recommended energy and intensities for these gamma lines, which may be used for the calibration of the Ge (Li) detectors. These values are found after an extensive work on the Ge (Li) spectra of the ^{152}Eu isotope. Fig. 1B.4 shows a typical relative efficiency curve of the detector.

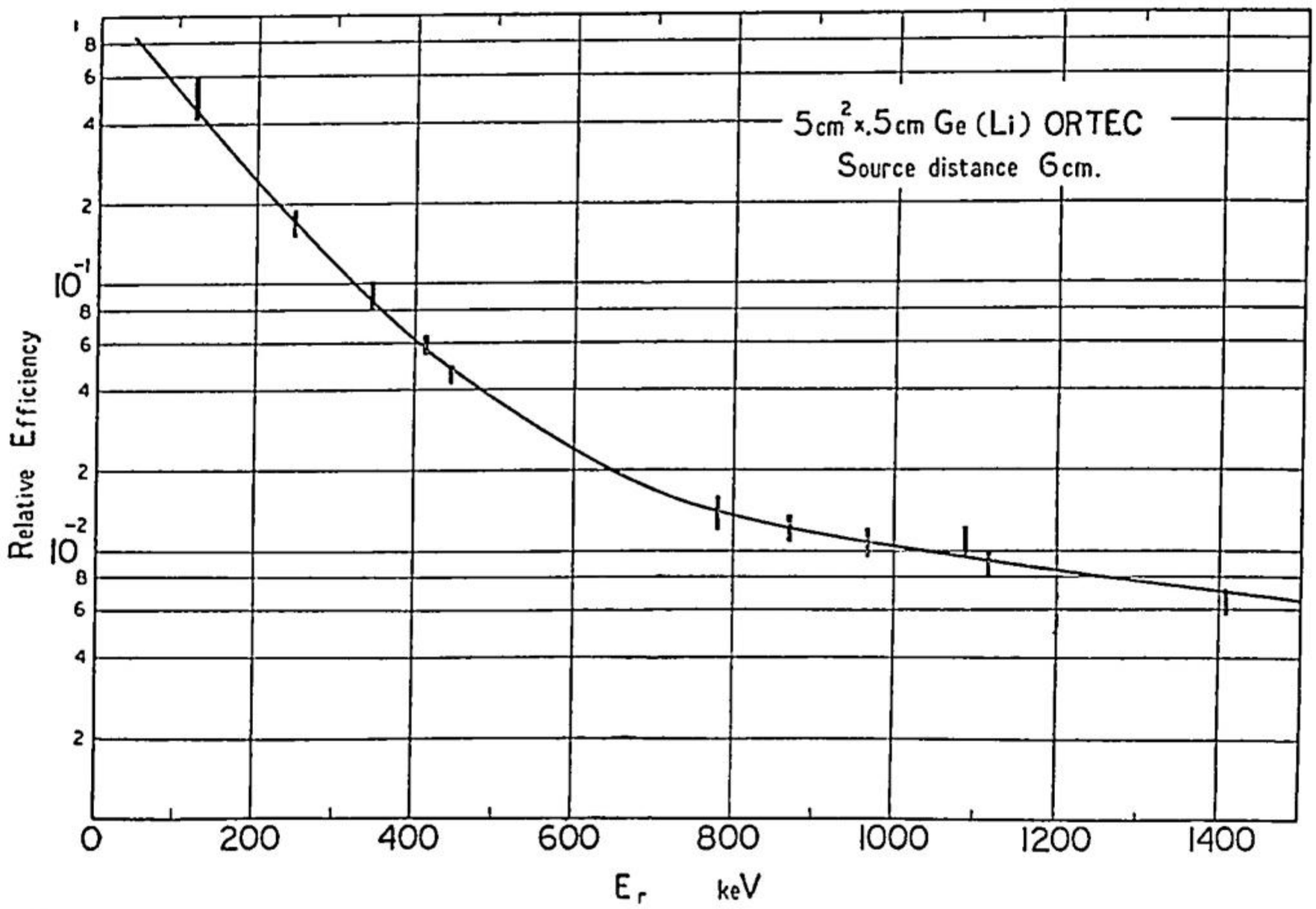


Fig. 1B.4. The relative photo-peak efficiency against gamma ray energy of a Ge(Li) detector.

Table 1B.9

Recommended gamma ray energies and intensities in ^{152}Eu (12.4 yr) for calibration of the Ge(Li) detector

E_γ (keV)	I_γ
121.77±0.01	32 ± 3
244.68±0.02	8.2±0.8
344.27±0.03	26 ± 2
411.12±0.06	2.1±0.2
443.96±0.10	3.0±0.3
778.9 ±0.2	13 ± 1
867.4 ±0.3	3.7±0.4
964.1 ±0.2	14 ± 1
1086.0 ±0.2	11 ± 1
1112.1 ±0.2	14 ± 1
1408.1 ±0.3	20 (Standard)

(P. Mukherjee and A. K. Sen Gupta, '^{152}Eu (12.4 yr) as a Calibrating Source for Ge(Li) Detector', to be published in *Nuclear Instrm. Meth.*)

P. Mukherjee and A. K. Sen Gupta

1B.7 *Beta-vibrational Band in ^{152}Sm*

Accurate determination of the gamma ray branching ratios between the levels of beta vibrational band and ground state rotational band is difficult but is extremely important from theoretical point of view. The intensity of the relevant gamma rays in ^{152}Sm have been determined with a high resolution (2.6 keV) Ge (Li) detector. These are listed in Table 1B.10 together with the α_k—values. The results of the present investigation indicate that the determination of B(E2) ratios in ^{152}Sm is beset with considerable experimental difficulties. It is found that the 444 keV $2^+_\beta \rightarrow 4^+$ gamma intensity is less than 5% of the total 444 keV gamma intensity observed. The 810.5 keV gamma is also found to be composite (Fig. 1B.5) indicating that the $2^+_\beta \rightarrow 0$ transition rate is to be reduced properly.

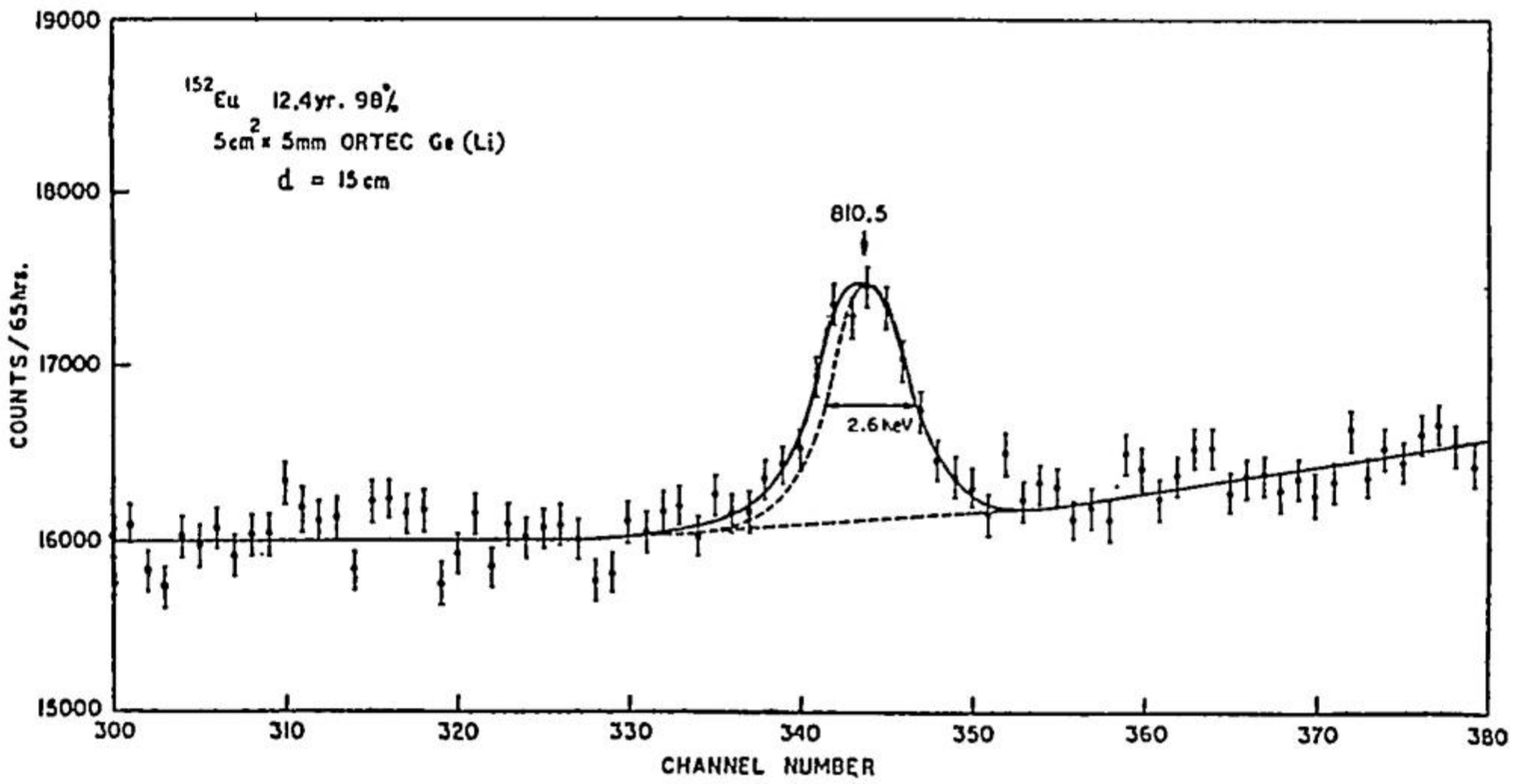


Fig. 1B.5. Line shape of the 810.5 keV photo-peak taken with Ge(Li) detector. The dotted curve is the line shape for the neighbouring 779 and 868 keV photo-peak with peak height normalised.

Table 1B.10

Gamma ray intensities and α_k for transitions between members of beta vibrational band and ground state rotational band in ^{152}Sm

Transition From	To	E_γ keV (±0.5)	I_γ I (344)=26	I_{ek}[a] I_{ek} (344)=72	$\alpha \times 10^3$ Exptl. (344)=0.0311	Theory[b] E1	E2	M1
4^+	6^+	310.0*	0.03	—	—	—	—	—
4^+	2^+	444.1	3.0 ±0.3	1.2 ±0.1	4.3±0.5	4.9	14.5	24.9
2^-	2^+							
0^+	2^+	564.0	0.34±0.08§	0.15±0.07	4.7±2.4	2.8	7.7	13.5

Table 1B.10 (Continued)

$4'^{+}$	4^{+}	656.1	0.15±0.05	0.59±0.11	43.0±7.7	2.0	5.4	9.3
$2'^{+}$	2^{+}	688.0	0.80±0.09	2.6 ±0.2	35.1±4.4	1.9	4.9	8.3
2^{+}	0^{+}	810.5**	0.34±0.05	0.09±0.05	2.8±1.5	1.3	3.3	5.6
4^{+}	2^{+}	900.3	0.04	—	—	—	—	—

§ From graphical analysis of 564.0 and 566.2 keV composite line using the energies from Ref. (a).

* Energy of the 6^{+} level is taken as 712 keV.

** 810.5 keV line is composite (see text).

(a) G. Malmsten et al., *Arkiv Fysik, 33*, 361, 1967.

(b) Sliv and Band. The values have been kindly provided by Dr. W. B. Ewbank, ORNL.

(P. Mukherjee and A. K. Sen Gupta, 'Beta Vibrational Band in ^{152}Sm', to be published in *Phys Rev.*)

P. Mukherjee and A. K. Sen Gupta

1B.8 *Level-scheme of ^{152}Gd*

With a high resolution (2.6 keV) Ge(Li) detector several new gamma lines have been identified which are attributed to ^{152}Gd in the decay of 12.5 yr

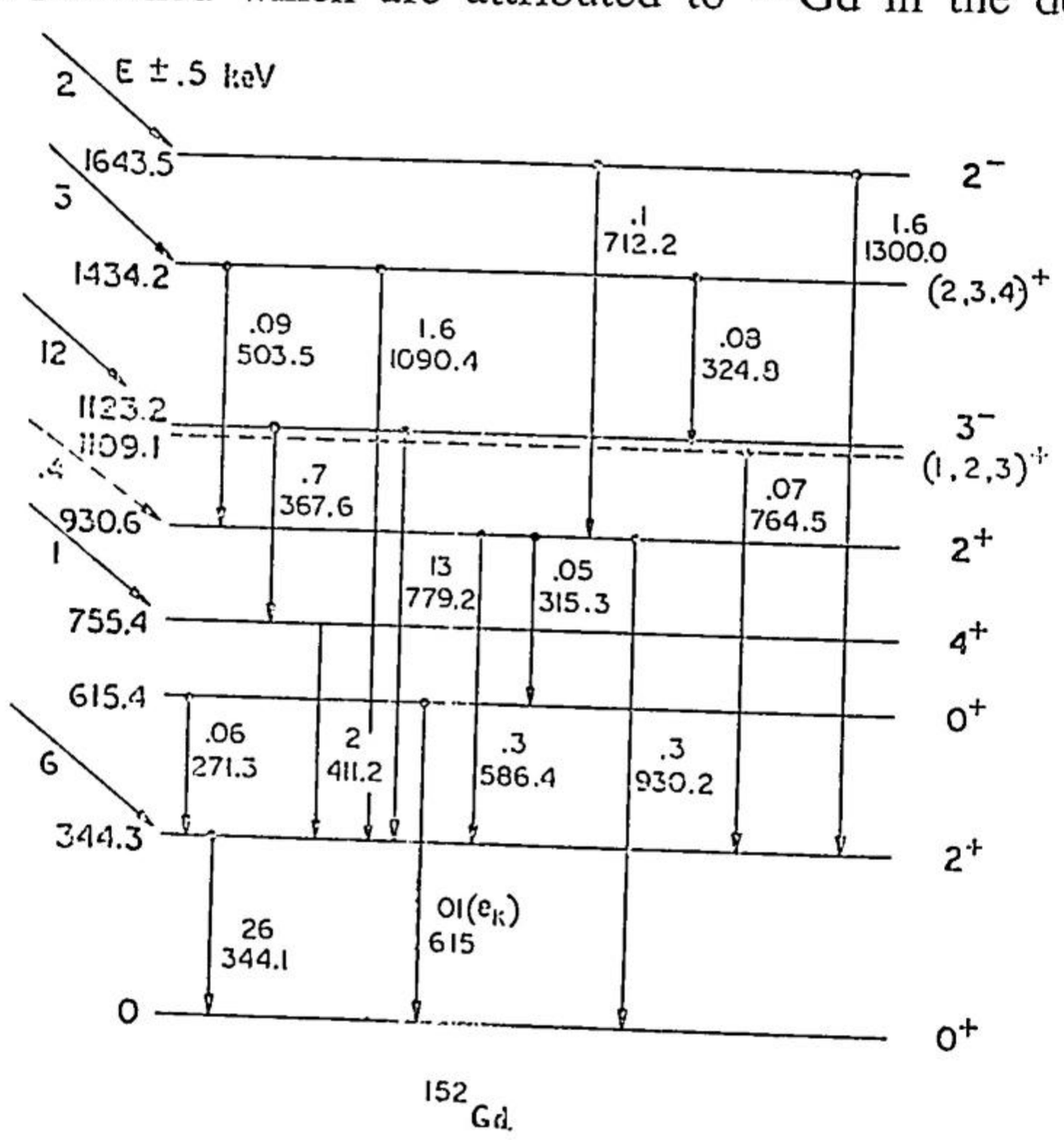


Fig. 1B.6. Level-scheme of ^{152}Gd. The numbers against vertical arrows are gamma ray intensities and energies.

^{152}Eu. The decay-scheme is shown in Fig. 1B.6, which is some what different from the scheme adopted in Nuclear Data Sheet. For the first time the level at 1434 keV is identified and also confirmatory evidence for the 2^+ spin of the 931 keV level is found. A new weak beta group is postulated to end at this level, which has not been found uptill now.

Work covered in sections 1B.5-8 have been made possible by the facilities kindly provided by Prof. A. P. Patro. The ^{152}Eu source was prepared by Dr. R. L. Bhattacharyya, whose help is also gratefully acknowledged.

P. Mukherjee and B. K. Das Mahapatro

1B.9 *DWBA and the 3.12 MeV State in ^{60}Ni*

It has been firmly established that there exists a 3.12 MeV state in ^{60}Ni with spin and parity 2^+. We have measured the (d, d′) angular distribution from this level at $E_d = 11.5$ MeV. It was found that DWBA analysis of the cepted 2^+ spin-parity assignment for this state. This apparent inconsistency and failure of DWBA analysis run contrary to the success normally experienced with (d, d′) data at these bombarding energies and in this mass region. Recently the 3.12 MeV state was excited in ^{58}Ni (t, p) reaction whence it was found that the data could be described only by a suitable linear combination of $l = 2$ and $l = 4$ angular distributions. The same procedure was tried on the 11.5 MeV (d, d′) data and it was found that no permissible combination except $l = 2$ and $l = 4$ described the data satisfactorily. The same combination also fitted the earlier (d, d′) data at 14.8 MeV. Thus with the conclusion that the 3.12 MeV state in ^{60}Ni in a 2^+, 4^+ doublet, DWBA analyses consistently explain both sets of (d, d′) data.

The experimental work was done at A.E.R.E., Harwell.

A. K. Sen Gupta

1B.10 *Life-times in ^{33}P and ^{31}P*

The mean-lives of the first and second excited states of ^{33}P have been measured by the Doppler shift attenuation method as 0.79 ± 0.23 and 1.36 ± 0.17 ps, respectively. The states were excited by (α, p) reaction on ^{30}Si targets. One of the targets was unbacked, yielding a fully-shifted γ-line and the other was backed by a metal, gold and/or tin. The γ-detector (either 7.6 cm. × 7.6 cm NaI(Tl) or 50 cc. Ge(Li) was at 0° and operated in coincidence with the protons

detected near 180° in annular surface barrier detectors. This twin-target particle-gamma coincidence technique has been discussed in details elsewhere (W. M. Currie and C. H. Johnson, *Nucl. Instrm. Meth., 63,* 221, 1968). The work was done at A.E.R.E., Harwell.

(W. M. Currie, L. G. Earwaker, J. Martin and A. K. Sengupta, 'Life-times in ^{33}P and ^{31}P, to be published in *Physics Letters*).

A. K. Sen Gupta

1B.11 *Half-lives of the Excited States of ^{37}Cl, ^{38}A, ^{41}K, ^{88}Sr, ^{131}Xe and ^{186}Os.*

The half-lives of the gamma transitions from the first excited 3^- state to the first 2^- excited state in ^{38}Ar and ^{88}Sr, and from the first $f_{7/2}$ excited state to the ground $d_{3/2}$ state in ^{37}Cl and ^{41}K and also the half-lives of the E2 transitions from the 304 keV level in ^{131}Xe the 137 keV level in ^{186}Os to the respective ground states have been measured, using delayed coincidence technique. Plastic scintillators of 2.5 cm dia × 3 mm thick and 2.5 cm dia × 2.5 cm thick have been employed to detect the beta and gamma radiations, respectively. These detectors are coupled to RCA 7850 photomultipliers. An ORTEC model 263 time-to-ampliture converter and a 512-channel analyser were used.

The radioactive samples of ^{37}S, ^{38}Cl, ^{41}Ar and ^{88}Rb were produced through $^{37}Cl(n, p)^{37}S$, $^{41}K(n, \alpha)^{38}Cl$, $^{41}K(n, p)^{41}Ar$, and $^{88}Sr(n, p)^{88}Rb$ reactions, respectively. The activities of ^{131}I and ^{186}Re were produced through (n, γ) reaction in CIRUS reactor at Trombay.

The half-lives have been determined by the centroid shift method and from the slope of the delayed coincidence curves, whenever possible. Computer programmes have been written for these analyses. The results of measurements are given in Table 1B.11.

Table 1B.11

Nucleus	Level energy (MeV) Initial	Final	Half-life (sec)
^{37}Cl	3.105	0	$(1.56 \pm 0.18) \times 10^{-10}$
^{38}A	3.77	2.17	$(2.2 \pm 0.2) \times 10^{-10}$
^{41}K	1.29	0	$(6.67 \pm 0.1) \times 10^{-10}$
^{88}Sr	2.734	1.836	0.1
^{131}Xe	0.304	0	$(2.8 \pm 0.9) \times 10^{-11}$
^{186}Os	0.137	0	$(0.85 \pm 0.01) \times 10^{-9}$

K. S. N. Murty, B. P. Pathak and S. C. Gujrathi

1B.12 *Study of Magnetic Dipole Transition Probabilities*

A systematic study of the magnetic dipole transition rates in different mass regions have been undertaken. To find the transition probabilities, half-lives of the excited states have been measured by delayed coincidence technique using ORTEC Model 263 time-to-amplitude converter and a 512-channel analyser. The following measurements have been completed and the others are in progress.

Nuclei	Mode of Production	Level	Life-time (ns)
^{75}As	^{76}Ge(n, 2n)^{75}Ge	199 keV	0.75 ± 0.01
	β – ^{75}As	265 keV	< 0.08
^{123}Sb	^{124}Sn(n, 2n)^{123}Sn	160 keV	0.61 ± 0.1
	β – ^{123}Sb		
^{147}Pm	(n, γ) reaction on	91 keV	2.67 ± 0.02
	natural Nd	531 keV	0.132± 0.02
^{199}Hg	^{198}Pt (n, γ) ^{199}Pt	158 keV	1.46 ± 0.03
	β – ^{199}Au		
	Ratio chemically separated from the irradiated natural platinum metal.		

Detailed measurements are being made in the case of the following nuclei. The preliminary results obtained are quite consistent, but need to be checked for suspected activities from impurities or for the interfering radiations from the isotopes other than those of interest.

Nuclei	Mode of Production	Level	Life-time (ns)
^{197}Pt	(n, γ) reaction on	77 keV	1.74
	natural Pt	268 keV	0.14
^{51}V	^{51}V (n, p) ^{51}Ti	320 keV	0.27
	β – ^{51}V		

The delayed concidence data have been analysed using slope and the moment methods. A computer programme has been developed for these analyses.

H. Singh, B. Sethi and K. S. N. Murty

1B.13 *Effect of Two-phonon Coupling on the Isobaric Analog Resonance in ^{206}Pb (p, p′) Reactions*

The structure of the ^{206}Pb (p, p′) isobaric analog resonance curve has been studied in terms of the particle core model. All the six positive parity states in N = 126 – 184 shell have been assumed to couple with the one and two-

phonon quadrupole vibrations of the ^{206}Pb core. As a first step, (d, p) spectroscopic factors in ^{207}Pb have been calculated for the positive parity states and an excellent fit with the experimental results have been obtained from two-phonon coupling scheme (Fig. 1B.7). The one-phonon model fails to reproduce the correct (d, p) spectra. With the two-phonon scheme the states having large inelastic widths are then located from an inspection of the eigen-functions. These are listed in Table 1B.12. From the table it is evident that altogether 31 states are expected to be excited in ^{207}Bi in the ^{206}Pb (p, p′) reactions.

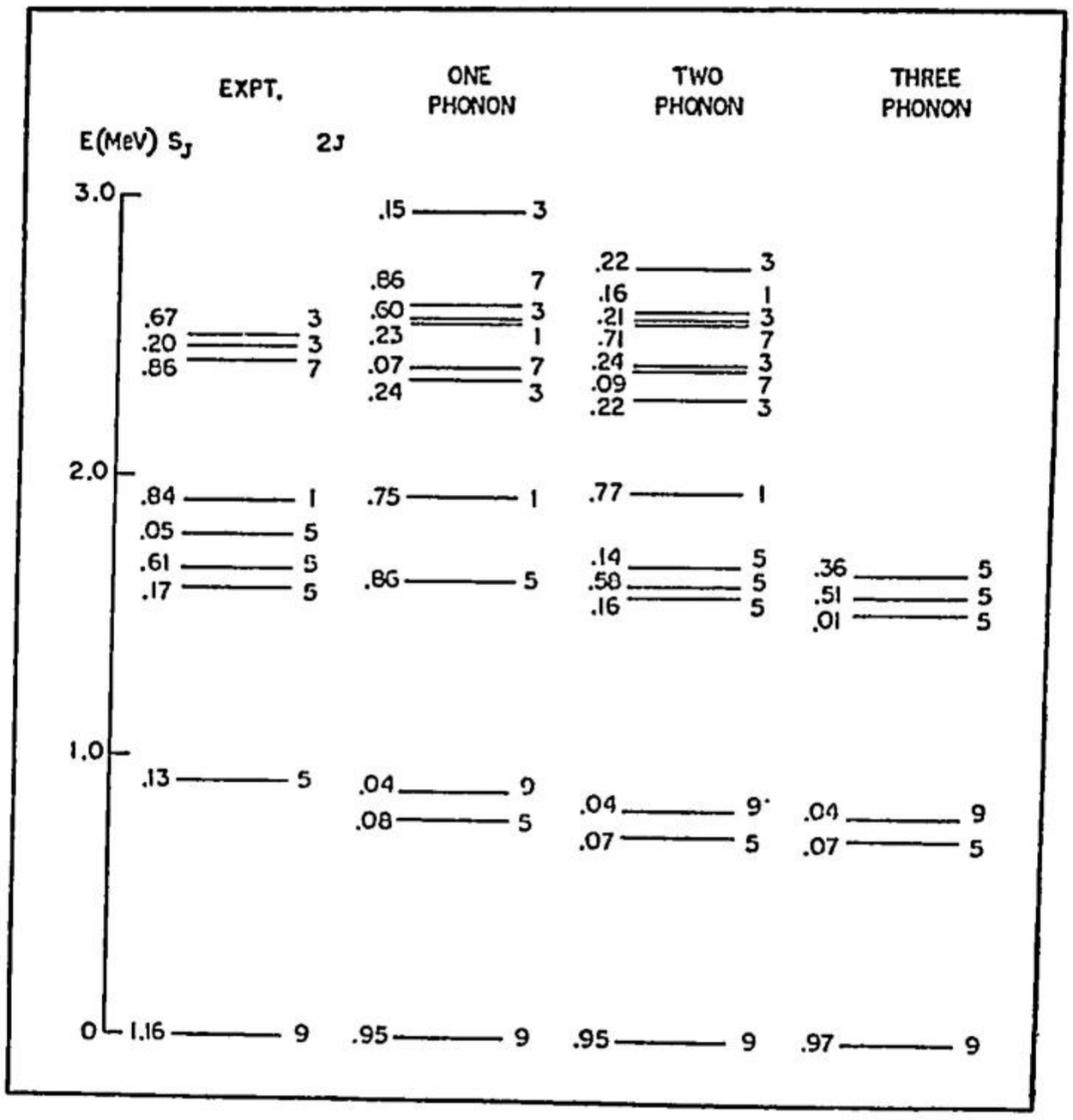


Fig. 1B.7. Theoretical and experimental level spectra and spectroscopic factors for ^{206}Pb (d, p) ^{207}Pb reaction.

Table 1B.12

Isobaric analogue resonance states in ^{207}Pb in the two-phonon scheme

E (MeV)	1J	2 a_{00J}	$a_{12j'}$					
			$j' = g_{9/2}$	$i_{11/2}$	$d_{5/2}$	$s_{1/2}$	$g_{7/2}$	$d_{3/2}$
2.73	$g_{9/2}$	.94	.04	0	0	—	0	—
3.46	$d_{5/2}$	.07	.88	—	0	0	0	0
3.55	$g_{9/2}$	.04	.88	0	0	—	0	—
3.55	$g_{7/2}$	.001	.98	0	0	—	0	0
4.24	$g_{7/2}$	.04	0	.76	.01	—	0	0
4.24	$s_{1/2}$	.04	—	—	.16	—	—	0
4.31	$d_{5/2}$	16	.04	—	.11	0	0	0

Table 1B.12 (Contd.)

4.33	$g_{7/2}$	.01	.01	.13	.07	—	0	0
4.35	$d_{5/2}$	.58	.01	—	0	.01	0	0
4.42	$d_{5/2}$	.14	.06	—	.01	0	0	0
4.68	$s_{1/2}$	.76	—	—	.09	—	—	.02
5.01	$d_{3/2}$	.22	—	—	.04	.03	.12	.01
5.11	$g_{7/2}$	.03	0	.02	.06	—	.06	0
5.12	$g_{7/2}$	.09	0	0	.65	—	0	0
5.12	$g_{9/2}$	.005	0	0	.80	—	0	—
5.13	$d_{3/2}$	.24	—	—	.28	.07	0	.01
5.19	$d_{5/2}$	.03	0	—	.82	0	0	0
5.28	$g_{7/2}$	.70	0	.05	.09	—	.03	.04
5.29	$d_{3/2}$	.21	—	—	.53	.11	0	.01
5.31	$s_{1/2}$	.16	—	—	.67	—	—	0
5.44	$d_{5/2}$	.01	0	—	0	.75	0	0
5.48	$d_{3/2}$	.22	—	—	.01	.50	.01	.01
5.86	$d_{5/2}$	.001	0	—	0	0	.002	.37
5.87	$g_{7/2}$	.03	0	0	0	—	0	.36
5.93	$s_{1/2}$	.01	—	—	.03	—	—	.55
6.00	$g_{7/2}$	.004	0	0	.04	—	.05	0
6.04	$d_{3}/_{2}$	.02	—	—	—	..03	.05	.34
6.03	$s_{1/2}$	.01	—	—	.03	—	--	.23
6.11	$g_{7/2}$	.05	0	0	0	—	.55	.08
6.18	$d_{3/2}$	.06	—	—	0	.02	.62	0
6.07	$d_{5/2}$	.004	0	—	0	.08	.04	.19

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

1B.14 *Nilsson Orbital Mixing in the Gd-Region*

The Nilsson wave-functions were derived under a simplifying assumption that $N = (2n+1)$, the total oscillator quantum number is a good quantum number. However, there will be matrix elements of the type $<N\pm2, j_z|r^2\ Y_{20}|Nj_z>$, which will mix N – state with $N\pm2$ states. These are neglected in Nilsson's work. Recently such N–mixing between $|6\text{-}3/2+>$ and $|4\text{-}3/2+>$ states are experimentally observed from the stripping reactions in the Dy region. In order to investigate this point the Nilsson Hamiltonian is diagonalised for all the orbitals with a basis

$$|j_z> = \sum_N |Nj_z> \text{ with}$$

$$N = 0, 2, \ldots\ldots 8 \text{ for positive parity}$$

$$\text{and } N = 1, 3, \ldots\ldots 7 \text{ for negative parity}$$

In the rare-earth region the inclusion of the N = 7 and 8 states are found to be extremely crucial. It is found that the wave-functions calculated with this basis have a very good overlap with those calculated from Saxon-Wood deformed potential (Table 1B.13). The effect of the N-mixing in Nilsson orbital is shown in Fig. 1B.8, where original Nilsson levels and those with N upto 6 and 8 mixing are shown. A close scale plotting of the two 3/2+ orbitals [402] 3/2+ and [651] 3/2 + is shown in Fig. 1B.9 at the region of crossing. The remarkable narrow band of change over is apparent from the plot of eigen-functions against δ, the deformation.

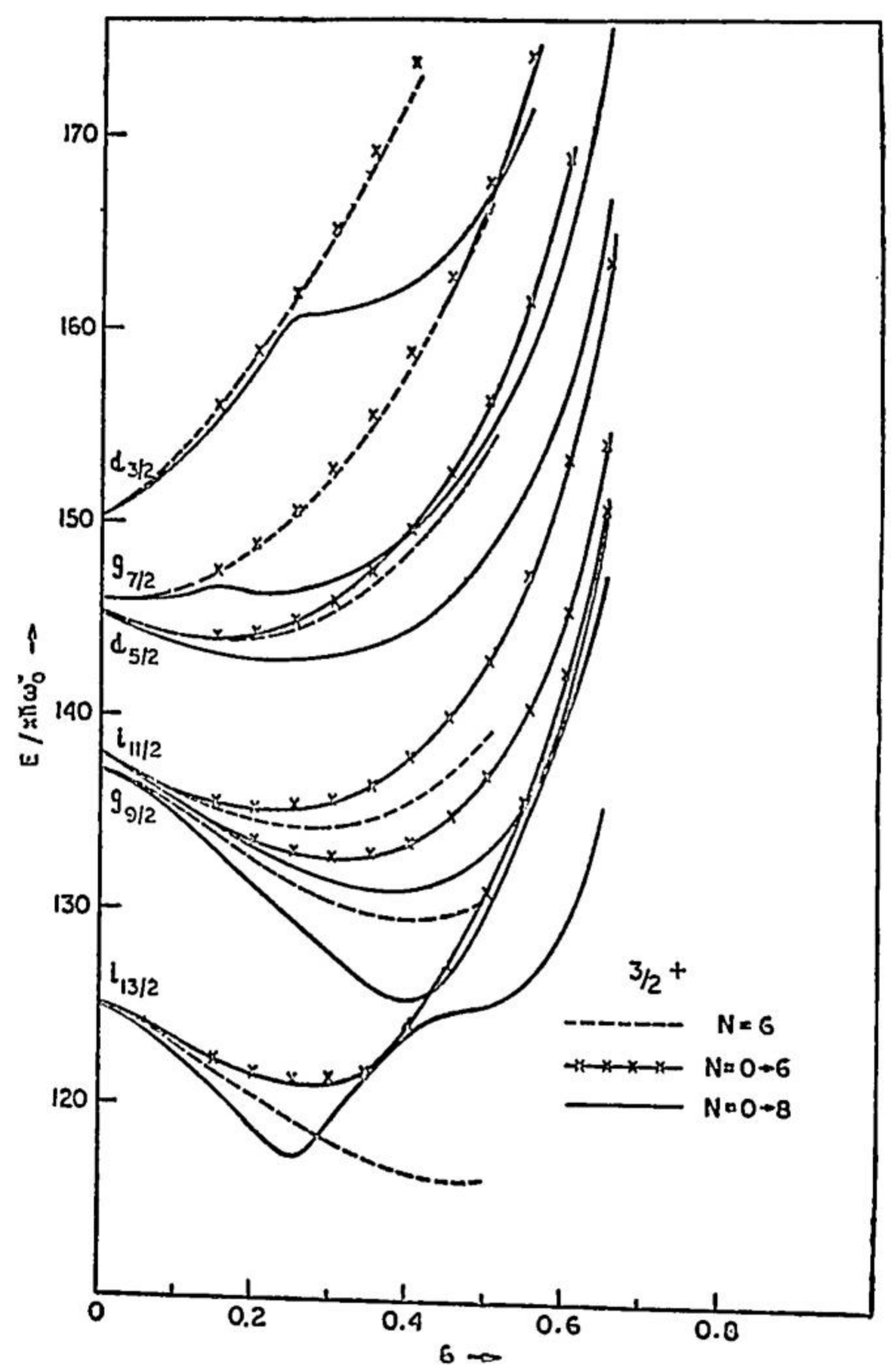


Fig. 1B.8. The Nilsson diagram for j = $3/2^+$ states in the N = 6 shell and the effect of N–mixing.

Table 1B.13
Comparison of Nilsson wave-functions for the ($i_{13/2}$, $3/2^+$) state

			C_j ($\delta = 0.20$)		
N	l	j	H.O. (Present work)	S.W. (Nemirovskii)*	(Nilsson)
8	8	17/2	0.278	0.214	
8	8	15/2	–0.023	–0.032	
8	6	13/2	–0.132	0.799	
6	6	13/2	0.866		0.957
8	6	11/2	0.020	–0.065	
6	6	11/2	–0.048		–0.052
8	4	9/2	0.058	–0.530	
6	4	9/2	–0.326		–0.277
4	4	9/2	–0.181		
8	4	7/2	–0.011	–0.056	
6	4	7/2	0.029		0.024
4	4	7/2	0.071		
8	2	5/2	–0.019	0.155	
6	2	5/2	0.074		0.052
4	2	5/2	–0.048		
2	2	5/2	0.015		
8	2	3/2	–0.004	–0.040	
6	2	3/2	–0.011		0.007
4	2	3/2	–0.008		
2	2	3/2	0.001		

* *Soviet Journal of Nucl. Phys., 3,* 730, 1966.

P. Mukherjee and G. Ramakrishna

1B.15 *El Transitions with N-mixed Nilsson Orbitals*

The effect of the N-mixed Nilsson wave-functions (see previous section) on electromagnetic transition rates, gyromagnetic ratios, RPC-calculation, N-forbidden beta decay F^{τ}–values and stripping widths will be noticeable. To start with, we have investigated the El transition rates, which are remarkably well explained by the original Nilsson wave-functions. We have studied about twenty El transitions in different odd mass deformed nuclei, where the Nilsson orbitals are well determined. Result of a typical analysis is shown in Table 1B.14. In all the cases we have studied, there is noticeable changes in the G(El) values

from the original values calculated with simple unmixed wave-functions. This indicates that N-mixing of Nilsson orbitals has very important effect on the El-transition rates.

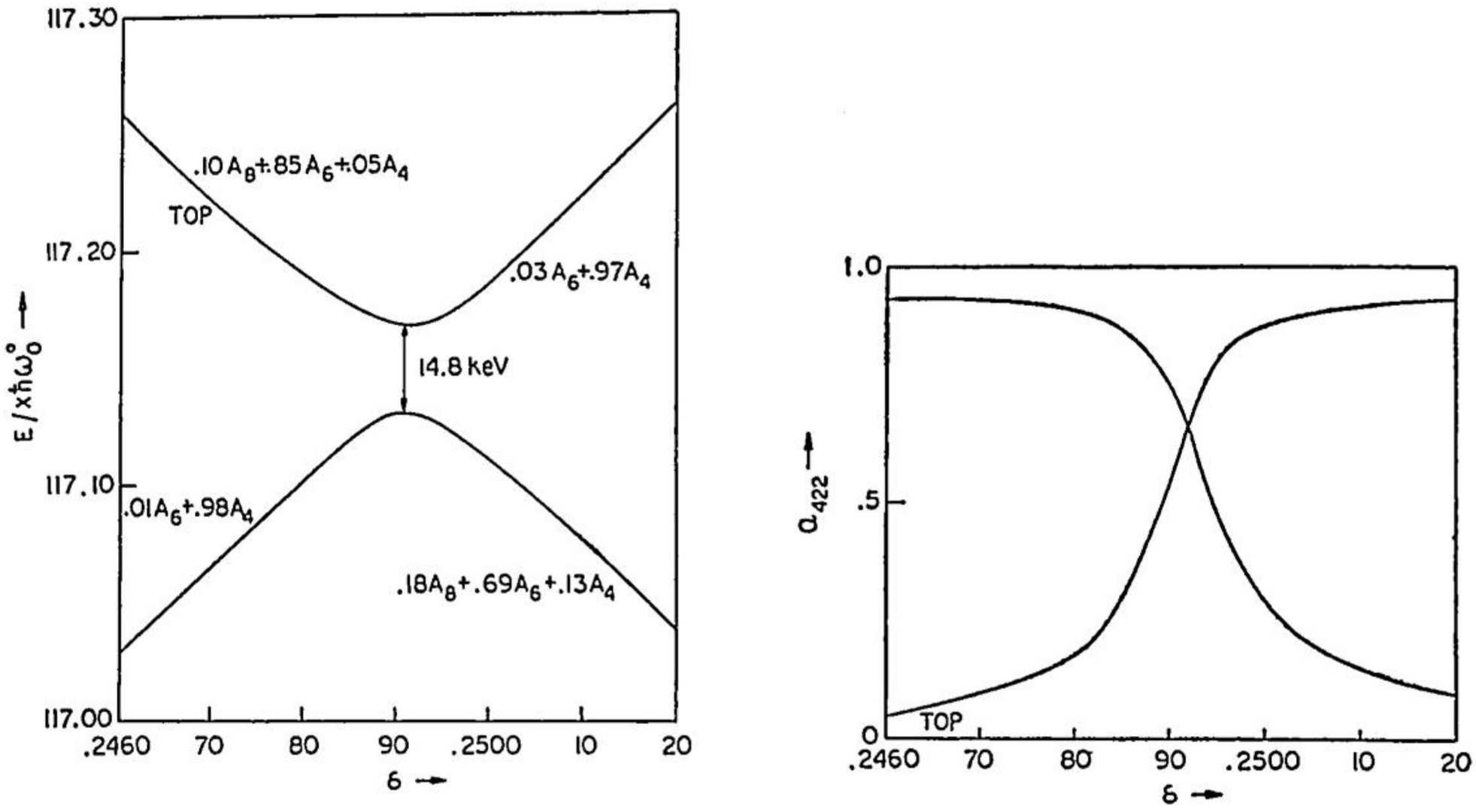


Fig. B.9. Nilsson diagram for the $3/2^+[402]$ and $2/3^+[651]$ levels near the region of crossing. The contributions from different N-shells in the wave-function are indicated against the level. The narrow changeover of the wave-function is indicated in the top diagram.

Table 1B.14
G (El) with N-mixed Nilsson wave-function

($\delta = 0.25$)

Nilsson Orbit No. ($j_z\pi$)	Nl Λ	$\alpha_{Nl}\Lambda$	Nilsson $\alpha_{Nl}\Lambda$	$\langle N'\|N\rangle$	G(El)
35 (7/2⁻)	773	.2213	—	$\langle 3\|4\rangle$	–.0176
	753	.0477	—		
	733	.0073	—		
	774	.0745	—	$\langle 5\|4\rangle$	–.0111
	754	.0022	—	$\langle 5\|6\rangle$	.0071
	553	.9009	.9394		
	533	.1723	.1822	$\langle 7\|6\rangle$	.0002
	554	.2965	.2903		
	333	–.1178	—	$\langle 7\|8\rangle$	.0001
25 (7/2⁺)	883	.0045	—	ΣG(El)	= –0.0213
	863	.0021	—		
	843	.0006	—		
	884	–.0175	—	G(El) (Nilsson)	= –0.0081

Table 1B.14 (continued)

864	.0026	—
844	.0040	—
663	.0349	—
643	.0062	—
664	–.1239	—
644	.0575	—
443	.2113	.2038
444	–.9670	–.9790

P. Mukherjee, G. Ramakrishna and I. Mukherjee

1B.16 *Studies on the Odd Mass Ag and Sb Isotopes in the Unified Model*

The low lying excited states of 107, 109 and 111-Ag isotopes have been explained on the basis of intermediate coupling approach of the unified model. It is assumed that the low lying states of Ag isotopes have a structure formed by the coupling of a proton to the quadrupole vibrations of the corresponding even-even Pd nucleus. The core states up to three phonons have been considered in the calculation. The phonon energy $h\omega/2\pi$ is taken as the energy of the first excited state of the neighbouring even-even Pd isotope. The proton states assumed are $2p_{1/2}$, $2p_{3/2}$ and $1f_{5/2}$, $2p_{1/2}$ state has been treated as the ground state and the energies of the other states are measured with respect to it. The energies of the $2p_{3/2}$ and $1f_{5/2}$ states with respect to $2p_{1/2}$ state and the coupling strength are treated as variable parameters to get the fit with the experimentally observed energy states. The fit has been observed with the following parameters.

Isotope	Core	$h\omega/2\pi$	$E_{3/2}$ — $E_{1/2}$	$E_{5/2}$ — $E_{1/2}$	ζ
^{107}Ag	^{106}Pd	0.5117 MeV	0.70 MeV	1.5 MeV	1.7
^{109}Ag	^{108}Pd	0.4339 MeV	0.65 MeV	1.4 MeV	1.5
^{111}Ag	^{110}Pd	0.373 MeV	0.60 MeV	1.3 MeV	1.3

The model has also been applied to odd-mass antimony isotopes from $A = 117$ to $A = 125$ and encouraging results have been obtained. The single particle states available to the extra-core proton are considered to be $2s_{1/2}$, $1g_{7/2}$, $3s_{1/2}$ and $2d_{3/2}$. The energy of the $2d_{5/2}$ state has been taken as zero and all the other energies are measured with respect to it. The energies of the states $3s_{1/2}$ and $2d_{3/2}$ are the same as used by Pinho *et. al.* (*Nuclear Physics, 116*, 408, 1968) $E_{7/2}^{+}$ has been varied from 0.55 MeV to 0.35 MeV. The phonon ener-

gies $h\omega/2\pi$ have been taken from the neighbouring even-even tin nuclei with mass number one unit less. The coupling strength ζ has been treated as a variable parameter. The core states up to two phonons have been considered.

B. P. Pathak, S. C. Gujrathi and S. K. Mukherjee

1B.17 *Analysis of High Resolution Gamma Ray Spectra*

A computer programme has been developed for the analysis of gamma ray spectra taken with Ge(Li) spectrometers. The spectra taken with Ge(Li) detectors have very narrow peak structures superposed on slowly varying compton continuum. This slowly varying base line can be assumed to be a smooth curve or sometimes even linear. For analysis the spectrum is divided in these two significant parts, i.e., (i) slow varying part (base line) and (ii) narrow peaks. To determine the most probable base line in a selected region of the spectrum a least square fit by orthogonal polynomials is made using all the points in the region except those included under the peak. The bound put on the degree of the polynomial to be tried at present is 15 which can be varied if needed; the program stops at the degree needed to fit the base line. The calculated base line points are subtracted from the actual spectrum to get isolated peaks.

The peaks have been fitted using the relation (Harvey and Stevens, ORNL—4082)

$$y = h\left[\frac{2}{e^{-(x-x_0)/s(1+\alpha)} + e^{(x-x_0)/s(1-\alpha)}}\right]^2$$

where h = approximate height of the peak, X_0 = approximate centre of the peak and α is the asymmetry parameter. A peak is considered to cover the portion of the spectrum from $(1+\alpha)W$ below X_0 to $(1-\alpha)W$ above X_0. S is determined from the full width at half maximum W using the relation

$$W = 1.763\ S(1-0.44\ \alpha^2).$$

The area under the peak has been calculated using the relation

$$\text{Area} = 2\ hS\ (1-\alpha^2).$$

The energies and the relative intensities are determined using the detection efficiency and the calibration of the spectrometer. Improvements in the programme are being done to avoid fictitious peaks and also to find exact energy and relative intensity of the weak γ-rays.

B. P. Pathak and S. K. Mukherjee

1B.18 *Fast Coincidence with Tunnel Diode*

A fast coincidence unit using tunnel diodes and fast transistors has been developed to operate the gate circuit of ORTEC model 263 time-to-amplitude coverter. The positive pulse of 0.3 volts derived across a small load in the plate of a cathode follower, whose output operates as start-stop pulses for the TAC, is used to trigger the coincidence unit. The tunnel diode pulse shaper and coincidence circuit can produce a positive pulse of 20 ns with a rise time of 0.25 ns. The coincident output is further amplified in a two stage pnp-npn cascade, which in turn operates an emitter follower to produce a positive 2 volt 25 ns pulse suitable for the gate input of the TAC. The tunnel diode circuits are all ac coupled as suitable tunnel diode and coupling diode could not be obtained. The overall operation and the rise time are expected to improve when these diodes will be available.

Study on the pulse duration and resolving accuracy of coincidence is in progress. Time-resolution in TAC for life-time measurement will be recorded to observe consequent improvements.

S. C. Mukherjee and S. K. Mukherjee

1B.19 *Development of HV Multiplier Circuit for the Focussing Supply*

Silicon rectifier is now being increasingly used in the construction of HV multiplier. The present convention is to use high resistance and HV condenser in in shunt across Si-rectifier in order to protect it from occasional surge voltages in the accelerating column. Cost of these additional components and the resultant bulky volume have been avoided in the development of HV multiplier with chain of Si-rectifiers (1S557) in series, which is now under progress. Distribution of of potential drop in the forward direction and histogram of the spread of C-value of the junction have been studied on a batch of rectifiers in order to isolate those rectifiers having different parameters due to production spread. This has been done in order to equalise the diode inverse voltage and drop in the forward direction for all the diodes in a series. Fast and compact protecting device against surge will be incorporated in the final design.

Simultaneously, another HV 8-stage multiplier cascade to give an output of 32kV at 5 mA is being constructed with high power silicon (avalanche) rectifier. The inherent property of such rectifiers to withstand large short duration reverse break-down current has been considered suitable for such application. Besides, the very large forward peak-current carrying capacity is advantageous, as a 48 kohm resistance in series with 10 diodes in each of the 8 multiplier stages can limit the flow of large current when the load resistance is

reduced, although at normal operating condition with low current the drop in 48 kohm resistance is quite small. The series resistance is expected to protect the rectifiers in the event of large reverse current flow. This unit is suitable for operation with an input of 3 kV, 400 c/s supply.

M. K. Sengupta and S. C. Mukherjee

1C. NUCLEAR CHEMISTRY DIVISION

1C.0 *Introductory Remarks*

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

We have been trying to take up the following lines of approach and it is a pleasure to note that considerable progress has been made during this year. As regards analytical chemistry considerable progress has been made to estimate microgram amounts of substances in natural sources through radiometric procedure. Effect of interfering ions has been thoroughly studied so that the particular analytical procedure that has been developed may find applications in minerals and alloys. In consideration of time and simplicity, this type of work can remove the tedium of classical operations. Estimation by pseudo-isotopic dilution method, as developed by us previously, has been successfully applied to elements whose compounds do not give convenient primary standard. As regards activation analysis it is well known that when we deal with a long-lived active isotope, sensitivity of the method is not sharp in consideration of the limit of time for period of bombardment. A quantitative preconcentration of the trace element that has to be analysed has been developed in some cases dealing with long-lived activity.

The uptake of radioactive nuclei through mixed crystal formation and other method of uptake have been pursued here since 1955. Because of the importance of inorganic exchangers this type of study has been very popular all over the world. The interesting observations and the mechanism which we postulated in certain systems have been found in good agreement with recent studies in other laboraotries. We have applied this principle to interesting aspects of classical inorganic and physical chemistry. Separation in laboratory scale through this principle is also under rigorous study. A method has been developed to examine whether the uptake in anomalous mixed crystal formation is through equivalent charge displacement or through double salt formation. The method of study of transition temperature which has been developed by us is finding application in various unknown systems.

Study with low level radioactivity is also being pursued. The present interest lies in the radiochemical study of the products of spontaneous fission.

For the last a few years we have been working in a mild scale in radiation chemistry. A radiation source at our own disposal is essentially desirable. The technical physics group started constructing an X-ray unit to meet our temporary demand. But it is still under the process of perfection. Ultimately we shall have to procure a multicurie Cobalt-60 source to pursue this interesting line of study.

We are thankful to the biology division of Bhabha Atomic Research Centre, Bombay, Chittaranjan Cancer Hospital, Calcutta and to the biophysics division of our Institute for giving us the facilities of irradiation for studies in radiation chemistry.

B. C. Purkayastha

ANALYTICAL AND SEPARATION CHEMISTRY

1C.1 *Radiometric Estimation of Silver in Galena*

In our previous investigation it has been found that by radiometric procedure γ – order of certain elements can be estimated even in presence of interfering ions. The results of our study as regards estimation of palladium, silver and iodide with ^{131}I and zirconium and hafnium as pyrophosphate using ^{32}P as indicator in presence of interfering ions have been reported. It was pointed out that these rare elements can be estimated in ores and alloys.

Estimation of silver by radiometric procedure in galena was undertaken. Milligram amounts of galena (25 mg to 75 mg) were taken in a 25 ml beaker and heated with 3 : 1 HNO_3 till black colour disappeared. It was finally evaporated on water bath to dryness to drive out HNO_3. was then treated with 10 ml of 0.5 N H_2SO_4 and excess of a known quantity of labelled iodide as KI was added. Silver iodide formed is co-precipitated with zirconium phosphate. A single operation does not require more than one and half hour. Results of analysed galena have been found in good agreement. In consideration of simplicity of the procedure, the method can be applied in samples of industrial importance. A few typical results are given below (Table 1C.1).

