Annual Report

1967

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

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 1967.

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

General information covering the workshop, library, administration and medical unit is incorporated. A list of publications in the year 1967 and a list of the staff of the Institute are also included. In addition, an author index has been appended this year to help locate the reports of individual workers.

The activities reported herein pertain to all the workers of the Institute, including those supported by other organisations, namely, the Calcutta University, Department of Atomic Energy, Council of Scientific and Industrial Research, and Scientific Man Power Committee.

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

Calcutta,
January 1968.

R. Bhattacharyya J. Basu
Editors

CONTENTS

Cover : High-resolution mass spectrometer built at the Institute

INTRODUCTION

The expansion of research and developmental activities led to the creation of three separate divisions during the year under report. A number of separate small groups working on a variety of problems on macromolecules, radiation biology and crystal structure have been consolidated into a division of crystallography and molecular biology. The increasing activity at the Pagladanga outstation on the model study programme using AVF principles by the old cyclotron workers led to the cyclic accelerator division. Starting with the Cockcroft-Walton generator, other methods of electrostatic acceleration of charged particles including Tandem device have engaged the earnest interests of a large team, which now forms the electrostatic generator division.

The researches in solid state physics have played a very dominant role in the work of the Institute of the current year. Although still labouring under limitations of instruments resulting mostly from foreign exchange scarcity, the solid state physics group is working in the entire range of activities of NMR, EPR, NQR, ESR, microwave spectroscopy and theoretical studies on crystalline matter. The theoretical nuclear physics division has continued its researches on problems of nuclear structure and elementary particle physics. In addition, the division has carried the bulk of the load of teaching for the post-M.Sc. teaching division. The technical physics group which was started as an experiment has already become an effective group developing technical know-how on research equipments and machines such as high current X-ray machine, induction heater, Debye-Scherrer powder camera, etc. The expanded work of the biophysics division at the new buildings has resulted in the development of areas of interest in ultrastructure and virology. The nuclear chemistry division has continued its study of problems relating to analytical, inorganic and physical chemistry and development of radiochemical technology.

As an overall picture of the progress it may be pointed out that there are sixty four papers and research notes in this year's report compared to forty four in the previous year.

It is a very significant event that the Department of Atomic Enery has decided to establish a large nuclear study centre at the Salt Lake area adjoining the proposed site of the Saha Institute with a large AVF cyclotron as the major accelerator. It may be recalled that the Saha Institute had originally submitted a proposal for a large nuclear accelerator in its second five year programme and had never ceased to take live interest in such a programme. It is, therefore, very fortunate that the Saha Institute now will have this opportunity on collaborating with BARC and TIFR in the forthcoming VEC project at Calcutta.

D. N. Kundu

1. ACCELERATOR GROUP

1A. CYCLIC ACCELERATOR DIVISION

1A.0 *Introductory Remarks*

In January, 1967, a cyclic accelerator division was formed out of the existing accelerator division. The division was further strengthened by the addition of two engineers. The activities include the improvement of the cyclotron and using it for research.

The cyclotron external beam current was increased by a factor of ten and is now being used for coulomb excitation studies. The machine is now being made available to users from outside the Institute, and the machine time has also been increased.

The 20″ model magnet was installed at Pagladanga laboratories and tested. A large number of components are being fabricated for model studies. The first model studies have been planned on a four-sector 5-6 MeV AVF machine with indigenous know-how and materials.

Development of instruments played an important role in the programme of work. Mention may be made of some success achieved in making surface-barrier detectors and of a fast coincidence system which was also developed to perfection.

The division loaned the services of Dr. B. B. Baliga for looking after the teaching programme of the Institute on a part-time basis.

A. P. Patro

1A.1 *Cyclotron*

With the extracted beam of protons preliminary runs were undertaken to study (p,α), (p, γ) and coulomb excitations of nuclei by protons. It became apparent very soon that the collimated beam of 1-2 mμA obtainable at the scattering chamber was too inadequate to make meaningful measurements.

The cause of the low extracted current efficiency was thought to be the deflector shoe and it was also found that the extracted beam was split vertically, which may have been caused by asymmetric distributions of the electric lines of force from the deflector shoe. It was decided to fabricate a new deflector shoe and also to make modifications in the deflector shoe-supports so

as to be able to position the shoe at the optimum position. The mechanical fabrications were complete by the beginning of March, 1967 and installed at that time. A new low voltage arc discharge ion-source was also fabricated and installed. This new ion-source allows the dees to be moved more freely and helped in optimising the extracted current. With these new modifications the cyclotron was operated and after some initial difficulties gave extracted currents which were of about the same magnitude as obtained previously. Thereafter, external shimming was undertaken, by which the extracted current could be increased substantially. At the present stage the cyclotron produces 30 μA of internal beam and 3μA of extracted beam just after the deflector channel. In the experimental room, the Q-pole focussed beam is 70-90 mμA and the collimated beam is 20-30 mμA of protons. This compares quite favourably with the values obtained last year.

The adjustable table for the deflection magnet is being fabricated in the workshop. The deflection magnet will be installed as soon as the table is ready.

The cyclotron has operated for more than 200 hours in spite of the various modifications introduced to the system. It would have operated for even longer periods but for the fact that in the monsoon it becomes very difficult to maintain voltage on the deflector due to corona losses.

During the year we had a request for internal bombardment from the isotope division of BARC. We sent a sample bombarded for a short time with 5μA current for evalution. We gathered that the results were encouraging but we could not bombard with larger currents as the particular sample could not take higher currents and also would tend to contaminate the machine.

We had a group this year from Andhra University, for whom we bombarded a sample for 6 hrs for gamma spectroscopy. We also provided them with the facilities for studying the gamma spectrum with our Ge (Li) detector set-up.

The engineers appointed last year have been trained, and they have proved very useful in the regular running of the machine.

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

1A.2 *Model Magnet Studies*

The new extension laboratory in Pagladanga is complete. The 6-ton 20″ diameter model magnet was shifted and installed. The ten coils, five each on either pole along with its water-cooled clamp plates have been mounted. The power supply for the magnet has been fabricated. In preliminary tests with unstabilised current the magnetic field produced was 18,000 Gauss with 1.5 inch gap. On the basis of preliminary tests, valley plates and spiral sector hill plates have been machined and will be installed shortly. On the basis of field

distributions obtained with the above valley and hill shims, the final profile of the valley and hill shims will be machined so as to produce the desired field for a 5-6 MeV AVF cyclotron.

The following are in the process of either designing or fabrication:

(i) magnet current stabiliser for 300 A,

(ii) evaporative cooling system for magnet coil and other equipment cooling,

(iii) 48″×38″ aluminium vacuum chamber,

(iv) vacuum manifold with two 6″ diffusion pumps.

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

A.3 *Fabrication of Silicon Surface-barrier Detectors*

In the present state of the art, the solid state detectors are very useful for detection and measurements of charged particles. Because of the large number of such detectors required and the high cost involved if obtained through commercial sources, a programme of fabricating surface-barrier detectors was undertaken in the laboratory. Dr. G. K. Mehta of IIT, Kanpur, kindly came and stayed with us for a fortnight to show us the techniques involved. A number of 3/4″ diameter surface-barrier detectors were fabricated. Most of them gave a resolution of about 60 keV, but the resolution deteriorated even further after a few days. The cause is suspected to be the commercial grade of araldite used. With better epoxy resins we expect to make better detectors.

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

A.4 *Coulomb Excitation*

With the increased external beam and the high resolution Ge (Li) detector, coulomb excitation work was started. Even though much of the coulomb excitation work has been completed earlier in other laboratories, using NaI (Tl) scintillation spectrometers, wide gaps exist in the published data where the resolution of scintillation counters was not enough to separate the close lying levels in the spectra. Our Ge (Li) detector set-up gives a resolution of 5.5 keV in the energy region of interest. Further attempts are being made to improve this resolution. This will lead to increased accuracies in the B (E2) values and a comparison with measured life-times will give better E2/Ml ratios. Already some other laboratories have started work in these lines.

We started with a survey of coulomb excitation in heavy and medium weight target nuclei. Our choice was restricted to the targets we had in stock. Preliminary measurements in a few cases have been presented below:

We were able to separate the levels 100, 110, 120 keV in the coulomb excitation of the natural sample of 'W' which could not be obtained by early workers with scintillation counters. These were observed with only enriched samples. Fig. 1A.1 shows the spectrum obtained with natural sample of 'W'. Other heavy targets studied were Au and Ta.