Table 1C.1

Micro-estimation of silver in galena with ^{131}I

Galena taken in mg	Silver present in galena in mg	Silver found in galena in mg	Standard deviations of activity measurements,
			per cent
75.2	0.05564	0.05478	± 1.8
50.1	0.03707	0.03728	± 0.8
28.4	0.02102	0.02205	± 4.9
25.1	0.01858	0.01932	± 4.1

Usha Purkayastha and H. P. Maity

1C.2 *Radiometric Estimations Using Labelled Pyrophosphate*

Radiometric estimation of zirconium and hafnium by labelled pyrophosphate has been further extended. It has been found that the method is specific for tetravalent ions only. Other valence states do not interfere in the estimation. The only tervalent ion which interferes is scandium which is, however, of rare occurrence. The procedure can therefore be applied to the analysis of samples of industrial importance.

Usha Purkayastha and H. P. Maity

1C.3 *Analysis by So-called Pseudo Isotopic Dilution Method*

It is well known that there is no suitable primary standard for determining Sc-activity by the method of isotopic dilution. Seandium is also costly. So a no isotopic diluent like calcium as was done by us in the determination of rare earth activity has also been found very suitable for determining the scandium activity in the solid way. Scandium activity is taken in a beaker, a known amount of calcium is added and it is precipitated by adding hydrofluoric acid in presence of alcohol. The medium is maintained at pH 2–3 by addition of ammonium acetate and acetic acid. The precipitate is boiled for some time. It is washed through centrifugation in the usual way and a portion is then transfered into a counting tray. Sc-activity is carried cent per cent and it is uniformly distributed. Any fraction of calcium fluoride precipitate represents the same fraction of scandium activity: Typical data on different amounts of calcium taken are given in Table 1C.2. A glance at the table will show that the method is very dependable. This has been developed for final estimation of scandium activity by neutron activation.

Table 1C.2

Estimation of calcium using ^{46}Sc by the method of isotopic dilution

Calcium taken in gm	Calcium found in gm	Error (%)
0.3517	0.3486	−0.902
0.4690	0.4702	+0.255
0.5862	0.5721	−2.405
0.7035	0.6996	−0.529

B. C. Purkayastha and N. R. Das

1C.4 *Analysis by Neutron Activation*

Estimation of scandium in minerals like zircon, monazite and beryl has been taken up last year. The method of concentrating scandium with ^{46}Sc has also been developed from these minerals. Final recovery yield does not exceed 90%. As a result, for accurate estimation, application of carrier-free scandium has been thought of. Scandium like ^{48}Sc produced by n, p reaction on ^{48}Ti is therefore a suitable choice because of its convenient short half-life. There is, however, no simple method for this separation procedure. It has been found that titanium metal dissolves easily in hydrofluoric acid. The acidity of this solution is neutralised by ammonia and pH is adjusted to 2-3 by adding ammonium acetate and acetic acid. Finally, the tracer is taken up along with calcium fluoride for complete removal of titanium. Calcium fluoride is dissolved in hydrochloric acid and reprecipitated as calcium fluoride under the same conditions. The precipitate is washed with dilute hydrofluoric acid and acetic acid mixture.

The precipitate is dissolved in perchloric acid and the solution is heated to fumes to drive out hydrofluoric acid. The solution containing carrier free ^{48}Sc is then ready for the study of the extent of recovery of scandium from the minerals mentioned above. All operations do not require more than 3-4 hours. It is expected that the final estimation of scandium will be completed within a few months.

B. C. Purkayastha and N. R. Das

1C.5 *Analysis of Rubidium : Cesium Ratio in Natural Sources by Neutron Activation*

It is known that molasses and plant products contain a considerable amount of potassium. An easy method of quantitative separation of cesium from molasses has already been described (Annual Report, 1967) with the aid of cesium tracer. Attempts are being made for finding out an easy method so that rubidium : cesium ratio from these sources can be estimated by β-counting in the usual way after neutron activation.

B. C. Purkayastha and S. Aditya

1C.6 *On the Study of Low Level Radioactivity with Special Reference to Spontaneous Fission*

It has been found that methods of separation that have been described in literature with reference to radioactive fission products associated with spon-

taneous fission, require further study and modifications. Low level counting device has also been improved. Data dealing with the study is expected to be reported next year.

B. C. Purkayastha and D. K. Bhattacharyya

STUDY OF UPTAKE THROUGH MIXED CRYSTAL FORMATION AND ITS VARIOUS APPLICATIONS

1C.7 *A Method for Determining Transition Temperature Through Mixed Crystal Formation. Determination of Transition Temperature of* $MnSO_4,8/3H_2O$

It has been previously reported by us (*J. Inorg. Nucl. Chem., 28,* 347, 1966) that a new method has been developed for determining transition temperatures with radioactive isotopes. The component whose transition temperature is to be determined is at tracer level and does not manifest its existence as such but gives its evidence through mixed crystal formation. Study of distribution coefficient of a morphologically analogous host having a greater range of stability with the guest at tracer level gives a prominent break at the transition temperature of the guest component. This new method has been applied this year in the study of determining the transition temperature of unknown $MnSO_4,8/3H_2O$. Cadmium sulphate ($CdSO_4,8/3H_2O$) has been taken as the host and ^{54}Mn is taken as the guest. The constancy of distribution factor gives a strong evidence that manganese also forms a vitriol similar in composition to that of $CdSO_4,8/3$ H_2O. The distribution factors (D), were determined at various temperatures and the results are shown in Fig. 1C.1. It is evident from the figure that the transition of $MnSO_4,8/3H_2O$ takes place at 31° ± 2°C. It will not be out of place to point out that this type of study, as has been done by us, not only shows the existence of an unknown compound but it also provides the range of stability of the unknown component in question.

Question naturally arises as to whether we can gather more information from the distribution study so that feasibility as regards the isolation of the unknown $MnSO_4,8/3H_2O$ in favourable circumstances can be made possible. It is known that by setting favourable experimental devices the metastable compounds like monoclinic $ZnSO_4,7H_2O$ (*J. Chem. Soc., 125,* 2538, 1924), Na_2SO_4, $7H_2O$ (*J. Am. Chem. Soc., 60,* 754, 1938) have been isolated and such attempts in the unknown system as mentioned can also be undertaken if some qualitative picture as regards the solubiiity of the compound from distribution factor can be envisaged.

Ratner has argued (*J. Chem. Phys., 1,* 789, 1937) that in a saturated solution ratio of the activity co-efficient of the tracer and the carrier may approximately be taken as unity. This is true in case of a system where one of the

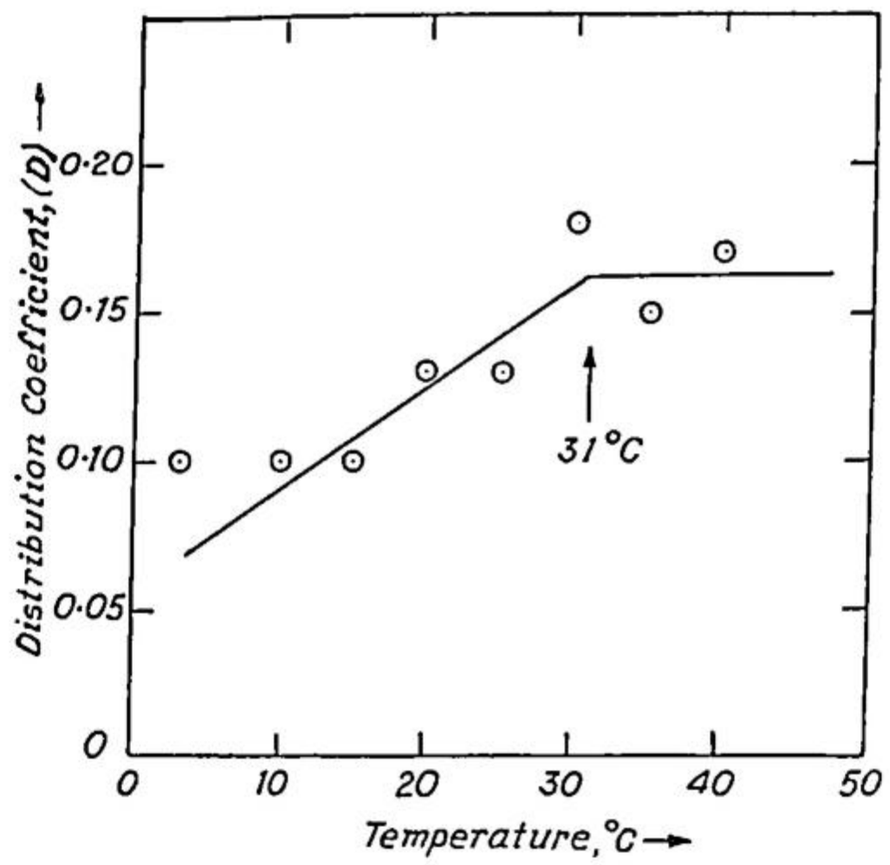


Fig. 1C.1. On the study of the transition point of 3 $MnSO_4$. $8H_2O$ through distribution studies between 3 $CdSO_4$. $8H_2O$ as host and Mn^{54} as guest. (Concentration of cadmium in the saturated solution at 35°C was 3.14M and that of natural manganese was $1.0\times^{-3}$ M in 0.5N H_2SO_4).

isotopes of the same element constituting the metal ion acts as the tracer. Further we go from this ideal state as regards chemical analogy, further deviation in the value of the ratio from unity is not unexpected. The systems under investigation are, however, chemically analogous. Too much deviations are therefore not likely to be expected. In such circumstances, molal solubility ratios will be of the same order of magnitude as that of distribution co-efficient. Some of the molal solubility ratios both in known and in the systems where guest compopents are unknown with their distribution co-efficients are given in Table 1C.3. A glance at the known systems will reveal that a qualitative relation exists between solubilities and distribution factors. This qualitative picture is also of great help in the isolation of unknown compounds. Solubilities of the unknown vitriols have been deduced from the partition values. From the data given in the above table it can be anticipated that favourable experimental conditions for the isolation of orthorhombic $CoSO_4,7H_2O$ may some day be made possible. As regards orthorhombic $MnSO_4,7H_2O$ the solubility in question as deduced from distribution measurements seems to be so high that it may never be possible to isolate it in a pure state. Even $MnSO_4,8/3H_2O$ whose solubility is deduced from distribution measurements seems to be much more soluble than the other hydrates which are stable in between this temperature range (Fig. 1C.1). The isolation, thus, may not be practicable. As regards the second variety of mono-

clinic heptahydrated zinc sulphate and cobalt sulphate, solubility factor does not stand so much on the way. It is probably highly metastable with respect to the stable variety.

From what has been mentioned above it should be pointed out that study of the transition temperature by the distribution method as developed by us, not only gives us evidence on the stability range of the component but it also gives us a valuable parameter like solubility which helps towards the isolation of the compound in question.

Table 1C.3

Relations between homogeneous distribution co-efficient and the ratio of the solubilities of the host and guest component

System	Composition of the solid phase in equilibrium with the saturated solution	Temp. (°C)	Solubility as anhydrous sulphate (moles per 1000gm H_2O)	Ratio of solubility.	Solubility of the guest component as predicted from distribution measurements in case of metastable or unknown compounds (As anhydrous sulphate in moles per 1000 gm H_2O)	D.
Barium sulphate	$BaSO_4$	20°	10.6×10^{-6}	1.63		1.8
Radium sulphate	$RaSO_4$		6.5×10^{-6}			
Ferrous sulphate	$FeSO_4$, $7H_2O$ (Monoclinic)	45°	2.524	0.809		0.77
Cobalt sulphate	$CoSO_4$, $7H_2O$ (Monoclinic)		3.122			
Ferrous sulphate	$FeSO_4$, $7H_2O$ (Monoclinic)	7°	1.238			
Cobalt sulphate	$CoSO_4$, $7H_2O$ (Monoclinic)		1.66 (Stable monoclinic variety)		1.996	0.62
Magnesium sulphate	$MgSO_4$, $7H_2O$ (Orthorhombic)	7°	2.259			0.783
Cobalt sulphate	$CoSO_4$, $7H_2O$ (Orthorhombic)				2.885	
Magnesium sulphate	$MgSO_4$, $7H_2O$ (Orthorhombic)	35°	3.33	0.83		0.60
Zinc sulphate	$ZnSO_4$, $7H_2O$ (Orthorhombic)		4.012			
Ferrous sulphate	$FeSO_4$, $7H_2O$ (Monoclinic)	20°	1.380	0.369		0.18

Table 1C.3 (Contd.)

Zinc sulphate	$ZnSO_4$, $7H_2O$ (Monoclinic)		3.739			
Ferrous sulphate	$FeSO_4$, $7H_2O$ (Monoclinic)	35°	2.15			
Zinc sulphate	$ZnSO_4$, $7H_2O$ (Monoclinic)				9.80	0.219
Ferrous sulphate	$FeSO_4$, $7H_2O$ (Monoclinic)	7°	1.238			
Manganous sulphate	$MnSO_4$, $7H_2O$ (Monoclinic)		3.639	0.34		0.115
Magnesium sulphate	$MgSO_4$, $7H_2O$ (Orthorhombic)	7°	2.259			
Manganous sulphate	$MnSO_4$, $7H_2O$ (Orthorhombic)				21.72	0.104
Cadmium sulphate	$CdSO_4$, 8/3 H_2O (Monoclinic)	25°	3.273			
Manganous sulphate	$MnSO_4$, $8/3H_2O$ (Monoclinic)				26.18	0.125
Sodium sulphate	Na_2SO_4, $10H_2O$	5°	0.40			
Sodium sulphate	Na_2SO_4, $7H_2O$	5°	1.37			

B. C. Purkayastha and S. Sarkar

1C.8 *On the Study of Tetrahydrated Double Sulphate of Tervalent Elements with Radioactive Indicators*

In continuation of our study on the tetrahydrated double sulphate of tervalent elements, distribution measurements with $(NH_4)Ce(SO_4)_2, 4H_2O$ and $(NH_4)Tl(SO_4)_2, 4H_2O$ as hosts and radioactive isotopes like ^{46}Sc, ^{114}In, $^{55+59}Fe$, $^{152+154}Eu$, ^{160}Tb, ^{170}Tm, ^{90}Y and ^{210}Bi as guests have been carried out in considerable details. From a large number of observations, conclusion has been arrived at that the former host takes up $^{152+154}Eu$, ^{160}Tb, ^{170}Tm, ^{90}Y and ^{210}Bi tracers through mixed crystal formation, and ^{46}Sc, ^{114}In and $^{55+59}Fe$ tracers through adsorption. The thallic host, on the other hand, takes up scandium indium and ferric iron through mixed crystal formation whereas europium, terbium, thulium, yttrium and bismuth are taken up by adsorption. The study gives a clear evidence on the existence of two series of tetrahydrated double sulphates of tervalent elements. Tetrahydrated double sulphate of aluminium, scandium, indium, ferric iron and thallic thallium fall into one group and those of rare earths and rare earth analogues like yttrium and bismuth belong to another group. Mixed crystal formation does not take place between the members of these two groups both at finite and tracer concentrations of the guest ions. Inference has therefore been drawn that the formation of tetrahydrated double sulphate is a general characteristic of tervalent cations.

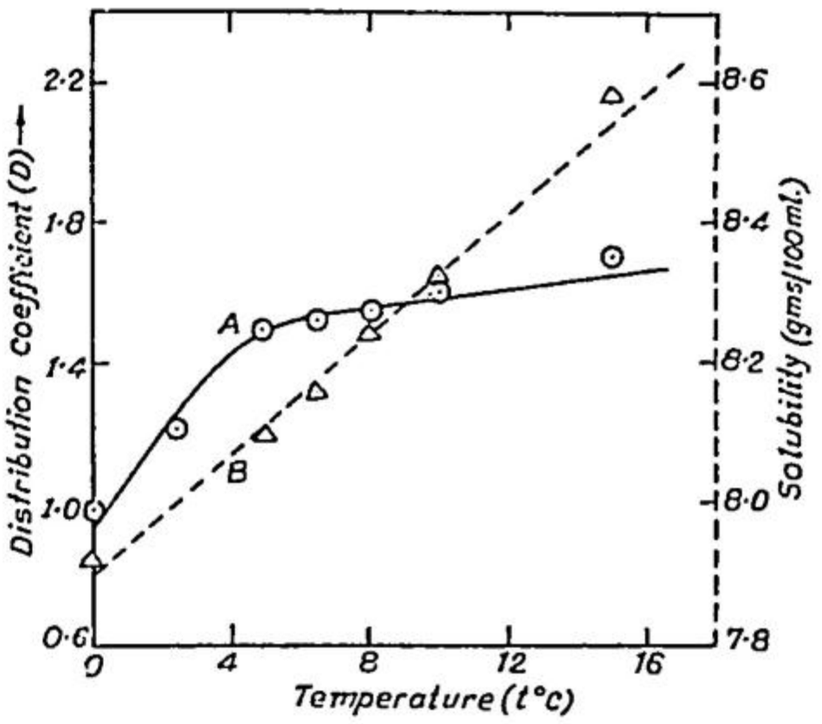


Fig. 1C.2. Curve A: Study of distribution co-efficient (D) of ^{46}Sc as guest and (NH_4) Tl $(SO_4)_2$. $4H_2O$ as host at different temperatures. Curve B: solubility of (NH_4) Tl $(SO_4)_2$. $4H_2O$ in 9N H_2SO_4 at different temperatures.

Attempts have been made on the isolation of the thus far unknown tetrahydrated double sulphate of scandium and ferric iron. It was found that the transition temperature of the tetrahydrated double sulphate of scandium lies in the neighbourhood of 5°C (Fig. 1C.2) and the compound in question is metatastable with respect to the anhydrous double sulphate. A sample of $(NH_4)Tl(SO_4)_2,4H_2O$ containing ~ 14 mol% of $(NH_4)Sc(SO_4)_2,4H_2O$ has been isolated at 3°C. $(NH_4)Tl(SO_4)_2,4H_2O$ containing ~ 11.4 mol% of the corresponding ferric iron has also been isolated. It has been argued that disulphato ions take the role of uptake.

Publication :

B. C. Purkayastha and D. K. Bhattacharyya, *J. Ind. Chem. Soc., 45,* 583, 1968.

B. C. Purkayastha and D. K. Bhattacharyya

1C.9 *Charge Displacement in Case of Anomalous Mixed Crystal Formation in Co-precipitating Systems*

The suggestion by Gordon (*Talanta, 10,* 351, 1963) that in anomalous mixed crystal formation it is better to express the conventional distribution co-

efficient (λ) in terms of equivalent charge displacement, has been examined in large number of cases. It has been found that the conception is valid where the uptake takes place through displacement of the cation of the host component. The proposed λ' does not show any constancy in cases where the uptake of the tracer component follows through double salt formation. In view of this limitation as shown by us it has been argued that the idea can not replace the conventional λ which embraces all types of uptake through mixed crystal formation. It has been shown that if in a system λ values come out constant and λ' on computation gives disconcordant values, it can be concluded that the uptake in question has taken place through double salt formation. The concept of λ' is thus helpful to go inside as regards the nature of uptake. It is evident that λ' as such does not give us a direct picture of separation efficiency whereas conventional λ values give us a ready answer towards extent of separation. The mechanism of uptake in a large number of systems forming anomalous mixed crystals have been cleared up.

It has been concluded that both λ and λ' should be calculated in a distribution study to get some insight into the mechanism of uptake.

B. C. Purkayastha and Shyamoli Sen

1C.10 *A Critical Review on Co-separation*

Hahn reviewed some aspects of co-separation phenomenon in 1936. Second comprehensive review on the subject was made by Bonner and Kahn in 1951. These two reviews were in a sense of great help to expand the study in an elaborate way. Literatures are scattered and many interesting findings have been recently derived. Even various critical approaches to the distribution laws have been made. The distribution phenomenon has been applied even in melts. It is expected that a better theoretical understanding is likely to result from such studies. Crystallisation from melt can also explain many geological phenomena. Inorganic ion-exchangers are finding popularity because of these studies. Unfortunately there has been no review since 1951 in this interesting line. We have been collecting necessary literatures since 1967. Probably the whole of the year 1969 will be required to write the facts in the form of a critical review or book. With this aim in view considerable progress has been made.

B. C. Purkayastha and Shyamoli Sen

1C.11 *On the Study of the Uptake of Strontium Tracer by Different Forms of Calcium Sulphate*

The study of uptake of alkaline earth tracers by different forms of calcium sulphate is being continued. It has been observed that anhydrite prepared by refluxing gypsum with 20% H_2SO_4 (*J. Am. Chem. Soc., 59*, 2242, 1934) does not take up any strontium tracer. In case of barium the uptake is about cent per cent. The observation may be of great help in separating barium from strontium in fission products.

It has previously been reported that gypsum, $CaSO_4$, $2H_2O$ is dimorphous in nature. Other methods of investigations as regards the existence of orthorhombic gypsum are being carried out.

B. C. Purkayastha and Anita Dutta

RADIATION CHEMISTRY

1C.12 *Radiolysis of Aqueous Solution of Ferric Ethylenediamine Tetraacetate*

Aqueous solutions of ferric ethylenediamine tetraacetate (F) at pH 1 was irradiated with X-rays both in the presence and in the absence of dissolved oxygen. Radiolytic yield of decomposition of (F) was determined. Formaldehyde and ferrous iron were detected amongst the radiolysis products and their respective yields were also determined. The presence of dissolved oxygen in the system was found to have no effect on the respective yield values. The dependence of initial decomposition yields on the concentration of (F) was investigated. It has been concluded that the radiolysis is initiated by an attack of the ligand of the metal chelate by the free radicals derived from water and the nature of the radiation induced degradation product has been worked out. A reaction mechanism for the radiolysis of (F) in aqueous solution has been proposed. Effects of ferrous ion and of methanol on the course of radiolysis were also investigated in order to find evidences for the validity of the proposed mechanism. Moreover, from such competition kinetic studies the ratios of rate constants, $K_{OH+F}/K_{OH+Fe^{++}}$ and K_{OH+F}/K_{OH+CH_3OH} were found to be 1.30 and 0.32, respectively.

S. N. Bhattacharyya and K. P. Kundu

1C.13 *Radiolysis of Aqueous Solution of Potassium Periodate*

Aqueous solutions of potassium periodate in neutral medium were irradiated with X-rays and with ^{60}Co gamma rays. It has earlier been reported that

the periodate on radiolysis is reduced only to iodate since no other reduction product could be detected. Radiolytic reduction yields in the system were determined both in the presence and in the absence of dissolved oxygen. A mechanism for the radiation induced reduction of periodate in aqueous solution has been proposed. From the proposed mechanism it follows that the reduction yield, $G(-IO_4^-)$, will be expressed as : $G(-IO_4^-) = 2G_H + G_{OH} + G_{H_2O_2}$. Taking $G_H = 2.8$, $G_{OH} = 2.2$ and $G_{H_2O_2} = 0.8$, the yield is calculated to be 8.6 which agrees well with the observed value of 8.8. Effect of methanol on the course of radiolysis has also been studied. In presence of methanol, the reduction yield on the basis of the proposed reaction sequences will be expressed by the relation :

$$G(-IO_4^-) = 2G_H + G_{OH} + G_{H_2O_2} + (G_H + G_{OH}) \frac{K' [CH_3OH]}{K [IO_4^-]}$$

where K and K′ are the rate constants for the competing reactions of OH with IO_4^- and CH_3OH respectively. A plot of $G(-IO_4^-)$ against $[CH_3OH] / [IO_4^-]$ will therefore yield a straight line with an intercept of 8.6 and the observed results are found to be in conformity with the requirements of the above relationship.

S. N. Bhatacharyya and D. K. Bardhan

1D. MASS SPECTROSCOPY AND OTHERS

1D.1 *Sputtering Phenomena in Single Crystals*

Studies on the sputtering of a silver single crystal by energetic ions was continued with the set up shown in Fig. 1D.1. The apparatus consists of a magnetic oscillation type ion-source with two ovens for vapouring solid samples to produce ions, focussing electrodes and the sputtering chamber. The sputtering chamber includes the single crystal of silver as the target details of which are shown in Fig. 1D.2.

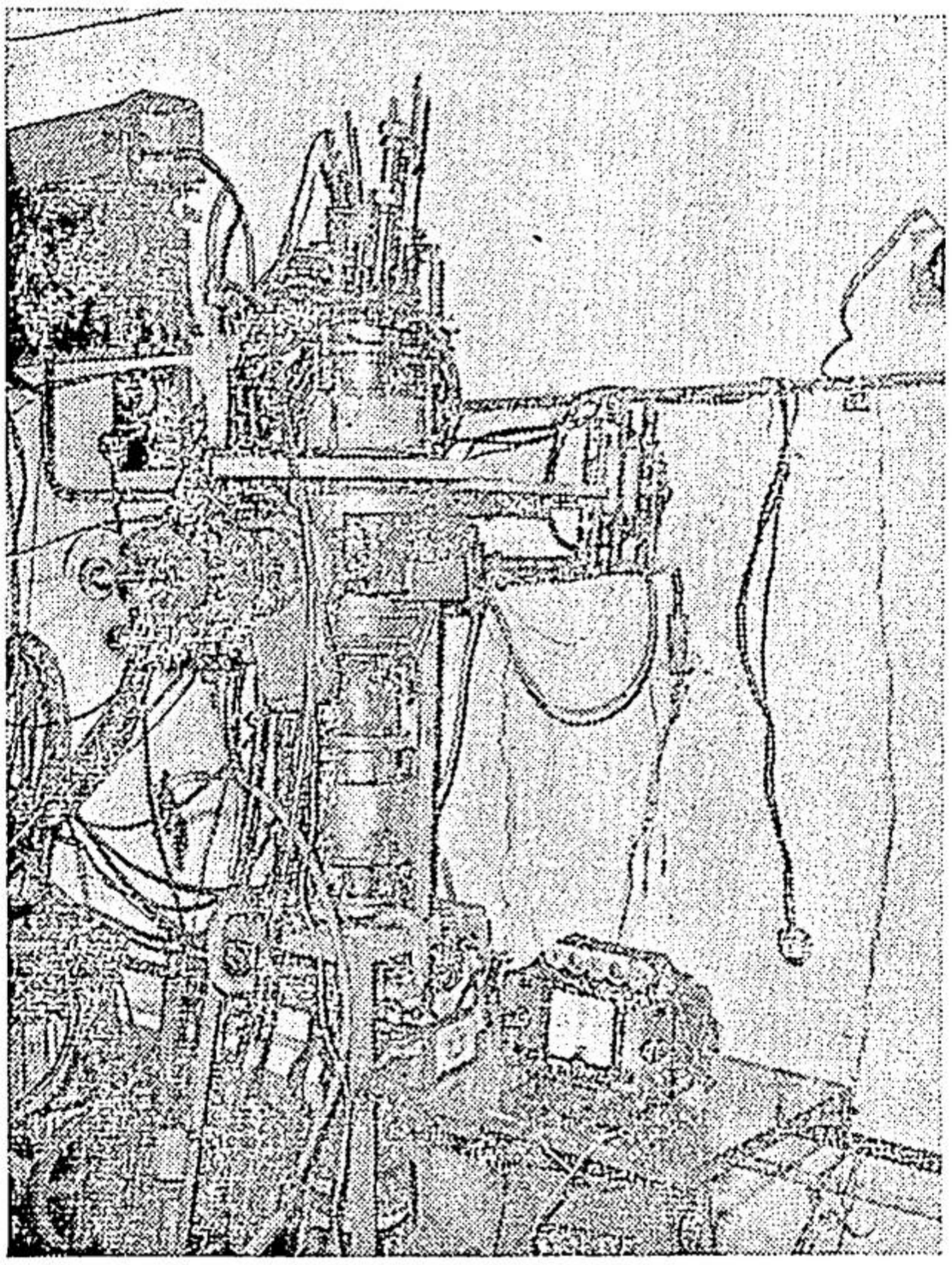


Fig. 1D.1. Photograph of the experimental set up for studying the sputtering phenomena in single crystals.

Ions of Zn and Cd are accelerated to 5 – 10 keV which strike the silver target to eject atoms from it. The single crystal of silver used being radioactive (^{110}Ag), the sputtered atoms are estimated by tracer technique. Sputtering yield vs. energy curve shown in Fig. 1D.3 is compared with Lindhard's

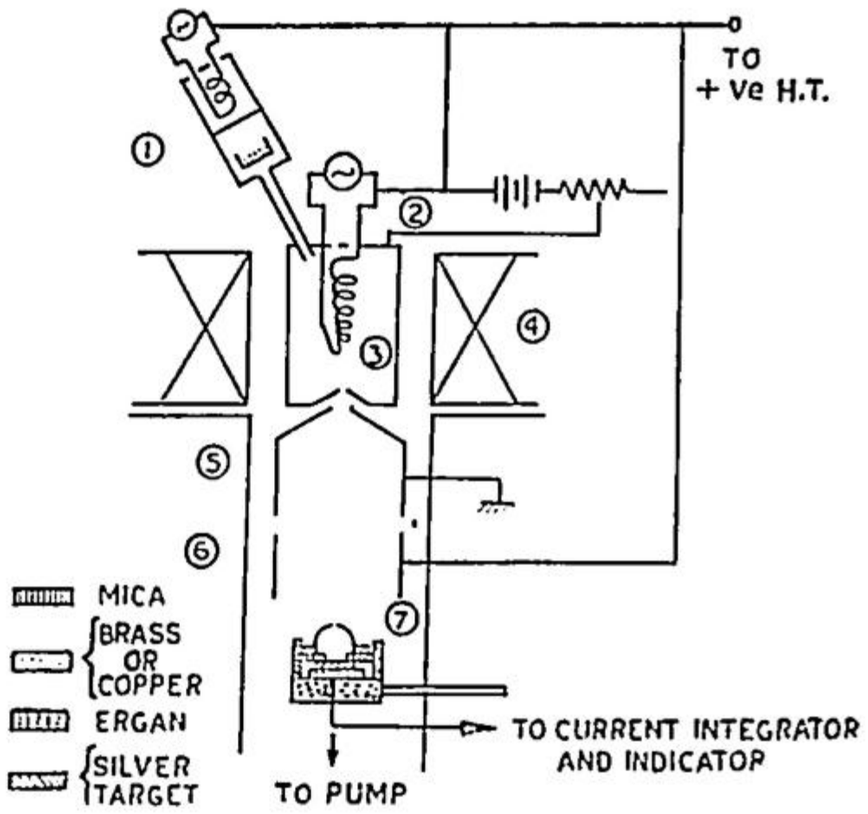


Fig. 1D.2. Schematic diagram of the experimental setup with the sputtering chamber and the target.

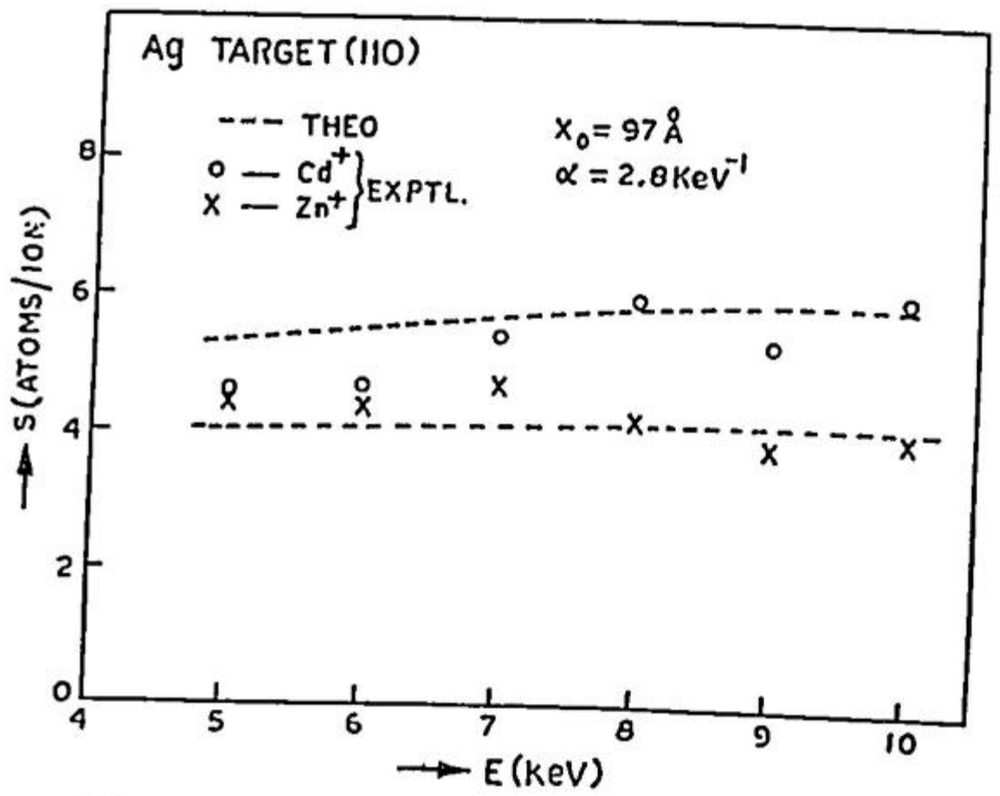


Fig. 1D.3. Sputtering yield S vs. energy curve for Zn^+ and cd^+ on Ag (110).

theory. Such comparison shows agreement if it is assumed that the sputtering phenomenon is dependent on focussing collicion sequences.

The angular distribution of the ejected atoms is measured. The preliminary results (Fig. 1D.4) show preferential direction of ejection of atoms from the single crystal pertaining to its structure.

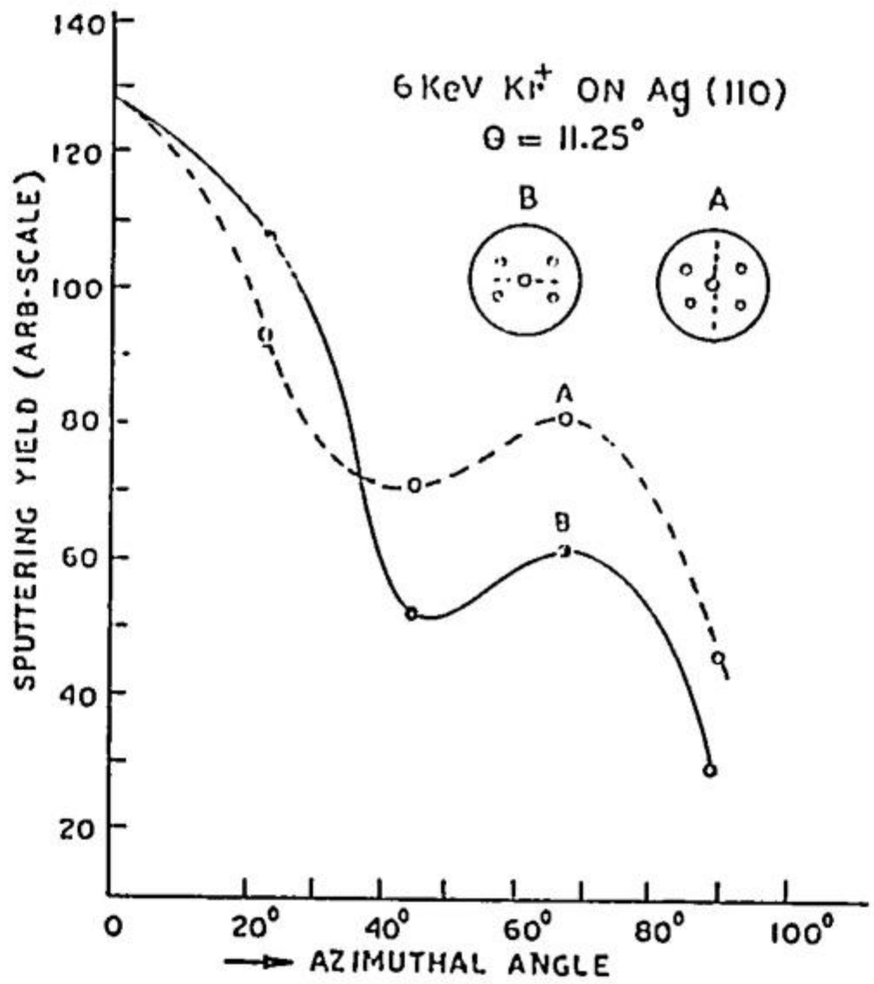


Fig. 1D.4. Angular distribution of the ejected atoms from Ag (110).

D. P. Dewangan, S. D. Dey and S. B. Karmohapatro

1D.2 *Development of a High Sensitivity Mass Spectrometer*

The W-Mo thermocouple used to measure the temperature of the surface ionisation ion-source is being calibrated with a standard disappearing filament type optical pyrometer, since more accurate measurement of temperature is required for studying the dependence of surface ionisation phenomena on Saha-Langmuir equation. Different characteristics of the ion-source are being tested so that it is useful for the high sensitivity mass spectrometer. The set up for testing the ion-source is shown in Fig. 1D.5.

The magnetic field in the ion path in the magnetic analyser is being measured with a Hall probe and a current balancing circuit to determine the requirement of any shimming in the pole pieces.

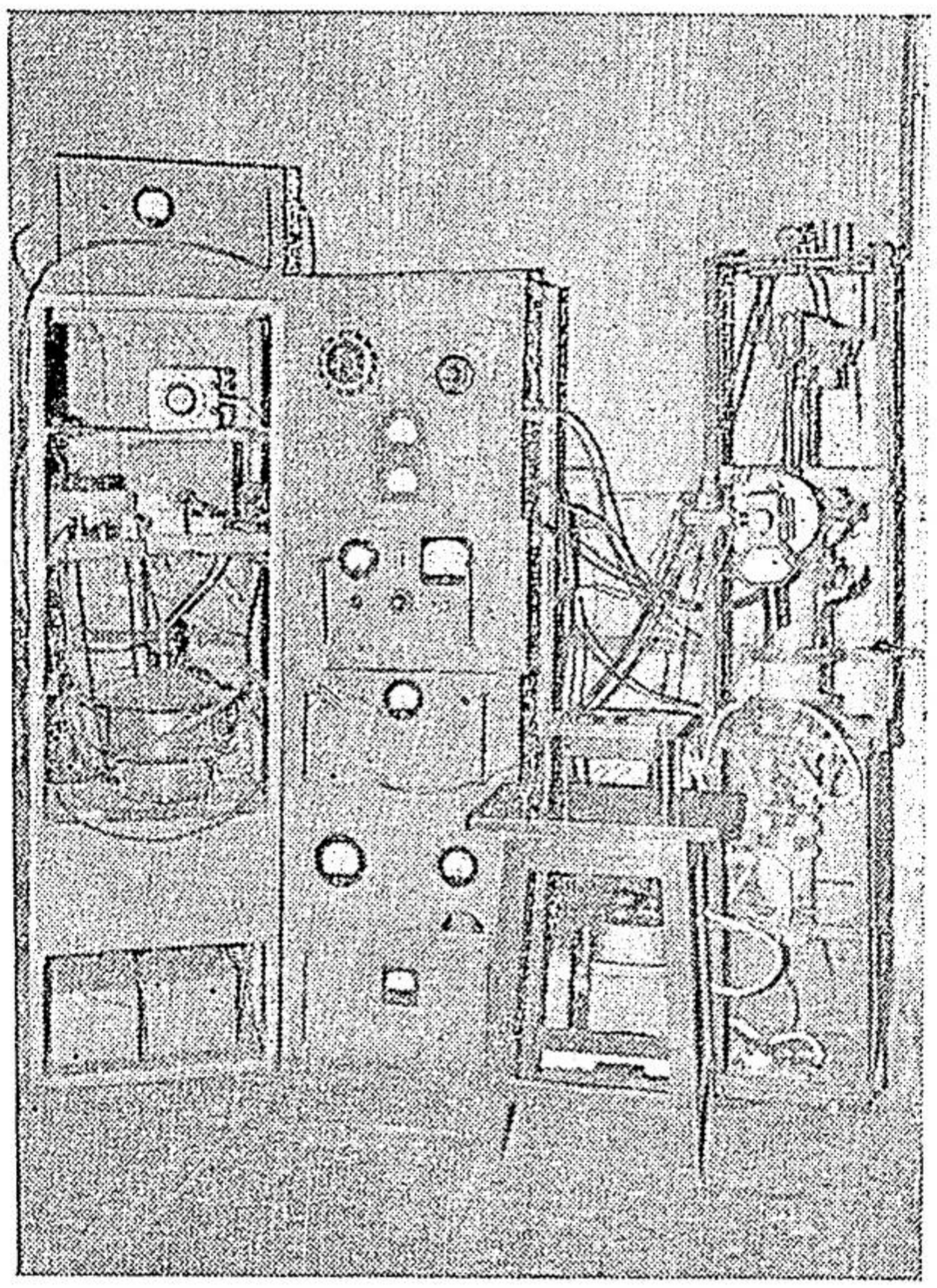


Fig. 1D.5. Photograph of the experimental setup for testing the surface ionisation type

The vacuum chamber is under test. The schematic diagram of the instrument is shown in Figs. 1D.6 and 1D.7.

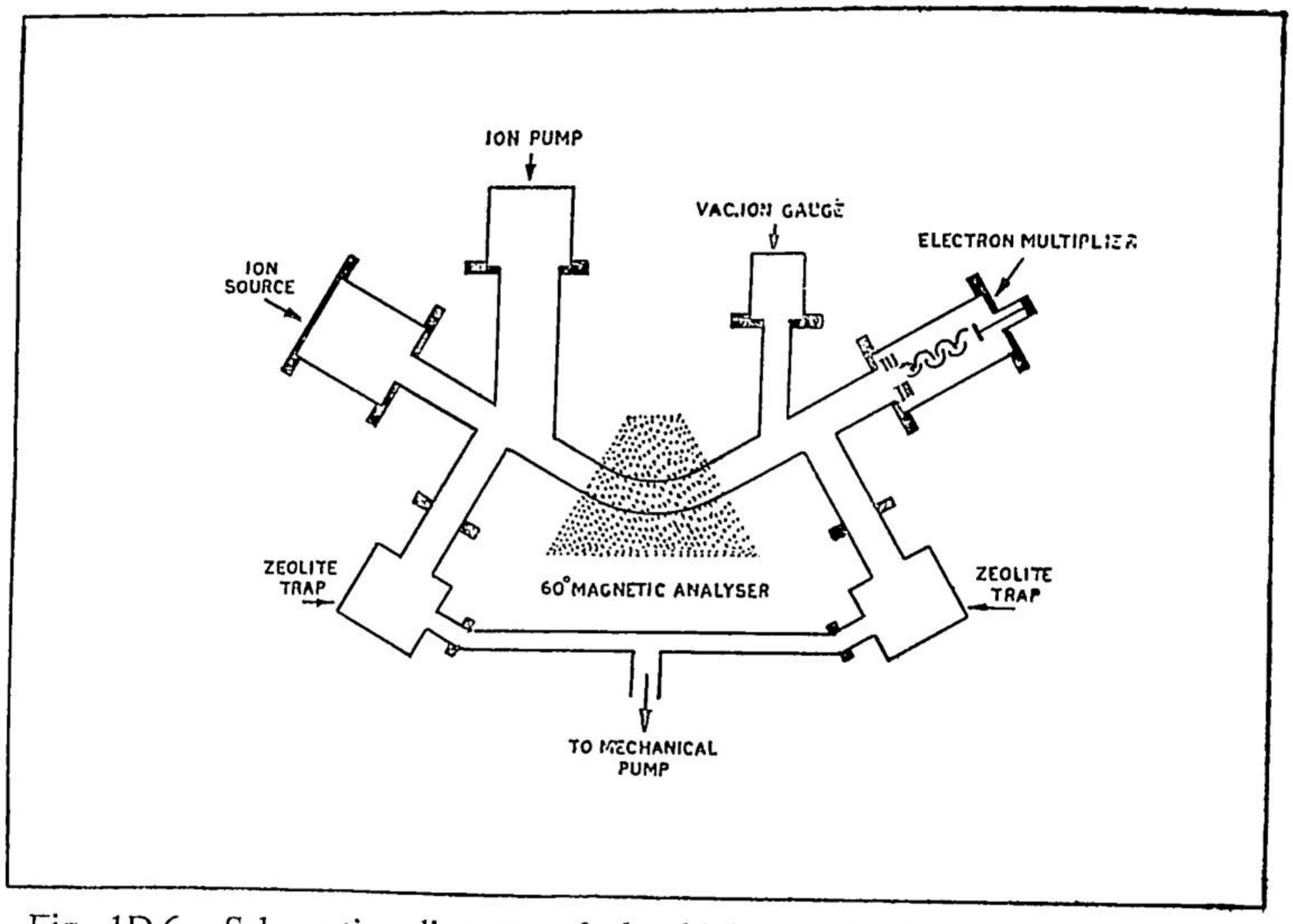


Fig. 1D.6. Schematic diagram of the high sensitivity mass spectrometer under construction.

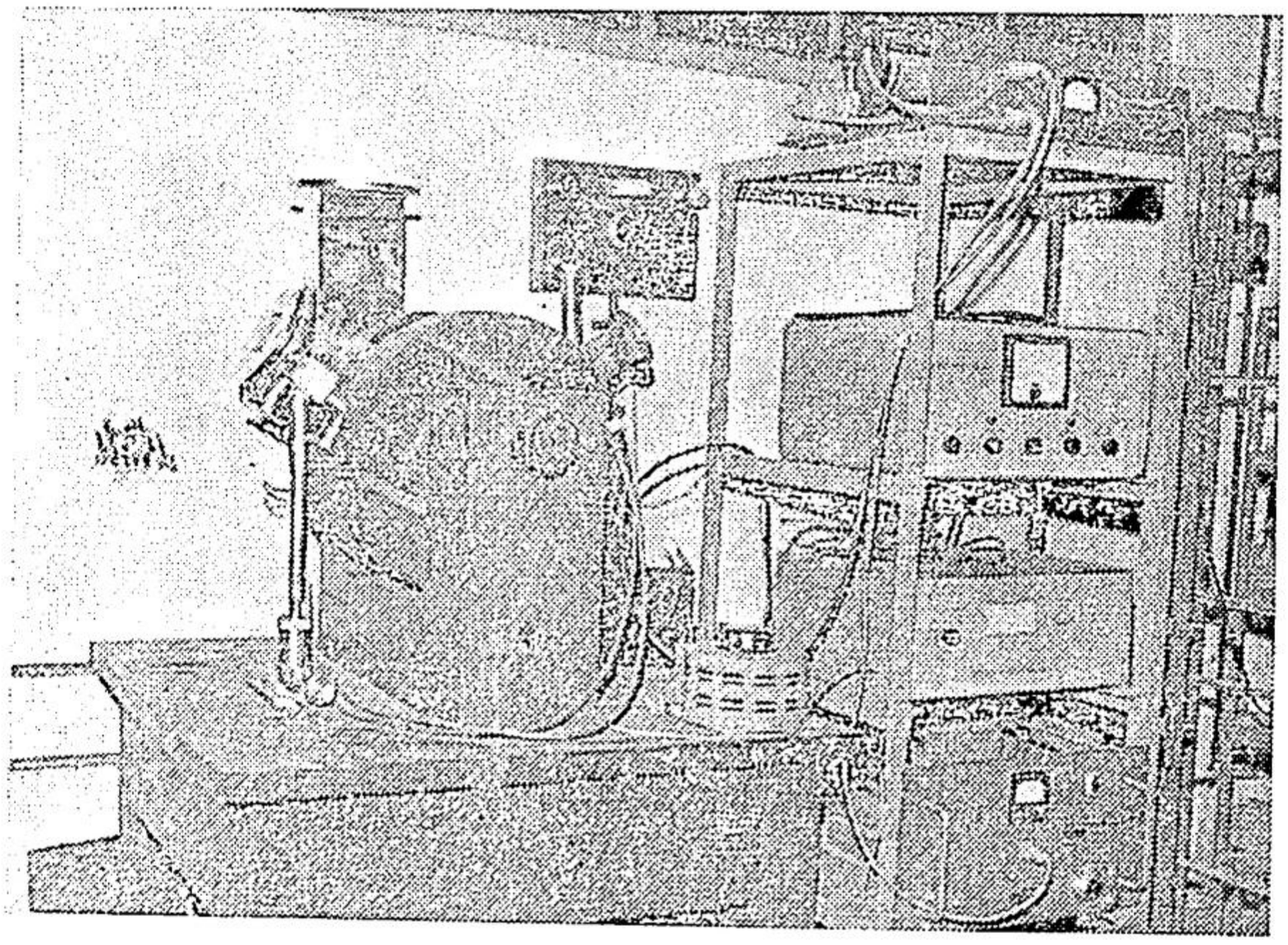


Fig. 1D.7. The magnetic analyser with vacuum chamber for the high sensitivity mass spectrometer.

S. D. Dey and S. B. Karmohapatro

1D.3 *High Intensity Mass Spectrometer*

The high intensity mass spectrometer has been used to study the characteristics of a duoplasmatron ion-source. Under suitable operating conditions it is possible to increase the number of atomic ions.

A quadrupole electrostatic lens has been designed and is under construction for use in focussing the ion beams before they enter the magnetic analyser.

As a measure against the fluctuations of the ion beam, a circuit is designed to feed back the voltage due to the ion current falling on either side of the detector slit to the deflector plate between the magnetic analyser and the quadrupole lens for compensating the deviating beam.

The instrument is now set up for measurement of total collision cross-section of ions in gases and for measuring the particular reaction cross-sections by Aston's band technique.

The instrument is also used by the post M.Sc. students in their advanced experiment.

D. P. Dewangan, S. D. Dey and S. B. Karmohapatro

1D.4 *Theoretical Studies on Atomic Collision*

Theoretical calculations of electron capture cross-sections have been done with an impact parameter method. By the use of a more accurate atomic wave-function for argon and a two state approximation the cross-sections have been calculated for the process.

$$A^+ + A \rightarrow A + A^+$$

for the energy range, 100 eV – 160 keV. σ_{1001} vs. $(eV)^{1/2}$ curve shows some structure (Fig. 1D.8) at energies 6.4 keV, 10 keV, 19.6 keV and 62.5 keV over a smoothly varying curve decreasing with energy.

For nonresonant reactions like

$$A^+ (2P_{3/2}) + A \rightarrow A + A^+ (2P_{1/2})$$

the $\sigma - (eV)^{1/2}$ curve has similar structures except that there is a maxima near 400 eV showing the applicability of the adiabatic hypothesis in the above reactions.