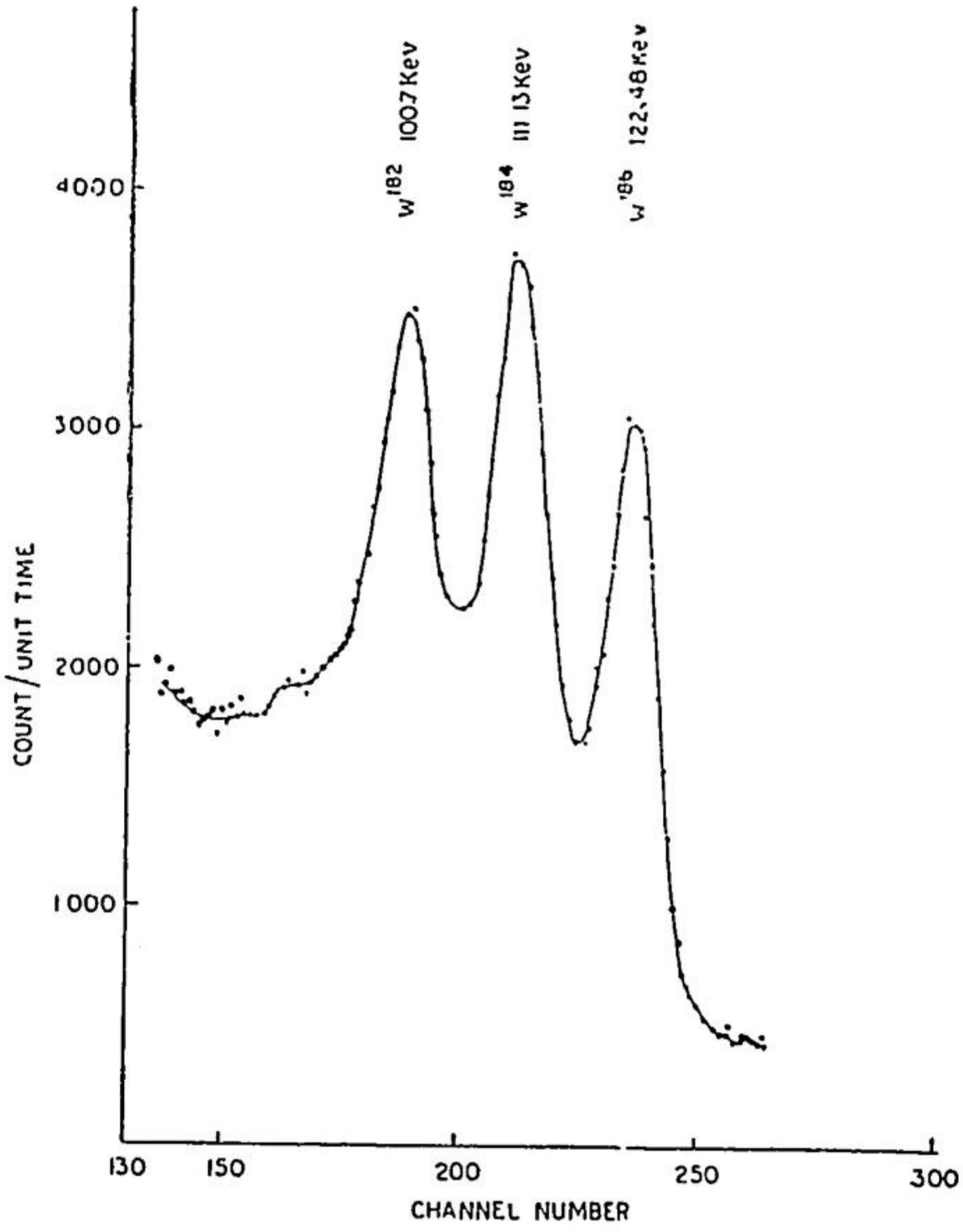

Fig. 1A.2. Coulomb excitation in natural sample of (~ 3 mil thick). The peaks shown are the first excited states in the respective isotopes.

In the medium weight nuclei we studied Pd (natural) and ^{102}Pd (enriched), ^{50}Cr (enriched), Sn, Cu and As. Fig. 1A.2 shows the spectrum obtained with natural sample of palladium and a sample enriched in ^{102}Pd. We find that the first excited states in ^{102}Pd and ^{104}Pd are very close and we are improving our resolution to separate the same. The first excited state in ^{102}Pd has been observed earlier at 550 keV in the decay of ^{102}Ag (P. Charoenkwen and J. R. Richardson, *BAPS,8*, 595 (Dl), 1963). We observed the first excited state of ^{50}Cr in a sample enriched in that isotope (Fig. 1A.3). Sn was studied to use the data to subtract bremsstrahlung background.

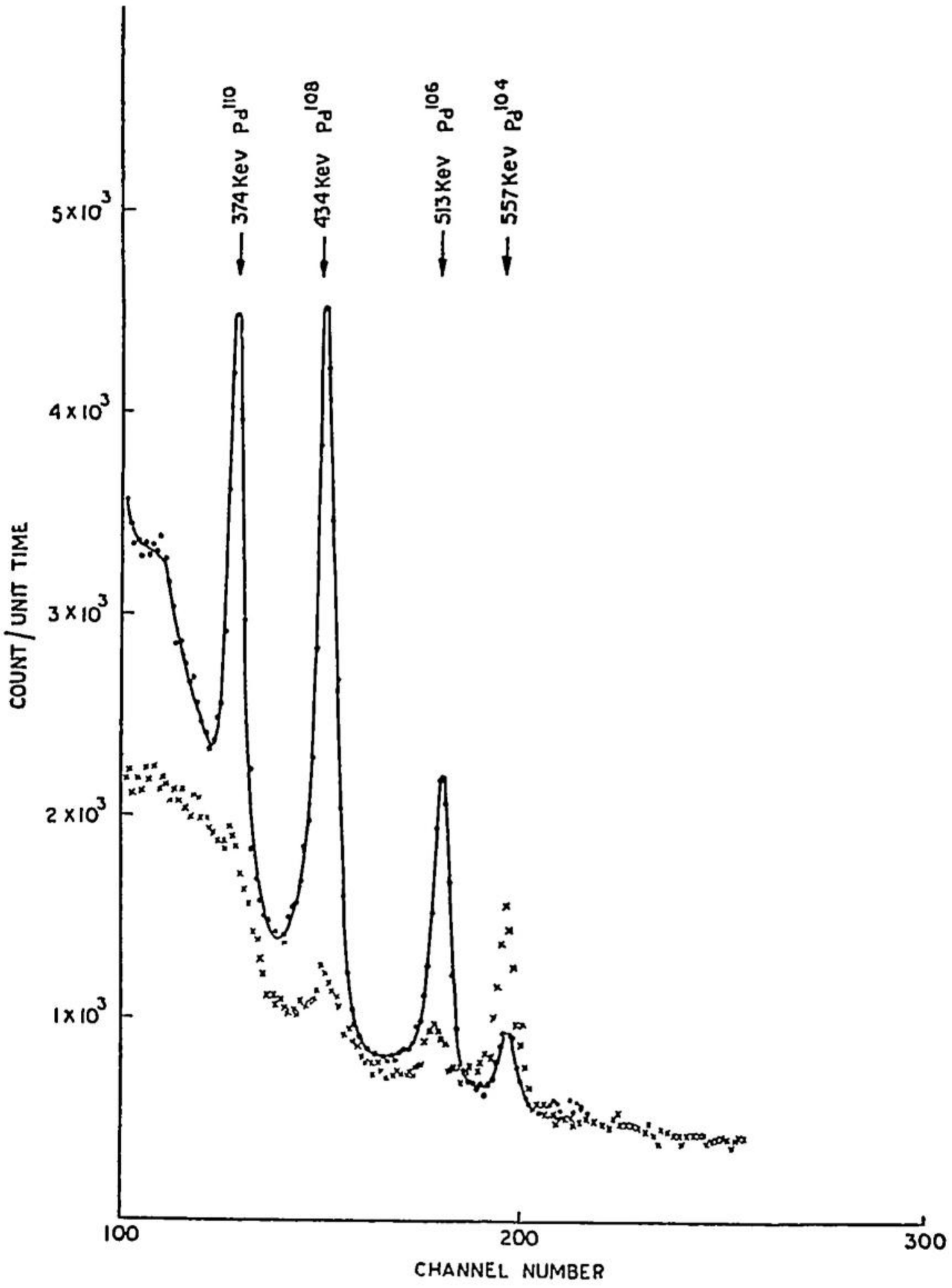

Fig. 1A.2. Coulomb excitation in natural sample of Pd (continuous curve) and Pd enriched in isotope 102 (50%) (crossed points).

Many more levels were observed in all the cases than reported uptil now. However, a careful study of these is required before establishing the genuineness of the new levels. We plan to measure the absolute B (E2) values for these coulomb excited levels.

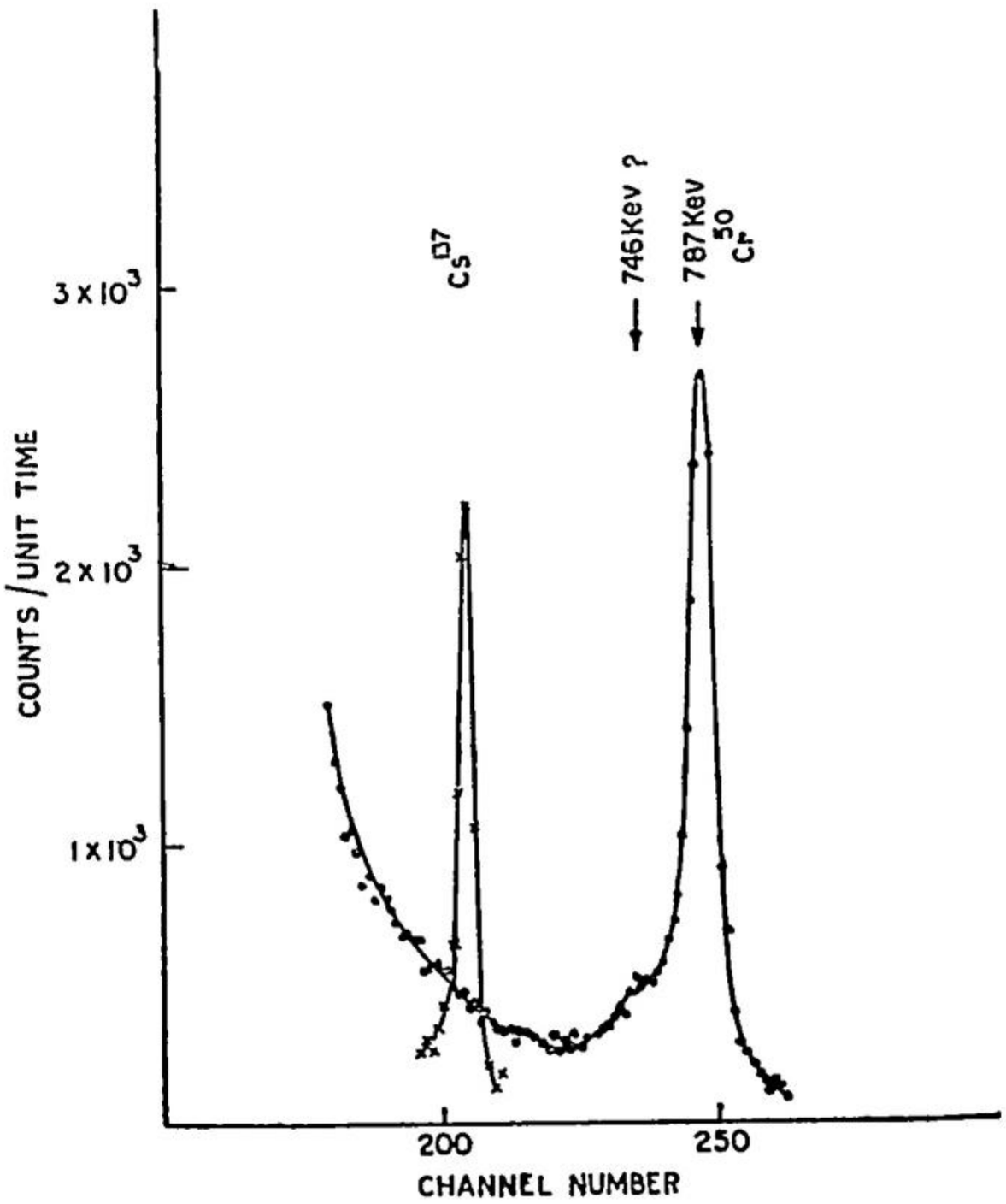

Fig. 1A.3. Coulomb excitation in enriched sample of ^{50}Cr ($\sim 90\%$). ^{137}Cs line is given for reference.