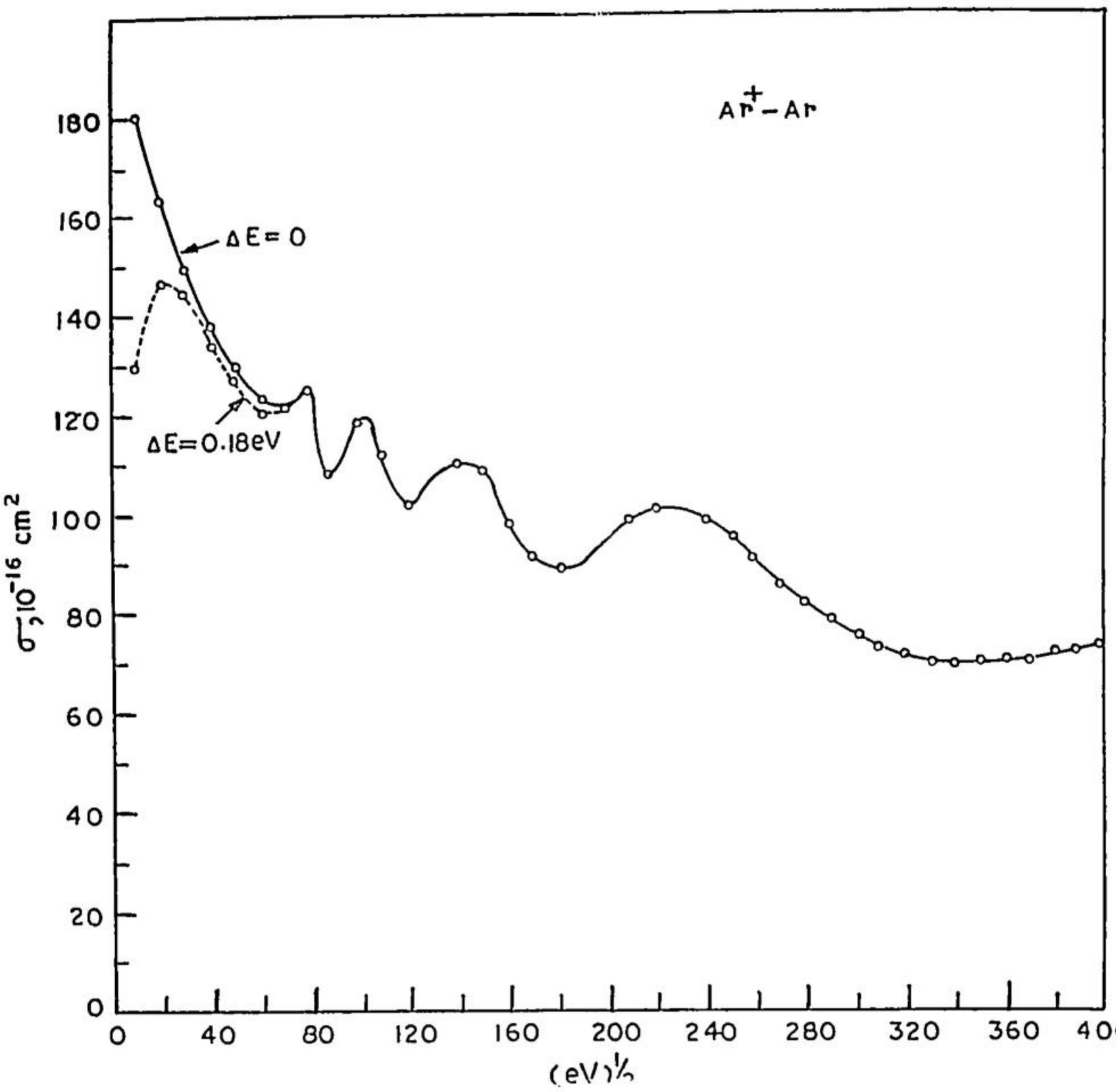


Fig. 1D.8. σ_{1001} Vs. $(eV)^{1/2}$ curse for $A^+ + A \rightarrow A + A^+$ showing the oscillating structures.

D. P. Dewangan and S. B. Karmohapatro

1D.5 *Isotope Separator*

During this year, the isotope separator was run successfully under optimum conditions. To study the performance of the machine, in the different mass regions, zinc was used from the lighter side and lead from the heavier. Zinc being highly voltatile is somewhat difficult to handle, but it gives a fairly wide separation as shown in Fig. 1D.9. A well-resolved spectrum of lead is shown in Fig. 1D.10.

A refrigerated-water cooled collector has been constructed for the collection of some of the volatile elements. Copper collector box for a single isotope is ready. A multiple collector with an externally operated shutter system is in

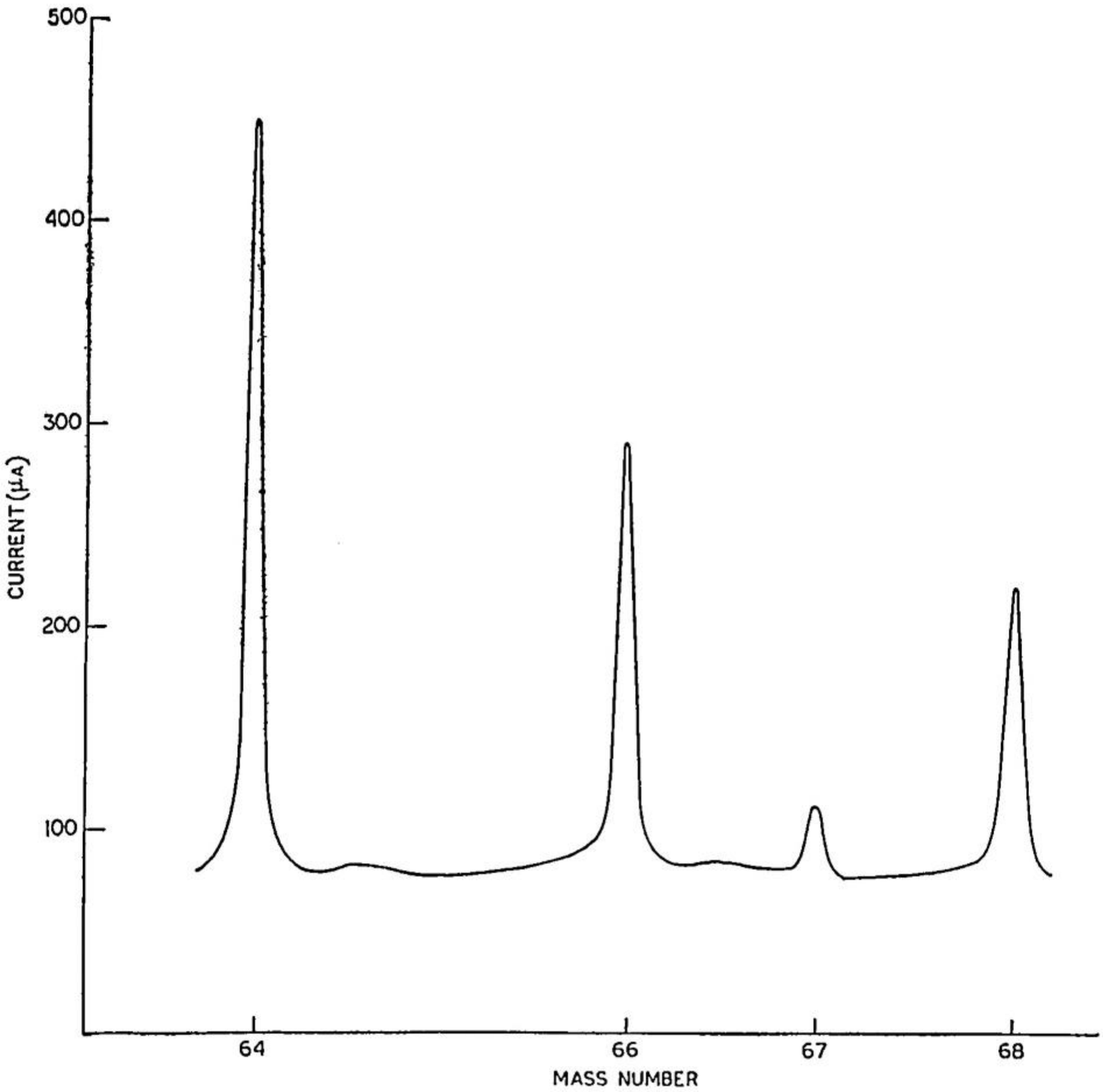


Fig. 1D.9. Spectrum of Zinc isotopes taken by varying the magnetic field.

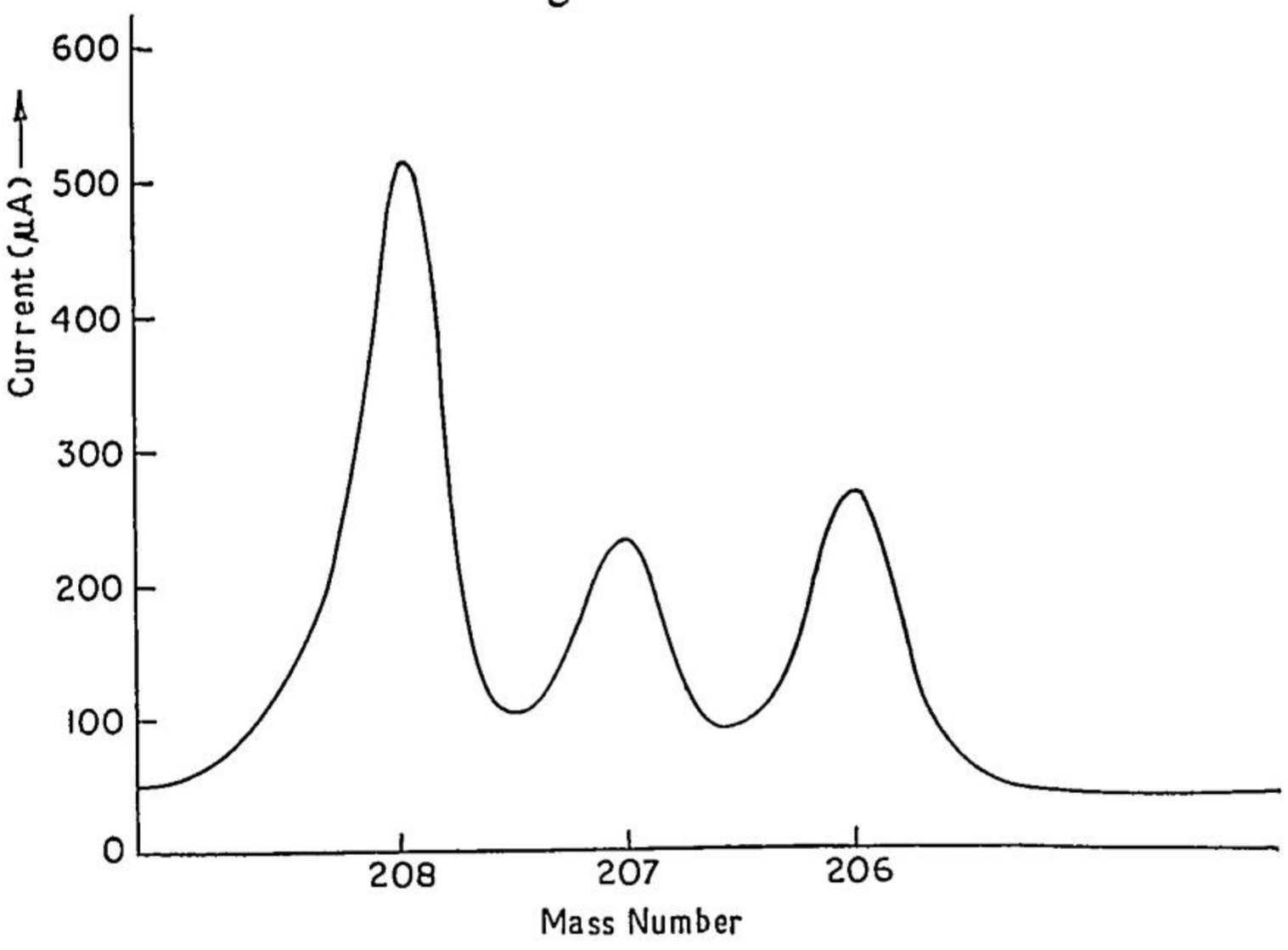


Fig. 1D.10. Spectrum of lead isotopes.

the process of completion. Other types of collector assemblies are going to be constructed according to requirements.

D. Basu

1D.6 *Studies on Thermal Neutron Fission of ^{235}U*

Studies on thermal neutron fission of ^{235}U initiated earlier with the help of an internal counter controlled cloud chamber have been pursued. Some modifications of the counter assembly and associated electronic circuitry were found necessary to ensure trouble free operation and these were incorporated. Several techniques were tried for the preparation of thin targets of uranium and the one adopted in the present studies consisted of making a solution of uranyl nitrate in alcohol of the desired concentration and spreading it uniformly on a thin backing film of cellulose previously prepared by the usual film drawing technique. It was possible by this method to obtain films of cellulose of thickness 100 $\mu g/cm^2$ and that of uranium 100 $\mu g/cm^2$.

By incorporating these modifications it has resulted in an improved performance of the instrument. It is possible to obtain a large number of data of fission events by the use of enriched ^{235}U isotope instead of natural uranium and also a stronger neutron source.

M. Rama Rao

NUCLEAR PHYSICS GROUP

2A. NUCLEAR PHYSICS DIVISION

2A.0 *Introductory Remarks*

The following report highlights the research activities of this division. Dr. R. L. Bhattacharya's group continued the measurements using magnetically perturbed angular correlation techniques and completed studies of g-factors of certain levels of ^{181}Ta, ^{140}Ce, ^{169}Tm, ^{177}Hf and ^{125}Te. Low levels of ^{116}Sn have been calculated on the hole-particle model. This group has also developed a transistorised wide range time-to-amplitude converter. Preliminary β–γ and e–γ coincidence studies are being carried on with the pair-electron spectrometer to test the performance of this instrument. The theoretical solid state group was engaged on a programme of work concerned with estimation of the contribution of the spin-phonon interaction to the thermal conductivity of crystals containing paramagnetic ions with spin $\frac{1}{2}$ using double time Green's function technique. Another contribution from this group was concerned with calculations of the crystal field parameters for Pr^{3+} ion in praseodymium and lanthanum metals and for Tm^{3+} ion in thulium metal. A second team was concerned with energy band calculations of lanthanum using symmetrised augmented plane wave technique. They also extended their previous work on the irreducible representations of non-symmorphic groups and worked out in detail the representations of D^4_{6h} and D^{14}_{4h} groups. Another topic investigated by this group was the theoretical study of the spin-lattice relaxation time with respect to the orientation of the Zeeman field relative to crystal axes for Co^{2+}, Ni^{2+} and Cr^{3+} ions in MgO crystal. Another team in the theoretical solid state group under Dr. A. S. Chakravarty worked on various aspects of octahedral complexes of transition metal ions, viz., high frequency contribution to paramagnetic susceptibility of these systems, magnetic dipole transition in them and the effect of charge delocalisation on the intensities of $d \rightarrow p$ transition, intensities of optical absorption spectra and a study of the covalency in $4d^n$ and $5d^n$ bands of these systems. They have also studied the effect of covalency and vibronic interaction on the absorption spectra of the complexes of the rare earth ions. Dr. A. Mukherji's group continued their programme of atomic and molecular calculations using self-consistent variation perturbation technique developed by them earlier. They have calculated atomic polarisabilities and shielding factors for open shell electronic systems, dynamic dipolar polarisability for isoelectronic sequence He to C^{4+} and dynamic quadrupolar polarisability. In particular, they have been able to obtain accurate excited state wave-functions by this technique. They have also applied this technique to calculate the Van der Waal force constant. Prof. D. K. Ghosh's group has extended the frequency range of their Stark modulated microwave spectrometer

to cover the X-band 8 kMc to 12 kMc. They have also completed the recording of the microwave spectrum of thioacetie acid. They also estimated the rotational constants for the rotation of the CH_2SH group and the ethylenic group about the C-C single band in allyl mercaptan. Prof. R. Roy's group has developed a superheterodyne ESR assembly using a single klystron in the X-band region. This group is also engaged in the fabrication of a UHF ESR spectrometer in the range 250 Mc for studies of free radicals in biological samples in aqueous solutions and also to study resonance in metals like Li, Na and K in the temperature range 77°K to 300°K. They have completed a design study of a K-band ESR superheterodyne spectrometer. A study of the g-tensor from the crystal rotation ESR spectrum of copper sarcosine has been completed. The results are being compared with the estimated values from the calculations based on the structure of copper sarcosine as determined by Prof. N. N. Saha's group. This group has also completed a study of g-anisotropy of polycrystalline sample of Cu-bis-N meta nitrobenzyl N phenyl hydroxylamine. This group has also measured the asymmetry parameter η in the EQR spectra from a study of polycrystalline sample of chloranil and frozen samples of trans-dichloroethylene. A new method has been given by them to obtain η and the electric quadrapole tensor by a 2–rotation goniometer which is being fabricated. Prof. M. Bose's group continued their study of spin-lattice relaxation times in three disubstituted benzenes (chlorotoluenes). They have developed a proton-lock cum frequency sweep device for the HR-100 NMR spectrometer of our laboratory. They have also investigated systematically NMR of ^{31}P in some polycrystalline anhydrous rare earth phosphates with a view to understand the nature of electron nuclear interaction and the bonding situation in rare earths.

Dr. S. K. Sinha's group working in acoustic magnetic resonance (AMR) has developed an ultrasonic pulse-echo apparatus working in the range 1 Mc to 18 Mc. The pulser has arrangement such that the equipment can also be used for magnetic resonance spin-echo measurements. They have, as a part of a project on ARM studies in metals and magnetic systems, formulated AMR phenomenon in terms of Block-Waugsness-Redfield formulation of magnetic resonance.

We are collaborating with other institutions and universities for the development of some of our basic equipments. Special mention may be made of a project recently undertaken in collaboration with Prof. J. S. Chatterjee and his associates in the computer group of Jadavpur University to fabricate indigenously a 1024 channel pulse height analyser and a continuous averaging equipment. The major facilities that are likely to be added in future will include a Mossbauer spectrometer and a liquid helium plant. A cryoganic laboratory is also being planned.

A. K. Saha

2A.1 *g-factor Measurement of the 482 keV Level of ^{181}Ta*

The gyromagnetic ratio of the 482 keV $5/2^+$ level (Half-life = 10.8 ns) of ^{181}Ta has been measured by perturbed angular correlation technique using the following two methods at a magnetic field 22Kgauss.

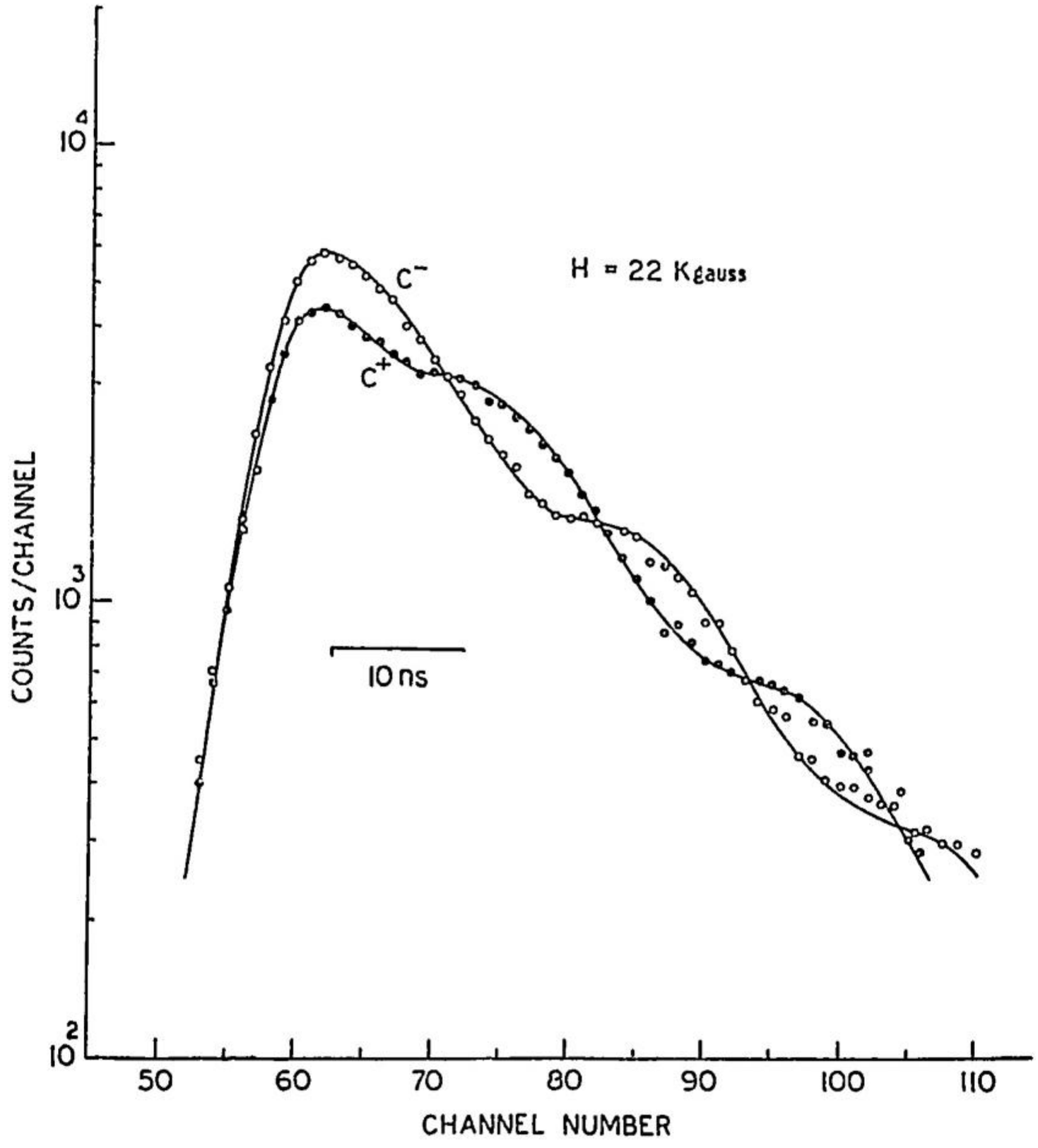


Fig. 2A.1 Coincidence counting rate C^+ and C^- for two transverse directions of the magnetic field for the 133-482 Kev cascade of ^{181}Ta.

(i) Differential delay constant angle (DDCA) method at 135°

(iii) Differential delay reserve field (DDRF) method at 112 $\frac{1}{2}$° and 157$\frac{1}{2}$°

The values obtained for g-factor, with both the methods are very nearly same and equal to 1.328 ± 0.010. Fig. 2A.1 shows the coincidence counting rate C^+ and C^- for the 133-482 keV cascade for both the directions of the field. The ratio R (t) calculated for a measurement of ^{181}Ta is shown in Fig. 2A.2.

A differential angular correlation measurement of 133-482 keV cascade was made and the values of A_2 and A_4 coefficients obtained as a function of

time delay t, show that the source used was free from the perturbations due to time-dependent quadrupole interaction.

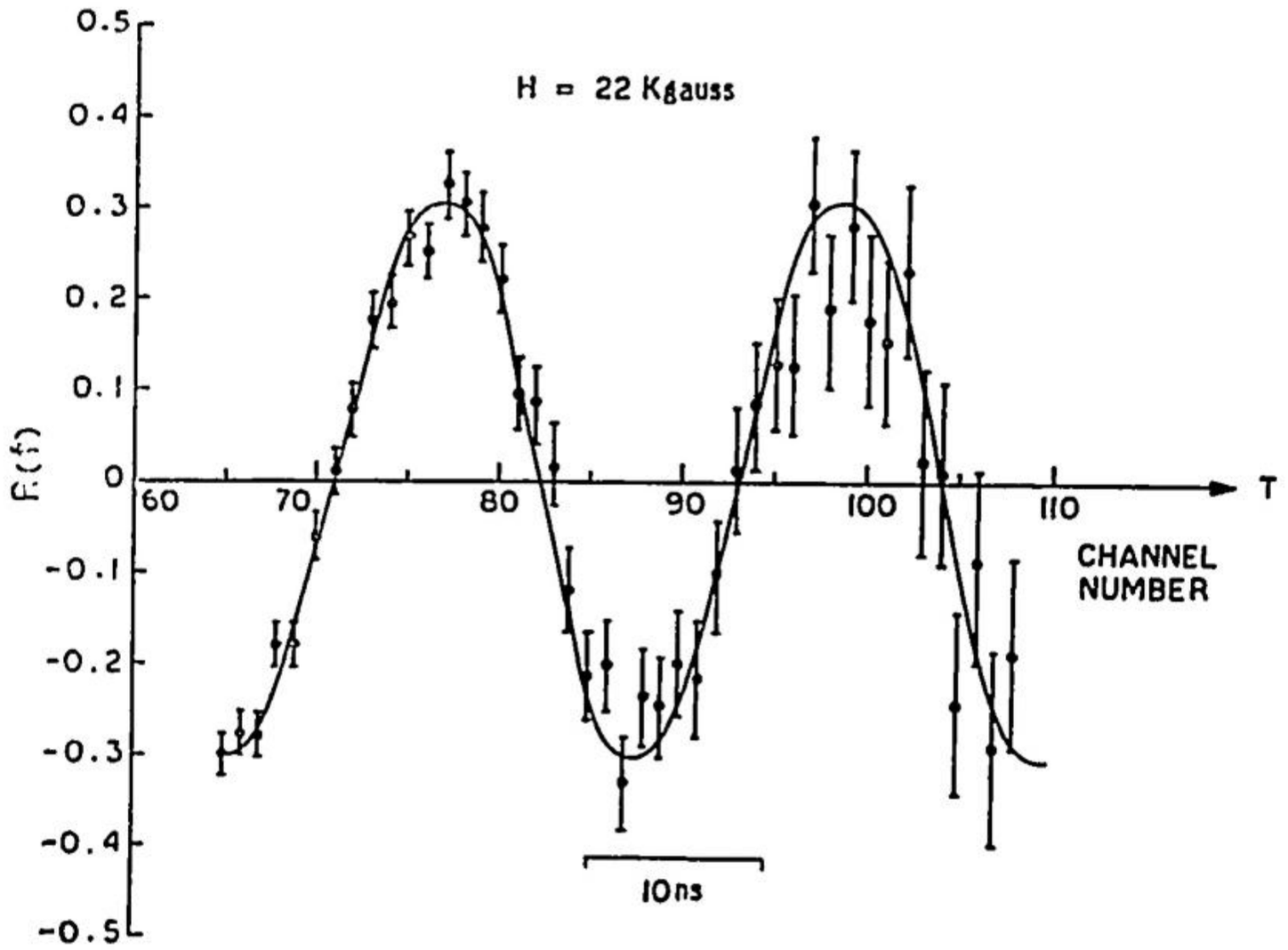


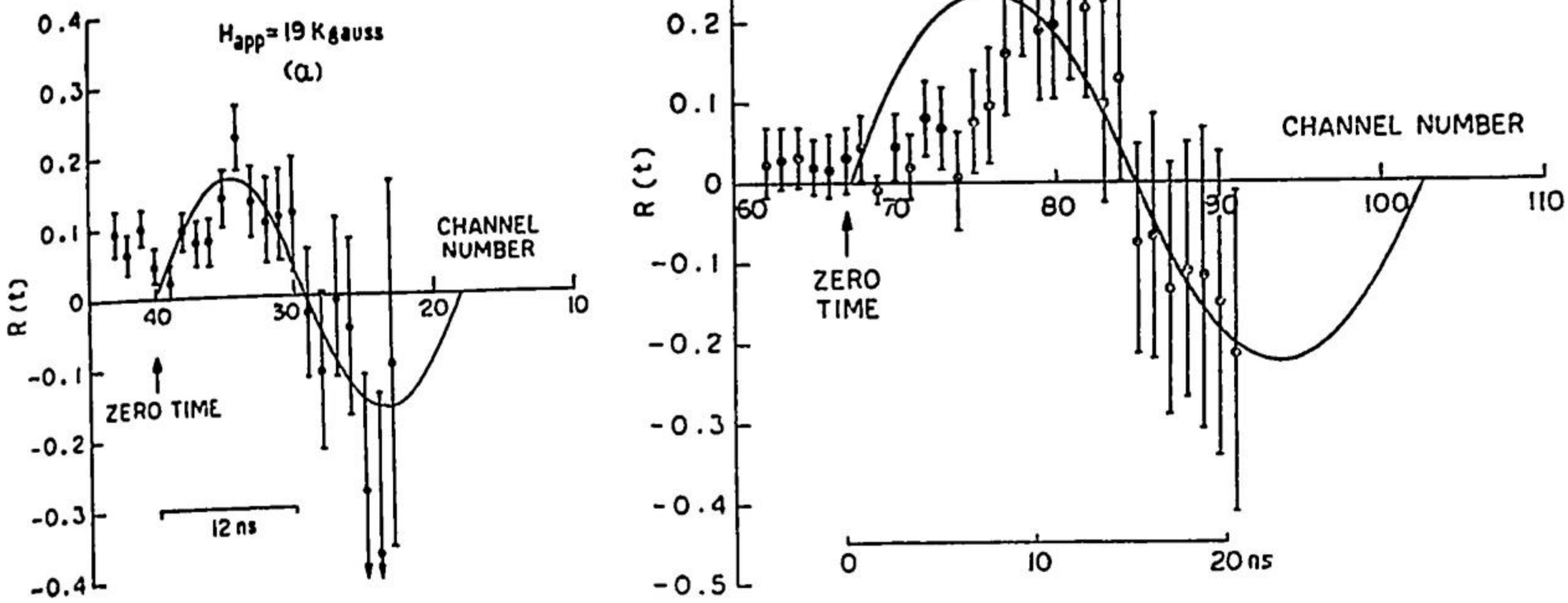
Fig. 2A.2 $R(t) = 2\dfrac{C^+ - C^-}{C^+ + C^-}$ is plotted as a function of time-delay t for the 133–482 KeV cascade of ^{181}Ta. The Larmor precession frequency ω was extracted from this curve.

A. K. Nigam and R. Bhattacharyya

2A.2 *Gyromagnetic Ratio of the 2090 keV 4⁺ Level of ^{140}Ce*

The g-factor of the 2090 keV level ($T_{1/2} = 3.31$ ns) of ^{140}Ce was measured using differential delay constant angle method at the magnetic field of 19 K gauss. The measurements were performed using γ_1–γ_2 and γ_1–γ_3 radiation cascades of the 320-490-1600 keV triple cascade, separately. The values obtained ($g = 0.95 \pm 0.02$) by both measurements are in good agreement. The ratio R(t) calculated for the γ_1–γ_2 and γ_1–γ_3 measurement of ^{140}Ce is shown in Fig. 2A.3(a) and (b).

Besides this, the angular correlation measurements using γ_1–γ_2 and γ_1–γ_3 cascades were performed and the spin assignments of all the four levels concerned were made. A differential angular correlation measurement, however, determined the attenuation of the angular correlation coefficients.



(a) (b)

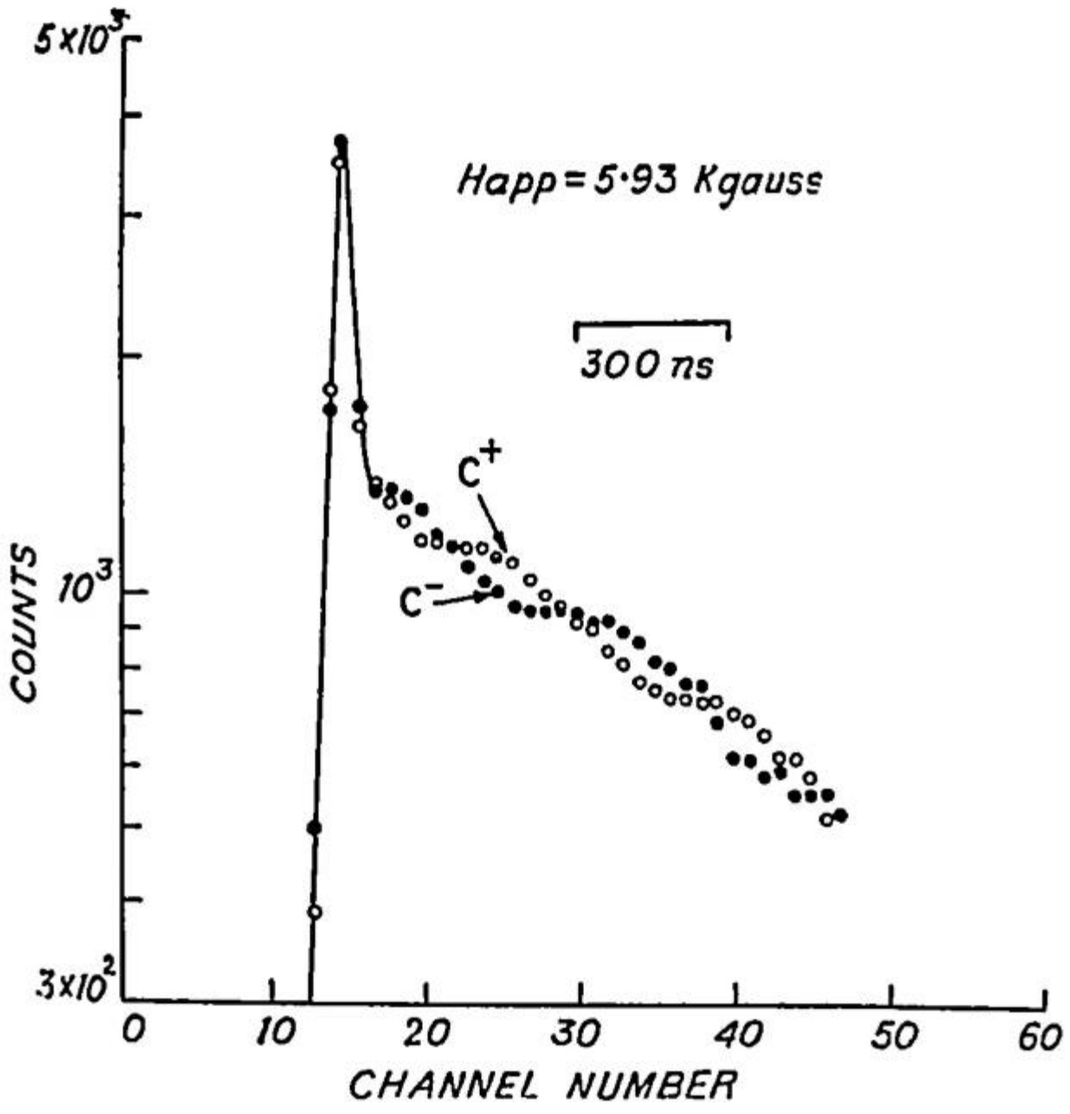
Fig. 2A.3 R(t) is plotted as a function of time-delay t for the (a) $\gamma_1 - \gamma_2$ and (b) $\gamma_1 - \gamma_3$ cascades of ^{140}Ce. The curves are obtained after making resolving time correction and least square fitting of data.

A. K. Nigam and R. Bhattacharyya

2A.3 *The g-factor of the Levels of ^{169}Tm*

(i) *The 316 keV 7/2⁺ level*

The half-life of the 316 keV level of ^{169}Tm is $T_{1/2} = 660$ ns. In order to measure the g-factor of this level, a Thieburger type wide range (0-10 μ sec)



for two transverse directions of the magnetic field

Fig. 2A.4 Coincidence counting rate C^+ and C^- for the 63-198 Kev cascades of ^{169}Tm.

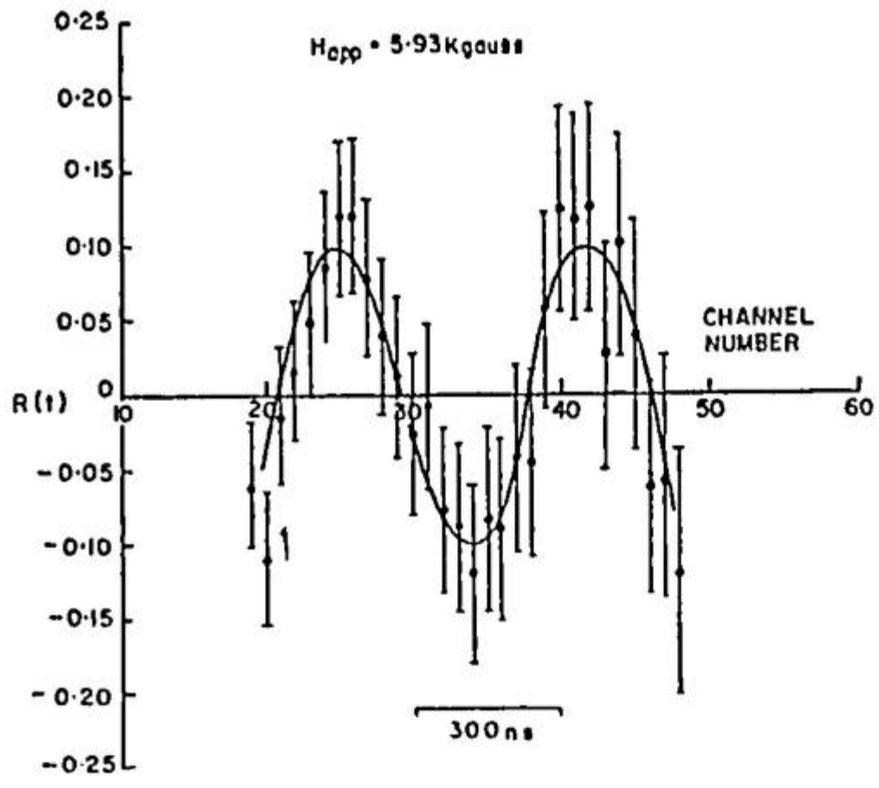


Fig. 2A.5 R(t) is plotted as a function of time-delay t for the 63-198 KeV cascade of ^{169}Tm.

time-to-amplitude converter was constructed. The measurement of the g-factor of this level was performed using differential delay constant angle (DDCA) method at a magnetic field of 12.2 K gauss. The measured value of the g-factor is $g = 0.045 \pm 0.005$. Fig. 2A.4 shows the counting rate C^+ and C^- for the 63-198 keV cascade for both the directions of the field. The ratio R(t) calculated for the measurement of ^{169}Tm is shown in Fig. 2A.5.

(ii) *The 139 keV $7/2^+$ and 118 keV $5/2^+$ levels*

The g-factors of 139 keV and 118 keV levels were measured using integral reverse field (IRF) method at a magnetic field of 20.65 Kgauss. Angular correlation measurements were also performed to assign spins of the levels.

A. K. Nigam and R. Bhattacharyya

2A.4 *The g-factor of the Level of ^{177}Hf*

The measurement of gyromagnetic ratio of the 113 keV $9/2^+$ level (half-life = 0.5 ns) of ^{177}Hf has been performed using integral reserve field (IRF) method at a magnetic field of 18.48 Kgauss. The value obtained is $g = 0.25 \pm 0.01$.

A. K. Nigam and R. Bhattacharyya

2A.5 *The g-factor of the 462 keV $5/2^+$ Level of ^{125}Te*

A final measurement on the g-factor of 462 keV level (half-life = 0.495 ns) of ^{125}Te has been made using integral reverse field (IRF) method at a magnetic field of 18.48 Kgauss. The value obtained is $g = -0.66 \pm 0.40$.

The theoretical calculation for the magnetic moment of this level of ^{125}Te is also done on the basis of Kisslinger and Sorensen model. The calculated results, summarised in Table 2A.1 shows a good agreement with the experimental result.

Table 2A.1

State Energy	Spin & Parity	μ_{sp}	μ^{o}_{qp}	μ_0	μ_1	μ_2	$\mu_{theoretical}$ with $gr = \frac{Z}{A}$	μ_{exp}
462 keV	$5/2^+$	–1.913	–2.5615	–0.6404	–0.7933	–0.0066	–1.4404 nm	–1.64 ±1.06 nm

A. K. Nigam and R. Bhattacharyya

2A.6 *Nuclear Structure Calculations on Low-lying Levels of ^{116}Sn*

Nuclear structure calculations on low-lying levels of ^{116}Sn in the hole-particle model have been completed. Low-lying 2^+, 3^-, 5^-, 6^-, 7^- states have been calculated and compared with recent experimental findings. In view of the simplified assumptions made, the agreement is quite satisfactory. Some structures calculations in the phonon-particle coupling model have also been undertaken.

Publication :

S. Sen and B. K. Sinha, *Proc. Nucl. Phys. Sol. St. Phys. Symp. Madras,* 1968, p. 267.

S. Sen and B. K. Sinha

2A.7 *Preparation of Thin Film*

Progress in thin film technique was made using the same solvent, viz., carbolic acid, as reported last year and the film thickness was brought down to about 200 $\mu g/cm^2$. Below this thickness, the removal of film from the supporting glass plate becomes extremely difficult. With these films as window of the GM counter in our Siegbahn Slätis beta-ray spectrometer the cut off energy of electrons in the window could be brought down to about 10 keV.

Publication :

B. K. Sinha and R. Bhattacharyya, *Nuclear Instrum. Meth., 64,* 107, 1968.

B. K. Sinha and R. Bhattacharyya

2A.8. *A Transistorised Wide Range TAC*

A completely transistorised wide range time-to-amplitude converter working on Thieberger's principle was constructed and tested with a built-in delay calibrator unit. During testing a sweep speed of 0.5 volt/ns was achieved with a high degree of linearity. The TAC can measure half-lives from a few ns to a ms. The circuit is particularly useful for measurement of g-factors of levels having wide range of half-lives. The apparatus is being tested for full performance.

B. K. Sinha and R. Bhattacharyya

2A.9 *Pair-electron Spectrometer*

Some changes have been incorporated in the detection system of the spectrometer and in the coincidence circuits, by way of which much better performance has been achieved. In the electron detector system, RCA 6655

photomultiplier tube has been replaced by a RCA 6810A tube and cent per cent transmission has been achieved down to about 80 keV electron energy.

Preliminary beta-gamma and electron-gamma coincidence studies have been carried out on ^{60}Co, ^{198}Au, ^{181}Hf, ^{192}Ir isotopes. Necessary arrangements for electron-gamma correlation studies are nearing completion.

S. Sen and R. Bhattacharyya

2A.10 *Thermal Conductivity in Magnetic Crystals*

The work on this problem was undertaken in the year 1967, and has been continued in the current year. For the theoretical calculation of the contribution of the spin-phonon interaction to the thermal conductivity in crystals containing paramagnetic ions with spin $S=\frac{1}{2}$, the expressions for the life-time and group velocity of phonons are required, and double time Green function technique has been used for the purpose. The expression for life-time found in this way is valid over a wide range of temperature and is more general than that obtained by perturbation theory. The explicit form of the group velocity has been worked out. These results have been used to write down the expression for the thermal conductivity tensor. Similar investigations for crystals containing the paramagnetic ions with spin $S>\frac{1}{2}$ and also for magnetically ordered systems will be taken up.

K. C. Das

2A.11 *Crystalline Electric Field in Rare Earth Metals*

In order to make a quantitative estimate of the contribution of the spin-phonon interaction to the thermal conductivity in the rare earth metals, it is necessary to know the numerical values of the crystalline electric field (CEF) parameters in these metals. So the investigation of the different sources contributing to the CEF in the rare earth metals was taken up. In the first stage of the work the contributions of the lattice of the positive ions in the ionic model approximation and the shielding by the closed shell of host ion have been considered. The CEF parameters for Pr^{3+} ion in praseodymium and in lanthanum metals and for Tm^{3+} ion in thulium metal have been calculated for this model of charge distribution. The investigations show that the overlap of the 4f functions belonging to the different rare earth ion sites may have important contribution. Further studies of this aspect of the problem and also of the contribution of the conduction electrons to the CEF parameters have been undertaken.

K. C. Das

2A.12 *Energy Band Calculations of Lanthanum*

The symmetrized augmented plane wave technique is being applied for the calculations of the energy bands of lanthanum. The crystal potential has been constructed in "muffin-tin" form. The coulomb part is obtained by superposing the coulomb part of the self-consistent Hartree-Fock atomic potentials. The exchange part is constructed from the superposition of atomic charge densities using the Slater free-electron-exchange approximation. The curves obtained by plotting the log-derivatives of the radial function on the surface of APW spheres against energy show strong deviations from the corresponding free-electron limit curves for the s^- and d^- electrons. The calculation of the energy eigen values for the construction of Fermi$^-$ surface is in progress.

Aparna Ghosh, K. C. Das and S. K. Gupta

2A.13 *Irreducible Representations of Non-symmorphic Space Groups*

A method of constructing the irreducible representations for non-symmorphic space groups has been worked out. For finding out the irreducible projective representations of P^kth group formed by the point group operations of the group of k vector—the concept of a suitably chosen invarian subgroup, I^k, of P^k and the group, F^k, formed by the properly chosen generators of all the distinct co-sets of I^k, is introduced. This enables us to draw complete information regarding the dimensionality of the projective representations. The conditions necessary for the existence of one-dimensional projective representations of P^k are investigated. Using this method, we have worked out the irreducible representations for D_{6h}^4 and D_{4h}^{14} space groups. Also the orthogonality condition for the space group representations, is reduced to the separate testing of orthogonality for the representations of I^k and F^k.

Aparna Ghosh and S. K. Gupta

2A.14 *Spin-lattice Relaxation in Paramagnetic Crystals*

(i) The anisotropy of the spin-latice relaxation time with respect to the orientation of the Zeeman field about the crystal axes has been studied theoretically for Co^{2+}, Ni^{2+} and Cr^{3+} ions in a MgO crystal for both single and two phonon processes, using a Debye model of the phonon distribution. For the single phonon process, the anisotropy in the relaxation time is large, for Co^{2+} but small for Ni^{2+} and Cr^{3+}. For the double phonon process, where the calculations are done without making the long wave-length approximation, the relaxation time is totally isotropic for Co^{2+} but for Ni^{2+} and Cr^{3+} it is slightly

anisotropic. The deviation from the expected T^7-law is found to be significant for Cr^{3+} ion.

Publication :

D. K. Ray, T. Ray and S. K. Gupta, *J. Applied Phys., 39,* 832, 1968.

S. K. Gupta

(ii) Work is in progress to take into account the contributions of u-modes to the spin-relaxation rates. This contribution is expected to be quite significant for Cr^{3+} case. Also the experimental phonon spectrum of MgO is being used in the next stage of the calculations in order to remove the approximations which creep in by taking the Debye spectrum.

S. K. Gupta

2A.15 *High Frequency Contribution to Paramagnetic Susceptibility of Octahedral Complexes of Transition Metal Ions (OCTMI)*

Making use of the strong field wave-functions derived by us, we have calculated the high frequency contribution to paramagnetic susceptibility of OCTMI arising from one electron excitation states. This contribution, which was hitherto assumed so be not significant, varies from 1% to 9% of the temperature dependent Curie term, depending upon the ion.

V. P. Desai and A. S. Chakravarty

2A.16 *Effect of Charge Delocalisation in the Intensities of $d \rightarrow p$ Transitions in OCTMI*

In order to estimate covalency effects in the intensities of $d \rightarrow p$ transitions in OCTMI, we have considered a model in which a fraction of charge on the metal ion is transferred to ligands in the excited stated. We take the ground and excited state wave-functions as

$$\phi_{Gr} = \psi_A\ (3d)$$
$$\phi_{Ex} = C_1\ \psi_A\ (4p) + C_2\ \psi_B\ (2p)$$

ψ_A (3d) and ψ_A (4p) are metal ion wave-functions and ψ_B (2p) is ligand wave-function.

With these functions, the expression for oscillator strengths is

$$f_{d\rightarrow p} = 1.085 \times 10^{11} \{ C_1^2 | <\psi_A\ (3d) | \mathbf{r} | <\psi_A\ (4p) > |^2 + C_2^2 | <\psi_A\ (3d) | \mathbf{r} | \psi_B\ (2p) > |^2 \}$$

The coefficients C_1 and C_2 depend upon the amount of covalency. For instance, when $C_1 = 1$, $C_2 = 0$, our model reduces to that of purely ionic case. The matrix elements $<\psi_A\ (3d) \mid \mathbf{r} \mid \psi_B\ (2p)>$ involve two-centre integrals. Since we are interested in rough estimate of covalency effects, instead of calculating the complicated two-centre integrals, we have made use of δ function type of wave-functions for ψ_B (2p) and have calculated the matrix elements. Oscillator strengths calculated in this way are in reasonable agreement with the experimental values.

A. S. Chakravarty and V. P. Desai

2A.17 *Intensities of Optical Absorption Spectra of the Octahedral Complexes of the Transition Metal Ions*

The visible absorption bands of the transition metal complexes have been shown to be explained reasonably well by the vibronic interaction model which we have proposed. This model takes into account the interaction of the odd vibrations of the ligands with the electronic motion of the centrally situated paramagnetic ions by which the d wave-functions of the transition metal ion get mixed up with some p wave-functions and thus the electric dipole transitions get allowed. The necessary integrals have been calculated using Richardson-Watson's SCF wave-functions. The algebraic structure of the oscillator strengths of the electric dipole transitions of kd^n complexes have been derived. The oscillator strength of atransition $i \rightarrow j$ has been expressed in terms of the vibronic part $\theta_{i \rightarrow i}$ multiplied by a factor λ (s) where s denotes a particular ion of the transition metal complex. It involves an unknown parameter $f_{d \rightarrow p}$ the oscillator strength of a $d \rightarrow p$ transition and we have calculated $f_{d \rightarrow p}$ theoretically using the delta-function wave-function for varying amount of charge delocalization onto the ligands. A somewhat detailed account has already been presented in the previous work with V. P. Desai. In this semi-covalent model we have finally succeeded in calculating the magnitudes of the oscillator strengths of the different transitions in $3d^n$ octahedral complexes which are in very reasonable agreement with the experimental optical absorption spectra of such complexes.

A. S. Chakravarty

2A.18 *Atomic Polarizabilities and Shielding Factors in the Case of Open Shell Electronic Systems*

We are investigating the extension of the self-consistent variation partur-bation technique developed for the calculation of dipole and quadrupole pola-

rizabilities of closed shell atoms and ions to the case of atoms with open shell configuration. The theory is being worked out and we plan to apply it in the case of boron atom.

P. K. Mukherjee, A. K. Bhattacharya and A. Mukherji

2A.19 *Self-consistent Calculation of Dynamic Dipole Polarizability*

We have developed a method for self-consistent calculation of dynamic polarizability. We have studied the isoelectronic sequence of He upto C^{4+}. Results are very satisfactory. Interpolation relations correlating dynamic polarizability and radius of maximum charge density have been obtained. These relations may be used to obtain the response of ions in actual crystals towards external electromagnetic radiation.

Publication :

S. Sengupta and A. Mukherji, *J. Chem. Phys. 47*, 260, 1967.

P. K. Mukherjee, S. Sen Gupta and A. Mukherji

2A.20 *Self-consistent Calculation of Dynamic Quadrupole Polarizability*

The effect of oscillating quadrupole field on atomic systems is being studied in a self-consistent variation perturbation procedure built in line with the calculation of frequency dependent dipole polarizability. Proper values in the exponents of the perturbed functions are chosen so as to ensure correct quantitative estimation of spectral frequencies and the resulting excited states arising out of quadrupole interaction.

R. K. Moitra, S. Sengupta and A. Mukherji

2A.21 *Approximate Self-consistent Excited p-State Wave-functions*

Calculation of dynamic polarizability offers a good method for determining the excited p-state wave-functions for many electron system. Reasonably

good representation of the different p-state wave-functions can be obtained by getting the self-consistent solution close to different point of discontinuities in the dynamic polarizability values caused by $1s^2 \rightarrow 1s$ np transitions. Proper exponents for different p-states are chosen and the matrix elements of different powers of 'r' calculated with the present function are in good agreement with the values obtained from other sources.

(P. K. Mukherjee, S. Sengupta and A. Mukherji, 'Self-consistent Calculation of Dynamic Polarizability and Excited p-State Wave-functions of 2-electron Atom and Ions', to be published in *J. Chem. Phys.*).

P. K. Mukherjee, S. Sengupta and A. Mukherji

2A.22 *Accurate Self-consistent Calculation of Excited State Wave-functions*

The procedure mentioned in the preceding paragraph yields approximate excited state wave-functions. It is possible to improve upon the function still further by a variation perturbation technique in a self-consistent procedure which corrects for the approximations inherent in the dynamic polarizability calculation. Different p functions of He isoelectronic sequence have been obtained by this procedure.

P. K. Mukherjee and A. Mukherji

2A.23 *Self-consistent Calculation of Van der Waals Force Constant*

A self-consistent variation perturbation method has been developed to calculate the Van der Waals force constant between spherically symmetric atoms and molecules. H-H and He-He systems have been studied. Results are in good agreement with the experimental values. Calculations are being extended to the systems like Ne-Ne, Ne-H, Ne-He, He-H, etc.