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

1A.5 *Gamma Spectroscopy*

With the availability of the high resolution Ge(Li) detector it was felt that some of the γ spectra taken earlier with isotopes prepared in the cyclotron should be reinvestigated, specially ^{97}Rh and ^{100}Rh which showed many unresolved lines with a $3'' \times 3''$ NaI detector. Preliminary runs have been taken with ^{85}Sr, ^{97}Rh, ^{100}Rh and ^{107}In (Fig. 1A.4).

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

1A.6 *Development of Fast Coincidence Arrangement and its Application to the Detérmination of Positronium Life-time*

Positron life-times in silicone fluids of different viscosity grades have been analysed to see the behaviour of the long component, τ_2, and its intensity, I_2, with the length of the chain of these polymers. Following a recent report

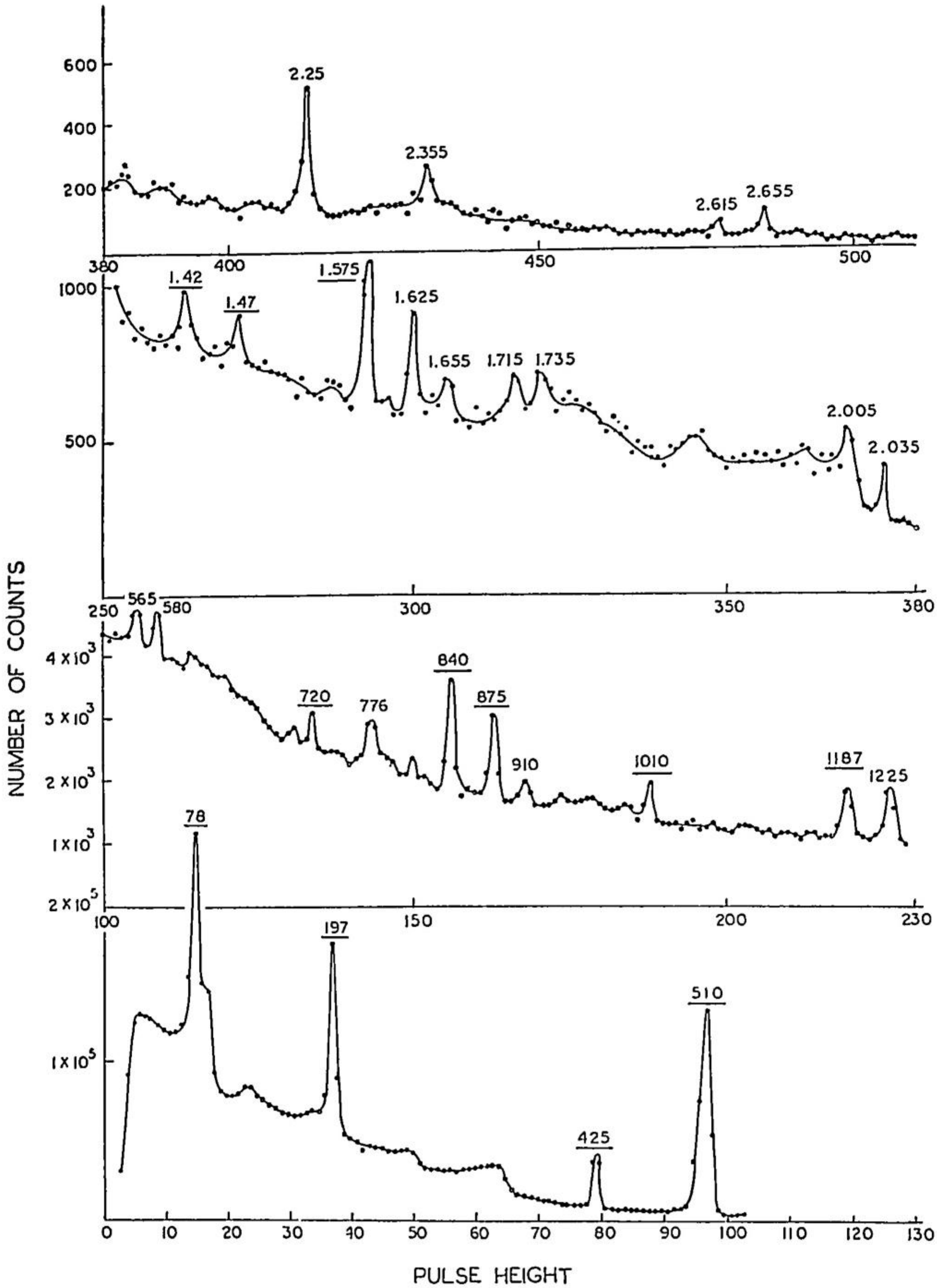

Fig. 1A.4. Gamma spectrum of ^{97}Rh taken with 2.5 cm diameter 5 mm thick Ge (Li) detector. The gamma energies underlined were also observed with NaI (Tl) spectrometer, though not all of them resolved. The extra lines are due to annihilation escape peaks.

by Lee and Cetitans that dissolved oxygen had a marked quenching effect on the life-time of triplet positronium, we wish to repeat the measurement with the deoxygenated samples. The results of positron life-times in CCl_4 and $SiCl_4$ are quite interesting. The former has a very small I_2 whereas $SiCl_4$ shows a large contribution of τ_2 (Fig. 1A.5) and we conclude that substitution of carbon by silicon increases I_2.