Publication :

S. Sengupta and A. Mukherji, *Phys. Rev. 166*, 36, 1968.

S. Sengupta and A. Mukherji

2A.24 *Extension of the Range of the Stark-modulated Micro-wave Spectrometer*

The window of our stark-modulated spectrometer was small. It was rather imperative to enlarge it because types of molecules of our interest have

to be investigated both in the higher and lower frequency ranges of the spectrometer. In order to extend the range of investigation of the existing stark-modulated microwave spectrometer (18 kMc to 26 kMc we have built a stark-modulated spectrometer covering the range 8 kMc to 12 kMc.

D. K. Ghosh and A. Chatterjee

2A.25 *Microwave Spectra of Thioacetic Acid*

The spectrum of thioacetic acid was contaminated with lines of acetic acid which was present in the sample as an impurity. On referring to the literature, it was found that only two workers had worked on this molecule. One of them gave a list of lines (frequencies measured with a wave-meter, accuracy $\pm$ 10 Mc) without any assignment or rotational constant whereas the other assigned four lines in the 22-25 kMc region and also gave a value for the potential barrier to internal rotation of the methyl group. On taking a run of the spectrum of pure acetic acid, we found that there were numerous lines present. It was thus necessary to attempt a theoretical analysis of acetic acid before proceeding any further with thioacetic acid. Work on both thio-acetic acid and acetic acid is in progress.

D. K. Ghosh and A. Chatterjee

2A.26 *Microwave Spectra of Allyl Mercaptan*

Attempt was made to find out any possible rotational isomer present in allyl mercaptan. The two possible configurations are cis and gauche with respect to relative rotation of the CH_2SH group and the ethylenic group about C-C single bond. Existence of cis configuration is distinctly established. The obtained rotational constants are

$$\frac{A-C}{2} = 4492 \text{ Mc} \qquad \frac{A+C}{2} = 7775.09 \text{ Mc} \qquad K = -0.78305$$

There may be slight error in the value of $\frac{A+C}{2}$ The agreement of the experimental results with the theoretical values in the case of gauche configuration is comparatively poor. The error is within 5 Mc or more and is outside the range of experimental errors. The difficulty is due to the fact that the Q

branch transitions are not within our range of investigation. The most probable rotational constants are : A = 20324.62 Mc, B = 2813.19 Mc, C = 2723.74 Mc, K = −0.9898.

The spectrum is quite rich. It may be due to SH torsional motion about CS bond. Since both the tops are asymmetric, it imposes a serious difficulty in the theoretical calculations.

R. Nandy and A. Chatterjee

2A.27 *Acoustic Magnetic Resonance*

Acoustic magnetic resonance, both pulsed and steady, has been formulated in terms of Bloch—Waugsness—Redfield theory of magnetic resonance, assuming the quadrupolar mechanism for the acoustic-spin coupling. The spin-lattice relaxation effects have been incorporated, in the steady-state, assuming the correlation-time large compared with the period of acoustic-spin coupling interaction. Specific calculations have been made for spin-one quadrupolar nuclei occupying the lattice sites of a simple cubic crystal, in which the acoustic energy propagates along one of the cubic axes longitudinally. Expressions for the induced bulk magnetization and the power absorbed at magnetic resonance have been worked out both for the small and the large amplitudes of the impressed acoustic field. The above formulation will be helpful in designing acoustic magnetic resonance experiments in order to measure, not only the spin-phonon coupling constant for a specific lattice mode, but also the different elements of the relaxation matrix which appear as parameters in the final expressions.

The equipments built up for acoustic magnetic resonance experiments consist of an ultrasonic pulse-echo apparatus working in the range 1 Mc to 18 Mc. The pulser can also produce a two-pulse sequence so that the apparatus can be used for studying magnetic resonance spin-echoes, especially in liquids.

A more sensitive pulse-echo equipment, and a continuous-wave acoustic magnetic resonance apparatus in the rf range is under construction.

S. K. Sinha and S. K. Ghatak

ESR SPECTROSCOPY

2A.28 *Single Klystron Superheterodyne Assembly*

An X-band microwave super-heterodyne system using one single varian X-13 klystron has been developed. The microwave source is frequency modu-

lated with 10 Mc signal from a signal generator keeping the modulation index less than 0.5. The carrier and the first pair of side-bands generated pass through an uniline and an attenuator to a shunt tee (Fig. 2A.6). A transmission type

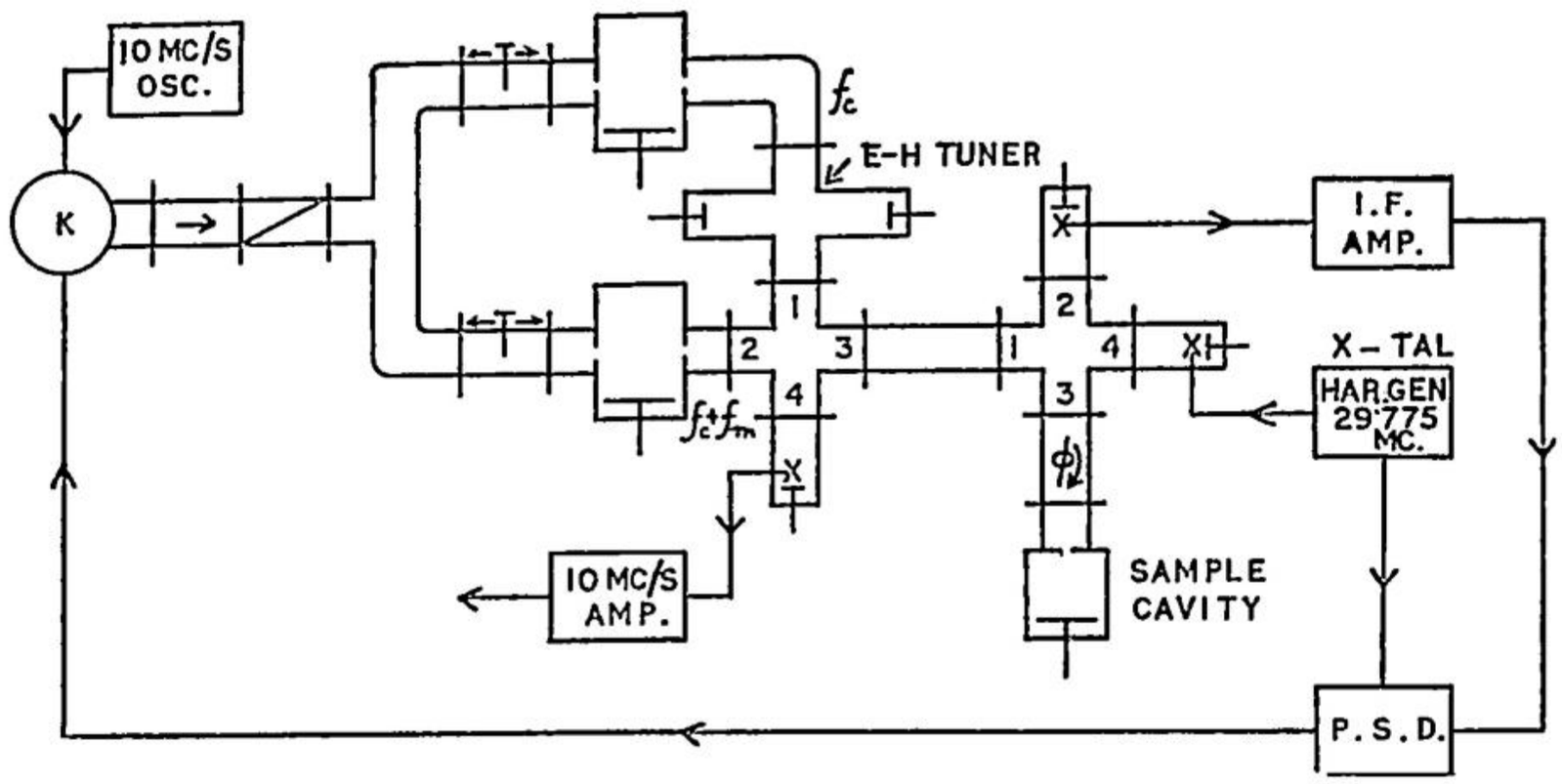


Fig. 2A.6. Single klystron superhet assembly for ESR spectroscopy.

tunable TE_{011} mode cylindrical cavity having Q = 7000 picks out the carrier frequency f_o and sends it through an E-H tuner to the first arm of a magic tee. A similar cavity tuned to $f_o + f_m$ feeds the heterodyning signal to the 2nd arm of the same magic tee. Microwaves at f_o reflected from the sample cavity are fed to the 3rd arm and in the fourth arm of the magic tee a detector crystal 1N23F is incorporated. Heterodyne detection in this crystal provides ESR signal at the intermediate frequency of 10 Mc. It may be pointed out in this connection that these cavity filters introduce an insertion loss of 15 db in each arm.

The sample cavity is held on the 3rd arm of a separate magic tee; the latter is utilised for obtaining the electronic interlock of the klystron frequency with the resonant frequency of the sample cavity with the help of a modified 'Pound stabiliser' operating at 29.775 Mc.

Publication :

R. Roy and A. K. Roy, *J. Inst. Telecomm. Engg.*, *14*, 319, 1968.

(R. Roy and N. Banerjee, 'A Superheterodyne System with a Single Klystron,' presented at the Twelfth Technical Convention of I.T.E., New Delhi, 1968 and to be published in *J. Inst. Telecomm. Engg.*)

R. Roy, A. K. Roy and N. Banerjee

2A.29 *UHF Spectrometer*

An ESR spectrometer has been designed at 250 Mc for studies on free radicals in biological samples in aqueous solution and also with a view to study resonance in metals like Li, Na and K over the range of temperatures 77°K to 300°K.

The rf. generator (Fig. 2A.7) consists of two acorn tubes (955) in a tuned-plate tuned-cathode configuration. An inductively coupled loop feeds the sample with UHF waves in a $1\frac{1}{4}$ turn coil held at the top of the auxiliary transmission line. A stub-tuner positioned on the vertical stem of the line adjusts for the impedance matching. The sample is placed between two Helmholtz

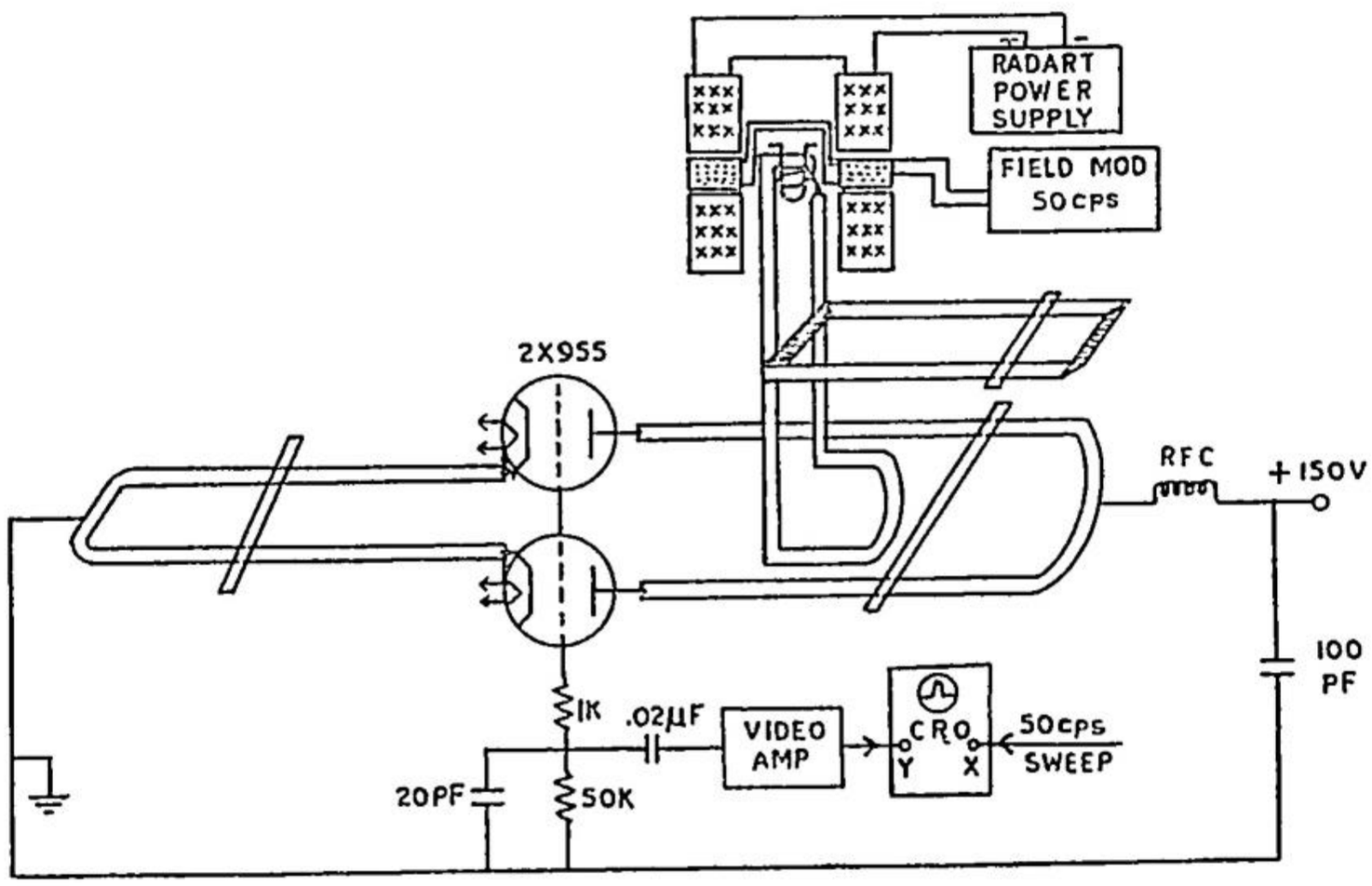


Fig. 2A.7. ESR spectrometer operating at 250 Mc.

coils fed by one electronically stabilised dc power supply unit, Radart 808-A. The modulation of the magnetic field at 50 cps is obtained with the help of an anxiliary coil sitting by the two sides of the sample tube. Absorption of power due to ESR phenomenon is detected as a negative pip from the grid circuit of the oscillator assembly. This signal after amplification in a video amplifier is displayed on the 50 cps sweep of the cathode ray oscillagraph.

Work is in progress to employ (i) field modulation at a frequency of 33 cps, (ii) amplification of the signal in narrow band twin-tee amplifier followed by phase sensitive detection at 33 cps and (iii) to develop a co-axial sample cavity in place of the non-resonant coil.

R. Roy, S. Sen Gupta and A. Mukherjee

2A.30 *K-band Superheterodyne ESR Spectrometer*

The initial layout of a K-band superheterodyne ESR spectrometer is ready. This spectrometer will be utilised for the delineation of narrow hyperfine lines in the ESR spectra from liquid samples and also for studying 'ENDOR' at liquid nitrogen and liquid helium temperatures.

R. Roy

2A.31 *Evaluation of the g-Tensor from the ESR Spectrum of Copper Sarcosine*

Weil and Anderson's method for evaluating the completely asymmetric g-tensor from the magnetic resonance data, is utilised in finding the anisotropic g values of the amino-acid complex, Cu-sarcosine. The ESR spectra in a single crystal of Cu-sarcosine, corresponding to rotation around each of three mutually perpendicular axes, are recorded. The principal g values obtained thereby are $g_1 = 2.16$, $g_2 = 2.08$ and $g_3 = 2.13$.

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

2A.32 *Studies on g-Anisotropy from ESR Spectra of Polycrystalline Samples*

An analysis of ESR spectra of polycrystalline sample of Cu-bis-N-meta nitrobenzoyl N-phenyl hydroxylamine was carried out at room temperature (27°C) and the values of g(||) and g($\perp$) were calculated from the observed derivative line-shape by the method suggested by F. K. Kneubuehl (J.C.P., *Phys. Rev.*, *33*, 1074, 1960). The g-values calculated from the peaks of the derivative trace of the ESR signal using D.P.P.H. marker, are as follows g(||) = 2.04, g($\perp$) = 2.12.

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

NOR SPECTROSCOPY

2A.33 *Crystal Parameters from Zeeman-split NQR Spectra*

Studies on the determination of the crystal parameters with a single crystal of sodium chlorate from the Zeeman split NQR spectra for the rotation of the crystal around the R.F. axis, and an axis perpendicular to the Zeeman field and R.F. axis, with a three rotation gonimeter have been completed. The fabrication of a two-rotation goniometer is in progress. It will be utilised for the studies on a single crystal of barium chlorate. The new gonimeter will provide an improvement in the filling factor and hence an increase in S/N ratio.

Publication :

A. K. Saha, S. Sen Gupta and R. Roy, *Proc. Nuc. Phys. Sol. St. Phys. Symp., Madras,* 1968, p. 312.

A. K. Saha, R. Roy and S. Sen Gupta

2A.34 *Asymmetry Parameter from Polycrystalline Samples*

Morino and Toyamas' method has been utilised for the determination of the asymmetry parameter η from the polycrystalline sample of chloranil and from a frozen sample of trans-dichloroethylene. Experiments are now being carried out to investigate the dependence of η and eq. Q for ^{35}Cl and ^{209}Bi nuclei in $BiCl_3$ on temperature, using a low temperature dewar assembly.

A. K. Saha, R. Roy and S. Sen Gupta

HIGH RESOLUTION NMR

2A.35 *Spin-lattice Relaxation Time Measurements*

In continuation of our previous work reported last year, spin-lattice relaxation times in three disubstituted benzenes (chlorotoluenes) have been measured in order to verify our assumption of the influence of symmetry on the relaxation times. The detailed study is still under progress.

N. Chatterjee and M. Bose

2A.36 *Proton-lock Cum Frequency Sweep Device for HR100*

Our present high resolution NMR spectrometer provides an arrangement for sweeping the magnetic field to locate the resonance position. Extreme stability and homogeneity of the magnetic field is essential for high resolution work. The field stability is achieved (1 part in 10^8) by the Varian power supply and super-stabilizer units which are quite satisfactory to nullify the rapid fluctuations in the magnetic field, but this system is unable to correct the very slow drift, which generally occurs due to change in temperature and line voltage. This slow drift sometimes causes difficulty in assigning the true line positions. Further, in our existing instrument there is no provision for sweeping the frequency instead of the magnetic field for recording the spectra. The frequency sweep method, moreover, is advantageous in many respects, particularly in

double resonance work. To control the slow drift and to provide the frequency sweep device we have undertaken a programme for modification of our instrument.

The main principle of locking is to hold the field value at the centre of the U-mode signal of a standard proton sample. This is achieved by feeding the output of the signal to the super stabilizer coils, through the galvanometer system. Any small change from the central position produces a comparatively large error signal for locking the field. However, it is necessary to use two radio-frequency sources, one for locking and the other for normal detection of NMR signals. But our present instrument has only one rf source (100 Mc crystal oscillator). The two radio frequencies, however, can be obtained from the existence instrument by modulating with two audio frequencies and by operating in side band modes. Our NMR integrator unit can provide for one audio oscillator and corresponding detector system. However, another set of oscillator and detector is required for observing the NMR signal. The actual locking arrangement is shown in the block diagram (Fig. 2A.8).

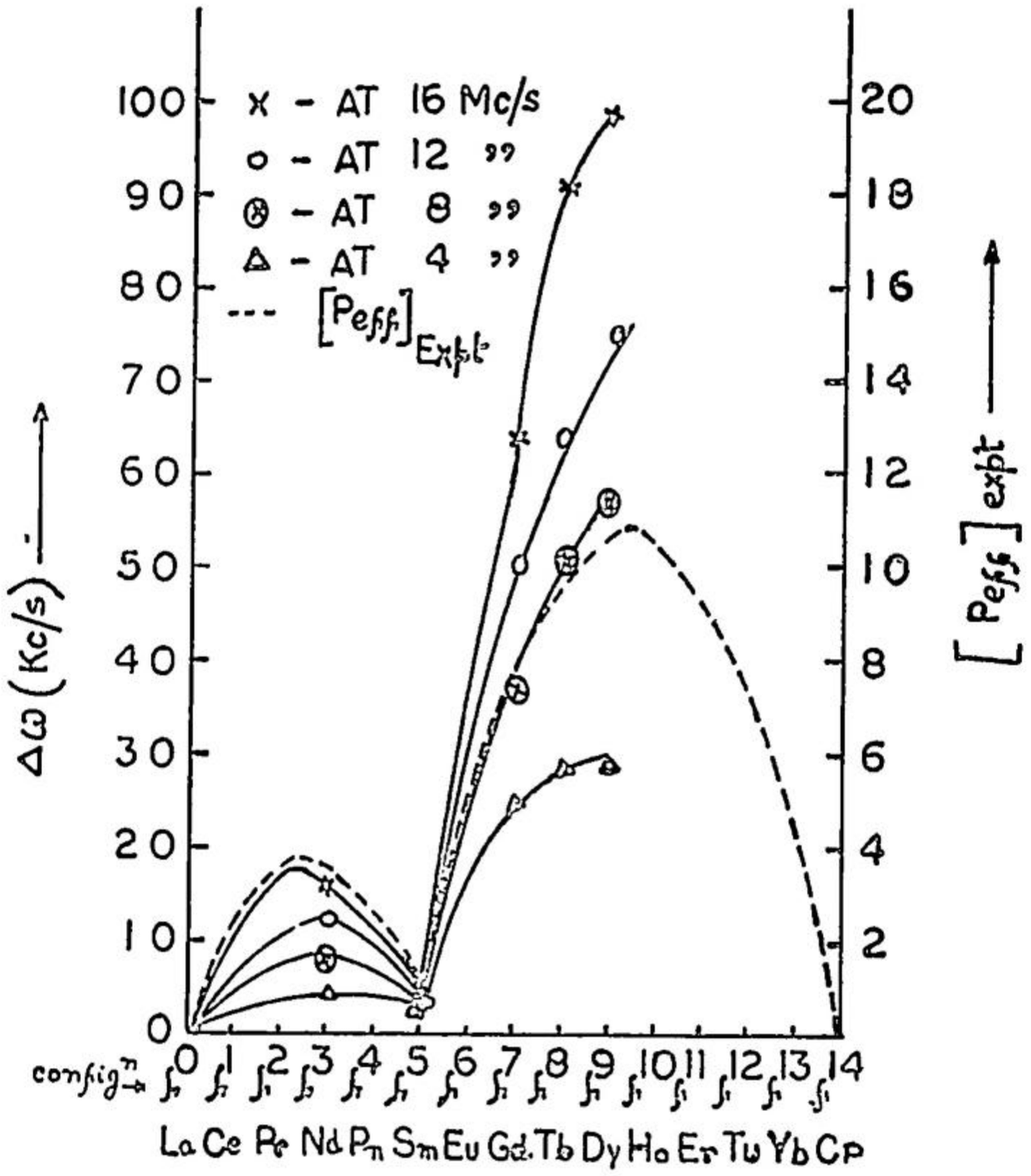


Fig. 2A.8. Line widths as a function of resonance frequency wo and configuration fn at room temperature.

Proton locking

The U-mode signal for the TMS sample is detected in the 2 kc first side-band mode (lower) which is obtained from the NMR integrator. The sig-

nal output from the phase-sensitive detector of the NMR integrator is fed to the galvanometer coil of the super-stabilizer unit to lock the magnetic field. If a slight drift occurs, the signal position will change and an error voltage will develop which will cause an imbalance in the galvanometer system. This imbalance, after proper correction is employed as a feed back signal to super-stabilizer coils, whereby the drift is eliminated and as long as this correction is proper in sign and magnitude, the field is locked to the proton signal of the standard TMS.

Recording NMR spectra by frequency sweep device

Now since the field is locked to a particular value, the signals for the test sample can be recorded by changing the applied frequency. This can easily be done by applying a second audio frequency modulation (1 kc) and by detecting the signals with the help of another phase sensitive detector tuned to the 1 kc lower side-band mode. A slow speed motor arrangement is incorporated to obtain the required frequency drive. Since TMS is a highly shielded compound (resonance position is about 1000 cps apart from common samples in 100 Mc spectra), it does not interfere with 1 kc side-band mode operation.

We have succeeded in locking our present spectrometer to the TMS signal. For recording the spectra we have at present only a nonlinear dial oscillator hp 200CD. The nonlinearity of the dial would prevent us from obtaining calibrated frequency sweep spectra. For this purpose we urgently require a linear-dial audio oscillator so that our present spectrometer can be effectively employed for high resolution work.

N. Chatterjee, A. Basu and M. Bose

2A.37 *Resonance in Some Anhydrous Rare-earth Phosphates*

Nuclear magnetic resonance of ^{31}P in some polycrystalline anhydrous rare-earth phosphates are being systematically investigated with a view to understanding the nature of electron-nuclear interaction and the bonding situation in the phosphates of rare-earths. The choice of anhydrous rare-earth phosphates was necessitated by the availability of crystal structure data for these systems, while no such data existed for the hydrated phosphates investigated previously. Further, the hyperfine interaction term would be expected to increase considerably in the anhydrous system, both from packing consideration, as well as from competing effects of the aquo-shell in hydrated systems.

The Hamiltonian for the nuclear magnetic moment may be written as

$$H = -\gamma h I H_o/2\pi + \sum_j \gamma h I g \beta S \frac{(3\,\mathrm{Cos}^2\phi_j - 1)}{2\pi\, r_j^3} + \sum_j I A_j S_j$$

The first term gives the interaction of the nuclear moment with the external

field. The second and the third terms represent the electron nuclear dipolar and the hyperfine interactions respectively. These terms determine the shifts and the line-widths in paramagnetic systems. Delineation of the individual terms is a difficult problem even in a single crystal, much more so in a polycrystalline material. However, shifts of the resonance frequency, if observable, is a definite indication of transferred hyperfine effects. The paramagnetic terms also contribute to the relaxation process which like the shifts is frequency and field dependent. As such we have studied the ^{31}P resonances in the rare-earth phosphates both as functions of field and temperature.

The NMR signal in a paramagnetic substance is generally observable only when the nucleus sees the average static components of the electron magnetic moment $\bar{\mu}_D = \frac{\mu^2_D H_o}{3kT}$ parallel to the Zeeman field, where μ_D is the instantaneous value of the magnetic moment. The local field produced at the nucleus by this static component is orientation dependent and a powdered sample would give a spectrum broadened by the superposition of spectra of

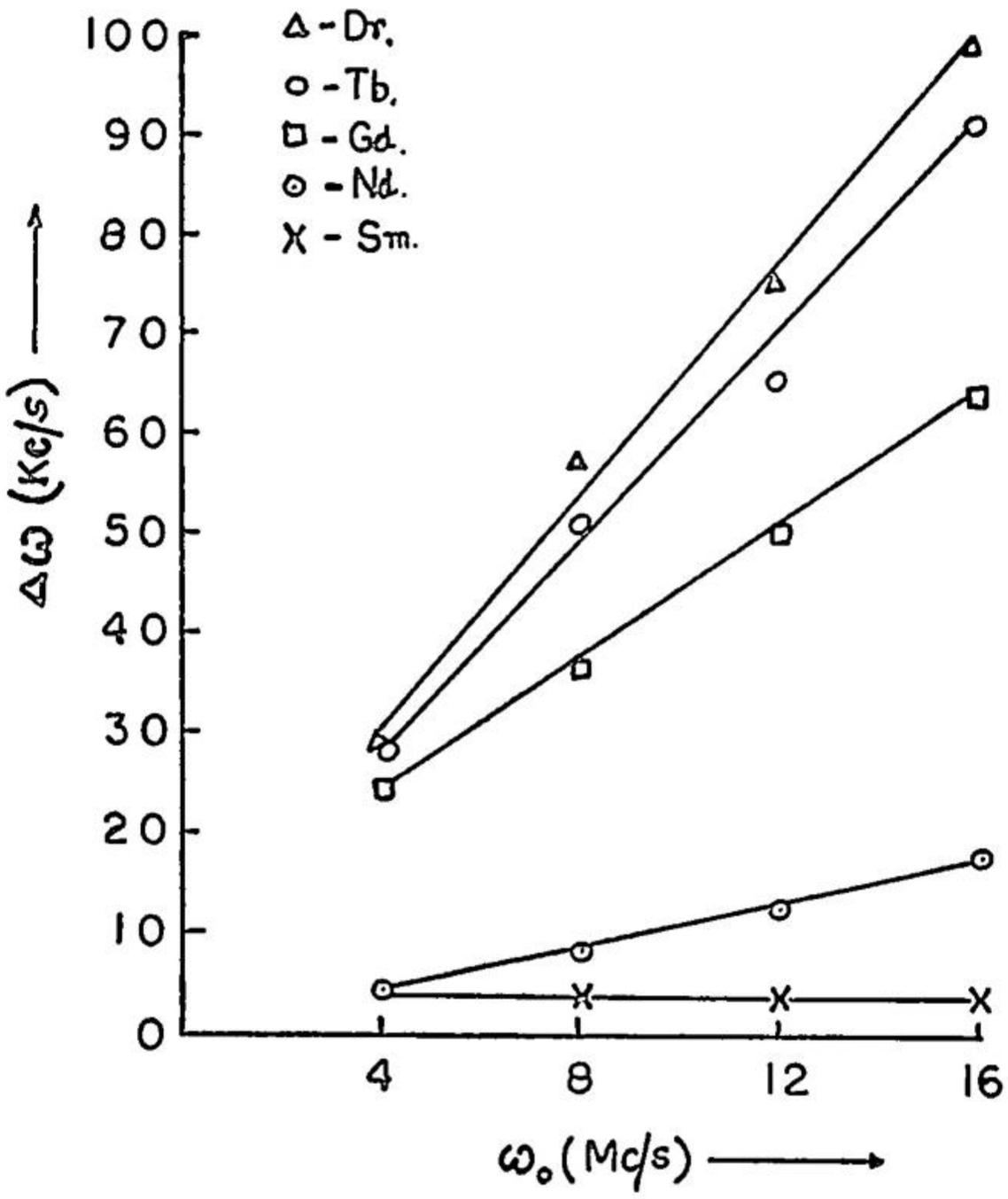


Fig. 2A.9. The dependence of line width on resonance frequency w_o.

individual crystallites. Assuming that the parameters in the rare-earth phosphates remain more or less the same, the line widths for the various compounds are expected to be parallel to the magnetic moments of the paramagnetic ions. Since the average static component is proportional to the applied magnetic field, the approximate linear dependence of the line width on the resonance frequency,

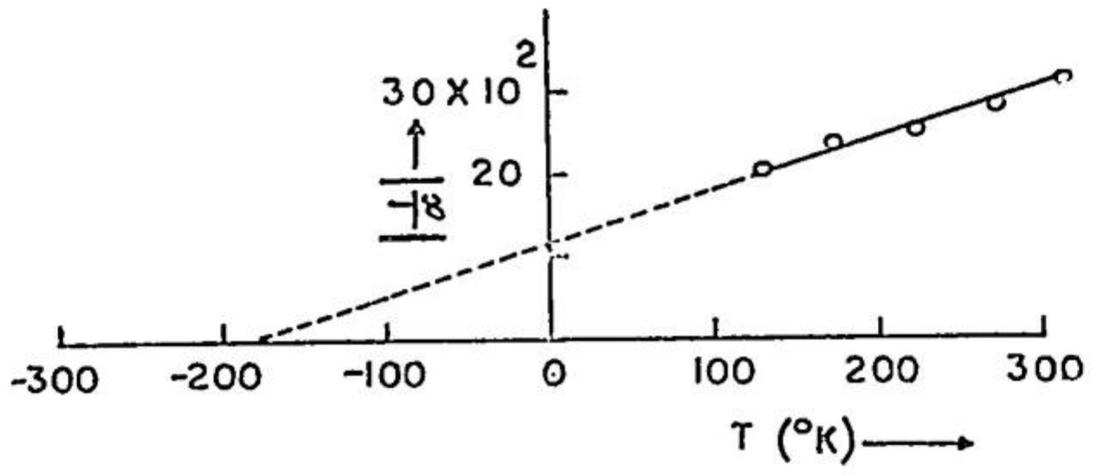
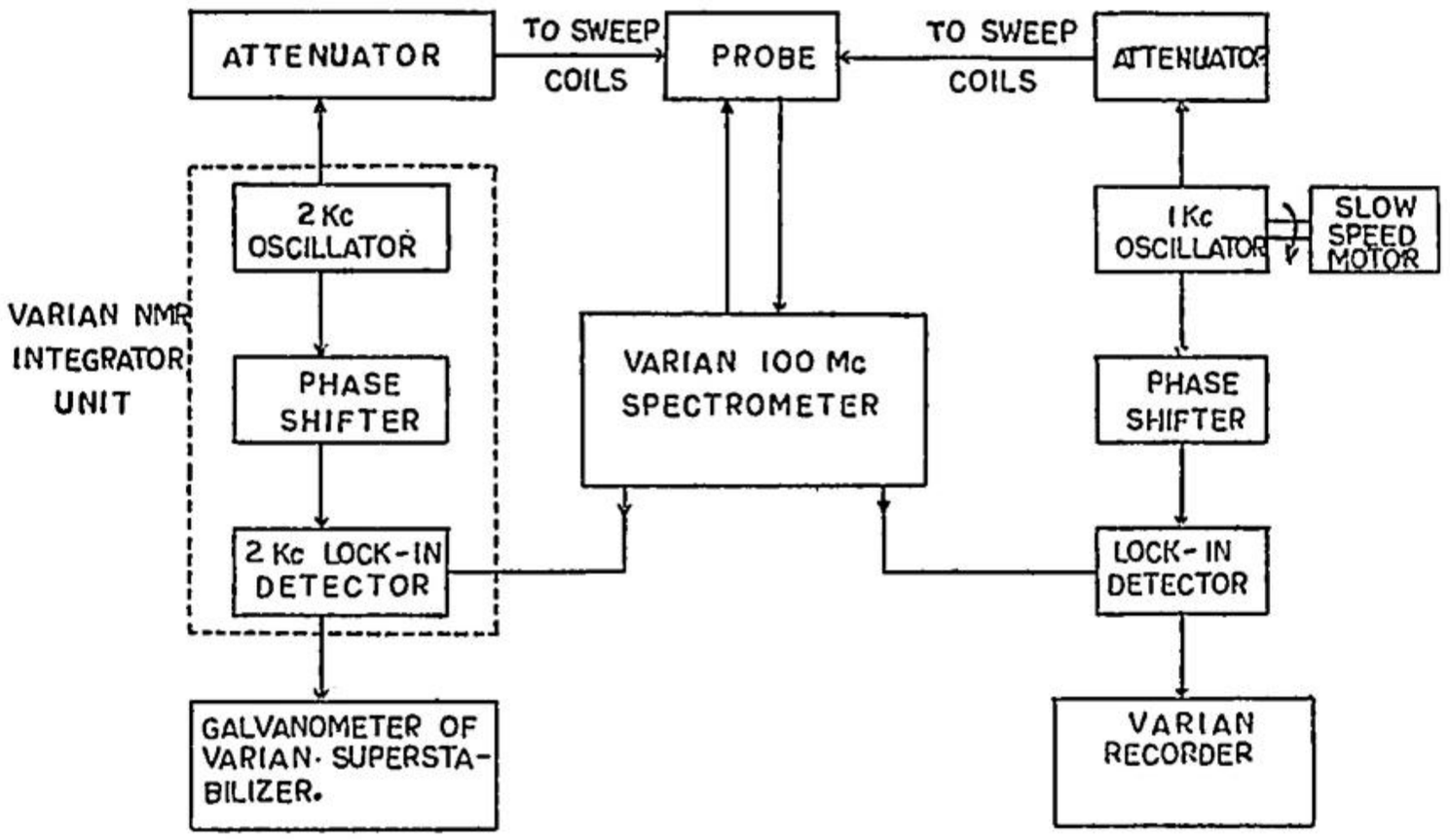


Fig. 2A.10 The dependence of $|1/\alpha|$ on temperature.

is quite understandable (Figs. 2A.9 and 2A.10). Dependence of the line width on the number of f-electrons reasonably show the same trend, as that of the p_{eff} vs. number of f-electron curve (Fig. 2A.9). Lines in paramagnetic rare-earth phosphates are in general asymmetric and this asymmetry increases with increase of resonance frequency and with decrease of temperature. The paramagnetic centres often produce shifts of the NMR spectrum of the adjacent nonmagnetic atom, through transferred hyperfine interaction. Hyperfine interaction of the rare-earth ion with the nearest neighbouring atoms has already been observed in number of cases both in liquids and solids. Interaction of the unpaired electron with nuclei separated by an intervening oxygen atom has also been observed in oxy-anions as nitrates and perchlorates in solution. One could then possibly expect to observe ^{31}P shifts in solid rare-earth phosphates. Experimentally, a small shift (0.04% at 300°K) has only been observed in Pr-phosphate. The zero shift in $SmPO_4$ is not unexpected, as Sm^{3+} ions behave like a diamagnetic at about 300°K. If the shifts in Gd, Tb, Dy are of the



BLOCK DIAGRAM FOR NMR LOCK-IN SYSTEM CUM FREQUENCY SWEEP

Fig. 2A.11. Block diagram for NMR lock-in system cum frequency sweep.

same order as in Pr, it probably escaped detection due to very much large line widths in the phosphates of Gd, Tb, Dy as compared to Pr. The absence of shift in Nd is yet to be understood. Fig. 2A.11 shows the dependence of $\left|\frac{1}{\alpha}\right|$ on temperature for $PrPO_4$, where $\alpha = \delta\omega/\omega_0$ is the fractional shift. The observed temperature dependence is described by means of Curie-Weiss law, where the Curie-Weiss constant comes out to be $(H) = 180°K$.

Further, work on other rare-earths is necessary and is being currently pursued before a more comprehensive understanding of the magnetic interactions in rare-earth phosphates is arrived at.

M. Bhattacharya and M. Bose

2B. CRYSTALLOGRAPHY AND MOLECULAR BIOLOGY DIVISION

2B.0 *Introductory Remarks*

The annual report of this division for the year 1967 clearly indicates that some of the research problems are reasonably long term ones and it is, therefore, natural that they have been continued during the year under review. Admittedly, there are some additions and alterations in the current year's programme; but this modification is amply justified in view of the progress, findings and their implications. The research activities of this division may be summarised under the following major heads :

(1) Crystal and molecular structure of biological molecules by X-ray crystallographic methods.

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

(3) Physico-chemical study of biomolecules and enzymes.

(4) Quantum biology and the study of the conformation of biomolecules by molecular orbital method.

(5) Radiation biology.

(6) Agrobiology.

(7) Development of techniques and instruments.

It may be noted that the topics headlined above are the ramifications of our major programme of research, i.e., the role of structure at different levels of organisation on biological functions. As before, the study of collagen from various sources at different levels of evolutionary scale is being made by wide and small angle X-ray diffraction, electron microscopic and physico-chemical methods. The study on the structure of amino acid derivatives and metal complexes has been a very successful venture and prompted us to pursue this programme with renewed efforts and more sophisticated techniques. An automatic diffractometer would have been a very welcome addition to our technical resources, particularly in view of time-economy and attainable accuracy in crystal structure determination. Eight structures have already been solved by us, while others are in progress. The study on the mechanism of calcification in bones has been extended to systems other than collagenous. Satisfactory progress in this problem has been made with sea-whale bones. The techniques for preparing the metal complexes and other compounds of biological interest have been perfected and they are being prepared in our laboratory.

The study on the structure of collagens and other fibrous proteins from various sources and DNA from sponge, hydra and wheat plants at higher level of organisation is being pursued by electron microscopic and small angle X-ray diffraction methods. The work on electron microscopy is being greatly handicapped for want of required plates and films. Nevertheless, the service of our

electron microscope has been extended to various research centres both in and outside Calcutta.

In our programme on physico-chemical studies on biological molecules, the major components of SF collagen separated by column chromatography have been purified and studied. This study has revealed some very interesting points about collagen in general and SF collagen in particular. The linkages other than peptides have been found to be present in the individual polypeptide chains and these primary linkages, according to our preliminary findings, appear to be ester-linkages. A tentative scheme about the origin of this type of linkages in the collagen chains biosynthesised at the ribosome sites in the cell has been proposed by us. The physico-chemical study of DNA from different sources is also being continued. Interesting findings are in evidence in our study on the role of metals in structural organisation and functions of biomolecules. Biomolecules, in which amino acids are linked through ester linkages instead of through peptide linkages as in peptides have been synthesised by us. So far as our study on enzymes is concerned, respiratory behaviour of inositol deficient S. Carlsbergensis is being investigated.

Investigation on the conformation of biomolecules is being continued on some amino acids with aromatic side chains, e.g., histidine, tryptophan, tyrosine, proline, hydroxyproline and phenylalanine. The method used for this calculation is the three-dimensional extended Huckel method of Hoffmann. Computation is being done on CDC 3600 computer at Bombay. The other aspects of our study in quantum biology is the calculation of σ-electronic charge distribution in amino acids by LCAO-MO method and its correlation with the structural parameters and properties of the compounds. The four molecules in cationic, anionic and neutral forms already studied by us have provided interesting background for correlation.

In our programme on radiobiology and argrobiology, some of the problems undertaken earlier are being continued and some new ones are in progress. The immediate requirements in this scheme of research are a sizable animal house and a Green house. Attempt is also being made to develop a tissue culture laboratory. Short of space and lack of some facilities have restricted the research activity of this section.

Three of our research workers have submitted thesis for the D.Phil. (Sc) degree during the year under review. One has already been awarded his degree and the other two are expecting the official reports soon.

In our programme on development of techniques and instruments, the one which deserves mention amongst others is the Frank type small angle camera. This has been fabricated in our workshop.

Weekly seminars and invited talks by those actively engaged in research have been organised as a regular feature of this division during the year under review. Our staff members were also invited to give lectures in different centres of research and took part in a number of symposia held during the year.

N. N. Saha

2B.1 *Crystal and Molecular Structure*

(a) *Sarcosine Hydrochloride* ($C_3H_7O_2N.HCl$)

The preliminary findings on structure of sarcosine hydrochloride based on 2-D analysis was reported earlier. The structure was later refined by three dimensional least-square method using isotropic temperature factors for all the atoms. The value of the disagreement factor R at this stage was 18%. On further refinement using anisotropic temperature factors the value of R came down to 13%. Further work is in progress for the complete solution of the structure by locating the position of hydrogen atoms by difference Fourier synthesis.

Publication :

S. C. Bhattacharyya, S. K. Mazumdar and N. N. Saha, *Ind. J. Phys. 40*, 850, 1967.

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

(b) *Copper sarcosine* $Cu\ (CH_3NH.CH_2.COO)_2.2H_2O$

Single crystals of copper sarcosine were prepared by slow evaporation of an aqueous solution of this compound at room temperature. Needle shaped blue crystals thus obtained belong to the triclinic system. The unit cell dimensions, as determined from rotation and Weissenberg photographs taken about a, b and c axes are : $a = 6.99$ Å, $b = 7.45$ Å, $c = 12.79$ Å, $\alpha = 107°45'$, $\beta = 116°$, $\gamma = 100°45'$. The space group is either P1 or $P\bar{1}$ and the unit cell contains two formula units of copper sarcosine.

The positions of the heavy atoms (copper) in the unit cell were determined from three-dimensional Patterson synthesis. A satisfactory model of the structure by using minimum function could not be obtained. So a three-dimensional copper-phased Fourier synthesis was calculated. This provided a clue to the structure. Further work is in progress.

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

(c) *Silver ortho-amino benzene sulphonyl glycine* $HAg[C_6H_4(NH_2)SO_2NHCH_2COO]_2$

Single crystals of silver ortho-amino benzene sulphonyl glycine was grown by slow evaporation of an aqueous solution of this compound. The crystal belongs to monoclinic system with two molecules per unit cell of dimensions $a = 5.73$ Å, $b = 12.16$ Å, $c = 13.94$ Å, $\beta = 95°$.

The space group has been found to be $P2_1/n$ with the heavy atom (silver) at the special position.

The positions of the heavy atoms, i.e., one silver in special position and two sulphur atoms, were determined from a 3D-Patterson synthesis.

Though some clue to the structure could be obtained from the two dimensional Fourier synthesis, complete solution by 2D data has not been possible. Consequently, a three dimensional Fourier synthesis was calculated from the observed structure amplitudes $|F_o|$ using the phases of silver and sulphur atoms. A model satisfying the stereochemistry has been postulated. The structure factors were calculated with the co-ordinates as provided by this model. At this stage the R value was found to be 0.23 and 0.24 for hol and okl reflections, respectively. Fig. 2B.1 shows the Fourier synthesis of silver ortho-amino benzene sulphonyl glycine projected along a-axis.

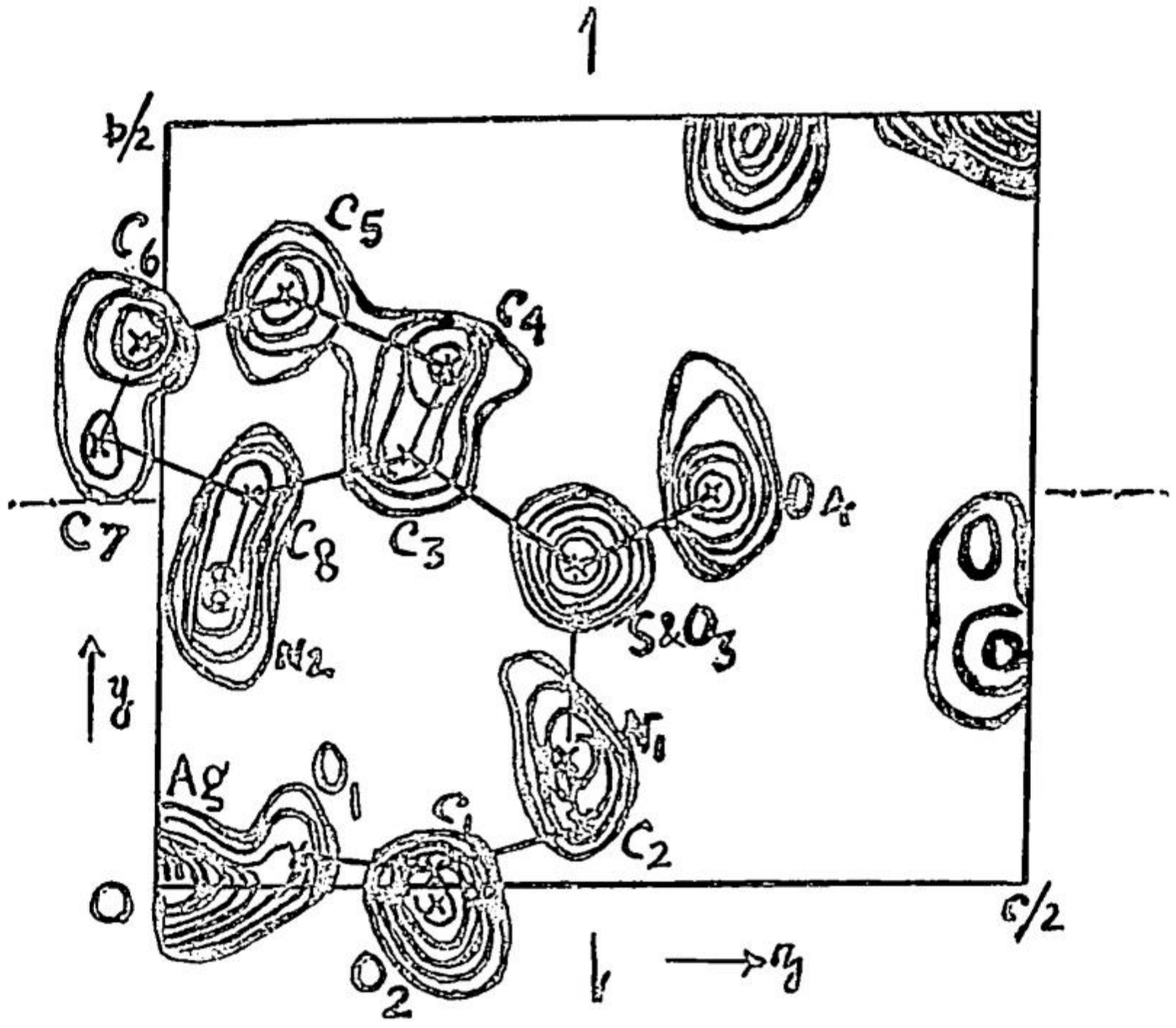


Fig. 2B.1. Ag-o-amino benzene sulphonyl glycine; density projection, p (yz).

The 3D refinement by least-square method is in progress.

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

(d) *l-ornithine hydrochloride*

Single crystals of this compound belong to the monoclinic space group $P2_1$ with cell dimensions a = 4.99 Å, b = 8.00 Å, c = 100,00 Å and $\beta = 97°$. An account of the determination of the crystal structure of this compound was incorporated in the annual report, 1967. The disagreement factor R at this stage was 0.098.

Further refinement of the structure was carried on by full matrix least-square method using individual anisotropic temperature factors for the atoms. After three cycles of refinement the R value came down to 0.082.

A three dimensional difference Fourier synthesis using all the reflections was calculated at this stage. This synthesis revealed all the hydrogen atom positions. Structure factor calculations were carried out after taking the contribution of the hydrogen atoms into account. The R value now was 0.066. After one more cycle of full matrix least-square refinement using individual anisotropic temperature factors for the nonhydrogen atoms and isotropic temperature factors for the hydrogen atoms the R value came down to 0.064.

The dimensions of the molecule are shown in Fig. 2B.2. The hydrogen bonding scheme is satisfactory.

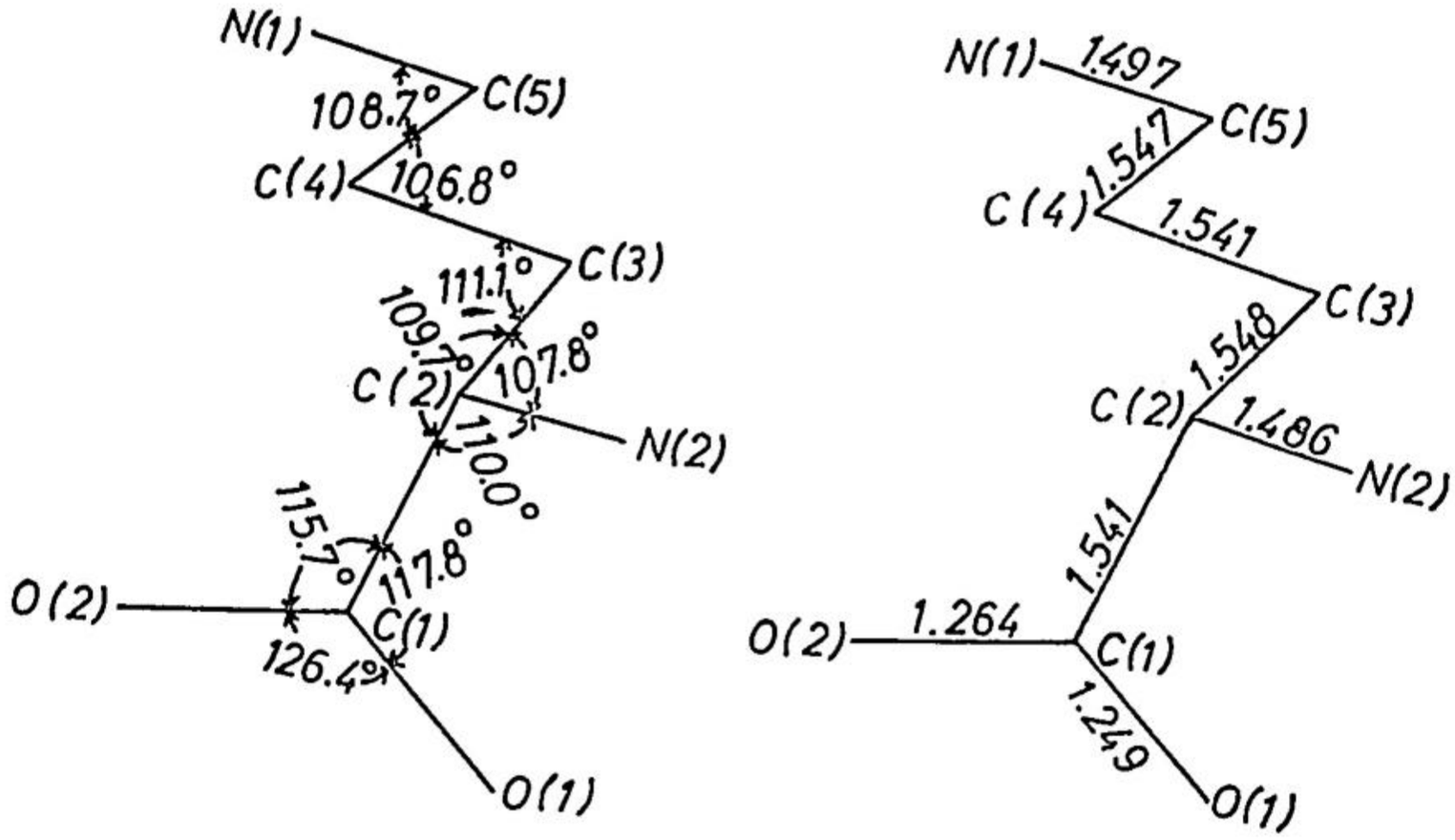


Fig. 2B.2. Bond angles and bond distances of l-orrithine hydrochloride molecule.