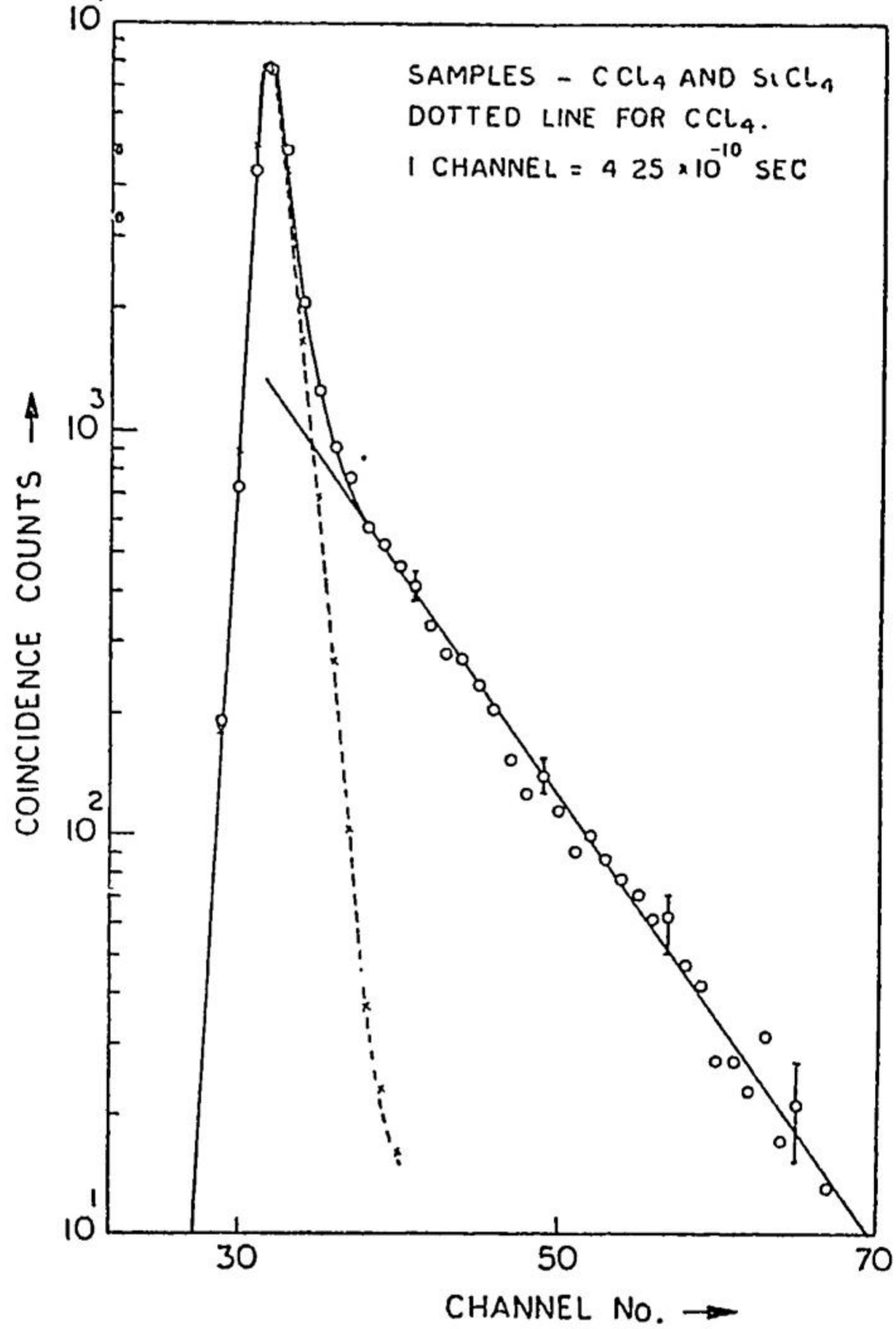

Fig. IA.5. Time distribution curves for CCl_4 and $SiCl_4$. Dotted line is for CCl_4.

In order to continue the work on positron life-times in solids, it was felt that the resolution of the existing set-up has to be improved. As we did not have better photomultiplier tubes, we investigated the methods of optimising with the existing RCA 6810A photomultiplier tubes. The attempts were in the following two directions :

(i) increased accelerating potential between photo-cathode and first dynode without impairing stability,

(ii) use of differential coincidence technique and pulse height compensator.

We have succeeded in improving the time resolution by the above two methods and a fwhm $\approx$ 0.5 ns with slopes of 9.0×10^{-11} sec for ^{60}Co gamma-rays has been achieved (Fig. 1A.6).