Publication :

S. Guha, S. K. Mazumdar and N. N. Saha, *Ind. J. Phys.*, *41*, 624, 1967.

(S. Guha, S. K. Mazumdar and N. N. Saha, 'Crystal and Molecular Structure of 1-ornithine Hydrochloride, to be published in Zeit. fur Krist.).

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

(e) *Copper complex of ornithine*

The deep blue single crystals of cupric diornithinate dichloride dihydrate grown in our laboratory belong to the monoclinic system with cell dimensions $a = 5.18$ Å, $b = 15.56$ Å, $c = 1189$ Å, $\beta = 93°17'$.

The only systematic absence observed was for k odd indicating that the space group is either $P2_1$ or $P2_1/n$. Density determination showed that there are two molecules per unit cell. Wilson's statistical test performed with okl data showed a centric distribution. Three dimensional Patterson synthesis and structure factor calculations indicated that the space group is $P2_1$ with a centre of inversion in the molecule.

The copper and chlorine atom positions, as located from the 3-D Patterson synthesis were used to calculated a 3-D heavy atom phased Fourier synthesis. This revealed the structure completely.

The exactness of the molecular centre of inversion was verified with the help of a point atom sharpened Patterson. The refinement of the structure was carried out on CDC 3600 computer by the full matrix least-square method using individual anisotropic temperature factors. The final R value was 0.088.

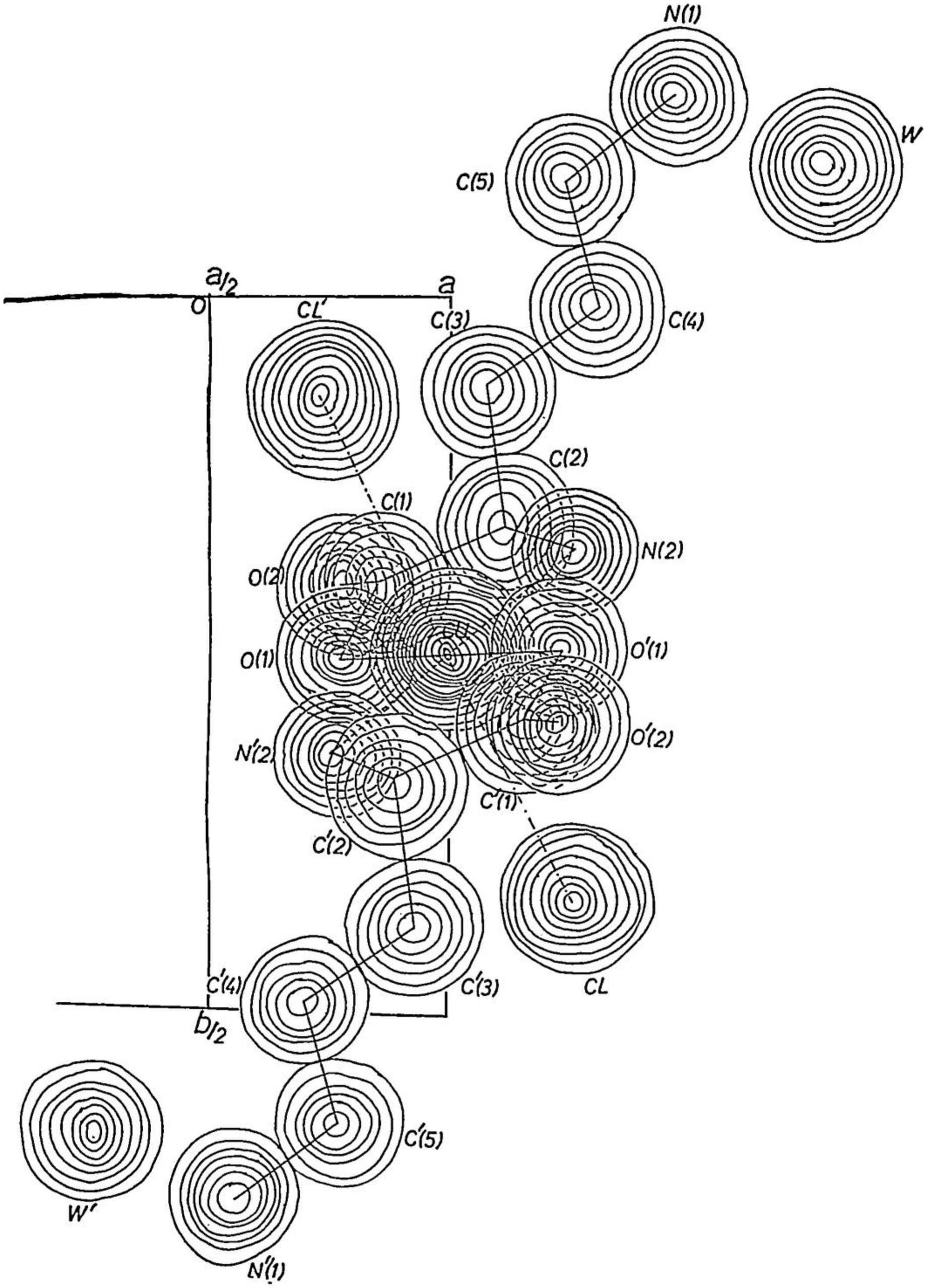


Fig. 2B.3(a). Composite drawing of the final Fourier of copper complex of ornithine viewed down C-axis.

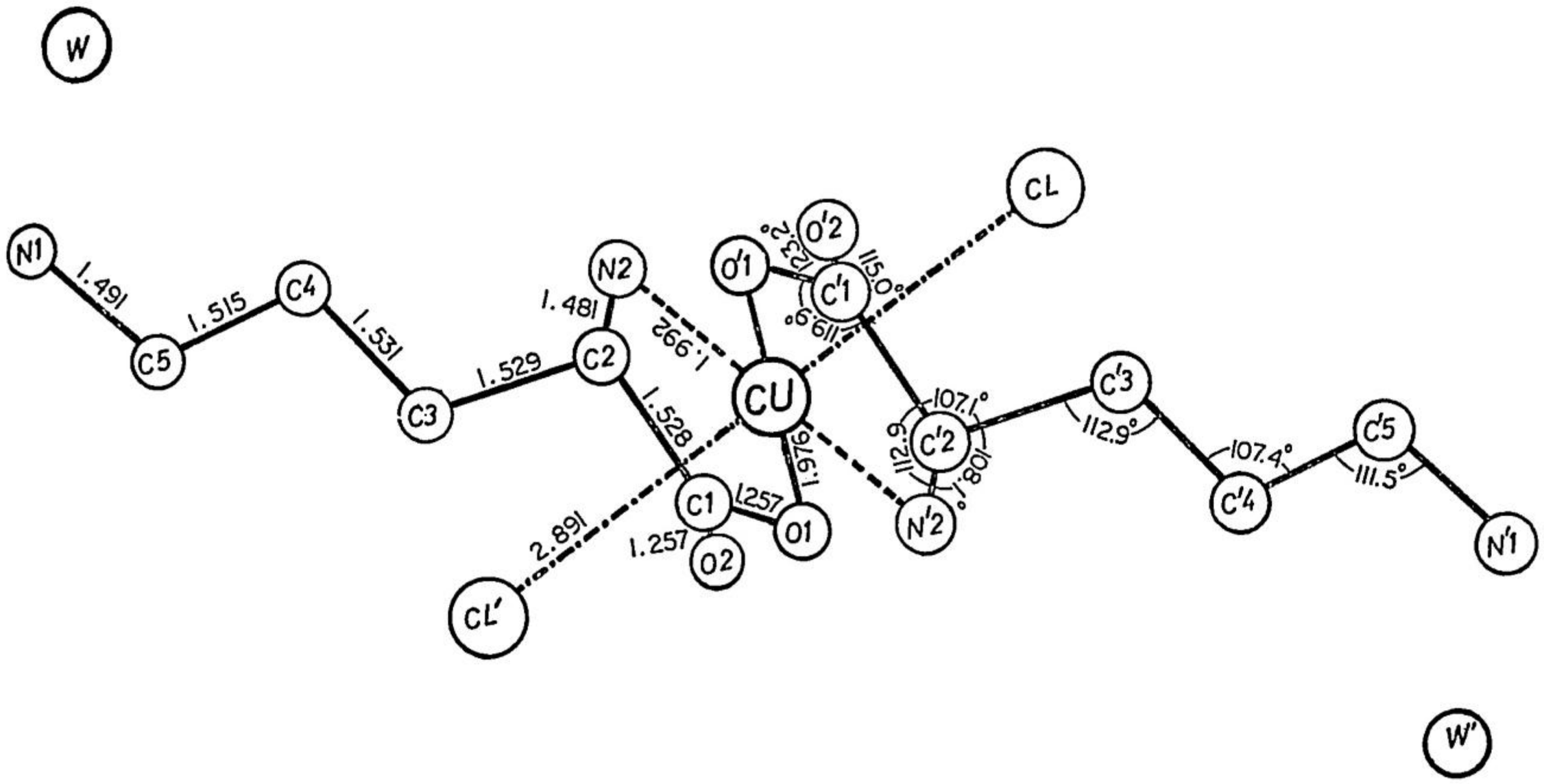


Fig. 2B.3(b). Bond angles and bond distances of copper ornithine molecule.

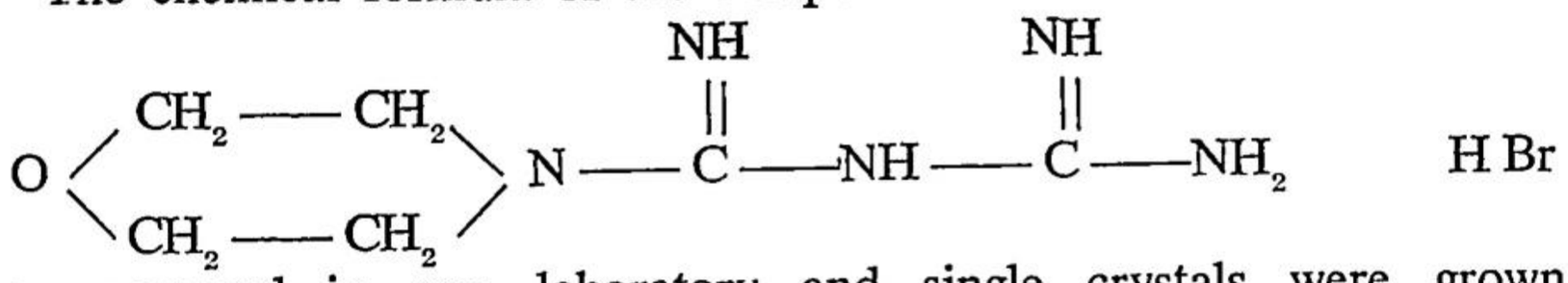
The dimensions of the molecule are given in Fig. 2B.3(a) and (b). The molecules are held together by a three dimensional network of hydrogen bonds. The packing of the structure viewed down the c-axis is shown in Fig. 2B.4.

(N. N. Saha and S. Guha 'crystal and Molecular Structure of Cupric Diornithinate Dichloride Dihydrate', to be published in the Proceedings of the 3rd Annual Symposium of the Indian Biophysical Society).

S. Guha and N. N. Saha

(f) *Morpholine biguanide hydrobromide*

The chemical formula of the compound is



It was prepared in our laboratory and single crystals were grown from a solution of this compound. Rotation and Weissenberg pictures showed that the crystals belong to triclinic system. The unit cell dimensions are : $a = 6.52$ Å, $b = 8.31$ Å, $c = 10.77$ Å, $\alpha = 108°42'$, $\beta = 109°28'$ and $\gamma = 97°43'$. Density of the crystals measured by flatation method was found to be 1.63 gm per cc. and that calculated for two molecules per unit cell was 1.66 gm per cc. Wilson's statistical test performed on hko data indicated the presence of a centre

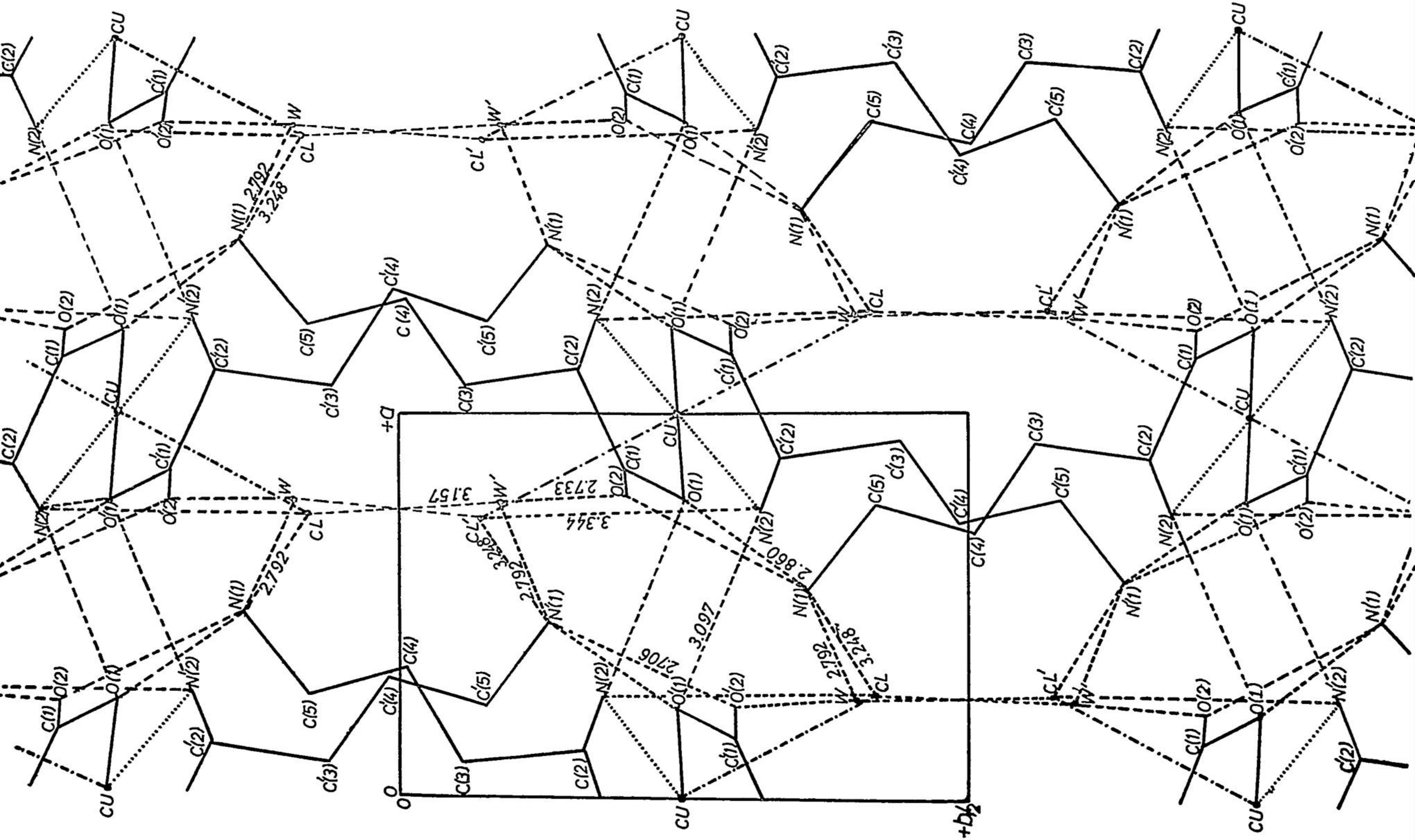


Fig. 2B.4. Packing of copper ornithine molecules viewed down C-axis.

of symmetry. The space group was thus P1. The unit cell was found to be a reduced one.

Three dimensional intensity data were collected by equi-inclination Weissenberg method about c-axis and corrected for spot shape, Lorentz polarization factors. The mass absorption co-efficient being large, data had to be corrected for absorption correction. The position of the heavy atom (bromine) was located from three dimensional Patterson synthesis. Using the phase of the heavy atom, structure factors were calculated for all the observed reflections. The disagreement factor was found to be 0.50 at this stage. The heavy atom phased Fourier synthesis was done. Spoke and lead model was used to represent the atomic positions corresponding to the peaks in electron density map. The full structure was revealed from this model and it was found to satisfy all the inter- and intra-molecular characteristics. Phases of all the atoms were used to calculate the structure factors of hko reflections and the discrepency factor came down to 0.37. After two cycles of refinement, the R-factor for hko data was found to be 0.24. Three dimensional refinement work is in progress.

R. Handa and N. N. Saha

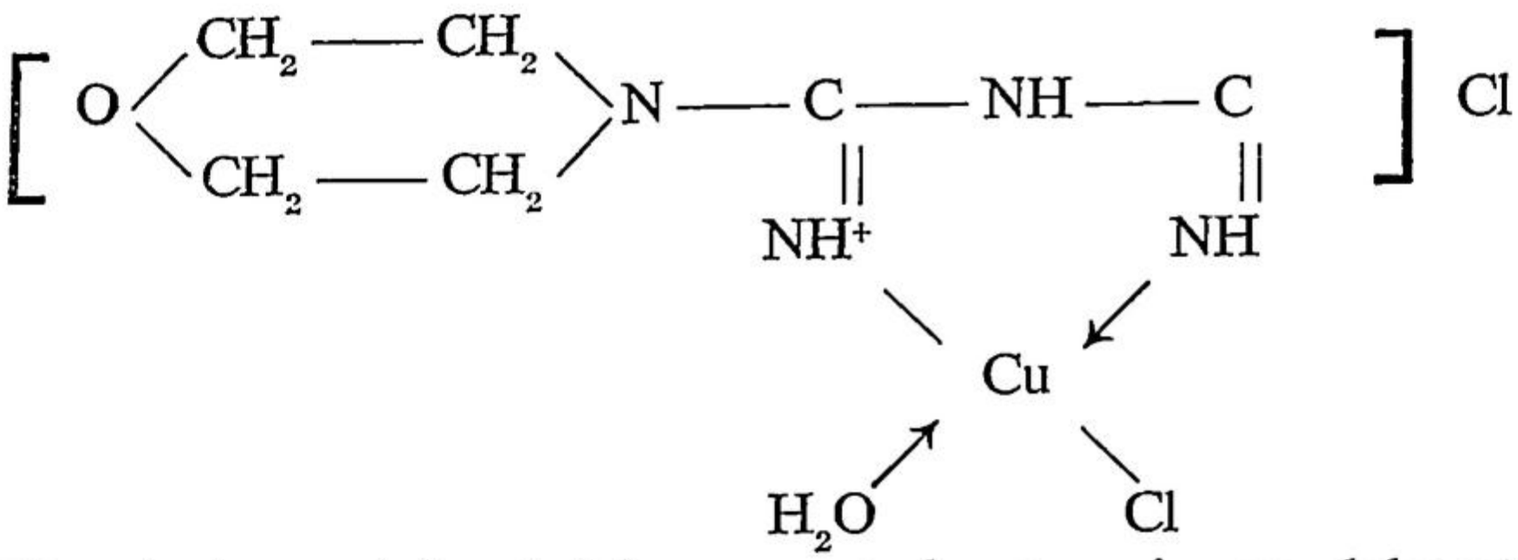
(g) *Copper complex of lysine*

Cupric dilysinate dichloride dihydride $Cu(C_6H_{11}O_2N)_2Cl_2$, $2H_2O$ was prepared by refluxing a mixture of lysine hydrochloride and freshly prepared basic cupric carbonate. Blue needle shaped crystals were grown by slow evaporation of an aqueous solution of this compound. Rotation and Weissenberg pictures showed that the crystals belong to monoclinic space group $P2_1$. Unit cell dimensions are : a = 5.21 Å, b = 16.83 Å, c = 11.65 Å, β = 97°, N = 2. Two dimensional intensity data were collected about a-axis. A Patterson synthesis was calculated to determine the y- and z-coordinates of copper and chlorine atoms. Three dimensional intensity data were then collected about a-axis and corrected for spot shape, Lorentz and polarization factors. The positions of copper and chlorine atoms determined from three dimensional Patterson synthesis were in good agreement with those obtained from 2-D Patterson. A three dimensional Fourier was calculated using the phases of heavy atoms, but it did not reveal the structure completely. The method of Fourier synthesis by successive addition of atoms has been used to locate the rest of the light atoms.

R. Handa and N. N. Saha

(h) *Copper complex of morpholine biguanide*

The chemical formula of this compound chloro-aquo-mono-morpholine biguanide copper chloride is [Cl(H_2O) (Morph. BigH) Cu] Cl. The structural formula is :—



The single crystals of this compound grown in our laboratory were green tiny needs shaped. Rotation and Weissenberg pictures were taken using Cu K-radiation. The systematic absence showed that the space group is $P2_{1/n}$. Unit cell dimensions were found to be : a = 8.33 Å, b = 16.33 Å, c = 8.89 Å, $\beta = 107°30'$, v = 1153.94 Å^3.

Density measurement by floatation method shows the presence of four molecules per unit cell. Intensity data collected about a-axis corrected for Lorentz, polarization and absorption factors have been used for okl Patterson synthesis. The y and z-coordinates of copper and chlorine atoms have been fixed. Three dimensional intensity data have been collected for the complete solution of the structure. The work is in progress.

R. Handa and N. N. Saha

(i) *L-tryptophan hydrochloride*

L-tryptophan is an essential amino acid and is known to be transformed into nicotinamide in biosynthesis. The determination of the crystal structure of L-tryptophan hydrochloride was taken up as part of the major work on the structural studies of amino acids and peptides in this laboratory.

Single crystals of tryptophan hydrochloride were grown by slow evaporation method. Rotation and Weissenberg photographs showed that the space group is $P2_1$ with cell dimensions : a = 14.50 Å, b = 5.28 Å, C = 7.21 Å, $\beta = 99°$.

J. K. Datta Gupta

(j) *Heavy atom derivatives and metal complexes*

Under our general scheme of research work on the metal complexes and halogen derivatives of the amino acids, peptides and related compounds of biological interest the crystals of the following compounds have been prepared, after incorporating heavy atoms in them. Compounds like citrulline-hydrobromide, nickel-bis-morpholine biguanide anhydrobase, copper-bis-valine chloride, copper-bis-theonine chloride have been prepared and their crystals were obtained by slow evaporation method. Attempts are now being made to obtain more suitable single crystals of the compounds for crystallographic study. Preparation of other compounds and the growth of the single crystals of amino acids, etc., are in progress.

J. K. Datta Gupta, N. G. Poddar and N. N. Saha

(k) *Preparation of crystals*

Crystals of morpholine biguanide hydrochloride, morpholine biguanide hydrobromide, nickel-bis-ornithine chloride, copper chloro-aquo-monomorpholine biguanide chloride have been prepared. O-amino benzene sulphonyl glycine has been synthesised following the method of Ghose et al. (*J. Ind. Chem. Soc. 43*, 541, 1966). Single crystals of its silver-bis-complex have been prepared and the magnetic susceptibility has been measured.

N. G. Podder and N. N. Saha

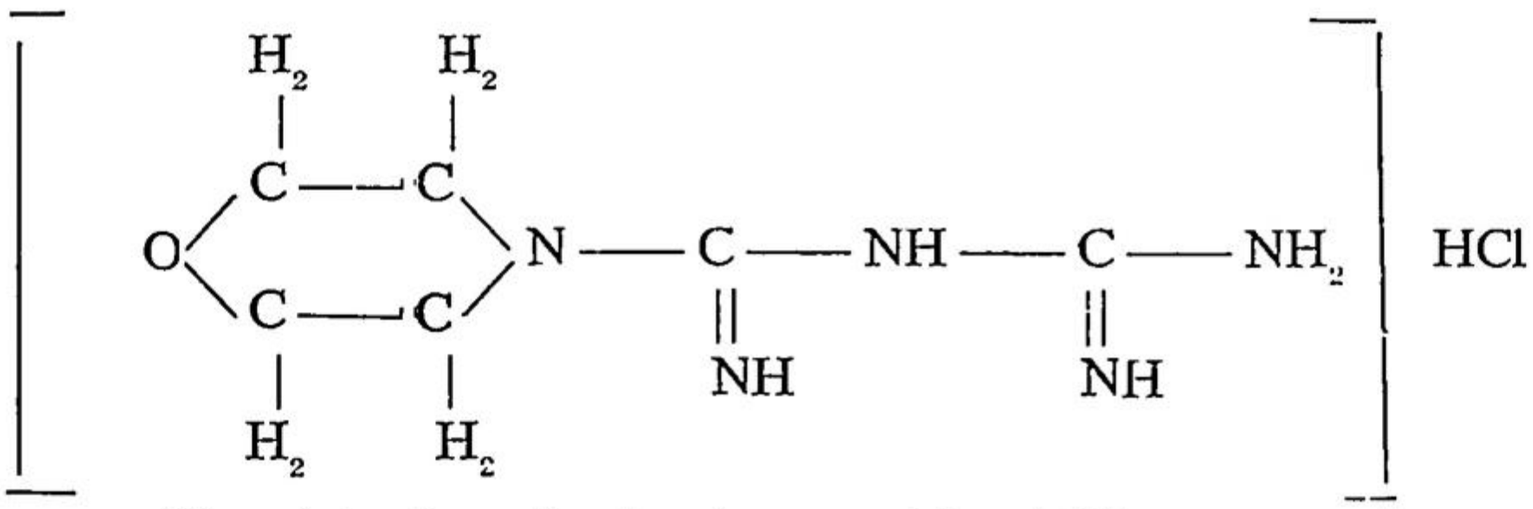
(l) *Copper arginine hydrochloride*

The crystals belong to the monoclinic system and the unit cell dimension are : a = 7.25 Å, b = 25.69 Å, c = 12.84 Å. The space group is either $P2_12_12$ or $P2_12_12_1$. The density of the crystal as determined by the method of flotation is 1.594 gm per cc, which indicates that there are four formula units of $Cu[(NH_2)_2CNH(CH_2)_3CH(NH_2)COO]_2Cl_2.2H_2O$. Three dimensional intensity data are being collected for structure analysis using low temperature technique.

S. K. Mazumdar and N. N. Saha

(m) *Morpholine biguanide hydrochloride*

Morpholine biguanide hydrochloride $(C_6N_5H_{13}O)HCl$ has the structural formula



The plate shaped colourless crystals of this compound were found to belong to orthorhombic system with space group Pbca. The unit cell dimensions are : a = 10.02 Å, b = 9.88 Å, c = 10.24 Å.

The calculated density 1.42 gm per cc. based on eight molecules per unit cell compares well with the measured density 1.39 gm per cc.

Three dimensional intensity data were collected about c-axis after correction for Lorentz, polarisation, spot-size and absorption factors. The chlorine positions were located from three Harker sections at $U=\frac{1}{2}$, $V=\frac{1}{2}$ and $W=\frac{1}{2}$. The 3–D heavy atom phased Fourier revealed the complete structure. The proposed structure satisfied the stereochemistry well. The three dimensional refinement by the method of least square is in progress.

R. Handa and N. N. Saha

(n) *Copper (II) complex of morpholine biguanide*

Deep red single crystals of Cu (II) complex of morpholine biguanide, $Cu(C_6N_5H_{13}O)_2$ were prepared in our laboratory. Rotation and Weissenberg pictures showed that the crystals belong to the monoclinic system with cell dimensions : a = 8.58 Å, b = 12.74 Å, c = 7.73 Å, $\beta = 93°30'$.

Systematic absence indicated that the space group is $P2_1$. Density determination showed that there are two molecules per unit cell. Complete three dimensional intensity data were collected using multiple-film equi-inclination Weissenberg technique.

A three dimensional Patterson function showed that the copper atom is at the origin and the two morpholine biguanide ligands are situated trans to each other. A 3-dimensional Cu-phased Fourier synthesis showed a pseudo symmetry due to the special position of the phase determining atoms. Six light atoms were, however, correctly located and added in the next Fourier. The whole structure could now be found out from this synthesis. The positional and vibrational parameters of all the atoms are now being refined by the method of least square.

S. Guha and N. N. Saha

2B.2 *Ultrastructural Study*

(a) *Electron microscopic study of collagen*

The band-interband structure of toad leg tendon, a collagen from amphibian species has been investigated under electron microscope by staining the specimen negatively with PTA. The electron micrograph shows that this collagen has substructures as light and dark striations in the repeat periods nearly similar to those in a shark fin collagen, a collagen of fish origin and differs from those in the repeat periods of mammalian collagen, viz., rat tail tendon or human bone collagen. However, further investigation on shark fin collagen itself by using ammonium molybdate as strainer showes that there are about twice as many striations per repeat period as have been found in it previously by using PTA either as positive or negative stainer and also by shadowing technique. Whether these extra striations are really the property of the native sharp fin collagen not brought out by PTA staining or artifacts developed during sample preparation is not yet decided. Further investigations on the fin and other collagens by using ammonium molybdate in varying conditions are under progress.

It is worthwhile to mention that the work with electron microscope has nearly come to a stop due to import restriction on the electron sensitive plates or films and their unavailability in the local market.

S. K. Ghosh and S. Das

(b) *Electron microscopy of DNA stained with cesium chloride*

The above method of Crawford and Crawford (*Biochim. Biophys. Acta,*

75, 267, 1963) is being tried on sponge and hydra DNA extracted in this laboratory, for electron microscopic studies. By this technique shadowcasting is not required to make the DNA visible. Further work is in progress.

Publication :

Anjali Mookerjee, *Science and Culture, 34*, 105, 1968.

Anjali Mookerjee

2B.3 *Psysico-chemical Study of Biomolecules*

(a) *Physico-chemical studies of the components and molecular subunits of shark fin collagen*

The work on the separation of the various components of shark fin collagen from its formic acid extract and their study is being continued. The separation of these components made by column chromatography using carboxymethyl cellulose as the absorbent has already been reported (Annual report, 1967). The individual components are now being purified and studied.

The purification and study of the major component have been almost completed. The homogeniety of this chromatographically purified material was checked in starchgel electrophoresis which was set up and standardized in this laboratory. The component exhibited a single symmetrical band in gelelectrophoresis performed at room temperature in urea formate buffer (pH = 3.2, $\mu = 0.03$) as well as in aluminium lactate buffer (pH = 2.8, $\mu = 0.03$) systems. Sedimentation studies of this component in phosphate buffer (pH = 7.0, $\mu = 0.1$) at 25°C showed a single component exhibiting a sedimentation co-efficient value of about 1.5 The wide-angle X-ray diffraction pattern of this component has been taken and found to be typical of a collagen showing the characteristic 2.86 Å ring. Attempts were made to reconstitute the fibres from solutions of this component by the usual temperature fluctuation method. But our electron microscopic study did not reveal any such reconstituted fibres of desired length.

The low value (1.5) of sedimentation co-efficient for this component compared with a value of 3.2 for the individual polypeptide chain in a collagen molecule, under similar conditions, suggests that the component under investigation is a part of a polypeptide chain. Formic acid treatment, therefore, appears to break the molecule into units smaller than individual polypeptide chain in collagen. It is well known that formic acid does not affect the peptide bonds. It, therefore, suggests the presence of some nonpeptide bonds which might have been broken by this treatment resulting the components under investigation. To know the exact nature of these bonds the purification and study of the other components have been taken up.

The portion of shark fin collagen remaining insoluble in formic acid seems to be interesting. It contains almost all of the tyrosine and cysteine of the parent material. It has a yellow colour and it contains about 2% hydroxy

proline. It is insoluble in almost all the aqueous buffers and it resists gelatinization when heated in water. Its wide-angle X-ray diffraction pattern is somewhat different from that of a typical collagen, the usual 2.86 Å ring being absent. In view of its low hydroxyproline content, yellow colour, insolubility and resistance to gelatinization, it was thought that this material may be elastin, a protein having all these properties and is often found to be associated with collagens.

The material was then heated at 98°C for an hour in 0.1 N alkali (usual procedure for the isolation of elastin). The fibrous precipitate obtained, when seen under electron microscope, showed the net work of extended, interconnected fibrils typical of elastin. On the other hand, most of the yellow colour of the material was found to be predominant in the solution. From the solution a protein has been isolated which absorbs in the ultraviolet region of the spectrum exhibiting maxima at 276 mμ and at 282 mμ in the neutral pH as well as at 295 mμ and at 360 mμ in the alkaline pH. Further work is in progress. Some of these results have been presented in the Third Annual Symposium in Biophysics of the Indian Biophysical Society in 1968.

S. K. Ghosh and N. N. Saha

(b) *Base copmposition of sponge DNA from Tm*

The melting temperature Tm of fresh water sponge DNA, extracted by Marmur's method has been determined and found to be 91.5°C. From standard data the mole per cent (G+C) for this temperature corresponds to 53, and, therefore, mole per cent (A+T) is (100 – 53) = 47. From this data the approximate mole per cent composition of the bases are given as follows : adenine = 23.5, guanine = 26.5, cytosine = 26.5, thymine = 23.5. A chemical method of bromination which gives the mole per cent (A+T), has also been tried to determine the base composition and to see how far the two results agree. Preliminary results indicate that this sponge DNA may not be homogeneous. Further experiments are in progress.

Anjali Mookerjee

(c) *Difference of Tm of DNA in high and low ionic solvents*

The studies by several authors have shown that thermal denaturation of double stranded DNA occurs in two distinct and separate steps at two characteristic ranges of temperature : the *first* known as the Tm, measured by determining the transition as a function of the ambient temperature, corresponds to the destruction of the rigid low temperature conformation and leads to a transformation of the helix into two random coils still attached to each other by an indeterminate number of crosslinks at critical junctions; the *second* called the $T_{1/2}$. measured by following the transition after heating, quenching in ice and returning to the starting temperature corresponds to the melting out of the junction points

and leads to a true separation of the strands of a double helix. This has been termed as the 'irreversible' process and the mid point lies ⩾ 5°C above Tm.

The Tm and $T_{1/2}$ of sponge DNA in SSC (standard saline citrate, 0.195M), 0.15M NaCl and 0.015M NaCl have been determined. The following Table (Table 2B.1) gives the data obtained with sponge and hydra DNA along with the data obtained by other workers with standard E. coli and calf thymus DNA.

Table 2B.1

Tm and $T_{1/2}$ of different DNA in solvents of different ionic strengths

DNA source	Solvent	Tm °C	$T_{1/2}$ °C	DNA source	Solvent	Tm °C	$T_{1/2}$ °C
E.coli	SSC (0.195M)	90.5,§ 91.5 §		Sponge	SSC (0.195M)	91.5	
	NaCl (0.15M)	86.5*	91.0*		NaCl (0.15M)	—	90.0
	NaCl (0.015M)	78.5*	84.0		NaCl (0.015M)		
Calf thymus	SSC (0.195M)	87.5§		Hydra	SSC (0.195M)		
	Nacl (0.15M)	—	86.0*		NaCl (0.15M)		88.0
	NaCl (0.015M)		79.0*		NaCl (0.015M)	66.0	

§ Marmur's data

* These data were obtained from Sri S. Basu of the biophysics laboratory of the Institute.

From table 2B.1 it is seen that the difference of Tm of E. coli DNA in SSC and 0.015 M NaCl is 12.0°C – 13.0°C where as in case of sponge DNA this difference is 21.5°C and for hydra DNA (in 0.15 M NaCl and 0.015 M NaCl) this difference is 20.0°C (experiments are in progress with hydra DNA). Marmur and Doty's (*J. Molecular Biol., 5,* 109, 1962) work with E. coli DNA in 0.195 M KCl and 0.01 M KCl gives a temperature difference of about 22.0°C.

It would be interesting to find out if this difference is a characteristic of the DNA samples or that of the solvents used.

Anjali Mookerjee

(d) *Role of metals in structural organisation and functions of biomolecules*

Metals play a prominent role in biological systems, so far as their

various functions are concerned, by their association with biomolecules either in the form of metalloproteins or in the form of complexes. Metals in trace amounts in the form of ions also have been found to initiate and control various specific unctions in living systems. In a review work functions of different biomolecules with which a metal is associated have been explained in the light of their structures at molecular level. Attempts have been made to make a correlative study of the structures and functions of metal complexes of small molecules, e.g., amino acids which build up large biomolecules with the idea that the study of these small molecules may provide such models as may be profitably used in elucidating the functions of large biomolecules in living systems. A few amino acid complexes like copper (II) ornithine, copper (II) lysine and silver (I) O-amino benzene sulphonyl glycine whose structures have been determined in our laboratory have been discussed. Physico-biochemical aspects of some biomolecules and the influence of metal ions on DNA molecules have also been discussed. This review was presented at the Third Annual Symposium in Biophysics of Indian Biophysical Society and will be published in its proceedings.

N. G. Podder and N. N. Saha

(e) *Thermodynamic parameters of copper (II) lysine and copper (II) sarcosine systems*

Every biological system contains a variety of metal ions in traces. At the pH of many biological tissues, most of these metal ions would precipitate as hydroxides if they were not strongly bound by molecules in the system. Which of the numerous groups or molecules in biological systems can bind the metal ions or which of the metal ions can be selectively bound to a particular group or molecule can be visualised from a measure of stability constants. Since these constants are also a measure of the free energy change, there ought to be some correlation with the strength and type of metal ligand bond to which these constants can be referred.

Determination of stability constants of copper (II) lysine and sarcosine complexes at different temperatures using pH-titration technique has been undertaken to evaluate the thermodynamic parameters involved in complex formation. Values pK_3 and pK_2 for lysine have been found to be 2.07 and 8.70, respectively, and those of pK_2 and pK_1 for sarcosine have been found to be 2.80 and 0.50, respectively, at 37°C and at $\mu = 0.1$ M KCl. The overall stability constants for the copper (II) lysine and sarcosine systems are 13.14 and 13.40, respectively, at 37°C and $\mu = 0.1$ M KCl. Values of $\triangle G$ (free energy change) for the copper (II) lysine and copper (II) sarcosine systems have been found to be 18.66 kilo calories and 19.01 kilo calories, respectively. Further investigation is in progress.

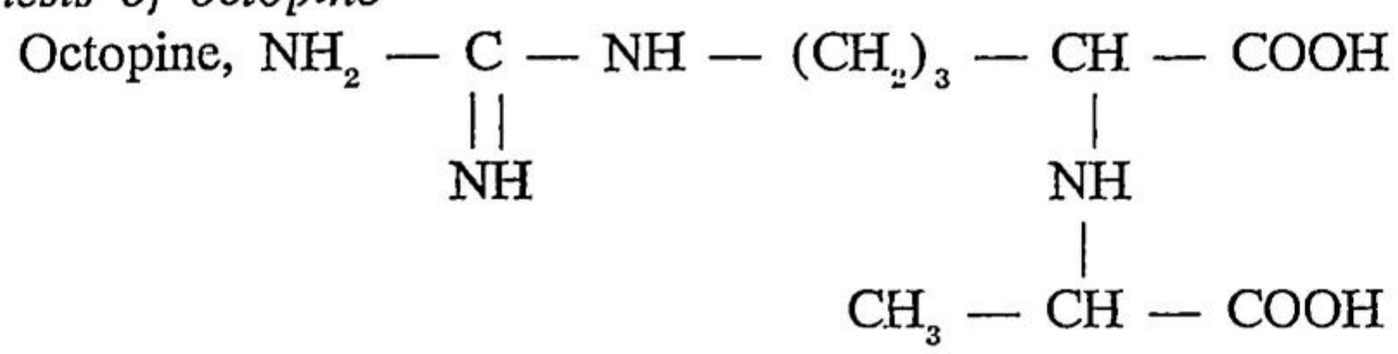
N. G. Podder and N. N. Saha

(f) *Synthesis of biomolecules in which the amino acids are joined together through ester linkage*

Attempts are being made to conjugate two amino acids through ester linkage (similar to that observed in collagen) by condensing the copper complex of an amino acid containing hydroxyl group (e.g., serine) with another free amino acid (e.g., alanine).

N. G. Podder and N. N. Saha

(g) *Synthesis of octopine*



an amino acid found generally in octopus, is being synthesised starting from propionic acid and arginine. Physico-chemical and structural studies of this amino acid will be made.

N. G. Podder and N. N. Saha

(h) *Effect of some metal ions on the structure of DNA*

Investigation has been undertaken to study the effects of some metal ions (e.g., Cr^{+++}) on the structure of DNA (isolated from wheat seedling leaves) from the physical point of view, e.g., viscosity, absorption co-efficient, fusion temperature, etc.

N. G. Podder, M. K. Ray and N. N. Saha

(i) *Respiratory behaviour of inositol deficient S. Carlsbergenis and effect of inositol in PFK activity*

It has been reported earlier that due to inositol deficiency the yeast cells show respiratory inhibition during aerobic utilization of glucose or ethanol. Glycolytic intermediates during aerobic glucose utilization were analysed and a cross over point at the enzyme phosphofructokinase (PFK) level was established.

In order to get a better picture of this effect, the respiratory behaviour of mitochondria isolated from deficient cells was studied. Mitochondria were isolated from deficient cells by lysing the protoplasts which involved the treatment of the cells with enzymes prepared in our laboratory from snail gut juice. During respiratory studies of isolated mitochondria it was found that substrate oxida-

tion was not stimulated by ADP, but only the oxidation of externally added NADH was stimulated by ADP. Further work on mitochondria is in progress.

Our study on the properties of PFK is also being continued. During the kinetic studies of PFK, it was found that this enzyme was inhibited by ATP and the inhibition was protected by FDP, FOP and AMP. This enzyme can be reversibly inhibited by $HgSO_4$, PCMB and Ca^{++}. It was also found that the PFK activity was not affected by the presence of inositol.

S. N. Bhattacharyya

2B.4 *Quantum Biology*

(a) *Conformation of amino acid residues with aromatic side chains by molecular orbital calculation*

The present scheme of research was undertaken with a view to throw light by theoretical calculations on the structure of certain amino acid residues which cannot be satisfactorily handled experimentally. As a first step we have taken up the aromatic amino acids. The method used is to calculate their equilibrium configuration and comparing this with the experimentally established structure. The discrepancy between the two has to be explained satisfactorily on the basis of inter- and intra-molecular interactions. The closeness of the theoretically calculated and experimentally observed structures gives an idea of the accuracy with which the unknown structure of the particular R-groups can be predicted.

The three dimensional extended Huckel method of Hoffman is being used for the conformation calculation of the aromatic amino acid residues. The usefulness of this method in predicting the conformation of molecules involving both π and σ bonds has already been established.

As a specific case, we are at present working with the molecular structure of histidine. Molecules to follow are tryptophan, tyrosine, proline, hydroxyproline and phenylalanine. The atom C_3 is expected to be in a tetrahedral position but the bond angles measured at C_3 are, however, different from the tetrahedral value. No satisfactory explanation has as yet been put forward towards this finding. In the present work, we are calculating the molecular evergy by varying the angle ϕ at C_3, taking the experimentally observed value of 114.9° as the initial data. The value of ϕ which will lead to a minimum value of the molecular energy will be taken to be the equilibrium value. In each step of calculation, an exhaustive Mulliken population analysis is done. The overlap population and gross atomic charges give an idea of the amount of conjugation existing between the different parts of the molecule.

A Fortran II programme has been written on the extended Huckel formalism. It has already been listed and debugged at the CDC-3600 computer.

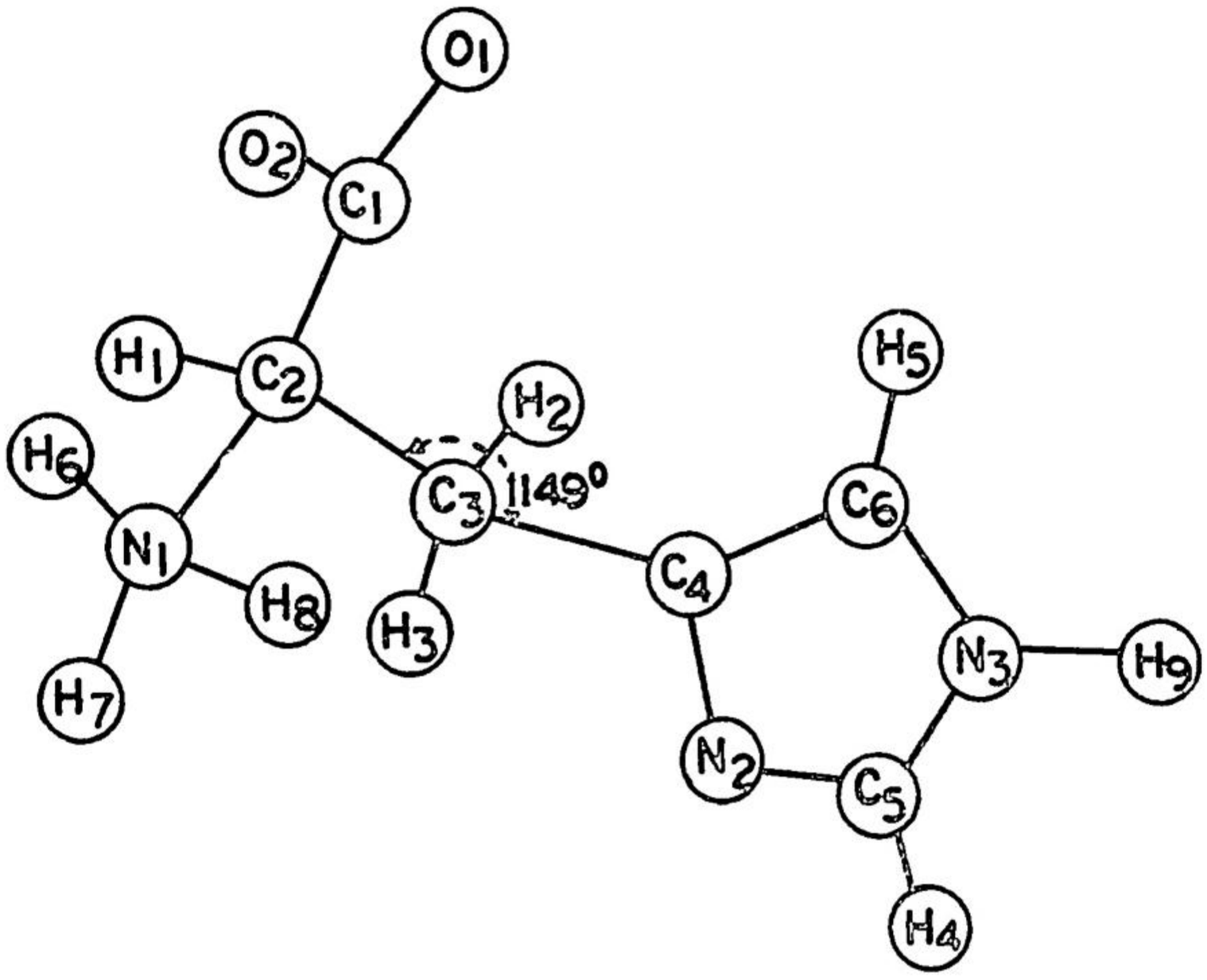


Fig. 2B.5. Chemical structure of histidine.

It is now awaiting test run, after which, final data will be fed and results will be obtained.

After the first step of working is over, two refinements are proposed. Firstly, the energy will be calculated as a function of more than one bond length or bond angle. The variables will be automatically changed in steps and energy-minimum searched, whereby a set of optimum values for the variable parameters will be arrived at. Secondly, the Hamiltonian matrix will be made self-consistent with respect to the charges of the atoms constituting the molecule, whereby much ambiguity as regards the calculated molecular characteristics can be removed.

Jayanti Lahiri and N. N. Saha

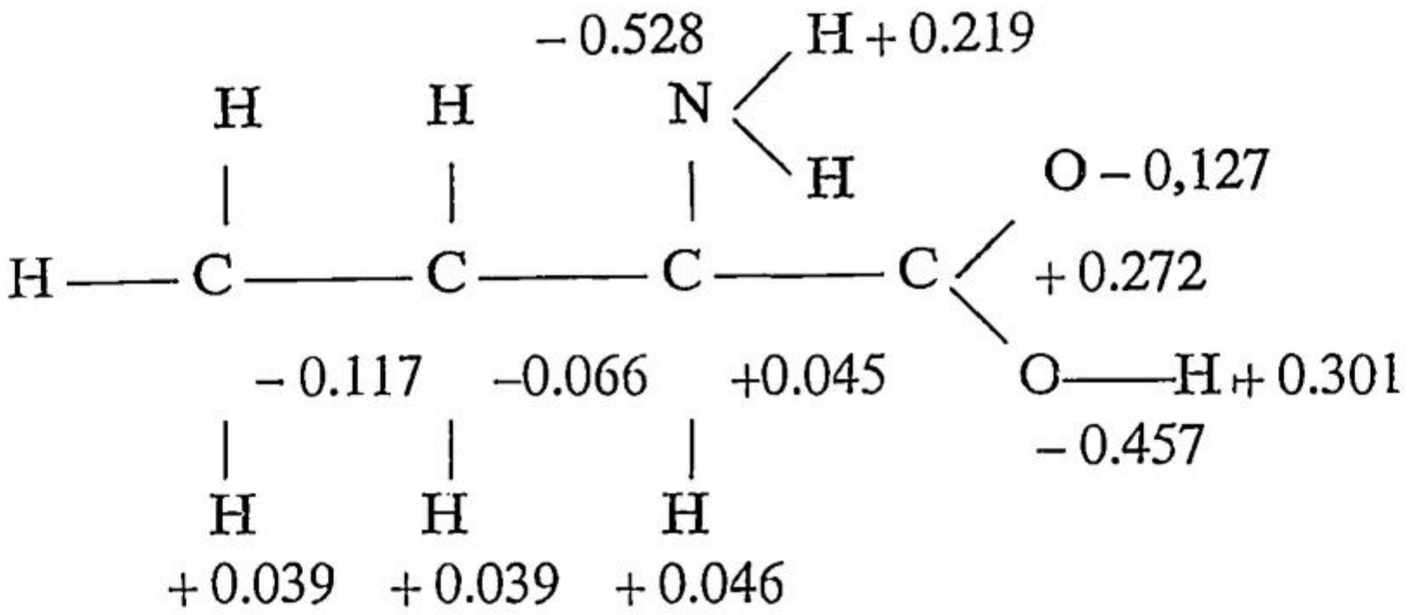
(b) σ – *electronic charge distribution and related properties of amino acids and their derivatives*

The earlier programme on the study of the electronic properties of the amino acids and their derivatives is being continued.

The calculation of the σ – electronic charges by the LCAO – MO method of G. Del Re for the different ionic forms (e.g., cation, anion, dipolar ion) of citrulline (i.e., $H_2NCONH(CH_2)_3CH(N^+H_3)COOH$,$H_2NCONH(CH_2)_3CH(NH_2)COO^-$ and $H_2NCONH(CH_2)_3CH(N^+H_3)COO^-$, etc.), of ornithine (i.e., H_3N^+

$(CH_2)_3CH(NH_2)COOH$,$H_2N(CH_2)_3CH(NH_2)COO^-$, and $H_3N^+(CH_2)_3CH(NH_2)COO^-$, etc.) and of the neutral form for butyrine, the higher homologue of alanine i.e., $CH_3CH_2CH(NH_2)COOH$) has been completed. The computation of the bond energies is also in progress.

In case of ornithine, σ – electronic charges for the molecule containing three charges, i.e., the ionic form corresponding to ornithine hydrochloride [$Cl^-H_3N^+(CH_2)_3(N^+H_3)CHCOO^-$] have also been calculated. The data of this form are being used for the calculation of dipolemoment of ornithine, as the accurate bond lengths and angles are available in this laboratory. The data for different compounds would also be used to study the bond properties, bio-physical and physico-chemical properties of the compounds under investigation. The charge distribution for the neutral form of butyrine is shown below :



(N. N. Saha, S. K. Mazumdar and S. Guha, 'Structure and Electronic Charge Distribution of Amino Acid Derivative', presented at the *International Conference on Chemical Bonds, Minsk, USSR*, 1968, and under publication in the book 'Chemical Bonds in Crystals').

Sephali Guha and N. N. Saha

2B.5 *Radiation Biology*

(a) *Fibrous protein of paramecium*

The cell surface of paramecium appears to be a net work of fibrils under a microscope and they are known as fibrous lines. These fibrous lines contain protein. The nature of this protein has been a matter of investigation for some time to see whether it resembles the known fibrous protein of higher animals, collagen, keratin, etc. Earlier electron microscopic study of trychocyst, by Jakus (M. A. Jakus, *J. Exp. Zool., 100,* 457, 1945) suggests the collagenous rather than keratinous nature of this protein. Work has been undertaken in our laboratory for the characterization of this protein. The fibrils of the cell surface are isolated by disecting the cells with sonic oscillator and differential centrifugation. The amino acid composition of this protein is compared with the whole body

protein and soluble protein by chromatographic separation of their hydrolysate and densitometric scanning. Study of these fibrils by X-ray diffraction and electron microscopic methods is in progress. The priliminary examination of the fibrous lines under polarizing microscope did not show birefringence, the characteristic property of collagen. The biosynthesis of this protein is also being studied using ^{14}C-labelled amino acids. In this context, the 4π counter already constructed is being used for counting ^{14}C samples.

Publication :

K. B. Udupa, Proc. Second Annual Symp. Ind. Biophys. Soc., Calcutta, 1967, p. 55.

K. B. Udupa

(b) *Tracer study in riboflavin deficiency*

Study of haematopoeisis has been undertaken in riboflabin deficient rats with ^{59}Fe as tracer. Rats have been fed for two months with the diet lacking in this vitamin. Radioactive iron is injected to these rats intravenously to study the half time for its disappearance from the plasma ($PDT_{1/2}$), plasma iron turnover, red cell iron utilization and its turnover. Similar experiments have been done in normal pair-fed rats and the results obtained are compared with riboflavin deficient animals. These studies suggest that there is a disturbance in the iron utilization and this leads to defective erythropoiesis under riboflavin deficiency.

Publication :

S. C. Jamdar, K. B. Udupa and A. Chatterjee, *J. Vitaminol, 14*, 219, 1968.

K. B. Udupa

(c) *Studies on protein and amino acid composition of the haemolymph in the antenal and femoral fluids from cockroaches*

It has been observed that there is difference of per milligram ion concentration in the fluid in the two parts, one in the dorsal vessel and another in the outside of it, of the haemolymph of P-americana by using radioactive tracer ions of Na^+, Cl^-, HPO_4^{2-}, I^-, Fe^{3+}, the first three constituting major ions and last two minor ions.

A natural consequence of inorganic ion imbalance should be a disturbance of osmotic pressure across the dorsal membrane and for restoration of the pressure difference one must examine the concentrations of other ions and also the difference in composition or change of organic constituents, e.g., proteins, peptides, amino acids of the two fluids.

Qualitative and quantitative determinations are made for free amino acids present in the femoral and antenal fluid. Same number of amino acids and same amino acids are present with two type of fluids.

It has been observed that there is no quantitative difference in the free amino acids present in both the fluids.

S. Bose and S. R. Basu

(d) *Studies on the effect of different doses of radioiodine on the thyroid*

The effect of different tracer doses of ^{131}I on thyroid function was carried out on rats earlier. A limited range of tracer dose is found to have specific effect on thyroid function.

Electrophoretic and chromatographic studies are being continued in this range of tracer doses to find the reason of this effect. From electrophoretic study an unknown iodinated compound has been detected as a possible explanation for this effect. The identification of this iodinated compound is under investigation.

S. Bose and S. R. Basu

(e) *Effects of radiation on amino acids*

During the course of our investigation on the behaviour of amino acids in aqueous solution under the influence of radiation, arginine and citrulline have been subjected to radiation. These two amino acids are almost similar in structure except that in place of guanidine in arginine, urea is present in citrulline. By treating hydras with the solutions of different concentration of these two amino acids, it was found that they could be kept in 0.25% solutions of both arginine and citrulline for 72 hours without any morphological change. Preliminary investigation on the effects of X-ray radiation of dose 25,000 rad on hydras in presence of 0.025% solutions of the amino acids, it was found that while citrulline serves as a protecting agent, arginine serves as a sensitising agent. Among the products of X-ray radiation on 0.025% solution of citrulline and arginine at 25,000 rad, ammonia and formaldehyde have been detected in both the cases as yet.

The sensitising action of arginine may be attributed to its greater degree of ionisation than that of citrulline.

N. G. Podder, Anjali Mookerjee and N. N. Saha

2C. TEACHING DIVISION

2C.0 *Introductory Remarks*

The fifteenth session of the Post M.Sc. Associateship Course for training in nuclear physics, molecular and solid state physics continued till May 31, 1968 under the guidance of Dr. B. B. Baliga, the then Acting Head of this division. As in the previous year, the diplomas were distributed at a function organised for the purpose on the last day. We were very happy to have for the first time the Vice-Chancellor of Calcutta University (who is also the Chairman of the Institute's Governing Body) to distribute the diplomas and give an exhortation to the outgoing students.

All the students of the fifteenth session were declared successful after examinations in various subjects. Out of the twenty-two students who joined the course, only nineteen remained to complete the same. Four students obtained fellowships in American universities and proceeded to States to continue advanced studies. Eight students were absorbed in various departments in the Institute. One has joined Physical Research Laboratory, Ahmedabad, one has joined B.A.R.C., one has joined I.I.T., Kharagpur, one got DAE fellowship to work in our Institute and the placement of others is not known.

As in previous years there was excellent co-operation from all the teaching staff of the Institute from various departments. The bulk of the teaching load was borne by the theoretical physics department.

Two series of lectures were arranged in the last academic year. The first series was given by Dr. S. K. Dutt Roy of I.I.T., Kharagpur on 'Phase transitions in crystals' and the second one by Dr. J. K. Roy of Pilani on 'Gas lasers'. Lecture notes were prepared for both the series.

In the fifteenth session, as mentioned in the last report, a new series of seminars were started for students. The list of this is given later. Another list gives the special problems worked out and reviews made by the students.

The sixteenth session of the Post M.Sc. Associateship Course started from July, 1968. We received 187 applications in prescribed forms out of which 126 students were selected for admission test. Out of the 85 applicants who actually turned up for their admission test, 20 students were offered admission and they joined the course. Teaching committee formed three sub-committees to design the subject matter of the general course, the advanced molecular and solid state physics course and the advanced nuclear physics course. Excellent co-operation was received from the convenors and members of the said sub-committees.

Dr. D. Chatterji of the Viswabharati University and G. Das of I.I.T., Kanpur, took part in our teaching programme. Several special and invited

lectures were also arranged this year in the Institute by scientists of our country and abroad.

As in the previous year a summer school in physics organised by NCERT for the B.Sc. students was conducted in the Institute during May and June. All the staff of the Post M.Sc. took part in the programme. 10 students attended the summer school. Eleven members of the Institute staff also worked as resource persons.

Another school under the same auspices was held in the Institute for M.Sc. students. A total of 5 students attended this course. The students were attached to individual resource persons and worked in the different laboratories of the Institute. Research report of the staff of the teaching division is given under the nuclear physics division.

D. K. Ghosh

2C.1 *Teaching Programme for the 15th Session, 1967-68 (January-May)*

Plasma physics	Dr. S. N. Goswami
	Dr. J. Basu
Nuclear physics	Prof. M. K. Pal
	Prof. P. N. Mukherjee
	Dr. A. Chatterjee
	Dr. I. Mukherjee
	Dr. D. Pal
Quantum mechanics	Prof. T. Pradhan
Solid state physics	Dr. A. Chakraborty
	Dr. S. Sinha
X-ray crystallography	Dr. S. K. Majumdar
Advanced quantum mechanics ..	Dr. A. Ray Chaudhuri
Group theory	Prof. A. K. Saha
N. M. R., etc.	Dr. N. Chatterjee
Elementary particle physics	Prof. H. Banerjee
Experimental physics	Prof. A. P. Patro
	Prof. S. K. Mukherjee
	Prof. D. K. Ghosh
	Dr. R. Bhattacharya
	Dr. J. K. D. Verma
	Dr. A. K. Sengupta
	Dr. N. K. Majumdar
	Shri B. K. Sinha
	Shri Subimal Sen

2C.2 *Seminars by Students*

Raj Kumar Moitra	..	Phonon scattering
Satish Kumar Sharma	..	RPA method
N. C. Bhattacharyya	..	Phenomenological theories of superconductivity
V. A. Managoli	..	Final state interactions
Ram Gopal Aul	..	Microwave spectroscopy
Pabitra Narayan Sen	..	Coulomb excitation
Y. M. Sengupta	..	Three body problem
A. Ramakanth		Acoustic magnetic resonance
J. K. Dutta Gupta	..	Molecular structure of protons
B. N. Rao	..	(p, α) reactions
Benoy Kr. Das Mahapatro	..	(p, γ) reaction studies by Van de Graaff generator
Sobhendu Ghatak	..	Study of colour centres
Swapan Kumar Basu	..	Angular correlation of nuclear radiation
K. C. Shah	..	Term splitting and group theory
D. P. Dewangan	..	Atomic collisions
Dibyendu Chakraborty		Knight shift
Debajyoti Bhoumick	..	Quasi-free scattering and nuclear structure
Ranajit Pal	..	Quantum Bose gas
Ahmed Ansari	..	Pairing correlation in spherical nuclei

2C.3 *Special Problems Worked out and Reviews Made by Students*

Ahmed Ansari	..	Pairing correlations in nuclei
+Ram Gopal Aul	..	Gas-phase molecular structure by microwave spectroscopy
Swapan Kumar Basu		Angular correlation of first and third gamma rays
+N. C. Bhattacharya	..	Superconductivity of metals and alloys
Debajyoti Bhoumick		Non-compact groups and their application to elementary particle physics
+Dibyendu Chakraborty		Knight-shift in superconductors
B. K. Das Mahapatro		Van de Graaff electrostatic accelerator
D. P. Dewangan	..	Atomic collisions in gases and solids
+J. K. Duttagupta	..	Determination of space group of (i) silver benzene sulphonyl glycine (ii) copper complex of morpholine biguanide

+ Sobhendu Ghatak	.. ..	Color centres in alkali halide
V. A. Managoli	.. ..	Dipion mass spectrum in Ke^4-decay and the determination of width of the resonance in $\pi-\pi$ scattering
+ Raj Kumar Moitra	.. ..	Scattering of electrons by hydrogen atoms
+ Ranajit Pal	.. ..	Dynamics of internal rotation of molecules
B. N. Rao	.. ..	(p, α) reactions
+ A. Ramakanth	.. ..	Spin-phonon interactions in solids
P. N. Sen	.. ..	Coulomb excitation and gamma-ray yield from tungsten
		Measurement of relative B(E2) values for different isotopes of tungsten
+ Y. M. Sen Gupta	.. ..	Three body scattering
+ K. C. Shah	.. ..	Magnetic properties of transition metal ions
Satish Kr. Sharma	.. ..	Deformed Hartree-Fock theory

+ Students with solid state physics specialisation.

2C.4 *Teaching Programme for the 16th Session, 1968-69 (July-December)*

Mathematical methods of physics ..	Dr. D. Chatterjee
Nuclear detector and associated technique	Dr. R. Bhattacharya
Electronics	Prof. R. Roy
	Dr. R. Bhattacharya
	Dr. J. Basu
Advanced classical electrodynamics ..	Dr. S. C. K. Nair
Solid state physics for nuclear physics group of students	Prof. T. Pradhan
Nuclear physics for solid state physics group of students	Prof. M. K. Pal
Elementary quantum mechanics ..	Dr. D. Pal
Advanced statistical physics ..	Dr. S. Sinha
	Shri B. Das Gupta
Computer	Dr. A. Mukherjee
Molecular vibrations	Dr. G. Das
Advanced nuclear physics and elementary particle physics	Prof. T. Pradhan
	Prof. M. K. Pal
	Dr. B. Baliga
	Dr. I. Mukherjee
	Dr. D. Pal
Advanced molecular and solid state physics	Prof. A. Mukherjee
	Dr. J. K. D. Verma

Experiments and Laboratory work	..	Dr. S. K. Majumdar Dr. A. Roychaudhuri Dr. K. S. Patel Dr. R. Bhattacharya Shri B. K. Sinha Shri Subimal Sen

2C.5 *Special Lectures*

Speaker	*Subject*	*Date*
Dr. N. Mukund T.I.F.R. Bombay	Non-compact group in particle physics (10 lectures)	Jan. 3 — Jan. 16
Dr. P. K. Kabir Rutherford High Energy Laboratory U.K.	Recent development in particle physics	Jan. 4, 1968
Academician A. I. Oparin, Bach Research Institute of Biochemistry U.S.S.R.	The present state and perspectives of the investigations on the origin of life—M. N. Saha memorial lecture	Jan. 11, 1968
Dr. Asok Bhattacharjee General Electric Co. Clevland Ohio	Microwave investigation of plasmas	Jan. 17, 1968
Prof. S. K. Sen Manitoba University Canada	Study of nuclear structure effects in the internal conversion process	Jan. 18, 19, 1968
Prof. E. C. G. Sudarshan	Particles faster than the velocity of light	Jan. 22, 1968
Prof. W. D. Allen Rutherford High Energy Laboratory Chilton U.K.	Some aspects of advanced Van de Graaff technology	Jan. 22, 1968
Dr. B. Misra Geneva University	Approximate symmetries and deformation of LIE groups	Feb. 27, 1968
Prof. M. A. Braun Leningrad University U.S.S.R.	Description of composite particles by condition Z=O	March 29, 1968

Speaker	*Subject*	*Date*
Dr. T. Das University of Rochester U.S.A.	Electromagnetic mass difference and radiative corrections to weak decays of hadrons	March 11, 12, 1968
Dr. R. Ramanna B.A.R.C. Trombay	A new model of atomic nucleus	April 3, 5, 1968
Dr. L. K. Pandit	Asymptotic SU(3) symmetry	April 15, 16, 1968
Prof. K. N. Metsheriakov Department of Atomic Energy Commission U.S.S.R.	Accelerators	April 22, 1968
Dr. S. K. Dutta Roy I.I.T. Kharagpur	Phase transitions in crystals	April 23, 24, 1968
Dr. M. A. Eshwaran B.A.R.C. Trombay	Studies in radiative transitions following nuclear reactions	May 9, 10, 1968
Dr. R. K. Bhaduri T.I.F.R. Bombay	Hypernuclei and NN forces	May 6, 1968
	The tensor force in nuclear matter	May 7, 1968
Dr. J. K. Roy	Gas lasers	May 8, 9, 10, 1968
Dr. D. Robson	Isobaric states and nuclear structure	June 22, 1968
Dr. P. Jastram Ohio State University U.S.A.	Double inner bremstrahlung	June 25, 1968
	Gravitation alone can't condense a universe	June 26, 1968
Prof. C. E. Nielsen Ohio State University U.S.A.	Remarks on plasma and the thermonuclear problem	July 5, 1968
	Gas bounded arc plasma	July 5, 1968
Dr. K. Kumar Niels Bohr Institute Copenhagen Denmark	Microscopic theory of nuclear shape	Aug. 8, 9, 1968

Speaker	*Subject*	*Date*
Dr. A. S. Ghosh Mazumdar B.A.R.C. Trombay	Studies on some unknown and unstable oxidation states by the technique of fast reaction kinetics	Oct. 9, 1968
Prof. Krishnaji Allahabad University	Width of microwave spectral lines	Nov. 1, 1968
	Dielectric relaxation and viscosity	Nov. 2, 1968
Dr. M. K. Mehta B.A.R.C. Trombay	Investigation of isobaric analogue state through (p, n) and (p, α) reactions	Nov. 18, 19, 1968
Dr. K. Wetzel Institute of Stable Isotopes Leipzig	Activities of the institute of stable isotopes at Liepzig	Nov. 21, 1968
Prof. J. M. Ziman University of Bristol U.K.	The Social dimension of science (M. N. Saha memorial lecture)	Nov. 26, 1968
Prof. P. M. Mathews Madras University	Relativistic wave-functions for particles of arbitrary spin	Dec. 2, 1968
	Self-conjugateness of internal symmetry multiplets	Dec. 3, 1968
Prof. G. N. Ramchandran	Molecular physics and molecular activity	Dec. 4, 1968

2C.6 *Colloqui*

Speaker	*Subject*	*Date*
Prof. S. Chatterjee	A. V. F. cyclotron	Jan. 20, 1968
Prof. S. K. Mukherjee	Tandem electrostatic accelerator	Feb. 2, 1968
Prof. B. M. Banerji	Wide band amplification	Feb. 17, 1968

3. BIOPHYSICS DIVISION

3.0 *Introductory Remarks*

For the past few years the activities of the biophysics division are being carried out in the following sections :

(1) Physical Biology
(2) Molecular Genetics
(3) Radiation Biology
(4) Ultrastructure Research
(5) Electron Microscopy and Virology, and
(6) Technical Biophysics.

In the *section of physical biology*, significant differences in the conformation of DNA in native, denatured and renatured states have been observed. Haemoglobin molecules of human and amphibian origin have been investigated as regards their size, shape, molecular weight, etc. Experiments on the dissociation of yeast ribosomes under different conditions led to the conclusion that the changes in the tertiary structure are involved in the process.

In the *molecular genetic section*, experimental evidence has been obtained to show that the damage, produced by ultraviolet irradiation in single stranded DNA, does not block its replication to doublestanded form and the subsequent *in vivo* repair of the damage by bacterial enzymes. A new strain of bacteriophage, smaller than T-series or λ, but larger than ϕX174 and other recently discovered small phages, has been isolated. Disturbances produced in the metabolism of ϕX-infested *E. coli* cells in presence of chloramphenicol was more intensively investigated.

In the *radiation biology section*, thymineless death in bacteria has been studied with cells having bromouracil in DNA and under condition of restricted protein synthesis. The cells having bromouracil in DNA showed increased sensitivity to X-ray, UV and thymineless incubation. Such cells showed a gradual decrease in sensitivity to X-ray and ultraviolet light on growth in the absence of DNA synthesis. In bacteria the interaction of X-ray and UV-light showed that these agents helped each other in the killing processes. After the decay of incorporated P-32, both X-ray and ultraviolet sensitivity of bacteria increased. Reactivation of heat-killed bacteria had also been observed.

In the *ultrastructure research section*, basic chromatinic fibres from the sperm nucleus has been found to be about 40 Å. Ultrastructure of the nucleohistone complexes from the amphibian and replibian erythrocytes are being analysed to get clear idea about the chromosome structure. Many interesting features of ciliated and flagellated protozoa have been observed after ultrathin sectioning.

In the *electron microscopy and virology section* electron micrographs of bacteriophages T7, ϕX174, ϕC and a few plant viruses have been made. Infected saps of some local plants and cellular contents of few infected brain tissues of dogs were tested for identification of viruses. Suitable methods for preparation of specimen for electron microscopy have been developed.

Technical biophysics section : Since the inception of this division, one of its major interests was to develop indigenously, instruments needed for biophysical researches. Besides construction of the electron microscope proper, many technical problems connected with the image formation by electrons were investigated in the past. In view of the present shortage of foreign exchange, attempts are now being made to build up other biophysical instruments. During the past year a radio-frequency operated bacterial colony counter and a precision regulated power supply have been developed.

During the year, two students from this division have been admitted to D. Phil. (Science) degree of Calcutta University :

Dr. A. B. Sanyal : Investigations on the Use of Tungstate and Uranyl Compounds in the Electron Microscopy.

Dr. S. R. Palchaudhuri : Study of Altered Metabolism of the Virus Infected Bacteria by Biophysical Technique.

This division organised a course of lectures on molecular genetics by Dr. H. P. Ghosh, a colleague of Dr. Har Govinda Khorana. Prof. G. N. Ramachandran, Director, Advanced Centre of Biophysics, Madras University, spoke on "Molecular Physics and Biological Activity".

Teaching in Biophysics to the M.Sc. Physics students of Calcutta University continued satisfactorily. This year seven students obtained M.Sc. degrees with Biophysics as their special subject of study. All of them have secured employment, mostly as teachers in different colleges in and around Calcutta.

N. N. Das Gupta

PHYSICAL BIOLOGY

3.1 *Biophysical Studies on Haemoglobin from Different Sources*

Physical characteristics of normal human adult haemoglobin (Hb-A) as regards its size, shape and ultrastructure have been studied by the techniques of sedimentation, spectrophotometry and electron microscopy. The electron microscopy of the molecules has been done after negative staining with uranyl acetate. Interaction of the stain with this protein has also been studied. Observed dimension and ultrastructure of the intact molecules have been found to agree with those of Perutz-model of haemoglobin. It has been concluded further that in spite of some interaction of the stain with the protein, the molecular

integrity is not changed and that this stain may be useful in the studies of such small biomolecules even if its pH is very low.

Similar studies have been conducted on haemoglobin from an amphibian, *Bufo melanostictus*. This haemoglobin has been found to have the same spectrophotometric and alkali denaturation characteristics as human haemoglobin. The sedimentation co-efficient is significantly higher. Electron microscopic findings have indicated that the molecule has four subunits arranged in a tetrahedral array. Further work is in progress.

Publication :

D. N. Misra and P. Ganguly, *Arch. Biochem. Biophys., 124,* 349, 1968.

D. N. Misra

3.2 *Electrical Properties of Haemoglobin Molecules*

Electrical conductivity measurements have been carried out on haemoglobin molecules, obtained from the blood of normal human adults. The results are being correlated with spectrophotometric data. Similar studies on haemoglobin molecules after irradiation by UV and X-radiation and also on haemoglobin molecules obtained from the blood of anaemic persons are in progress.

H. P. Mitra, S. Das Gupta and M. L. De

3.3 *Conformation of U.V.-Irradiated E. coli. DNA*

It is known that ultra-violet irradiation is responsible, to a large extent, for the inactivation of transforming DNA. The formation of dimers between the pyrimidine bases is one of the causes of this inactivation. However, UV-irradiation of DNA has also been reported to cause other physical changes, namely, cross-linking, back-bone scission, protein-DNA linkage, etc. The purpose of the present work has been to study the effect of UV-irradiation on *E. coli* DNA, simultaneously with ultra-violet spectroscopy, ultracontrifugation and electron microscopy.

The effect of UV-irradiation on DNA has been found to be manifold. The initial effect, characterised by a fall in absorbance, rise in sedimentation co-efficient and appearance of kinks in many places of the molecules, has been attributed to dimerisation of the pyrimidines. Together with the formation of kinks, the molecules become folded up and assume a ring-like appearance at several places, which is partly due to cross-linking. With the increase of dose,

a third effect, i.e., back-bone scission comes into play and predominates over the other two. This effect is manifested in a further decrease in absorbance, a fall in sedimentation constant and in the appearance of still shorter molecules in the electron micrographs. At very high dose, an equilibrium state is reached when with absorbance and sedimentation co-efficient remain steady.

B. Bagchi, S. Basu, D. N. Misra and N. N. Das Gupta

3.4 *Conformation of Heat Denatured and Renatured E. Coli DNA*

Within the melting range, denaturation of DNA by heat proceeds through several successive steps : dissociation of hydrogen bonds between the complementary strands of the double coiled structure, loss of helical stability and finally separation of individual strands. Reversal of the above process leads to rejoining of complementary bases over short or long regions depending upon the rate of cooling of the heat-denatured sample.

In the present work, UV absorption has been used to measure the degree of denaturation and renaturation of DNA from *E. coli*, heated at different temperatures. Simultaneously sedimentation and electron microscopic studies have been made to obtain quantitative information about the physical state of irreversibly denatured and of annealed DNA. Definite evidence has been obtained about the separation of the twin strands, their degradation and random coiling when heated at about T_m + 15°C. Annealed DNA in the high molar solvent had comparatively native-like regions with flower-like unmatched single strands at the two ends, but the effect of annealing was much less in the low molar solvent. The molecular weights of denatured and renatured molecules have been obtained from electron microscopy, and compared with those derived from sedimentation studies. It has been shown that the renatured DNA is not mologous with the native.

Publication :

N. N. Das Gupta, D. N. Misra, B. Bagchi and S. Basu, *Proc. Fourth Europ. Reg. Conf. Elec. Micros., Rome, II,* 85, 1968.

D. N. Misra, B. Bagchi, and S. Basu

3.5 *Ultraviolet Absorption Studies on Deoxyribonucleic Acid and its Constituents*

Complete ultraviolet absorption spectra (200-320 mμ) of the DNA bases, nucleosides, and nucleotides were obtained at pH 2 and 7. The spectra showed

that there were two prominent maxima occuring in each case at about 260 mμ and 200 mμ.

From a comparison of the absorptions at the two peaks, for a calculated mixture of nucleotides and highly polymerised *Escherichia coli* B DNA, the maximum attainable hyperchromicities at the two peaks were estimated to be 55% and 77%, respectively. From a study of hyperchromicities produced by treatments with alkali, heat, lowering of ionic strength and deoxyribonuclease, etc., it was established that the degree of denaturation under any condition could be more correctly estimated from the hyperchromicity at the Y-peak. This peak was more hyperchromic on denaturation than the X-peak in all cases.

In the extreme cases of denaturation, some red-shift (2 mμ) occured at the X-peak, while under similar conditions the Y-peak showed no spectral shift. Similar shift for the calculated mixture of nucleotides has been obtained. From the theoretical standpoint it is unlikely that hyperchromism of DNA should accompany spectral shift, which is supposed to occur in polymers due to exciton splitting of energy levels. Furthermore, absorption data become complex if the wavelength shift is involved. In this respect, the hyperchromism at the Y-peak should be the better choice for studying conformational changes in DNA than that at the familiar X-peak.

Publication :

S. Basu, Studia Biophysica, 10, 109, 1968.

(S. Basu and N. N. Das Gupta, 'Ultraviolet Absorption Studies on Deoxyribouncleic Acid and its Constituents', to be published in *Biochim. Biophys. Acta*).

S. Basu

3.6 *Kinetics of Denatured, Aggregated and Renatured DNA*

Kinetics of denaturation of DNA at different high temperatures was found to obey first order rate equation. The kinetic study was also extended to low temperatures (14°C and 37°C). The influence of formaldehyde, DNA concentration and ionic strength of the solvent was investigated. It was observed that at temperatures much below the melting region, the reaction was apparently first order in the presence of formaldehyde, while without this reagent, the reaction proceeded with time and was not truly first order. The energy of activation under different condition was estimated.

It was found that RNA contamination with DNA, produced some stabilizing effect on native DNA during storage at low temperature. The stabilization increased with the increase of RNA contamination.

Spectrophotometric studies were also carried out on the aggression of storage denatured DNA. The effect of temperature, molarity of the solvent and DNA concentration was studied with mammalian and bacterial DNAs. It was con-

cluded that aggregation of denatured molecules was maximum at an optimum temperature which was about 30° below the melting temperature. The rate of aggregation was higher the greater the DNA concentration and the molarity of the solvent.

In order to study the renaturation of DNA, irreversible denaturation curves, obtained by the method of rapid cooling were determined. Mid points ($T_{1/2}$) of these curves did not vary with DNA concentration. However, at any temperature above $T_{1/2}$, the fractional hyperchromism was always greater at the lower DNA concentration. This result was also evident in the presence of formaldehyde. Reversibility on renaturation, by the process of annealing, decreased with the progress of thermal denaturation along the melting profile. The effect was much enhanced at low DNA concentration and for a DNA of low G–C content.

Publications :

S. Basu, Z. Naturforsch., 23b, 561, 1968.
S. Basu, Z. Naturforsch., 23b, 1268, 1968.

S. Basu

3.7 *Spectrophotometric Studies on the "in vivo" T 7 Phage DNA*

The absorption spectra (220mμ – 400μ) have been studied under the following conditions (a) Untreated phage solution, (b) The phage solution, heated at 55°C for thirty minutes, and then rapidly cooled, (c) The phage solution with 0.05% S.D.S., heated for thirty minutes at 55°C and then slowly cooled to room temperature, (d) The phage solution, heated at 90°C for ten minutes, and then rapidly cooled and (e) The phage solution with 2% formaldehyde heated at 55°C for thirty minutes and then slowly cooled to room temperature.

The true optical density versus wave length spectra gave indication of a slightly denatured condition of the DNA molecules within the phage.

R. K. Sinha and S. Basu

3.8 *Molecular Weight of the DNA Genome from Bacteriophage* T7

There is accumulating evidence that the measured lengths of DNA molecules are a good measure of their molecular weights, provided that the length to molecular weight conversion factor is correctly known. Recent work has, however, indicated that the length of the DNA molecules is dependent on the method of sample preparation.

In the light of these findings, length measurements have been done on the DNA from T7 bacteriophage under different conditions of sample preparation. T7 DNA obtained in a highly polymerised form by phenol extraction method, has been prepared for electron microscopy by the protein monolayer technique using two different solvents for the hypophase. In another part of this work, the phage DNA has been obtained by osmotic shock method. Quantitative analysis of the resulting micrographs have been done.

D. N. Misra and R. K. Sinha

3.9 *Physical Studies on the Ribosomes from Yeast Cells*

These studies were undertaken to ascertain any observable structural differences between the subunits of yeast ribosomes under various experimental conditions. Ribosomes were taken in .01M Tris + .005 M $MgSO_4$ buffers, pH 7.4 and after the required treatments, the extracts were examined in a Spinco Model E analytical ultracentrifuge.

When Mg^{++} ions (which are known to be responsible for the structural integrity of ribosomes) were gradually removed from the solvent the 80S ribosomes dissociated into its subunits in the following way :

$$80S \rightarrow \left\{ \begin{array}{l} 60S \rightarrow 50S \\ 40S \end{array} \right\} 25S \rightarrow 4S$$

Only the larger subunit was observed to be converted to a low molecular weight component. This conversion may be either due to loss of material from 60S or some conformational change. Systematic studies were made to confirm one of them by examining RNA and protein content of such subunit. Preliminary studies indicated that the conversion was possibly due to a change in the tertiary structure.

The action of RNase (25 μg/ml) on the ribosomes was studied and the following results were observed : (i) Intact 80S degraded showing a continuous heterogeniety on the high molecular weight side, (ii) All subunits, viz., 60S, 50S and 40S were susceptible to RNase action.

When irradiated with X–rays, intact 80S neither dissociated nor degraded nor showed any change in the S–value. If Mg^{++} ions were removed gradually from the solvent, both the processes, viz., dissociation of 80S to 60S and 40S and conversion of 60S to 50S were enhanced in the irradiated ribosomes. Here again there was no change in the S–values. This observation suggested that with the required amount of Mg^{++} remaining in the solvent, ribosomes retained their structure irrespective of the breaks present in the RNA chain. Isolated RNA from irradiated ribosomes, however, showed different S–values.

Nandini Ghosh

MOLECULAR GENETICS

3.10 *Host Cell Reactivation of UV-irradiated Bacteriophage φX174*

In experiments reported so far bacteriophages which contain single strand ed (SS) DNA as their genetic material, such as φX174, S13 or φR did not show any host cell reactivation ("hcr") i.e. the damage produced by UV-irradiation of these phages was found not to be repaired even by hcr^+ cells capable of repairing such damages of double-stranded DNA-containing phages like T1, T3, T7 or λ. Also it was observed that "hcr" was absent for UV-irradiated, free SS–DNA of φX174, although the UV-damages of its corresponding double-stranded "replicative form", (RF), was host cell reactivable. We have been able to show that it is possible to observe "hcr" even in the case of the SS-DNA-containing phage φX174 under certain experimental conditions.

Log phage starved cells of *E. coli C* (*hcr*$^+$) and *E. coli* $Csyn^-$ (hcr^+) was infected with φX174, pre-irradiated with ultraviolent radiation to 1% survival (UV-φX), and allowed to grow in TG medium at 37°C with acration in dark. After 2 hrs of growth, it was observed that the number of plaque formers increased about 10^4-fold in the culture containing *E. coil* C+UV φX complexes, but only about 10^2-fold in that containing *E. coli* $Csyn^-$+UV-φX complexes. Burst size of φX174 when *E. coli* C or *E. coli* Csyn used as a host cell was almost same (about 100). When the growth medium of (*E. coli* C+UV-φX) complexes contained .02 M KCN for an initial period of 15 min (which was subsequently removed), the increase in the number of plaque former was not there and these complexes behaved almost like (*E. coli* $Csyn^-$+UV-φX) complexes.

From the above experiments it may be concluded that the UV-damage in SS-DNA of φX174 could be repaired by host cells containing hcr-enzyme system provided that SS-DNA is converted to RF before the repair enzymes act on it. KCN is known to prevent conversion of SS-DNA of φX174 to its RF, so that during KCN incubation SS-DNA of φX174, containing UV-damages was acted upon by the repair enzyme of *E. coli* C which caused chain-scission and consequent loss of its biological activity.

Bani Datta and R. K. Podhar

3.11 *Isolation of a New Bacteriophage, φC*

Bacteriophage φX174 make clear lysis of its natural host *Escherichia coli* C, but neither absorb nor lyse *E. coli* B or *E. coli* K12. On rare occasions lysates of φX174 made on *E. coli* C were found to be contaminated such that these lysates were able to make completely clear lysis of *E. coli* B and *E. coli* K12. From one such contaminated lysate, by means of repeated single plaque

isolations, we have identified a new strain of bacteriophage and designated it as ϕC.

When bacteriophage ϕC, was run on sucrose density gradient in the swinging bucket rotor a single peak of infectivity was observed, which sedimented as 342s particles, if 114 was taken as the S-value of ϕX174 used as markers. In the Schlerein patterns during the analytical ultracentrifuge run a purified sample of ϕC, however, revealed two components, a faster 364s component and a slower 110s component. These phages show the phenomenon of "host cell reactivation" (hcr). Sensitivity of ϕC to UV-irradiation was found to be greater when plated on a hcr strain, *E. coli* Csyn$^-$ than when the hcr$^+$ strain, *E. coli* C, was used as host. This indicates that the genetic material of ϕC is most probably a double stranded nucleic acid.

Work is in progress for complete physico-chemical characterisation of this phage and its nucleic acid.

U. Chaudhuri and R. K. Poddar

3.12 *Fate of ϕX174-infected Bacteria in Presence of Chloramphenicol*

The total RNA synthesis in ϕX174-infected cells was compared with that in uninfected ones by measuring the ^{32}P counts of TCA-insoluble alkali-labile fractions in the two cases at different times of growth period. 50 μg/ml of chloramphenicol (CM) was used in both cases as an inhibitor of protein synthesis. It was found that there was no difference between the rate of RNA synthesis in two cases for about 25 minutes of infection. Cause of this discrepancy with our earlier finding (*J. Mol. Biol., 32,* 505) is not understood at present. After 25 min there was a gradual decrease in the rate of RNA synthesis in the infected cells and after 2 hours of growth the counts became as low as 50% of that for uninfected cells.

That this reduction of RNA synthesis was partly due to lysis of infected cells was revealed by optical density (O.D.) measurements. But the rate of decrease in O.D. values was slower for 100 μg/ml of CM compared to that for 50 μg/ml, suggesting that synthesis of some chloramphenicol sensitive material was responsible for the lysis of the infected cells. It has to be mentioned that no mature ϕX is produced under these conditions. Synthesis of phage DNA also seems not to be involved in the lysis of infected complexes in presence of CM, because when cells of *E. coli* CR, a thymine-requiring mutant, were infected with ϕX174 and the time course of growth was noted by turbidity measurements, no decrease in O.D. values was observed if both CM and thymine were present in the cuture medium.

Publication :

S. Palchoudhury and R. K. Poddar, *J. Mol. Biol.*, 32, 505, 1968.

Sheela Mukherjee and R. K. Poddar

RADIATION BIOLOGY

3.13 *Influence of Chloramphenicol on Thymineless Death in Bacteria*

Thymine requiring bacteria lose viability on incubation in absence of thymine. Experiments were conducted to study the influence of protein synthesis on the induction of such thymineless death with bacteria *E. coli* 15 $T^-A^-U^-$. Chloramphenicol (CM) was used as the inhibitor of the protein synthesis. When chloramphenicol was added at the zero minute of incubation and was present in the thymineless medium throughout the experiment, the rate of thymineless death decreased with the increase in the concentration of the CM, though the plateau in the thymineless curve remained unaffected. Ultimately at concentration of 50 μg/ml and above, a maximum decrease in the rate of thymineless killing was reached and the death rate was reduced by a factor 4. In later experiments, CM administration was done at 100 μg/ml, because it was found that only at concentration of 50 μg/ml and above, the O.D. rise at 450 mμ stopped completely. When it was present at zero minute of incubation the death was reduced to the minimum, but there was no change in the plateau of the survival curve. Similarly, if the inhibitor at this concentration, was added at 30 and 60 minutes of thymineless incubation it was found that in each case, the rate of thymineless killing followed initial pattern for some time and then the survival curve broke up into a new curve with reduced rate of killing, identical with the one in which the CM was present at the start of the thymineless incubation. It is possible that the induction of thymineless death in this strain of bacteria involved two mechanisms, only one of which could be neutralized by inhibition of the protein synthesis.

Publication :

N. Ganguli and S. B. Bhattacharjee, *Biochim. Biophys. Acta, 169,* 545, 1968.

Nati Ganguli and S. B. Bhattacharjee

3.14 *Interaction of X-ray, Ultraviolet Light and Thymineless Incubation in Killing 5- Bromouracil Grown Bacteria*

Substitution of thymine by its halogenated analogs such as 5-bromouracil (BU), in DNA of living cells has been found to considerably increase their radiation sensitivity. Experiments were done on the interaction of X-rays and thymineless incubation, thymineless incubation and ultraviolet light with the cells grown in presence of 5-bromouracil. Normally X-ray survival curve had an initial shoulder. The effect of BU substitution was the removal of the shoulder and an enhancement of the rate of killing. When the BU grown cells were held

in the condition of thymineless incubation, a change in X-ray sensitivity occurred. With increasing periods of thymineless incubation, the cells tried to regain their normal sensitivity to X-rays and ultimately reached the normal sensitivity. The result of BU substitution was the removal of the build up time from the thymineless survival curve and the slope also increased. At about 1% survival level the curve broke up into another curve having much lower rate of killing. When the cells were X-irradiated there was no change in the initial part of the X-ray survival curve. In case of pre-irradiated cells, the survival curve broke up into two parts and whereas the initial part was coincident in all cases and the later part had the same slope, the curves broke up at the higher percentage of survival levels. The UV-survival curve of the thymine grown cells had the shoulders but on BU-substitution, the shoulder vanished and the slope increased. When these cells were allowed to undergo incubuation in the absence of thymine the slope in the survival curve decreased and there was gradual appearance of the shoulder in the survival curve. On UV-irradiation thymineless survival curve broke up into two parts, the slope of the later part was the same for all cases of UV doses. At higher dose the curve did not break up into two parts but had a single slope all along which was exactly equal to that in the second part of the UV-irradiated survival curves. It has been suggested that the observed results could be explained by assuming dehalogenation on incubation in the absence of thymine.

(N. Ganguli and S. B. Bhattacharjee, 'Interaction of X-ray, Ultraviolet Light and Thymineless Incubation in Killing 5-Bromouracil Grown Bacteria', to be published in *Radiation Research*).

Nati Ganguli and S. B. Bhattacharjee

3.15 *Interaction of X-ray and Ultraviolet Ray in Killing Cells*

In continuation of the work earlier reported (annual report 1967) further experiments were undertaken to study the action of X-ray and ultraviolet light on the killing of bacterial cells, *E. coli* 15 $T^-A^-U^-$. From the interaction studies on killing of various bacteria with X-rays and ultraviolet light, it was concluded that preliminary UV-exposures increase the X-ray sensitivity of the cells, but preliminary X-ray exposures could only remove the shoulder from the UV-survival curve. In the case of auxotrophic strain *E. coli* 15 $T^-A^-U^-$ the finding was different. Normally the X-ray survival curve was of multihit type with extrapolation number 3. With increasing doses of previous UV-exposure there was a gradual decrease in the shoulder and then an increase in the slope of the X-ray survival curve; ultimately a saturation in the increase in sensitivity was observed. On previous X-ray exposure, the shoulder could be removed and sensitivity to ultraviolet light increased to a maximum saturation value. It

was observed that the increase in UV-sensitivity occurred in two steps—one upto the X-ray dose of 24 K rads and the other beyond that. This two step increase in sensitivity may be considered to be due to two processes one of which was obviously due to the destruction of the repair processes.

Publication :

G. Bhaumik and S. B. Bhattacharjee, *Nature, 218*, 1077, 1968.

G. Bhaumik and S. B. Bhattacharjee

3.16 *Synergistic Killing of Bacteria by X-ray, Ultraviolet Ray and P-32 Decay*

Experiments to study the interaction of X-ray, ultraviolent light and incorporated P-32 decay on killing of bacterial cells were done with *E. coli* 15 $T^-A^-U^-$. From the studies of the cells labelled with different specific activities, it was observed that previous X-irradiation upto dose of 24 K rads had no effect on cell killing induced by P-32 decay. Only when the cells were previously exposed to doses more than 30 K rads, the sensitivity of the cells to P-32 decay increased. On previous UV-irradiation, increase in sensitivity to P-32 decay was observed at all the dose levels studied. Due to previous P-32 decay, the cell sensitivity to both X-rays and ultraviolet light increased. In the case of X-ray the survival curve showed a gradual decrease in the shoulder as well as increase in the slope. Increase in UV-sensitivity seemed to be much more prominent than that in the case of X-ray sensitivity. These studies also confirmed that for the strain of bacteria *E. coli* 15 $T^-A^-U^-$, there were two processes in the X-ray induced killing, one upto the dose of 24 K rads, and other acting at higher dose.

G. Bhaumik and S. B. Bhattacharjee

3.17 *Recovery of Heat Killed Bacteria*

Bacteria are killed if they are held at temperatures greater than 40°C. Studies were made with *E. coli* B to see if the heat killed bacteria could be revived again. Temperature used for heat killing was 52°C. Immediately after the heat-treatment, the bacterial cells were plated for the survival and the bacterial suspension was held at different temperatures, such as 0.5°, 20° and 37°C for various periods of time. It was observed that compared to the survival percentage obtained immediately after heating, the survival level on incubation at 0.5°C did not increase but at both 20° and 37°C the level increased significantly. At 20°C, the increase in the survival level was as much as 40 fold. This increase reached the maximum value in about 1 hr of incubation time. At 37°C, the

increase in the survivors were not so great. That this was genuine recovery and not an increase by division was inferred from the fact that under identical conditions of incubation in buffer, the control cells had constant viable number for about 3 hours. However, if the heated cells before incubation, were exposed to X-ray doses greater than 2 Kilorads, this increase in the survivors immediately stopped. Lower X-ray doses had no effect on the recovery phenomenon. Further work is in progress to understand the mechanism.

P. Mukherjee and S. B. Bhattacharjee

3.18 *Studies on the Liquid Holding Recovery of Bacteria*

When UV-irradiated log-phase bacterial cells were held in dark in buffer at 37°C, the number of survivors were found to increase with increase in the incubation time. Such phenomenon is called *Liquid Holding Recovery* (LHR). In case of *E. coli* B cells it was found that LHR reached saturation in about 4 hours of incubation. Experiments were conducted to study the effect of X-irradiation on the LHR of UV-irradiated cells. It was observed that X-irradiation could not influence LHR. If synthesis of protein just before UV-irradiation of the cells were inhibited by chloramphenicol, the LHR was found to be significantly depressed.

P. Mukherjee and S. B. Bhattacharjee

3.19 *UV- and X-ray Sensitivity of Bacteriophage T_2*

In continuation of the work earlier reported (Annual Report, 1967) experiments were done with T_2 and its two other mutants. It was observed that previous UV-irradiation did not increase the X-ray sensitivity of the UV-survivors; similarly previous X-irradiation also did not increase sensitivity to UV light. The observation was true for all the three bacteriophages studied.

K. Banerjee and S. B. Bhattacharjee

ULTRASTRUCTURE RESEARCH

3.20 *Ultrastructural Changes in the Nucleus During Sperm Formation of Calotes Versicolor*

The ultrastructural organisation of spermatid nucleus of the reptile, *Calotes versicolor*, shows a number of changes before the formation of mature

spermatozoan. In a very early stage of development, the spermatid nucleus represents very faintly stained body, which is later found to contain 40±10 Å thin fibrils. In further late stages, the thin fibrils become thicker to about 100 Å and then to 200Å to 250Å in diameter. The thick fibrils are formed as a result of coiling and supercoiling of the thin 40 Å fibrils, which in the last phase of development give rise to the compact, dense nucleus of the sperm head. Sometimes, the spermatid nucleus shows the sign of rotation along its longitudinal axis. Like the mammalian sperm tail, the tail filament of this reptile is encircled by a fibrous sheath.

Jyotsna Chakraborty

3.21 *Fine Structure of Interphase Chromosome*

Studies on the structure and organisation of the interphase chromosome fibers, from nucleated erythrocytes of different vertebrates, have been continued by the method reported earlier (Annual Report, 1967). In order to study the fine structure of the fibers, they were treated with (a) DNase and (b) Bronase. DNase treatment broke up the network of chromosome fibers length-wise into shorter fragments without reduction in diameter. Such fragmentation was not detected in compact networks. However, in sustained preparations, a clear density difference between the middle and the sides of the fibers was seen, as if the fibers were scooped only along the middle without changing the gross appearance. Exhaustive digestion with pronase, on the otherhand, reduced the diameter of the fibers to as thin as 30 Å, which was close to the dimension of a single DNA molecule. Thus the response to nuclease on one hand and to pronase on the other, firmly established the nucleoprotein nature of the chromosome fibers.

Publication :

D. K. Chattoraj, P. Sadhukhan and J. Chakraborty, *Experimental Cell Research, 53*, 65. 1968.

D. K. Chattoraj, P. Sadhukan and Jyotsna Chakraborty

3.22 *Studies on the Protozoan Cells*

Different types of ciliated and flagellated protozoa cultured in this laboratory, have been studied under the optical microscope after different cyto-

chemical techniques. Many abnormal features of the macronucleus during cellular division of *Oxytricha platystoma* have been observed. In a series of optical micrographs, the abnormalities of macronucleus have been investigated in details.

Jyotsna Chakraborty and J. Nag

3.23 *Electron Microscopic Studies on the Nucleated Erythrocytes from Different Vertebrate Species*

Blood was collected from the heart puncture of different vertebrates, such as, fish, amphibians, reptiles and birds and a comparative study on the nucleated erythrocytes is under progress. An extensive observation on the membrane and nuclear structure, nucleoprotein and DNA has been made. The experimental specimens so far used are lata, toad, calotes, tiktiki and munia. This work is being extended to other species of these groups in order to compare the basic structural similarity and disimilarity in the different components of their RBC.

P. Sadhukhan and Jyotsna Chakraborty

ELECTRON MICROSCOPY AND VIROLOGY

3.24 *Electron Microscope and Biological Assay Studies on the Cell-virus Kinetics*

Electron microscopy has given direct information about the size, shape, morphology and fine structure of different viruses. In this laboratory, electron microscopic investigations on some animal and bacterial viruses, such as, Rabies Brain, T7, ϕX, ϕC etc. have been initiated. It has been planned to study the interaction of virus and host cell, the mechanism of viral attack, viral growth and multiplication, release of viruses from the infected cell and the role of protein and nucleic acid of host cell in the formation of new viruses. This work will however require building up of a new tissue culture laboratory for regular virus growth and development of particle counting technique by electron microscopy.

P. Sadhukhan

3.25 *Biophysical Characterization of a Few Plant Viruses*

Different types of plants (Egg plant, Papaya, Cucurbits) infected with viruses were collected from places like Kalyani, Suri etc. and attempts were

made to isolate the native viruses. Some of the crude virus preparations were tested for sap transmissible infectivity in local lesion hosts. Systemic infection could not be made due to lack of green house and allied facilities. Some electron micrographs of the infected sap were taken to identify the viruses.

The Indian Agricultural Research Institute, New Delhi was visited, to see their methods of growing the plants and harvesting the viruses in the green house environments. Authentic strains of TMV, Y.A. TMV, DEMV, C. V4, etc., were collected from the University of Pittsburgh, Texas, California (U.S.A.) and Madras, respectively. Sample seeds were obtained from the Rothamsted Experimental Station, England and the Tobacco Research Institute.

K. Banerjee and P. Sadhukhan

3.26 *Isolation and Characterisation of DNA from Toad (Bufo Melanostictus)*

Polymerised DNA was isolated from nucleated erythrocytes of toad by a minor modification of Marmur's method. Blood of toad is found to be a rich source of DNA, since about 3-4 mg of DNA could be extracted from only 2 ml of blood which in turn could be obtained from a single adult toad. The native character of DNA was tested by means of UV absorption spectrophotometry, hydroxyapatite column chromatography, sedimentation analysis and electron microscopy. The GC content of DNA as found from the ambient-temperature melting profile was 48%. The sedimentation co-efficient of DNA was found to be 30.7S and the corresponding molecular weight was about 20 million. The distribution of length of the DNA molecules on the electron micrographs was found to be very broad (0.1 μ to 36 μ) and highly skewed towards shorter molecules. The measured weight-average length was deduced to be $(9,9 \pm 6,2)\mu$ in close agreement with the length 11μ obtained from sedimentation analysis.

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

TECHNICAL BIOPHYSICS

3.27 *The Electron Microscope—Its Past and Present*

The limit of vision of the unaided human eye is about 0.1 mm. This limit was pushed downwards by a factor of 1,000 (to about 1,000 Angstroms or .0001 mm.) by 300 years' work on the optical microscope. However, within the incredibly short time of the last 35 years, the electron microscope has been able to further extend this limit of human vision by another 1,000 times, i.e., down to about 1 Angstrom or atomic dimensions. Starting as an unexpected child

of high voltage cathode ray oscilloscope, development of the apparatus has been very rapid. The basic principle of the instrument is to use electrons as the image-forming beam and symmetrical electrostatic or electromagnetic fields as lenses. For several years after the discovery, both electrostatic and electromagnetic instruments were built side by side; however, almost all modern instruments today are fitted with electromagnetic lenses, as these have been found to give better performance. Although basically the operation of the instrument is simple, a large amount of highly complicated instrumentation had to be incorporated in the microscope, before the present state of performance could be attained. This monumental achievement of the present century has been possible due to the work of a large number of academic scientists, technologists and engineering concerns in Europe, U.S.A. and Japan. This article contains a historical account of the important steps and the advances made in different countries in the development of this basic scientific instrument.