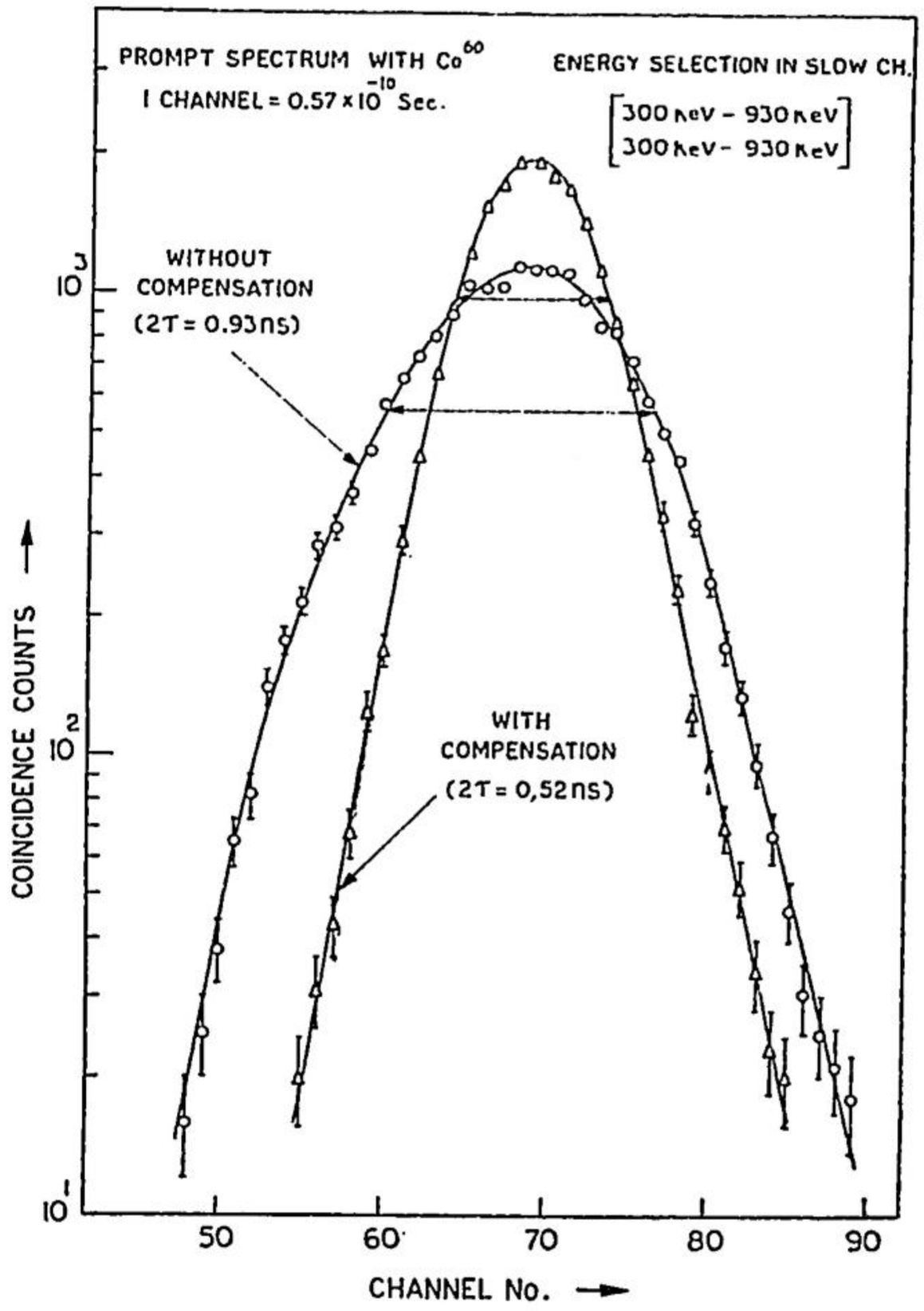

Fig. IA.6. Prompt curves with and without compensation, obtained with a ^{60}Co source accepting, in both channels, pulses corresponding to energy losses between 300 and 930 keV.

(P. Sen and A. P. Patro, 'A Pulse-height Compensator for use with Time-to-Amplitude Converters', to be published in *Nuclear Instrm. Meth.*)

P. Sen and A. P. Patro

1A.7 (p, γ) *Reactions in the Giant-resonance Region*

Work done at Columbia University on proton capture gamma-rays from ^{8}Be, ^{12}C, ^{24}Mg and ^{40}Ca in the giant-resonance region was analysed.

The 90° yield for gamma-rays from ^{8}Be, ^{12}C, ^{24}Mg and ^{40}Ca was determined for (p, γ) reactions using 10.4 to 14.5 MeV protons from the Columbia University variable energy cyclotron. For ^{11}B (p, γ) ^{12}C, the yields to both the first excited and the ground states of the residual nucleus are presented. In the case of ^{39}K (p, γ) ^{40}Ca only the ground state yield was determined. Because the ground state yields are very small, we report only the yield due to transitions to the first excited state for the ^{7}Li (p, γ) ^{8}Be reaction and the combined first excited and ground state yields for the ^{23}Na (p, γ) ^{24}Mg reaction. In the region investigated, the yield curves exhibit a considerable amount of fine structure in all cases except ^{7}Li (p, γ) ^{8}Be. Fine structure peaks are observed for the following excitation energies : 21.9, 22.4, 22.7, 23.0, 23.3, 24.1, 24.7 and 25.4 MeV for ^{23}Na (p, $\gamma_0 + \gamma_1$) ^{24}Mg; at 18.8, 19.2, 19.5, 20.0, 21.0 and 21.7 MeV for ^{39}K (p, γ_0) ^{40}Ca; at 25.5, 26.9, 28.0 and 28.45 MeV for ^{11}B (p, γ_1) ^{12}C and at 25.5, 27.45, 28.0 and 28.9 MeV for ^{11}B (p, γ_0) ^{12}C. A comparison with other experiments shows that some of these peaks have not been previously observed.