Publication :

N. N. Das Gupta and M. L. De, *Indian Journal of History of Science, 3, No. 1*, 25, 1968.

N. N. Das Gupta and M. L. De

3.28 *Recent Progress in Electron Microscopy*

The different applications of the Electron Microscope in biology, metallurgy and solid state physics have been reviewed in this paper. The various phases of the development of specimen preparation techniques have been outlined and the improvements effected for high resolution electron microscopy have been indicated. Different modifications of the electron microscope such as reflection electron microscope, emission microscope and scanning microscope, which have found useful applications in the examination of surface structures and in micro-analysis of samples have been discussed. Most of the currently available electron microscopes have been listed, showing their important operating features.

Mention has been made of the modern trends to attain better resolution and improved performance. An account has also been given of the development of Supervoltage Electron Microscope, operating at about 1,000 kilo electron volts. The advantages of such instruments have been discussed.

Publication :

M. L. De, and N. N. Das Gupta, *Trans. Bose Research Inst., 30*, 147, 1967.

M. L. De and N. N. Das Gupta

3.29 *Construction of a Bacterial Colony Counter*

A transistorized bacterial colony counter has been built up, operating from the 220 volts A.C. mains. A Colpitts type oscillator generates high fre-

quency electromagnetic waves of about 1 Mc. This rf energy is capacitively fed to the petridish containing the bacterial colony whose individual numbers are to be counted. The rf energy from each colony is picked up by a probe and is fed to a detector-amplifier unit. A mechanical counter placed at the output of the amplifier registers the counts. Besides high frequency operation, the counting unit can also be operated manually if necessary.

M. L. De

4. THEORETICAL NUCLEAR PHYSICS DIVISION

4.0 *Introductory Remarks*

The main activities of the division are research and teaching. Research is conducted mainly in :

(i) Low Energy Nuclear Physics.
(ii) Elementary Particles and High Energy Physics.

Some work in the theory of classical and quantum electron gas is also being carried out.

Research work consists of individual work by staff members and research guidance given to research students. Seven members of staff undertake guidance of approximately fifteen students.

During the year under review our research output is :

(i) Thirteen publications in international journals
(ii) Thirteen publications in conference proceedings
(iii) Seven D. Phil. theses submitted to Calcutta University
(iv) Fifteen talks by members of the staff
(v) Nine research reports (preprints)

One of our research fellows has been awarded D.Phil. degree of the Calcutta University and another Premchand Roychand Scholarship of the Calcutta University.

Weekly informal seminary on topics of current interest and on research work in progress in the division were held regularly.

Scientists from research institutes and universities in India and abroad were invited to deliver lectures on subjects of their research work. During the year under review, twelve physicists were invited to deliver talks and discuss informally various problems of current interest.

Teaching of basic as well as advanced courses in the Post M.Sc. class was done by members of staff. During the year under review, six members delivered approximately 190 lectures. The details of the activities mentioned above are given below.

The division brings out regularly reports on research work done by members of the staff and students in the form of preprints which are distributed to all active centres of research in theoretical physics inside as well as outside India. Lecture notes on 'Non-Compact Groups in Particle Physics', delivered by Dr. N. Mukunda of Tata Institute of Fundamental Research, Bombay, were compiled by D. Bhowmik. The following preprints were brought out during 1968.

SINP-TH/68-1 : Deformed configuration mixing model for some s-d shell nuclei – L. Satpathy and S. C. K. Nair.

2 : PCAC consistency condition and ρ-meson contribution in s-wave for on-shell π-N scattering—H. Banerjee and S. Mallik.

3 : Conductivity of a plasma in a steady magnetic field—T. Pradhan and B. Das Gupta.
4 : The direct (p,n) reaction in ^{7}Li—Jayanti Mahalanabis.
5 : Analysis of Nuclear Scattering by Regge poles—R. Shanta and C. S. Shastry.
6 : Projected Tamm-Dancoff spectra of ^{20}Ne and ^{24}Mg—L. Satpathy.
7 : Universality of Rho-Meson coupling and sum rules for pion scattering on hadrons—H. Banerjee, B. Dutta Roy and S. Mallik.
8 : Correlations in Pasma I—B. Das Gupta and P. Das Gupta.
: Vlassov equation in magnetic field—Padmanabha Das Gupta and Brahmananda Das Gupta.

Talks delivered by visiting scientists

Speaker	*Subject*	*Date*
D. N. Mukunda Tata Institute of Fundamental Research, Bombay.	Non-compact groups in particle physics	Jan 3, 5, 6, 8, 9, 10, 11, 12, 15, 16, 1968
Dr. P. K. Kabir Rutherford High Energy Lab. U.K.	Recent developments in particle physics	Jan 4, 1968
Prof. E. C. G. Sudarshan Syracuse University U.S.A.	Faster than light particles	Jan 22, 1968
Dr. B. Misra Geneva University Geneva	Approximate symmetries and deformation of lie groups	Feb 27, 1968
Dr. T. Das Rochester University U.S.A.	Electromagnetic mass difference and radiative corrections to weak decays of hadrons	March 11, 12, 1968
Prof. M. A. Broun Leningrad University U.S.S.R.	Description of composite particles by condition Z=O	March 29, 1968
Dr. L. K. Pandit Tata Institute of Fundamental Research, Bombay.	Asymptotic SU (3) symmetry	April 15, 16, 1968

Speaker	*Subject*	*Date*
Dr. M. A. Eswaran Bhabha Atomic Research Centre, Trombay	Studies on radiative transitions following nuclear reactions	May 9, 10, 1968
R. K. Bhaduri Tata Institute of Fundamental Research, Bombay.	(i) Hypernuclei and Λ NN forces. (ii) The tensor force in nuclear matetr.	May 6, 7, 1968
Dr. Krishna Kumar Niels Bohr Institute Copenhagen, Denmark	Microscopic theory of nuclear shape	Aug 8, 9, 1968
Dr. M. K. Mehta Van-de-Graff laboratory Bombay	Investigation of isobaric analogue states through (p,n,) and (p, α) reactions.	Nov 18, 19, 1968
Prof. P. M. Mathews Madras University Madras	(i) Relativistic wavefunctions for particles of arbitrary spin.	Dec 2, 1968
	(ii) Self - conjugateness of internal symmetry multiplets.	Dec 3, 1968

Invited talks by members of staff in India and abroad :

Nuclear Structure Calculation with Realistic Two-nucleon Potential, Low Energy Symposium, Madras, 1968—M. K. Pal

Lectures on Nuclear Structure, Aligarh Muslim University, 1968—M. K. Pal

Selected Topics on Nucleon Theory, Seminar on Nuclear Physics held in I.I.T., Kanpur, 1968—M. K. Pal

On Deformed Hartree-Fock Calculations, Seminar on Nuclear Physics held in I.I.T., Kanpur, 1968—S. C. K. Nair

Recent Developments in the Description of Collective Modes in Nuclei, Low Energy Symposium, Bombay, 1968—S. C. K. Nair

Strangeness Changing Leptonic Decay of Hadrons, Delhi University and Madras University—T. Pradhan

PCAC Consistency Condition and φ-meson Dominance in S-wave for On-shell πN Scattering, Geneva University, Padova University, Rutherford Laboratory and Delhi University, 1968—H. Banerjee

Photo-production of Pions from Nuclei on the Basis of PCAC, Matscience, Madras, 1968—S. C. K. Nair

Low Energy Pion-pion Interactions, Rockfeller University and Rutherford Laboratory, 1968—B. Dutta Roy

Spectral Function Sum-rules and Scalar Mesons, Brookhaven National Laboratory, 1968—B. Dutta Roy.

Conferences attended by members of staff and research fellows

International Symposium on Contemporary Physics, Trieste, June, 1968—H. Banerjee

Symposium on Mathematical Foundations of Scattering Theory, Geneva University, July, 1968—H. Banerjee

Symposium on Particle and Solid State Physics, Delhi University, September, 1968 H. Banerjee and T. Pradhan

M.IT. (U.S.A.) Symposium on Nuclear and Particle Physics, May, 1963 —M. K. Pal

Low Energy Symposium, Madras, 1968—M. K. Pal, S. C. K. Nair and S. Samaddar

Low Energy Symposium, Bombay, 1968—S. C. K. Nair, R. K. Satpathy and S. Samaddar

American Physical Society Meeting, Washington, U.S.A., April, 1968—B. Dutta Roy.

Weekly divisional seminars

Subject	*Speaker*	*Date*
(1) Recent work of Bethe on Nuclear Matter and the Thomas-Fermi Approach to Finite Nuclei	Prof. M. K. Pal SINP	Started on 14th May, 1968
(2) Review of the Recent Work of Lane and Robson on Nuclear Reaction Theory	Prof. M. K. Pal SINP	,,
(3) Configuration Mixing in the Continuum	Dr. S. C. K. Nair SINP	June, 1968
(4) Model for Nonleptonic Decays	Miss M. Pattnaik SINP	Nov. 25, 1968
(5) Interference Model, Argand Loops, Duality and All that	Dr. P. Dasgupta SINP	Dec. 9, 1968
(6) Gauge Conditions and Massive Fields	Dr. P. Ghosh Vishva Bharati Univ., Bolpur	Dec. 17, 1968
(7) Believe it or not : the Velocity of Sound in Superdense Matter May Exceed the Velocity of Light or Superluminality of Matter	Sri B. Dasgupta SINP	Dec. 23, 1968

(8) Hard Pioneering	Sri J. N. Passi SINP	Dec. 27, 1968

Participation in the teaching programme

Introductory solid State Physics ..	Prof. T. Pradhan	..	16 Lectures
Advanced Elementary Particle Physics	„	..	30 „
Advanced Quantum Mechanics ..	„	..	10 „
Classical Electrodynamics ..	Dr. S. C. K. Nair	..	25 „
General Nuclear Physics ..	Prof. M. K. Pal	..	30 „
Special Nuclear Physics ..	„	..	11 „
Quantum Field Theory	Prof. H. Banerjee	..	30 „
Elementary Quantum Mechanics ..	Prof. B. Dutta Roy	..	30 „
Advanced Statistical Physics ..	Sri B. Dasgupta	..	10 „

Degrees and distinctions conferred

D. Phil	Sri Padmanabha Dasgupta Thesis entitled 'Nonrelativistic Dispersion Relations and Regge Poles'
Premchand Roychand Scholarship ..	Sri Prahmananda Dasgupta Thesis entitled 'Studies on the Statistical Mechanics of Gaseous Plasma'.

Theses submitted during the year 1968

Name	*Title of the thesis*	*Supervisor*
Sri D. N. Tripathy	Charge Transfer and Other Atomic Processes in An Electron Gas	Prof. T. Pradhan
Sri L. Satpathy	Study of s-d Shell Nuclei	Prof. M. K. Banerjee
Sri B. Dasgupta	Some Problems of Irreversible Processes in Plasma	Prof. T. Pradhan
Sri C. S. Shastry	Analytical Approach to Nuclear Scattering	Prof. S. Mukherjee
Sri J. N. Passi	Elementary and Composite Particles in Quantum Field Theory	Prof. T. Pradhan
Miss M. Pattnaik	Current Operator Approach to Quantum Theory of Elementary Particles	Prof. T. Pradhan
Miss R. Shanta	Analysis of Nuclear Scattering Through Pology	Prof. M. K. Pal

T. Pradhan

4.1 *Weak Axial-vector Coupling Constant in the Static Chew-Low Model*

By properly defining weak current so as to include the mesonic contributions and thereby have them satisfy the Chiral $SU_2 \times SU_2$ algebra, it is shown that

the Axial-vector coupling constant is renormalized by a factor / G_A / G_V = 1.13 due to static pion-nucleon interaction. $\chi = (f_0/\mu)\ \tau \frac{\tilde{\alpha}}{a} \nabla \phi \tilde{\alpha}$ It is also shown that $1 \leqslant (GA/GV)^2 \leqslant {}^3/_2$ in this model.

(T. Pradhan and Mamata Pattnaik, 'Weak Axial-vector Coupling Constant in the Static Chew-Low Model', to be published in *Nuovo Cimento*).

T. Pradhan and Mamata Pattnaik

4.2 *Axial Vector Renormalization Constant from Algebra of Current II*

A general sum rule connecting the matrix elements of the SU(4) current operators between zero momentum states, characterized by arbitrary spin and isospin quantum numbers is derived using SU(4) current commutation relation and Racah algebra. The sum rule thus obtained gives more insight into the problem and reproduces the results obtained by other authors for calculating the axial vector renormalization constant.

(Mamata Pattnaik, 'Axial Vector Renormalization Constant from Algebra of Current II', to be published in *Ann. Phys.*)

Mamata Pattnaik

4.3 *Axial Vector Renormalization Constant from SU(4) Current Algebra*

A set of relations among the reduced matrix elements of current operators is obtained by suitably choosing a set of intermediate states in the SU(4) commutator algebra of currents. These relations when solved give a value for axial vector renormalization constant $g_A = 1.22$, which is quite close to the experimental value $g_A = 1.18$.

(Mamata Pattnaik, 'Axial Vector Renormalization Constant from SU(4) Current Algebra, to be published in *Ann. Phys.*)

Mamata Pattnaik

4.4 *Analysis of Nuclear Scattering by Regge Poles*

The validity and usefulness of complex angular momentum formulation in nuclear scattering are investigated by studying the elastic scattering of alpha particles by ^4He, ^{32}C and ^{16}O in terms of the Regge trajectories through suitable

Regge type representations for the S-matrix. The trajectories are obtained from the resonant levels of the compound nuclei, and residues were calculated by imposing unitarity on the Regge-type representations for the S-matrix. The differential cross sections obtained by this method are compared with those obtained by experiment and Ackhiezer-Pomeranchuk-Blair-McIntyre (APBM) model with resonant phase shifts. In order to establish the merit of Regge-pole approach, cross sections are calculated in terms of the poles of the S-matrix in the momentum plane and compared with the results obtained by using complex angular momentum formulation. These studies provide an interesting method for the analysis of nuclear scattering.

(R. Shanta and C. S. Shastry, 'Analysis of Nuclear Scattering by Regge Poles', to be published in *Phys Rev.*)

R. Shanta and C. S. Shastry

4.5 *Studies of Odd Mass Co-isotopes in the Unified Model*

An explanation of the properties of the low-lying levels of the odd mass Co-isotopes and the interpretation of the (t, $\propto$) reactions on the even-mass Ni isotopes are presented on the basis of the intermediate coupling approach of the unified model. It is assumed that a Co-isotope has a structure formed by coupling of a proton hole to the quadrupole vibrations of the corresponding even-mass Ni nucleus. The core states up to three phonons are considered in the calculation. The phonon energy $h\omega/2\pi$ is taken as the energy of the first excited state of the neighbouring Ni isotope. The proton-hole states are assumed to be $(1f_{7/2})^{-1}$, $(1d_{3/2})^{-1}$ and $(2s_{1/2})^{-1}$. The coupling strength is the only variable parameter which enters into the calculation of the negative-parity states. The energies of states $(1d_{3/2})^{-1}$ and $(2s_{1/2})^{-1}$ with respect to $(1f_{7/2})^{-1}$ are treated as the variable parameters in the calculation of the positive-parity levels. The isotopes considered are ^{57}Co, ^{59}Co, ^{61}Co and ^{63}Co. The calculated energy levels, spins and parities, nuclear moments and the transition probabilities are in good agreement with the experimental results.

The calculated spectroscopic factors for the $7/2^-$, $\frac{1}{2}^+$ and $3/2^+$ states agree reasonably well with the experimental results of the (t, α) reactions on the even-mass Ni isotopes.

Publication :

L. Satpathy and S. C. Gujrathi, *Nuclear Physics, A110*, 400, 1968.

L. Satpathy and S. C. Gujrathi

4.6 *Validity of Hartree-Fock Calculation Before Angular Momentum Projection —A Test in ^{20}Ne*

A variational calculation after angular momentum projections for the first three states of ^{20}Ne is performed. A comparison of these results with those of a Hartree-Fock calculation before angular momentum projection provides a justification for the latter procedure.

Publication :

L. Satpathy and S. C. K. Nair, *Physics Letters, 26B*, 257, 1968.

L. Satpathy and S. C. K. Nair

4.7 *Deformed Configuration Mixing Model for Some s-d Shell Nuclei*

The existence of large energy gaps between occupied and unoccupied Hartree-Fock states in even-even N=Z nuclei in and s-d shell provides the basis for a configuration mixing model in the intrinsic k-space of the valence nucleons outside the even-even core. The application of this model to ^{22}Ne yields excellent results for the energy spectrum.

Publication :

L. Satpathy and S. C. K. Nair, *Physics Letters, 26B*, 716, 1968.

L. Satpathy and S. C. K. Nair

4.8 *Projected Tamm-Dancoff Spectra of ^{20}Ne and ^{24}Mg*

From the static Hartree-Fock (HF) solutions of ^{20}Ne and ^{24}Mg, the intrinsic wavefunctions of the excited bands are obtained in the Tamm-Dancoff Approximation (TDA). For both the ground and excited states, axially symmetric deformation has been assumed. A phenomenological interaction with Yukawa radial dependence and exchange mixture of the Rosenfeld type is used in the calculation. The good angular momentum states are then projected out from the TDA wavefunctions. The agreement between the calculated and the experimental spectra of ^{20}Ne is only reasonably good. Contrary to the expectation, the projected spectrum in one case deviates significantly from the J(J+I) law.

Publication :

L. Satpathy, *Phys. Rev., 174*, 1324, 1968.

L. Satpathy

4.9 *Scattering Amplitudes Generated by Pole Terms of Regge-type Representations*

Calculations of partial-wave amplitudes are performed for various Regge-type representations for attractive Yukawa potentials, and the results are compared with those obtained from exact calculations.

Publication :

Suprakash Mukherjee and C. S. Shastry, *Phys. Rev., 169,* 1234, 1968.

S. Mukherjee and S. C. Shastry

4.10 *Low Energy Pion-Pion Interaction*

Low energy pion-pion scattering is assumed to be dominated by the ρ resonance in the I = 1, J = 1 channel, the f° resonance in the I = 0, J = 2 channel, and a broad resonance of mass about 700 MeV in the I = 0, J = 0 channel. This simple model is found to be in substantial agreement with: (a) Adler's sum rule for pion-pion scattering, (b) the $K^\circ_1 = K^\circ_2$ mass difference, (c) t-channel contributions to backward pion-nucleon dispersion relation, (d) Malamud and Schlein's "experimental" determination of the pion-pion phase shifts, (e) constraints on the s-wave pion-pion phase shifts at the K mass deduced from the two pion decays of the neutral K mesons, (f) characteristics of the K_{e_4} decay, and (g) odd-pion spectral shape for K decay into three pions.

Publication :

B. Dutta-Roy and I. R. Lapidus, *Phys. Rev., 169,* 1357, 1968.

B. Dutta-Roy and I. R. Lapidus

4.11 *Regge-type Representations for Coulomb-nuclear S-Matrix*

Using a Yukawa type 'nuclear' potential Regge poles and residues of Coulomb-nuclear *S*-matrix are calculated for various strengths of repulsive Coulomb interaction. Partial wave amplitudes and residues generated by different Regge-type representations are then compared with exact results. These results are helpful in establishing the usefulness and validity of Regge-pole approach to charged particle-nucleus scattering.

(C. S. Shastry and R. K. Satpathy, 'Regge-type Representations for Coulomb-Nuclear S-Matrix,' to be published in *Phys. Rev.*)

C. S. Shastry and R. K. Satpathy

4.12 *A Method for Fast Convergence of t-Matrix in Nuclear Matter*

A fast converging expansion of Brueckner t-matrix for a local potential is derived through the help of a non-local separable potential. The parameters of the auxilliary potential are determined by comparison of matrix elements over a range of relative momenta. By numerical calculations, the convergence is found to be satisfactory such that, to a fairly good accuracy, the first order calculation may be taken to be reliable. As an application, a preliminary calculation for the binding energy of nuclear matter is done by the reference-spectrum method, without Pauli exclusion effect and self-consistency.

S. Mukherjee and R. K. Satpathy

4.13 *Regge Trajectories for Coulomb-nuclear S-Matrix*

Calculations are performed to investigate the effects in the 'nuclear' part of the Coulomb nuclear S-matrix. Regge trajectories for the pure nuclear S-matrix and Coulomb-nuclear S-matrix are compared. The possible applications of these studies in analysing scattering problems are discussed.

(C. S. Shastry and R. K. Satpathy, 'Regge Trajectories for Coulomb-Nuclear S-Matrix,' to be published in *Nuovo Cimento*).

C. S. Shastry and R. K. Satpathy

4.14 *A Model of Chiral-invarient Nonlinear Lagrangian*

We demonstrate that the three wellknown models of Chiral-Invariant nonlinear Lagrangian can be uniquely obtained from the general model of Chang and Gursey, by demanding the criterion of simplicity. By demanding that the boson part of Axial Vector current has a simple form, we uniquely obtain a nontrivial fourth model.

A. V. Khare

4.15 *Effective Hamiltonians for Quantum Field Theories with Derivative Couplings*

A general method is developed to study the derivative couplings by an explicit solution of Tomonaga-Schwinger equation for Dyson's U operator. The method is then applied to study in detail the pseudovector interaction between

mesons and nucleons. Remarkable feature is that a closed expression can be obtained for interaction Hamiltonian in terms of free fields, which although nonlinear in the meson field, is free of derivative terms. It is shown that the complications created by isospins of particles are not trivial. For pseudovector interaction, the effective Hamiltonian for particles carrying isospin is considerably different from that of isospinless particles. For the vector interaction between nucleons and scalar mesons carrying isospin, the effective Hamiltonian is nonvanishing in contrast to that of isospinless mesons and nucleons for which the effective interaction vanishes.

T. Pradhan and A. V. Khare

4.16 *Positronium Formation by the Passage of Positrons through an Electron Gas*

A new approach to the problem of positronium formation in an electron gas is attempted where the question whether the so-called second life-time exists in metals or not, is discussed by considering the four competing processes of thermalisation of the incident positron by its passage through an electron gas, formation, disintegration and annihilation of the positronium. Calculations of probabilities of these processes are made by the Feynman diagram techniques of many body theory. It is found that except for a very narrow band of incident positron energy, for which positronium formation probability far exceeds those of the rest, all the processes are equally probable. Therefore the so-called second life-time in positron annihilation in metals would be seen if experiments could be done with variable energy monoenergetic positron source.

(T. Pradhan and D. N. Tripathy, 'Positronium Formation by the Passage of Positrons through an Electron Gas,' to be published in *Nuovo Cimento*).

T. Pradhan and D. N. Tripathy

4.17 *Faddeev Theory Applied to Stripping Reactions*

Using Faddeev integral eqns. for three-body problems and Lovelace approximation for saturating the intermediate states by bound states and resonances only, angular distribution for ^{28}Si (d, p) ^{29}Si has been calculated. In this calculation Coulomb effect is neglected and only ground states of (^{28}Si–p), (^{28}Si–n) and deuteron as S-state were used in connection with Lovelace approxi-

mation. The cross-section obtained is too-high compared to experiment. This work is still in progress.

S. Mukherjee and S. K. Samaddar

4.18 *Low Energy Pion Phase Shifts from Backward Pion Nucleon Dispersion Relations*

$\pi - N$ backward dispersion relations for the $F^{(+)}$ and $F^{(-)}$ amplitudes were written in the variable k^2 (k being the centre of mass momentum) and a subtraction was given at the $\pi\pi$ threshold ($k^2 = -1$). The spectral functions were evaluated using the recent $\pi - N$ phase shift analysis done independently by Lovelace *et al* and Bareyre *et al.* The left hand out integral (discrepancy function) was parametrised in terms of a polynomial in a suitable conformally transformed variable and the coefficients were determined by least square fit to experimental values of the discrepancy in the $\pi - N$ physical region. On extrapolation to the left hand out the phase of the $\pi\pi$ $I=1$, $J=1$ wave (obtained from $F^{(-)}$ was found to resonate at about 730 MeV with a scattering length 0.03 m_π^{-1} while the phase of the $\pi\pi$ $I=0$, $J=0$ wave (obtained from $F^{(+)}$) was found to have either a single broad resonance at about 630 MeV or two resonances at 330 and 680 MeV respectively with a scattering length of the order of 2.6 m_π^{-1}.

H. Banerjee, S. Mallik and V. J. Menon

4.19 *Angular Momentum Projection from Asymmetric Hartree-Fock Solutions*

It has been found earlier that the energy spectrum calculated with good angular momentum wavefunctions projected out of axially symmetric Hartree-Fock solutions for ^{24}Mg and ^{25}Mg disagrees significantly from the experimental ones. This and the fact that the assymmetric Hartree-Fock solutions for these nuclei are more stable has lead us to attempt at angular momentum projections from the asymmetric solutions. The work is in its final stages.

L. Satpathy and S. C. K. Nair

4.20 *Structure of Higher Isospin States in ^{20}Ne*

The structure of higher isospin states in ^{20}Ne which are analogous of ^{20}F and ^{20}O ground states are being studied with the view of extracting direct evidence on the change in the intrinsic deformation.

L. Satpathy and S. C. K. Nair

4.21 *Magnetic Susceptibility of a Plasma*

Following the 'Martin-Schwinger approach' developed for many-particle system, a classical derivation of the expression for magnetic susceptibility of a plasma in a uniform magnetic field is attempted. The electromagnetic properties of a system are expressed in terms of a special two particle Green's function which describes current correlation. The first task is to derive an expression for the current induced by one general external field with a scalar and vector potential.

T. Pradhan and B. Das Gupta

4.22 *Higher Correlations in Plasma*

An attempt is being made to derive expression for the triple and higher correlation in plasma in the Prigogine-Balescu diagram technique. From the general expression for the three-particle correlation function the diagrams dominant in the 'long-time' approximation have been selected. The main task is to set up an integral equation representing the sum of the dominant term and to solve that integral equation. This work is in progress.

B. Das Gupta and P. Das Gupta

4.23 *Pion Nucleon Dynamics*

Reggeised crossed channel exchanges are being considered as input of the strip N/D equations. In view of the interesting consequences of the low energy extrapolation of Regge exchanges noted recently, it is proposed to study the effect of unitarization within the low energy strip and the possibility of generating the dip-bump details of low energy scattering, taking few low partial waves.

P. Das Gupta

4.24 *Exchange Degeneracy and Competing Channels*

There exists certain amount of ambiguity regarding the question of exchange degeneracy being broken by the existence of competing channels. Where-

as the expectation of quark models is that the residues will no longer be degenerate, the Finite Energy sum rules lead to degenerate residues and trajectory functions. We are studying a potential model with two coupled channels with one channel experiencing no exchange potential in the uncoupled approximation. Fairly exact trajectory functions and residues are being calculated from the Schrodinger equation and the modified Cheng representation.

P. Das Gupta

4.25 *Current Algebra Calculation of Coupling Constant Ratio $f_{\pi NN^*}$ and $f_{\pi NN}$*

Taking pion-nucleon interaction similar to that of static-model, and assuming that isospin Current $V_{\vec{\alpha}}$ and Meson source term $P_{\vec{\alpha}}$ satisfy Gell-Mann's current algebra, we obtain the ratio of (πNN*) coupling constant f* and (πNN) coupling constant f. We obtain $(f^*/f)^2 = 4/3$ which corresponds to N* width of 98 MeV. An extension of this approach to photoproduction of pions from nucleons is under investigation. It is expected to give a relation between the coupling constant γNN* and the nucleon magnetic moment.

T. Pradhan and A. V. Khare

4.26 *Four Divergence in Lagrangians*

It is wellknown that four-dimensional divergences in the Lagrangian density have no effects on the field equations. Nishijima and Swank have recently argued that if the Lagrangian density becomes equal to this form as a consequence of field equations, then that four-dimensional divergence cannot be thrown away in the customary fashion. However, it is known that vector interaction ($L_{int}(x) = \psi(x)\gamma_\mu \delta_\mu \phi(x)\ \psi(x)$) between isospinless scalar mesons and nucleons becomes a four-dimensional divergence on account of field equations, and is equivalent to no interaction. Thus it seems that in certain cases four-dimensional divergences formed in the Lagrangian on account of field equations, can be thrown away. We show that in case

$$[\{\delta_0 F_0(x_0), F_0(x_0)\}, F_0(x_0)] = 0$$

then the four-dimensional divergence $\delta_\mu F_\mu(x_0)$ in the Lagrangian density, formed even as a consequence of field equations, has no effects.

T. Pradhan and A. V. Khare

4.27 *Study of the (p, n) Reaction in ^{9}Be*

The direct (p, n) reactions in ^{9}Be exciting the isobaric analogue states in ^{9}B are being studied at medium energies. Assuming the two nucleon interaction to be known in impulse approximation we use different models for these nuclei to test the validity of the model. At present we are using the α – particle model of the Blair and Henley (*Phys. Rev. 112*, 2029, 1958) and would like to compare our results with the prediction of shell model.

Jayanti Mahalanobis

4.28 *Use of Projected Hartree-Fock Wave-functions to Study the Proton Scattering from ^{7}Li*

The discrepancy between experimental data on proton scattering by ^{7}Li and theoretical predictions would not be removed using shell model wave-functions obtained by method of generator co-ordinates. We propose to use the projected Hartree-Fock wave-functions for ^{7}Li (which has been shown to give excellent agreement with the electromagnetic properties and form-factors for electron scattering) to study the proton scattering data and compare with our previous results.

Jayanti Mahalanobis

4.29 *Test Particle Problem in Balescu-Lenard Kinetic Equation*

Relaxation processes in plasma obeying Balescu-Lenard kinetic equation has been investigated. Frictional drag experienced by a test particle injected into a single component plasma (i.e. electrons moving against a fixed neutralizing background) and two component plasma (i.e. ordinary fully ionised electron-proton plasma) has been calculated as a function of different injection velocity. The coefficients of diffusion for the test particle in velocity space have also been calculated. These calculations show substantial departure from the results obtained from Landau kinetic equation (ordinary Fokker-Planck). The time evolution of the test particle distribution assumed to be sharp Gaussian initially has also been studied numerically.

B. Das Gupta

4.30 *Correlations in Plasma I*

We derive for non-equilibrium isotropic plasma the correlations of fluctuation in electric field intensity and current density. The calculation is based on the ring approximation results of Balescu and Taylor. The results reduces to the results obtained by Rostoker in the special case when the velocity distribution function is Maxwellian at the initial time.

B. Das Gupta and P. Das Gupta

4.31 *Vlassov Equation in a Magnetic Field*

This paper presents the derivation of the Vlassov kinetic equation together with the screening function for a plasma in a uniform magnetic field within the framework of the diagram technique of Prigogine and Balescu. This involves the behaviours of the plasma over a time period of the order of plasma oscillation time. The Van-Kampen-Case eigenfunctions for magneto-plasma are obtained by solving the linearised Vlassov equation, treated as an eigenvalue problem. These functions are shown to form a complete orthogonal set and their use greatly simplifies various magneto-plasma calculations. An application to a certain integral equation obtained by Haggerty and de Sorbino in connection with the ring equation is also discussed.

P. Das Gupta and B. Das Gupta

4.32 *Self-consistent Study of Nuclear Shapes*

In this paper we report on the self-consistent Hartree-Fock (HF) and Hartree-Fock-Bogoliubov (HFB) calculations which have been performed for the even Ti, Cr, and Fe isotopes. The residual two body interaction is assumed to be a central potential with Yukawa radial dependence, and an exchange mixture which has been adjusted to fit the low lying shell model states of $^{18}_{10}O$ and $^{18}_{9}F$. It is found that the HF minima occur for prolate shapes and hence the HFB calculations are done only for prolate deformations. The HFB calculation yields normal solutions for $N = Z$ nuclei and spherical shapes for $Z < N = 28$ nuclei.

The effect of pairing on the ground state properties is also studied. The value of mass quadrupole moment for the HFB solution is smaller than that for HF solution for all the nuclei under consideration.

A spherical BCS calculation has been performed to make a comparison of energy minima corresponding to the deformed HFB and BCS shapes.

We construct the excited states for the $Z < N = 28$ nuclei from the spherical BCS ground state solutions in the Random Phase approximation. This gives values for the $0^+ \rightarrow 2^+$ energy separation and the B(E2) rates which are in good agreement with experiment.

Harish Chandra

4.33 *Intrinsic Quadrupole Moment Transition Rates and Spectroscopic Factors for the Self-consistent HFB Shapes of the Ti, Cr and Fe Isotopes*

Intrinsic quadrupole moments for the self-consistent deformed Hartree Fock-Bogoliubov (HFB) shapes for the even Ti, Cr, and Fe isotopes are calculated and compared with results obtained from the self-consistent Hartree-Fock (HF) approximation. It is pointed out that in the HFB approximation for even $Z < N = 28$ nuclei one gets spherical shapes and hence to calculate the $B(E_2)$ rates it is not proper to use the deformed HF wave-functions. We calculate the B(E2) rates with the excited state wave-functions constructed over the spherical BCS solutions in the RPA.

Harish Chandra

4.34 *A Study of ^{7}Li (p,n) Reaction in the Impulse Approximation*

The (p,n) reaction in ^{7}Li at 94 MeV has been studied in the impulse approximation. The differential cross-section exciting the isobaric analogue state and 0.431 MeV state in ^{7}Be is obtained using the L-S coupled shell model wave-functions. Fairly good shape agreements with the available experimental results are obtained. These results are discussed as a mode of investigating the model wave-functions used together with the inelastic proton scattering to the 0.478 MeV state in ^{7}Li, where the small angle results as predicted by the theory appear to be in conflict with the experimental data. Need for more experimental data at small angles for these reactions is stressed.

(Jayanti Mahalanobis, 'A Study of ^{7}Li (p,n) Reaction in the Impulse Approximation', to be published in *Proc. Phys. Soc.* (*London*)).

Jayanti Mahalanobis

4.35 *The Charge Exchange Reactions in ^{6}Li*

We have studied the (p,n) and (n,p) reaction in ^{6}Li using the impulse approximation. Shell model wave-functions yield good shape fit to the experimental data for (n,p) reaction at 152 MeV, although the magnitude fit is not satisfactory. Assuming the two-nucleon interaction to be known in the impulse approximation we have attempted to analyse our results to test the validity of the model wave-functions used in the calculation.

Jayanti Mahalanabis

4.36 *HFB Calculations in the 2s, 1d Shell*

Ground state parameters have been calculated for $N=Z$, $N=Z+2$, and $N=Z+4$ even-even nuclei for which both neutrons and protons fill the 2s, 1d major shell, using the Hartree-Fock-Bogoliubov theory. The mass quadrupole moments and moments of inertia relative to the intrinsic reference frame are calculated, and qualitative features of the intrinsic deformations are discussed. Comparison is made to the results obtained when pairing correlations are absent, i.e., the Hartree-Fock predictions. The Hartree-Fock-Bogoliubov results are the same as the Hartree-Fock results for $N=Z$ even-even nuclei. It is found in general that the HFB procedure need not predict an axially symmetric intrinsic shape.

L. Satpathy, D. Goss and M. K. Banerjee

4.37 *Analysis of Nuclear Scattering Through Polology*

The analyticity of the S-matrix in the complex momentum (k) plane is utilised for studying the elastic scattering of alpha particles by ^{12}C using a representation for the S-matrix expressed as a product over its poles and zeros in the complex k-plane. Differential cross sections are calculated with this representation for the S-matrix and compared with experiment. The effect of the phase factor in the representation for the S-matrix on the angular distributions is also studied.

(R. Shanta, 'Analysis of Nuclear Scattering Through Polology', to be published in *Nuovo Cimento*).

Rajagopal Shanta

4.38 *Decay Width, Magnetic Moments and Transition Moment of Nucleon Isobars from Algebra of Currents*

Using the equal time commutation relations of axial vector current-current and current-magnetic moment operators, sum rules for the reduced matrix elements of these operators are obtained. These sum rules correspond to a set of infinite number of coupled equations which are solved by truncating the intermediate states at various stages. A systematic study has been made to examine how quantities like axial vector renormalisation constant, decay width of N*(1238), ratio of $(N^{*(+)}\ N^{*(+)}\ \pi^{(0)})$ to $(NN\pi)$ couplings, magnetic moments of nucleon isobars, and the transition moments of nucleon to $N^{*(+)}$, vary with truncations. It is also noticed that if one truncates the states in a particular fashion, results normally ascribed to higher symmetry groups are reproduced. Over and above it is found that if all the diagonal states I=J are retained, the sum rules yield N* width equal to 125 MeV and the transition moment $<P|M_3|N^{*(+)}> = 1.25(2\sqrt{2/3}\,\mu\ (P))$, compared with the experimental values 120 MeV and $(1.28\pm0.02)\ (2\sqrt{2/3}\,\mu\ (P))$, respectively.

Mamata Pattnaik

4.39 *Optical Potential for Deuterons*

The optical potential for deuteron is calculated in terms of the optical potentials of neutron and proton using the expressions of Mukherjee. An energy dependence in the imaginary part of the nucleon optical well is considered. The cross-sections for elastic scattering of deuterons from nuclei, obtained with the calculated optical potentials are compared with the experimental results.

S. Mukherjee, R. K. Satpathy and S. K. Samaddar

4.40 *Strip Equations in Pagels Approximation*

Pagels' method has been adopted with some modification to solving the new strip approximate N/D equations. The method has been applied to generate the nuclean trajectory in the πN system from N, N* and ρ-exchanges in the crossed channels. Enormous simplification of the computational task could be achieved by replacing the Pagels' pole fitting by Gaussian interpolation. Reasonable value of the nucleon mass and the slope of the trajectory has been obtained for a small range of values of the strip parameter.

P. Das Gupta

4.41 *The Omega Minus Trajectory*

The method of treating the strip equations with Pagels' method was applied to K = Ξ scattering. The dynamics involved the vector meson exchanges together with the γ^* exchange. The γ^* contribution was found to be relatively small. The Reggeised Ω^- was generated with a slope 0.4 per kaon mass.

P. Das Gupta

4.42 *A New Look at Vacuum Polarisation Contribution to Lamb Shift*

The conventional 2nd order covariant perturbation theory calculation of vacuum polarisation is re-examined in the light of recent developments in equal time current commutation relations. The usual stringent requirements for gauge invariance are relaxed in redefining the vacuum polarisation tensor. The new vacuum polarisation tensor makes the real photons transverse leaving the virtual photons free to have a longitudinal component.

T. Pradhan

4.43 *Current Commutators in Quantum Electrodynamics*

The structure of equal time current commutators in quantum electrodynamics is investigated in 2nd order covariant perturbation theory by relaxing the requirement of gauge invariance on the vacuum polarisation tensor.

T. Pradhan and M. Pattnaik

4.44 *Dispersion Theoretic Approach to PCAC Consistency Condition and Meson Contribution in S-wave for On-shell π-N Scattering*

Assuming unsubtracted backward dispersion relations for physical N scattering we are able to : (i) obtain the PCAC consistency condition and (ii) relate the contributions from the ρ-meson to S-wave scattering lengths with those from the dominant P-wave singularities. Our on-shell derivation emphasises

the analogy between the PCAC consistency condition and the Goldberger-Treiman relation.

H. Banerjee and S. Mallik

4.45 *Universality of Rho-meson Coupling and Sum Rules for Pion Scattering of Hadrons*

Following the method recently proposed by two of the present authors and assuming the universality of ρ-coupling to hadrons we obtain sum rules for pion scattering on K, $\equiv$ and Σ. Our sum rules for πK scattering directly relates the widths of K*(890) and ρ-meson. In the $\pi\equiv$ and $\pi\Sigma$ sectors we obtain two sum rules for the SU(3) mixing parameter $\propto \equiv$ F/(F+D) for PBB coupling both of which are consistent with the value $\propto \approx 0.4$.

H. Banerjee, B. Dutta Roy and S. Mallik

4.46 *Pion-nucleon Scattering Lengths*

Pion-nucleon scattering lengths have been calculated using a model in which N, N*, ρ and ε exchanges are assumed to dominate the low-energy pion-nucleon interaction. This simple model yields remarkably good agreement with the experimental s- and p-wave scattering lengths. We find that the coupling of the ε meson to the nucleon is consisten with estimates made using Chiral symmetry and current algebra.

(B. Dutta Roy and I. R. Lapidus, 'Pion-nucleon Scattering Lengths', to be published in *Phys. Rev.*).

B. Dutta Roy

4.47 *A Scalar Nonet, Semi-leptonic K-decays and Spectral Function Sum Rules*

In this paper we show that if one takes $\varepsilon(700)$, n_v (1071) π_v (1016) and K_v (perhaps the one at 1080) as forming a scaler nonet, then the widths and branching ratios for the decay of these resonances into two pseudoscalar mesons is quite consistent with observation. In addition the mixing of ε and n_v explains the puzzling smallness of the branching ratio $(n_v \to 2\pi)/(n_v \to K\bar{K})$ and simultaneous accounts for the K_{e4} axial vector form-fractors. In addition these scalar

resonances are found to fit quite well in the framework of spectral function sum-rules.

(B. Dutta Roy and Alexander Martin, 'A Scalar Nonet, Semi-leptonic k-decays and Spectral Function Sum Rules', to be published in *Phys. Rev.*).

B. Dutta Roy

4.48 *Equivalence of $\Phi = \Phi_c$ And $Z_3 = 0$*

It is pointed out that the vanishing of the wavefunction renormalization constant, Z_3, associated with the elementary-particle field operator Φ is a necessary condition for the equivalence of the elementary-particle field operator Φ and the composite-particle field operator Φ_c.

J. N. Passi

4.49 *Self-consistent Study of Nuclear Shapes with Realistic Interaction*

Self-consistent study of 2p-1f shell nuclei, using an effective interaction derived from the realistic Hamada Johnston potential corrected for the core polarisation effect (taking ^{40}Ca as core) is in progress.

Harish Chandra

4.50 *Hill-Wheeler Integral Wave-functions for the Description of Collective Modes in Nuclei*

The possibility of using the Hill-Wheeler integral wave-function of the type $\int f(\alpha) P^{J}_{MK} \psi(\alpha) d\alpha$ where α refers to a set of deformation parameters and $P_{J\ MK}$ is an angular momentum projection operator to describe collective models in deformed nuclei is being investigated. At the moment it appears that this approach offers the possibility of studying the interaction between different collective modes.

S. C. K. Nair and L. Satpathy

4.51 *Dynamical Approach to Higher Symmetries*

By applying the method recently proposed and assuming the universality of ρ-coupling to hadrons we obtain sum rules for $\pi\rho$, $K\rho$, K^*K scattering. These

sum rules enable us to determine the coupling constant $g_{\omega\rho\pi}$ which is in agreement with its value found by using the experimental width for the decay $\omega\to\pi\gamma$ assuming-dominance. Also we obtain $g(K^*K^*\pi)$, $g(\rho K^*K)$ and find the values consistent with U(6, 6) predictions for VVP and VPP couplings. This leads us to expect a deeper understanding, on a dynamical basis of the higher symmetries which we are at present attempting.

H. Banerjee and B. Dutta Roy

5. INSTRUMENTATION DIVISION

5.0 *Introductory Remarks*

Wide Band Amplification formed the subject matter of a review paper presented in the International Conference on Nuclear Electronics. Bandwidth in the range of 600 MHz or rise time a little better than 0.5 nanosecond, with a gain of four per stage, is the performance currently attained by the best transistor amplifiers. A bandwidth of 1000 MHz may be realized in the near future. Practical difficulties in the construction of tubes restrict the bandwidth attainable in tube amplifiers, which remained at 400 MHz since 1955.

A review on U.H.F. and Microwave amplifiers focussed attention on the advantages and possibilities of the transistor. The transistor amplifier is now capable of amplifying 4GHz with a gain of 5 db and bandwidth of 1 GHz. The upper limit of frequency may rise to 10 GHz in the near future.

Good progress was made on the development of stable sources for U.H.F. and Microwaves. A 500 MHz tube amplifier produced an output of 1.6 watts. The 1000 MHz doubler driven by it developed 1.0 Watt. Improvements made on the coupling and matching networks increased the output of the 2 GHz and 4 GHz doublers to 200 mW and 120 mW. A transistor amplifier for the 220-400 MHz band developed 1.6 Watts at 250 MHz and 1.0 Watt at 400 MHz.

A critical study was made on the performances of Varactor and Step Recovery Diode frequency multipliers. This led to a clear understanding of these devices and fabrication of a Varactor Multiplier Transistor system for L band is nearly complete. Step Recovery diode Multiplier systems are being planned for the S and X bands.

Development of transistorized closed circuit Television system is in progress.

A transistorized pulse height to time converter—Analogue to digital type—has been connected up and is under test.

A transistor amplifier for a handwidth of 500 MHz has been connected up, but the performance is not yet satisfactory.

B. M. Banerjee was invited to the International Conference on Nuclear Electronics held at Versailles (September). He read a review paper entitled "Advances in Wide Band Amplification."

Three papers were read in the Symposium of the Institution of Electronics and Radio Engineers held in New Delhi (September). They are the following :

1. "A Frequency Standard for a Microwave Spectrometer" by B. M. Banerjee, A. Chatterjee, S. Chowdhury, P. K. Gupta and K. S. Patel.

2. "A Four Gigahertz Frequency Multiplier" by B. M. Banerjee, C. K. Chatterjee and P. K. Gupta.

3. "Analysis of Step Recovery Diode Frequency Multiplier with New Series Model" by C. K. Chatterjee and P. K. Gupta.

A paper entitled "Development of Active Devices for High Frequencies" by B. M. Banerjee was read in the Symposium of the Institution of Telecommunication Engineers held in Calcutta (November).

B. M. Banerjee

5.1 *Development of Transistorized Closed Circuit Television*

During 1968 development of closed circuit television was continued. Component circuits were developed. The work on receiver is now in progress.

The problem of wide band amplification was investigated with transistors. It was concluded that performance of these amplifiers in this respect could not be improved very much over their tube counterparts, if no major development is achieved by manufacturers.

Adaptation of an existing fast oscilloscope for recurrent sweep was finalised.

S. C. Nath

5.2. *Transistorized Pulse-Height-to-Time Converter*

The design of the transistorized pulse-height-to-time converter of discharge type has just been completed utilizing 2N2369 and 2SC715 transistors. All transistors used are of NPN Silicon type to reduce temperature effects. The frequency of the gated clock pulse generator is for the present selected at 10 Mc/s. The linear discharge of the charging condenser is attempted through sets of emitter followers utilizing bootstrap mechanism. The converter is designed to handle input pulses in the range of 0 to +100 volts. The circuit is under test. The integral non-linearity of the converter and the effect of variations in ambient temperature on the performance of the circuit are under study.

In the coming year, the improvements in the design of the converter will be made. The frequency of the clock pulse generator will be raised to 50 Mc/s. An amplifier to raise the power of the generator output to the level required for actuating the scaler will be developed. The design of the scaler to count pulses from the pulse generator will also be undertaken.

(B. M. Banerjee, A Chatterjee. S. Showdhury, P. K. Gupta and K. S. Patel,

'A Frequency Standard for a Microwave Spectrometer,' to be published in *J. Inst. Electronic and Radio Engg.*)

K. S. Patel

5.3 *Studies and Development of a Wide Band Amplifier*

Development of transistors has brought in a revolution in the field of wide band amplification as these can have an enormous transconductance. The upper limit of band width with reasonable gain, so far attained by distributed amplifiers, rose from 200 MHz to 600 MHz in the last five years with the use of transistors. The limit, as in the case of valves, was set by the transit time which determines the f_T value, the current gain bandwidth.

Expression for f_T, as given by Philips, is

$$\frac{1}{f_T} = \frac{2\pi}{\alpha_0 K_\theta}\left[\underset{\text{emitter delay}}{r_e c_e} + \underset{\text{base transit}}{\frac{W^2}{2.43D}} + \underset{\text{collector transit}}{\frac{X_m}{2v}} + \underset{\text{collector delay}}{r_c c_c}\right]$$

where

α_0 = low frequency current gain $\approx$ 1,

K_θ = phase factor, usually lying between 0.7 to 0.82,

W = base thickness; D = diffusion constant,

X_m = thickness of intrinsic layer between base and collector,

v = saturation velocity of carriers as they shoot through the intrinsic layer.

In a well designed circuit, bandwidth is nearly one-third of f_T, for a reasonable gain. Presently, by reducing the dimensions of emitter base sites, f_T has been increased to 2 GHz.

As a part of the scheme for developing a 500 MHz wide band amplifier, an impedance matching preamplifier circuit has been developed. The circuit is essentially a cascode comprising two transistors. This drives an emitter follower. The signal is given from a GR—unit oscillator through a 20 db attenuator. The performance of the circuit is not satisfactory yet and this is now being probed into.

Sneha Chowdhury

5.4 *Stable Microwave Frequency Source at 4 GHz*

This will use a series of doublers from 500 MHz through 4 GHz. It was reported in the last annual report that output power from the 2 GHz to 4 GHz

doubler was 80 mW. This was because the drive available at 2 GHz was inadequate. To overcome this difficulty the system was planned to be driven by an amplifier at 500 MHz with an expected output of approximately 1 watt.

In accordance with the plan, an amplifier was designed and fabricated around 5876, both anode and cathode having tunable co-axial resonators. Experiments were performed to optimize the matching networks. The power output finally obtained was 1.6 watts, input to the amplifier being 200 mW

Driven by this amplifier the 1 GHz doubler, which also uses 5876, gave an output of 1 Watt—a tenfold improvement over the previous value. The matching network of the 2 GHz doubler unit was further improved. Driven by the GR unit oscillator it delivers an output of 200 mW with an input of 300 mW. But this unit could not be connected as such to the system consisting of 500 MHz amplifier and 1 GHz doubler as the anode resonator of 2 GHz multiplier was found to have a resonance frequency of 1.95 GHz. Mechanical changes are being made to bring the resonance frequency to 2 GHz. Meanwhile the power output of the 4 GHz frequency multiplier has been increased to 120 mW by improving input and output matching networks. A diagram of the 4 GHz multiplier is shown in Fig. 5.1.

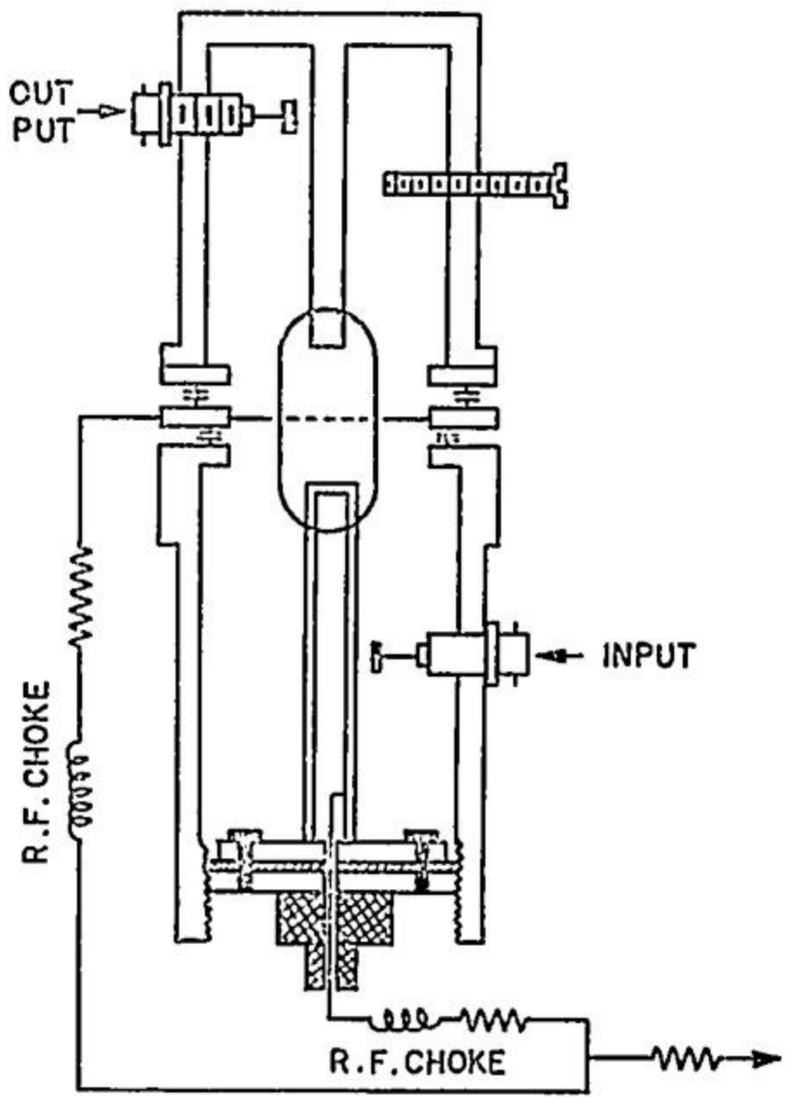


Fig. 5.1. 4 GHz multiplier circuit.

C. K. Chatterjee and P. K. Gupta

5.5 *UHF Amplifier Using Transistors*

A Power Amplifier operating in the 200-400 MHz band using a transistor type 2N3866 has been fabricated. Driven by an Unit oscillator (G.R. 1209-BL)

it delivers 1.6 watts at 250 MHz and 1.0 watt at 400 MHz. It will be used to drive a Transistor Varactor Multiplier system—under development—which is expected to produce more than one watt of power at frequencies of 750 MHz through 1400 MHz.

C. K. Chatterjee and P. K. Gupta

5.6 *Analysis of Step Recovery Diode Frequency Multiplier*

An analytical approach to estimate step Recovery Diode Frequency Multiplier performance was proposed and the efficiency of the Multiplier was calculated. The model chosen is such that both the junction capacitance and the series resistance vary with applied voltage in a different manner from that of an abrupt junction device like varactor diode. The analysis is simple and straightforward. The theoretical efficiency upto ten times multiplication was calculated and compared with published experimental results. It is now planned to fabricate an experimental set up with the available step Recovery Diode.

(C. K. Chatterjee and P. K. Gupta, 'Analysis of Step Recovery Diode Frequency Multiplier with New Series Model', to be published in *J. Inst. Electronic and Radio Engg.*).

C. K. Chatterjee and P. K. Gupta

6. DIRECTOR'S RESEARCH GROUP

6.0 *Introductory Remarks*

The work in this group is divided into two main areas of investigation. The study of gas discharges and solid semi-conductors were developed, a few years ago, with a view to studying plasma behaviour of the condensed state and that of the dispersed state. In case of ordinary plasma, a programme of studying physical properties under various conditions has been taken up with a view to seeing how far the theoretical description can be fitted with the observed phenomena. The glow discharges, pig discharges and the duoplasmatron gave an opportunity of studying at different concentrations of electron density. In the condensed plasma the work has really been mainly on alloy semi-conductors of 2-6 group and the ring type structure organic semi-conductors such as naphthalene and anthracene. Most of the effort has gone to ensure materials with the requisite purity and control so that experimental results are reproducible and reliable. The few measurements made so far are not exhaustive and are used mainly as indicators to establish techniques firmly.

B. D. Nag Chaudhuri

6.1 *Transport Properties of Thallium Selenide*

Investigations on the transport properties of single crystals of thallium selenide (TlSe) grown by Bridgman technique have been continued. The properties studied are thermoelectric power and doping properties of this compound. Other transport properties such as electrical conductivity and thermal conductivity have been reported earlier.

(i) *Thermoelectric power of TlSe*

The effective masses of carriers, the temperature co-efficient of energy gap and the ratio of electron to hole mobility are important parameters in the study of semiconductors. These can be easily evaluated from the measurement of thermoelectric power of the material.

The thermoelectric power of TlSe crystals was measured by differential method in the temperature range between 100°K and 540°K. The resistivity of the samples varied from 1.2 ohm-cm to 53 ohm-cm. The thermoelectric power was found to be positive for all the samples in the temperature range investigated. The values of the effective masses of holes and electrons have been estimated to be $0.045m_0$ and $0.012m_0$ respectively. The temperature co-efficient of energy

gap, obtained from the extrapopulation of thermoelectric power curve is -1.19×10^{-4} ev/deg. The ratio of electron to hole mobility has been estimated to be 0.383.

Publications :

P. S. Nayar, J. K. D. Verma and B. D. Nag, *J. Appl. Phys., 39,* 4465, 1968.

P. S. Nayar, J. K. D. Verma and B. D. Nag : *Proc. Nucl. Phys. Sol. St. Phys. Symp., Madras,* 1968, p. 432.

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

(ii) *Doping Properties and Valence-Band Structure of TlSe*

Measurement of thermoelectric power of undoped single crystals of TlSe yielded a higher value of mobility of holes than that of electrons and the effective masses of the carriers were rather small. These results lead to speculate that thallium selenide may posses a two valence-band structure. A study of electrical conductivity and thermoelectric power of doped crystals is expected to throw light on the dual valence band structure of the compound. These properties have, therefore, been measured for lead doped samples in the temperature range 300°K, and 540°K. The doping concentration varied from 0.001 to 0.1 weight per cent. The crystals were grown by Bridgman technique. All samples showed p-type conductivity. The thermoelectric power was found to decrease with increase in conductivity and thereafter increases, reaches a maxima and then decreases with increase in conductivity. The nature of thermoelectric power versus electrical conductivity curve can be qualitatively explained on the basis of two valence band theory.

(P. S. Nayar, J. K. D. Verma and B. D. Nag, 'Doping, Properties and Valence-Band Structure of Tl Se', to be published in *J. Appl. Phys.*)

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

6.2 *Semiconducting Properties of Naphthalene*

Investigations on the semiconducting properties of naphthalene have been continued. Measurements on electrical conductivity of single crystals of naphthalene have been completed.

Electrical Conductivity of Naphthalene

A special sample holder for the measurement of electrical conductivity of naphthalene was constructed since organic semiconductors usually have

resistivities greater than 10^{12} ohm-cm. Special precautions were taken to avoid errors due to leakage current and spurious pickup. The current was measured by Keithly electrometer, using guarded electrode technique.

The resistivity of the crystals was measured in argon atmosphere upto 78°C. The dark current was found ohmic upto a field strength of 1500 v/cm. The value of the activation energy obtained from conductivity plot was 1,096 eV and was independent of crystal orientation. The absolute value of the conductivity in ab-plane was higher by a factor of 1.9 than in the perpendicular plane.

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

6.3 *Plasma Studies in Duoplasmatron*

Oscillations and instabilities in high current ion sources are of great importance from the point of view of stable beam formation. The effect of magnetic field on the operation of duoplasmatron has been of our interest because it has a beam generated plasma of very high density. The instabilities are observed by measuring various plasma parameters along and perpendicular to the magnetic field. The value of the electron temperature is found to depend strongly on the magnetic field and is between 5 to 20 ev. The plasma density is more than 10^{13}/c.c. By measuring the radial distribution of density in between the anode and intermediate electrode, q the 1/e value of density decay has been calculated for the whole range of magnetic field. It is seen that 1/q vs H plot deviates from the theoretical one and the outward diffusion of charges suddenly increases after 200 gauss, reaches a maximum at about 500 gauss and then decreases again. The high energy component of the electrons coming axially out of the anode shows a number of peaks with the magnetic field. This type of behaviour has been explained in terms of the stability of the beam-plasma system at definite cyclotron frequencies. The origin of low frequency oscillations (500 kcs-2Mcs) of large amplitude indicates existence of instabilities at very low magnetic field. These instabilities may be responsible for the observed anomalous diffusion. Because of the instabilities the measured values of the diffusion co-efficient across the magnetic field do not agree with those calculated from collision theory.

D. K. Bose and B. D. Nagchaudhuri

6.4 *On the Construction of a Duoplasmatron*

The scheme for making duoplasmatron ion sources for high ion currents has been continued. The construction of one duoplasmatron is complete and

the ion source is tested using argon and the performance is satisfactory. The ion source is fitted with an additional lens system to produce ion beam of low energy and low divergence. For an arc current of 1 A the extracted ion beam current is 3 mA at an extraction voltage of 10 kV. At higher arc current and extraction voltages higher beam current is expected.

To study the ion beam characteristics in detail, the phase-space diagram of the beam will be plotted. A gear arrangement has been made to change the target position from out side the vacuum under different extraction conditions.

D. K. Bose and B. D. Nagchaudhuri

6.5 *Diffusion of Charged Particles in a PIG Discharge*

The diffusion of charged particles across a megnetic field has been investigated in a PIG discharge. The method consists of measuring the radial density distribution of charged particles by using a pair of floating electrical probes and estimating the perpendicular diffusion coefficient from the measured density distribution. The results of the measurements show that the diffusion is normal in magnetic fields upto about 600 Gauss. Above this value of the magnetic field the measured diffusion exceeds the diffusion expected from the collision theory. This excess diffusion at higher magnetic field might have originated in a drift instability of the PIG plasma.

D. K. Bose, A. K. Chatterjee and S. N. Sen Gupta

6.6 *Solenoid Magnet for Plasma Studies*

The construction of a large solenoid magnet consisting of 4 coils of external diam. 20″ each and capable of producing a uniform magnetic field of nearly 5 K gauss has been completed. Arrangements are now being made for providing power to the magnet and also for its desired cooling. The magnet will be used with PIG type discharges for studying the energy loss processes, such as, diffusion, instability, radiation, etc. of plasmas in presence of a magnetic field.

D. K. Bose, A. K. Chatterjee, and S. N. Sen Gupta

6.7 *RF Impedance Method for Determining the Electron Density and Collision Frequency in a Plasma*

As the probe sheath should be properly taken into account for making meaningful rf probe measurements on a plasma, an rf impedance method for

plasma diagnostics, which pays due regard to the probe sheath, has been proposed. It has been shown that the electron density and collision frequency in a plasma can be determined by measuring, at two frequencies, the impedance between two plane probes immersed in the plasma and biased with a suitable voltage.

(J. Basu and C. Sen, 'RF Impedance Method for Determining the Electron Density and Collisions Frequency in a Plasma', to be published in *Ind. J. Pure Appl. Phys.*)

J. Basu and Chitra Sen

6.8 *RF Measurements on a Glow-Discharge Plasma*

A new rf method has been used to give the sheath thickness s of a plane probe immersed in a glow-discharge plasma and biased with a dc voltage. The variation of s with the bias voltage as well as the discharge current is studied.

It is noted that s being known, the effective sheath resistance R_s corresponding to the incremental resistance on the standard Langmuir probe characteristic in the electron current region can be calculated. The plot of ln R_s vs V_p (probe bias voltage) can give the electron temperature T_e and electron density N. It is interesting to find that T_e and N could be obtained in this manner although the same could not be obtained from the dc probe characteristic; the nature of the dc characteristic did not correspond to that of the standard Langmir probe characteristic.

The sheath thickness at the floating potential, calculated from T_e and N, shows that the results obtained by the rf method are of the right order.

Chitra Sen and J. Basu

6.9 *RF Methods for Determining the Conductivity of a Cylindrical Plasma Column*

An rf induction method has been devised for the determination of the complex conductivity of a cylindrical plasma column by external probes. The probes consisting of a pair of coils placed around the plasma tube act as the primary and secondary coils of a transformer. The magnitude and phase of the secondary voltage with plasma in the tube, normalised with respect to that without plasma, have been expressed in terms of the plasma conductivity, operating frequency and radius of the plasma column, assuming that the primary

current is held constant. Results have been plotted covering a wide range of the complex conductivity, and it has been shown how the conductivity of a plasma can be deduced.

Another method studied for determining the complex conductivity involves the measurement of a normalised impedance of a coil placed around a plasma tube. It has been noted that the result obtained in the earlier case may be used for giving the plasma conductivity.

The effect of the glass wall of a plasma tube in conductivity measurement, assuming that the plasma is a good conductor, has also been studied.

J. Basu and J. N. Maiti

6.10 *Study of Shock Wave*

In the electromagnetic shock tube designed and constructed here, shock waves have been produced by the discharge of 24 joule energy (3 μF at 4 kV) through two tungsten electrodes (dia $\approx$ 4 mm) separated by about 5 mm. A triple probe is being used as the diagnostic tool for determining the electron density and electron temperature in the plasmas produced by shock waves. The design and construction of a piezoelectric pressure gauge with X-cut quartz crystal for the measurement of shock pressure, using the pressure bar principle, have also been undertaken.

J. N. Maiti and J. Basu

6.11 *Van de Graff Type Electrostatic Accelerator*

Power generation and distribution for ion-source assembly and focussing elements of the 2 MeV electrostatic generator under construction are nearing completion. Performance data have been taken. A test generator has been assembled. The test generator shall be housed in a pressure vessel. The construction of the pressure vessel to house the 2 MeV generator is almost complete in the Garden-Reach Workshop. A supersonic cleaner for cleaning the accelerator stack elements is under construction. The dc type ion source has been made operational at 300 μA target current.

A. Chatterjee, N. K. Mojumdar, A. Ganguli and S. Ghosh

6.12 *Ion-Source Extraction Studies*

Quantitative studies of the ion-beam exit from ion-source have been made in terms of instantaneous r and z values by solving the respective equations of

motion and conditions of optimum extraction and collimation are being investigated.

N. K. Mojumdar

6.13 *Energy Distributions in Prompt Fission Fragments*

Excitation energies of prompt fission fragments are predicted from a renormalised fermi gas model in which the residual interactions are included. The structural energy corrections in the fragments over those of the excited fissile compound nucleus directly give the fragment excitation energies. The kinetic energies follow from the conservation of energy. Both energies in the fragment mass spectra agree well with observation.

Ratna Sarkar and A. Chatterjee

6.14 *Static Quadrupale Moments of Deformed Nuclei*

Deformation energies have been calculated in the framework of the superfluid model. The static quadrupole moments have been calculated in a Nilsson-type potential by using a procedure similar to that of Bes. Here, however, an explicit dependence on the coupling constant and the deformation parameter is avoided. The predicted values are about 75% of the observed moments.

S. Chatterjee and A. Chatterjee

7. TECHNICAL PHYSICS DIVISION

7.0 *Introductory Remarks*

Activities of this division mainly lies in developing and constructing apparatus that are needed for research by the various divisions of this Institute. Some apparatus, such as high intensity X-ray machine, induction heating furnace, etc., were designed and constructed for this purpose. A Root's pump and a 6″ oil diffusion pump have been designed and constructed. A vacuum evaporating machine and a zone melting furnace have been designed and constructed. A pressure switch suitable for use in vacuum plumbing has been designed and constructed. The development of getter-ion pump and molecular-sive pump could not be carried on due to shortage of man power, since four of our workers left this Institute.

G. N. Sarkar

7.1 *High Intensity Rotating Target X-ray Tube*

Even with arrangements for cooling the chamber, as was reported last year, the X-ray tube can not be run continuously at its optimum rating. It can be run for two hours with a voltage of 60 kV rms and a current of 40 mA. It has been observed that whenever the current is increased beyond 40 mA, a discharge passes within the tube, the vacuum measured by a calibrated Penning gauge remaining almost unaltered. This leads us to infer that at a current more than 40 mA, copious gas evolves from the neoprene sealing gaskets by electron bombardment. We are trying to improve the performance by electrostatically shielding the garkets. Another weak point in the design is that the rotating target is sealed by a flat gasket with the rotating shaft which also supplies the cooling water. So there might be occasional bursts of water vapour leaking in the chamber causing the discharge. Both the above defects are being now rectified and we hope to reach the target performance in a short time.

G. N. Sarkar and B. D. Nag Choudhuri

7.2 *High Frequency Induction Heating Equipment*

The design and the priliminary construction of the induction heating machine is complete. We are now trying to improve the performance of the

machine by replacing the old vacuum tubes with more suitable ones for the oscillator. Attempts are being made to make the machine more compact so that space occupied by that might be less in a laboratory where it would be used.

D. N. Basu Mallik

7.3 *Zone Refining Furnace*

A tubular zone refining furnace to be heated by the induction heating machine constructed by us has been designed and constructed. A sketch of the furnace is given in Fig. 7.1. The design permits melting in the furnace in vacuum or in an inert atmosphere. It consists of a 2″ I.D. and 2′ long transparent quartz tube. The ends, which are vacuum sealed, permits entry of a thermocouple and the driving shaft through Wilson seals at the end caps. The temperature obtained inside a graphite susceptor by a two turn coil attached to the output of the induction heater was 950°C. At this temperature, low melting point metals can be purified and attempts would be made in that line.

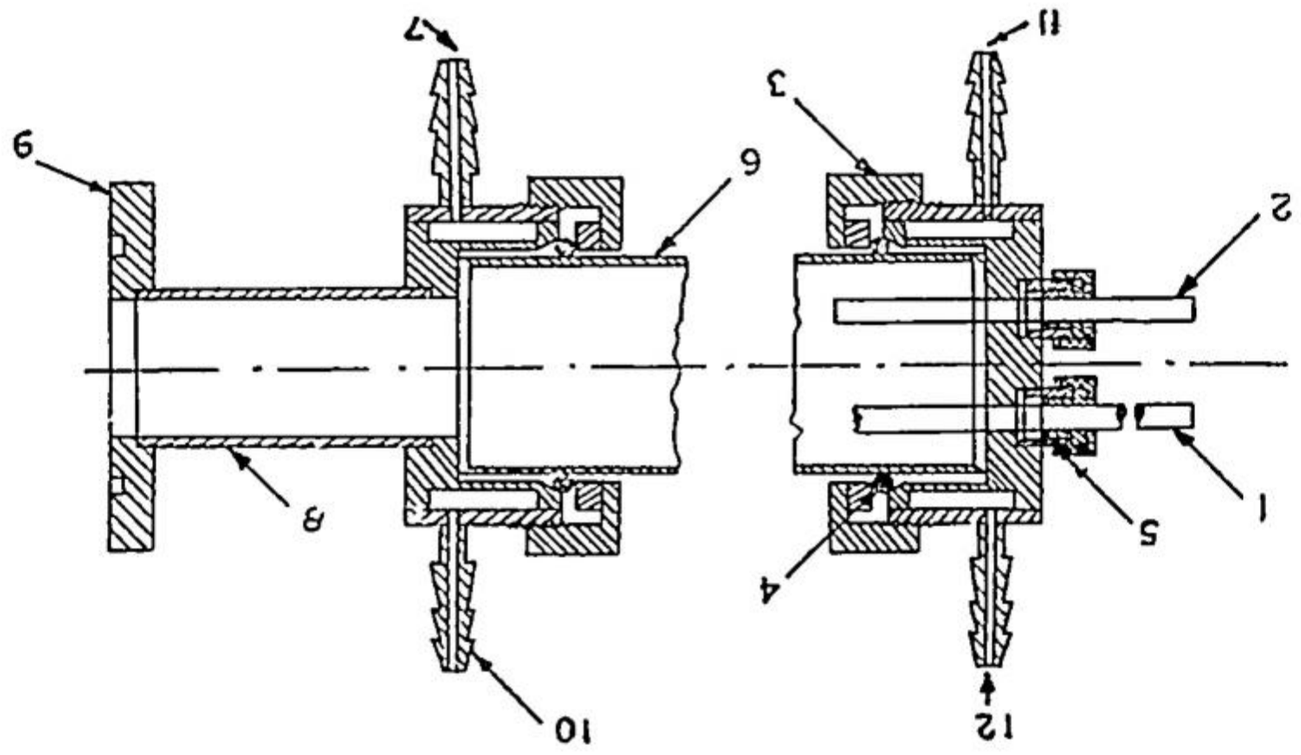


Fig. 7.1. Zone refining furnace.

Temperature is usually measured by optical pyrometers in zone refining furnaces where thermocouples do not give accurate readings when induction heating is used. Also, controlling the temperature that should be maintained within stringent limits is a problem. Attempts are being made to develop a temperature indicator by passing the emitted infrared radiations from the melt through a light guide and detecting it by an infrared sensitive silicon detector. The output of this detector can be used as an indicator for the temperature and a signal for operating the electronic temperature controller.

G. N. Sarkar

7.4 *Metal Evaporating Apparatus*

Sophisticated metal evaporating apparatus that are available commercially in India and abroad have been found to be much complicated for having too many controls and due to the vital parts being placed within the cabinet. The servicing of these machines have been found to take a lot of time. Keeping in view the above mentioned difficulties, a metal evaporating apparatus, which is in great demand in many laboratories of the Institute, has been designed and constructed, a photograph of which is given in Fig. 7.2. We have used no by-pass line for the mechanical pump to facilitate quick change of heating elements because of the fact that to reach a vacuum of the order of 10^{-6} mm of mercury from the atmospheric pressure it takes only one hour. Thus, the evaporating element can be changed twice or thrice in a day which is enough for most labo-

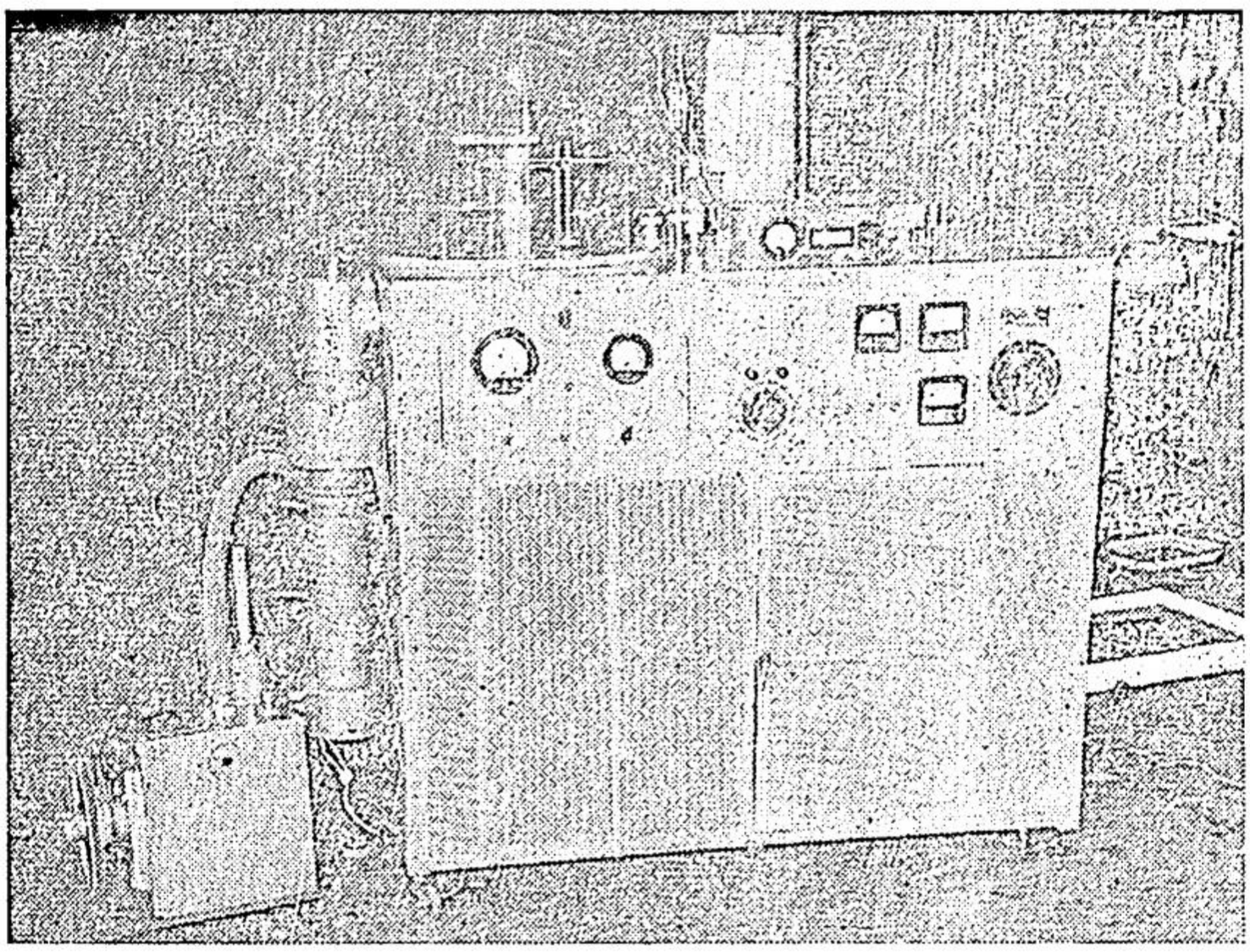


Fig. 7.2. The metal evaporating apparatus.

ratory purposes. The bypass line has been eliminated also for the fact that the addition of a two way valve very often worsens the situation due to any leak in the valve. The controls are all brought out in the front panel. The diffusion pump is outside the cabinet and is connected to the beljar through a right angled joint for easy servicing of the pump. The diffusion pump is provided with a water cooled baffle and a liquid air trap. The mechanical pump is placed on the floor to avoid unnecessary vibration of the whole apparatus when mounted on the cabinet. The vaccum gauges are on the top of the table supporting the beljar for easy handling. There are arrangements for both ion bombardment and electron bombardment cleaning of the substrata with 10 keV electrons.

G. N. Sarkar

7.5 *High Vacuum Pumps*

(i) *Oil diffusion pump*

The 6″ oil diffusion pump that was designed last year is now complete. A sketch of the pump is given in Fig. 7.3. A brief description of its working principle is given here. The pumping action in a vapour pump is dependent on the jet action. The velocity of the vapour jet is expected to be much higher than the mean random velocity of the gas molecules. A high speed of the jet, therefore, is a basic requirement in getting high pumping speeds. In conventional pumps, the vapour discharged into the casing through the high vacuum nozzle has a lower temperature than the vapour at the boiler. This loss in energy is compensated by the axial heater (4). To increase the ability to pump

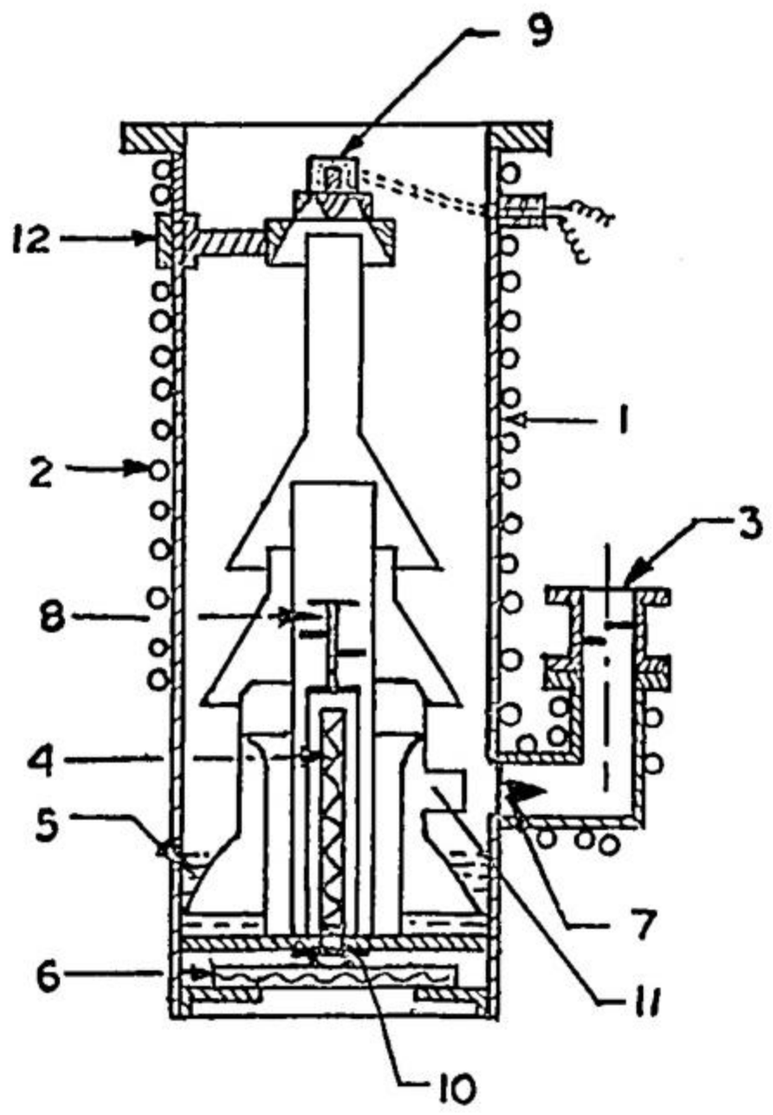


Fig. 7.3. The sketch of the oil diffusion pump.

against higher fore pressures, a lateral ejector jet (11) is incorporated. To get a high pumping speed, the jet reflected back from the top cap must have a high velocity and so a high temperature and to prevent back streaming the periphery of the cap must also be colder than the top of the cap. The above two contradictory phenomena are achieved by a "guard ring" designed by B. D. Power and D. J. Crawley (B. D. Power and D. J. Crawley, *Vacuum 4*, 431, 1954) and is shown in the drawing. In this design, the inside of the top cap has a streamlinged shape. Heat is supplied to the top of the cap by means of a small heater mounted there. At the lower pheriphery of the cap is brazed a massive cylindrical copper guard ring which is attached to the cooled wall of the pump by a copper block. This cools the rebounding gas that immediately loses energy and has little chance to escape backward. The pump is now under test and, if proved

satisfactory, will be taken up for production in the workshop. A photograph of the pump is given in Fig. 7.4.

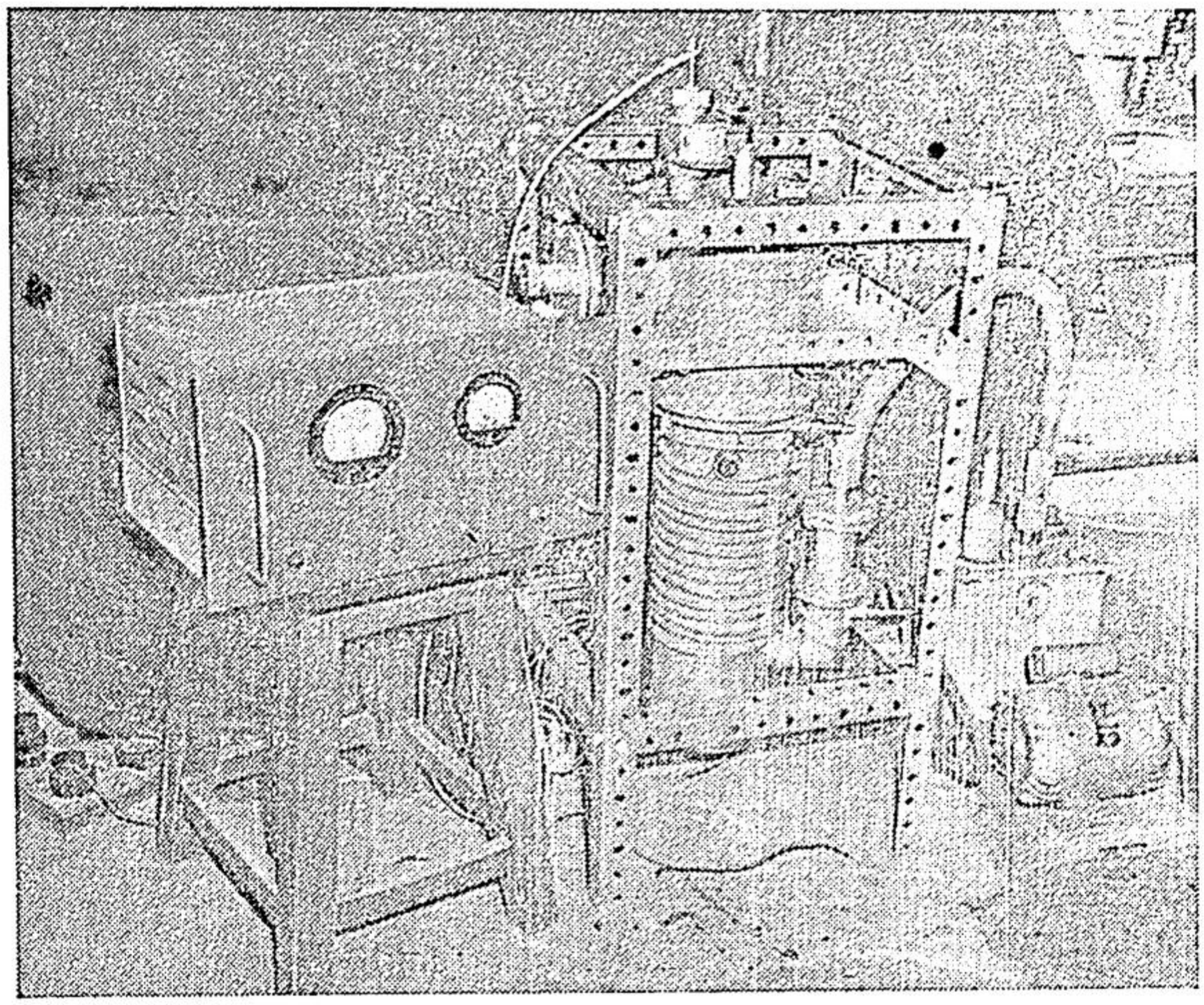


Fig. 7.4. The oil diffusion pump.

G. N. Sarkar

(ii) *Root's pump*

The design and construction of this pump was taken up last year. It is now completed and is ready for testing. A drawing of the pump is given in Fig. 7.5 and in the photograph of Fig. 7.6. The calculated volumetric dis-

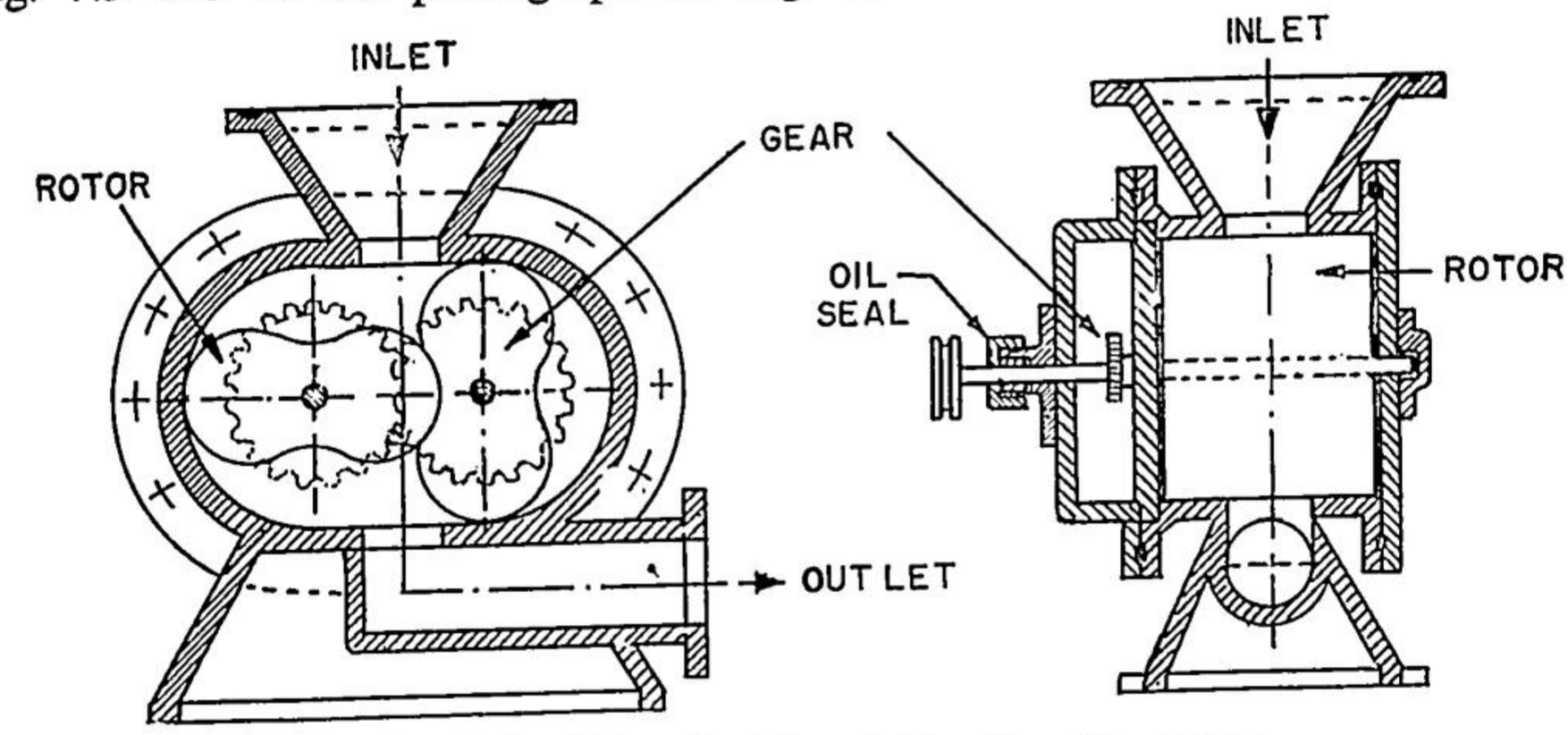


Fig. 7.5. The sketch of the Root's pump

placement of the pump is 1100 litres per minute at 1440 rpm. Some difficulty is being experienced in its operation. It is backed by a mechanical pump having a speed of 150 litres per minute as usual. But when the vacuum reaches

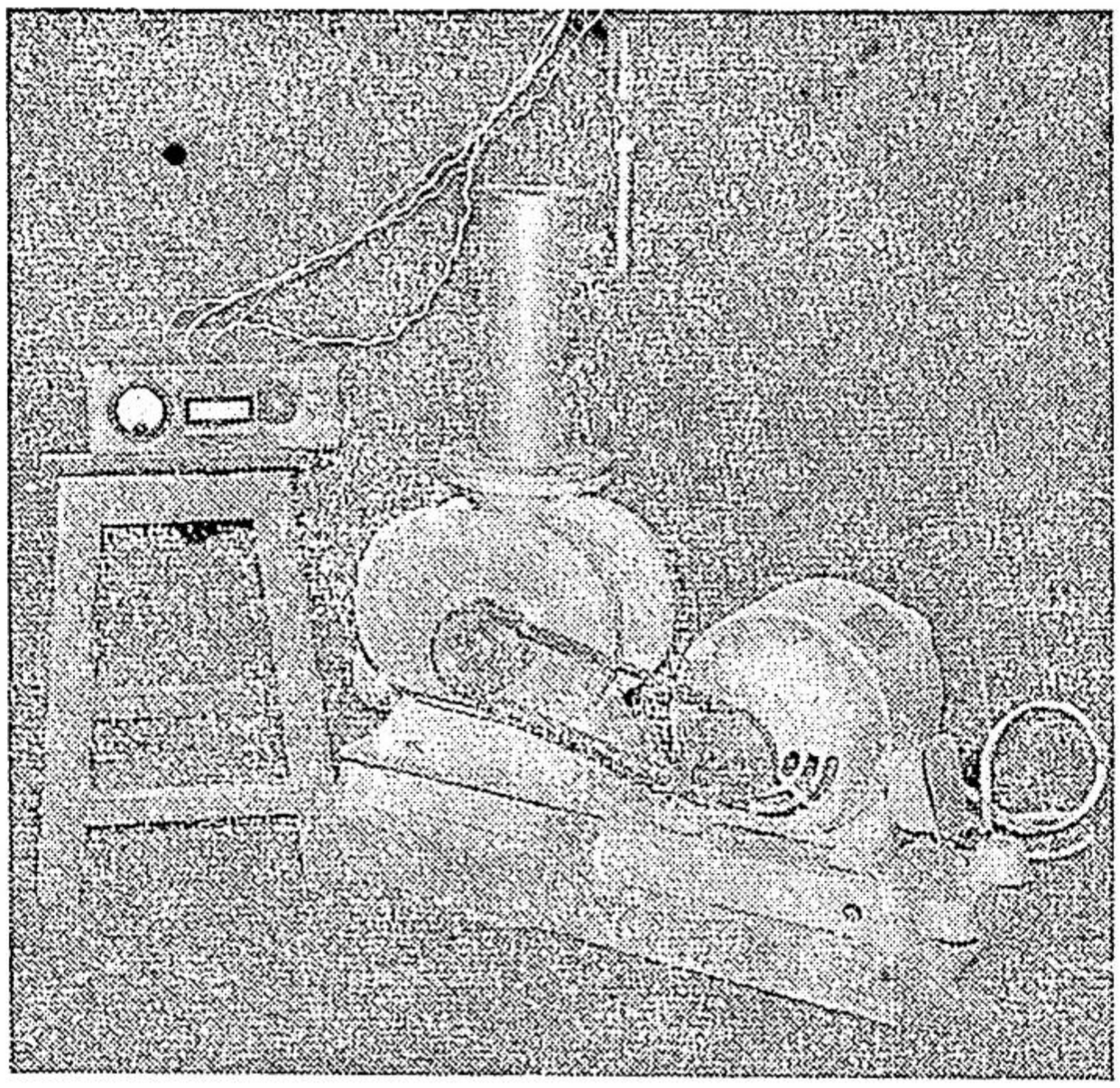


Fig. 7.6. The Root's pump.

10^{-2} mm of mercury in the system the Root's pump stops, though the motor coupled to the Root's pump is a 3 H.P. one. The reason might be the flexure of the shaft causing the seizure of the rotors that have got a clearance of 10 mil. Attempts are being made to remedy this defect.

G. N. Sarkar

7.6 *Pressure Switch*

Commercially available pressure switches that work on water pressure generally operate at a minimum pressure of thirty pounds per sq. inch. These are not suitable for work in low pressure lines where pressure from 5 lb per sq. inch to 30 lb per sq. inch is generally encountered in the cooling of oil diffusion pumps, target of X'ray tubes, etc. In these cases generally small mercury manometers with tungsten contacts fabricated at the glass blowing shop are generally used as pressure switches. But mercury is very costly and is very often spoilt due to the breaking of the glass U tubes.

To remove these troubles, a pressure switch has been developed which

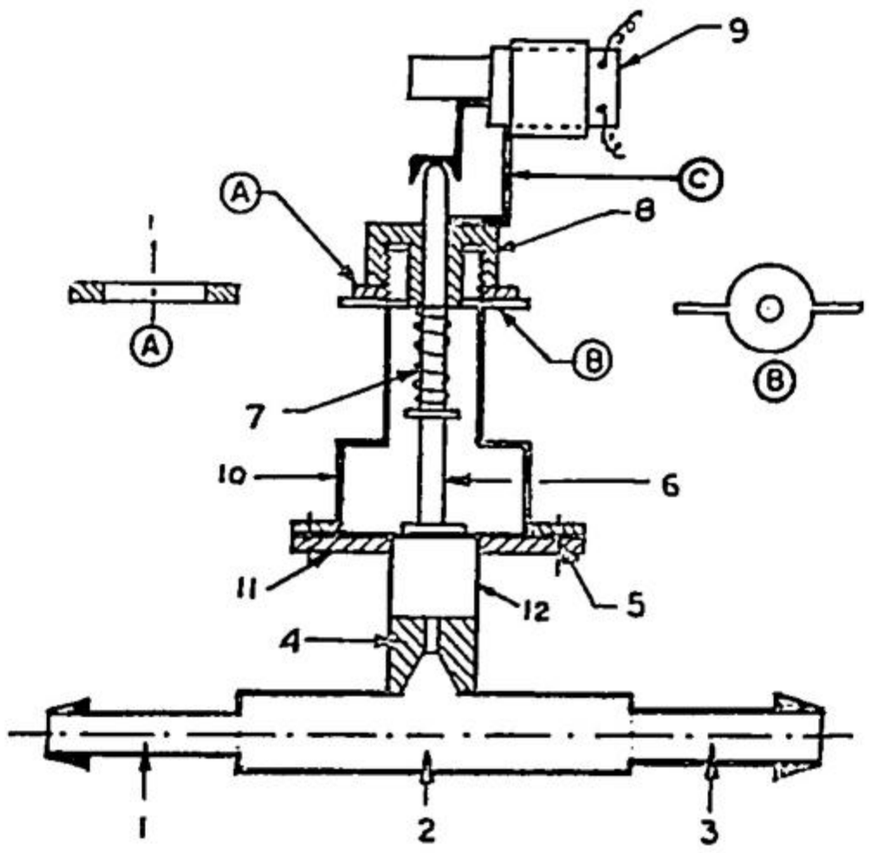


Fig. 7.7. The sketch of the pressure switch.

can very easily be fabricated. A sketch is given in Fig. 7.7. A brief description of the construction and working of the switch is given.

Water enters through nozzle (3) to the main tube (2) to which a side tube (12) with a flange (11) is brazed. It then leaves through the outlet (1) the bore of which is slightly less than that of the inlet (3) in order to increase the pressure at the side tube. The pressure at the bottom of the rubber membrane is further increased by a convergent nozzle (4). As water flows, the spindle (7) which is spring loaded rises by the pressure exerted on the rubber membrane with which it is in contact and finally operates the micro switch. The spring pressure can be adjusted by means of the nut A and the washer B. The spring pressure can be varied in order to make the switch operate at different pressures. The barrel housing the spring can be graduated and a calibration can be made against known pressures.

G. N. Sarkar

8. WORKSHOP

During the year under review, the workshop completed 491 jobs. The glass blowing shop fabricated 125 pieces of apparatus. The electrical shop completed 613 ft. of three phase power wiring and 188 ft. of dc wiring for fans and lights. 5 pieces of fans and 10 pieces of motors were also repaired. The jobs worth mentioning are :

1. Duoplasmatron ion-source.
2. Vacuum chambers of different dimentions
3. 22″ diameter solenoid coils
4. Perspex cavity resonator
5. Styron taper for waveguide insert
6. Table for 60° mass spectrometer with longitudinal and transverse movements
7. Electron-gamma correlation apparatus
8. Adjustable table for quadrupole magnets
9. Goniometer
10. Multiple collector with shutter for isotope collection
11. Header for variable condenser of trasistor varacter multiplier
12. Filament holder for cyclotron ion-source.
13. Parts of prototype electrostatic generators
14. Root's pump
15. 6″ oil diffusion pump

The new machine installed in the workshop during the year is a three diamensional pantograph milling machine. With this we can duplicate small parts of an apparatus and can mill curves of any shape from a replica.

We are contemplating to introduce Argon-arc welding facility in the workshop. It will then be possible to weld aluminium and stainless steel tubes and flanges for vacuum plumbing.

A scheme for the expansion of the workshop is being prepared keeping an eye to the expanding plans and programmes of the Institute.

G. N. Sarkar

GENERAL

As on 1st March, 1968, the total staff strength of the Institute was 364. Out of this 138 were scientific, 97 technical, 43 administrative and 86 auxiliary/ maintenance staff.

There were, during the year under report, 3 DAE Fellows, 5 CSIR scholars, and 4 Research Training Scholars (Ministry of Education, Govt. of India) working under different senior scientists of the Institute. In addition, two Pool Officers of the CSIR were attached with the Institute during this period.

Prof. B. D. Nagchaudhuri, Director of the Institute is on leave from the Institute.

Prof. D. N. Kundu continues to be the Acting Director.

The activities of the Institute continue round the different divisional and sectional laboratories as reported in the preceeding pages.

The 5-year (1969-74) programme of work—existing activities and new proposals—has been submitted to the Dept. of Atomic Energy and is awaiting approval.

The money sanctioned by the Government of West Bengal in the previous year for purchasing more or less 7 acres of land in the Salt Lake Township having been received has been spent for the purpose. The Institute has taken over possession of the land together with that for the VEC project of the Bhabha Atomic Research Centre. Soil testing work has been completed and work for the erection of the common boundary wall of the two adjoining lands has been started.

Prof. S. Chatterjee continues to participate in the VEC project of the BARC on deputation from the Institute.

The 13th Meghnad Saha Memorial Lecture was delivered by Professor J. M. Ziman, F.R.S. of the University of Bristol on "The Social Dimension of Science."

During the period representatives from the Institute participated in the following International Conferences/Congresses/Symposia :

(i) International Conference on Nuclear Electronics, Versailles, France —represented by Prof. B. M. Banerjee

(ii) Symposium on Nuclear & Particle Physics, M.I.T., U.S.A.—represented by Prof. M. K. Pal.

(iii) International Symposium on Contemporary Physics. Trieste, Italy—represented by Prof. H. Banerjee.

(iv) Symposium on Mathematical Foundation of Scattering Theory, Geneva, Switzerland—represented by Prof. H. Banerjee.

In addition, Scientists from the Institute participated in the following Annual Congresses/Symposia/Conferences held in India :

(i) Indian Science Congress.

(ii) Nuclear Physics and Solid State Physics Symposium.
(iii) Symposium of the Indian Biophysical Society.
(iv) Conference of the Electron Microscopic Society of India.

Prof. H. Banerjee was invited to deliver talks at Geneva University (Switzerland), Padora University (Italy) and Rutherford Laboratory (Harwell, England) and Prof. B. Dutta Roy was invited to deliver talks at Rockfeller University (U.S.A.), Rutherford Laboratory (Harwell, England) and Brookhaven National Laboratory (U.S.A.).

Sarvasree P. Das Gupta, A. B. Sanyal, Anand Kumar, S. R. Palchaudhuri and S. Das have been admitted to the D. Phil. (Science) degree of Calcutta University during the year under reference.

Sarvashree B. Das Gupta, D. N. Basu Mullik and P. Rudra have been awarded the Premchand Roychand Scholarship of Calcutta University during this year.

The following is the audited statement of accounts for the year 1967-68:

Receipts		amount	Payments		amount
Opening Balance	Rs.	2,325.56	Leasehold land	Rs.	4,20,000.00
Grant-in-aid from Calcutta University	Rs.	36,000.00	Equipment	Rs.	19,855.00
Grand-in-aid from D.A.E.	Rs.	41,30,000.00	Salary	Rs.	22,64,817.76
Gran-in-aid from Govt. of West Bengal	Rs.	4,20,00.00	Maintenance	Rs.	14,63,766.83
Income from Misc. Sources :				Rs.	41,68,439.59
Sale of books	Rs.	191.24	Advance for Purchase Stores, Custom Deposit, Festival Advance, Drought Relief, etc.	Rs.	3,465.01
Hostel rent	Rs.	5,828.17			
Misc. Income	Rs.	6,949.70	Balance	Rs.	4,33,635.57
Medical aid funds	Rs.	4,245.50			
	Rs.	17,214.61			
	Rs.	46,05,540.17		Rs.	46,05,540.17

The present holding of the library of the Institute is 16,565 books and bound volumes and that of the reports and reprints is 12,780.

Besides the students, there were 303 'members' of the library during the year.

The library subscribed to 247 periodicals and received another 247 in exchange/gifts from various sources.

The library has been serving the reference need of research workers of

the various post-graduate departments of the Calcutta University and of the several research institutions of the city through "Inter-Library Loan" system.

The microfilm service of the library—procuring microfilm copies of papers and reading these through Microfilm Reader is proving very useful.

The medical service activity of the Institute is providing to be very popular and useful. At present there are 300 members who have joined the scheme. During the year under report more than 5300 prescriptions were served after attendance. Vaccination against small-pox and innoculations against cholera, typhoid and para-typhoid were carried out as a regular yearly feature. There was no case showing major radiation effect. The Medical Officer of the Institute underwent a training for six weeks at the BARC on medical uses of radio-isotopes, control of radiation hazards and health physics.

H. K. Basu

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