Publication :

B. B. Baliga, *Phys. Rev., 157*, 921, 1967.

B. B. Baliga

1B. ELECTROSTATIC GENERATOR DIVISION

1B.0 *Introductory Remarks*

The work of this new division, formed around the nucleus of the old neutron physics section of the accelerator division, continued mainly along the lines previously followed by the neutron physics group and was centered around the neutron generator machine.

The programme of research on nuclear spectroscopy has continued with the production of short-lived isotopes by means of the neutron generator and studies of their radioactive decay. The isotopes selected were mainly those which were not studied before nor known exactly. Another programme of research was concerned with the angular and energy distribution studies for (n, α) reactions in the region of light nuclei. In the light mass region, the angular distribution for (n, α) reaction at 14 MeV has not been thoroughly surveyed. The purpose of the programme is to look into the mechanism of such reactions. Since the application of the statistical theory is restricted in this region by virtue of limited number of nucleons and large level spacings and since cluster structure like ^{3}He and ^{4}He are more favoured, we expect the direct reaction to play an important role here. This has been borne out by the experimental and theoretical results obtained. For theoretical fit to the experimental results, DWBA calculations for pick-up and knock-on mode were adopted. The experimental work was carried out with the help of nuclear emulsion plates, using the Kumabe technique of exposing the plates. Theoretical studies of the properties of the low lying levels of some odd mass isotopes were also done. Another group was engaged in the theoretical studies of the different aspects of (d,p) and (t,p) reactions. In the rare earth region, the experimental data on (d,p) reactions were analysed, using Nilsson wave-function. The bound state functions were surveyed, using Saxon-Wood potential. Original contributions were made in all the above fields, as will be evident from the following reports of the papers published or to be published.

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

Some modifications and additions were done to improve the working of the generator. A magnetic beam bending device was adopted to take the beam in a horizontal direction. Significant progress has been made in the programme of extending the high voltage of the present generator. Acute shortage of available space hindered the attainment of the full voltage of 1500 kV.

S. K. Mukherjee

1B.1 *Half-lives of the Excited States of ^{46}Ti, ^{84}Rb, ^{99}Tc, ^{162}Dy, ^{164}Er and ^{196}Au*

The half-lives of the excited states of some nuclei have been measured by using the delayed coincidence method. The upper or lower limits of half-lives are obtained in a few cases. The results are as follows :

Nucleus	Level (keV)	Half-life (sec)
^{99}Tc	181	$(3.40 \pm 0.10) \times 10^{-9}$
^{84}Rb	250	$(3.08 \pm 0.55) \times 10^{-10}$
^{162}Dy	1155	$(2.10 \pm 0.40) \times 10^{-10}$
^{164}Er	90	$(1.52 \pm 0.06) \times 10^{-9}$
^{46}Ti	2006	2×10^{-11}
^{99}Tc	920	1×10^{-10}
^{196}Au	85	4×10^{-6}

(B. Sethi and S. K. Mukherjee, 'Half-lives of the Excited States of ^{46}Ti, ^{84}Rb, ^{99}Tc, ^{162}Dy, ^{164}Er and ^{196}Au', to be published in *Phys. Rev.*)

B. Sethi and S. K. Mukherjee

1B.2 *Studies of Nuclear Structure of Odd Mass Nuclei* ($50<A<150$) *in the Intermediate Coupling Unified Model*

The properties of the low lying nuclear energy levels of the odd mass nuclei whose even even neighbouring isotopes exhibit a characteristic vibrational spectrum can be explained with a reasonable success by the intermediate coupling approach in the unified nuclear model. We have undertaken a problem of systematic studies of low energy spectra of odd mass nuclei in the mass region $50< A <150$. Since the excited states of many even even nuclei in this mass region show vibrational character, it seems plausible to explain the low lying energy levels of the neighbouring odd mass isotopes by treating them as a coupled system consisting of an even even vibrating core, plus the last odd particle (or hole) which may have available several single particle states. It is further assumed that the single particle states of the extra core nucleon are neither weakly nor strongly coupled to the vibrational states of the even even core.

Three kinds of adjustable parameters are involved in such calculations:

(i) the quantum energy associated with the vibrations of the even even core. This is usually taken from the spectrum of the neighbouring even even isotope.

(ii) The effective single particle energy spacings. It may be regarded as an adjustable parameter since the correct unperturbed single particle energies may not be available for each isotope.

(iii) The coupling strength. It is also regarded as an adjustable parameter.

The application of this model to explain the low lying energy levels of the odd mass Co nuclei is quite successful. Similarly we have tried to appiy this model to odd mass Ag isotopes. Although the results are quite encouraging, we expect to get still better results after modifying the choice of the single particle energies. The work is under progress.

S. C. Gujrathi and B. P. Pathak.

1B.3 *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, α) 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 nucleus has a structure formed by the coupling of a proton hole to the quadrupole vibrations of the corresponding even mass Ni nucleus. The core states upto 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 ξ 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 $7/2^-$, $7/2^+$ and $3/2^+$ states agree reasonably well with the experimental results of the (t, α) reactions on the even mass Ni isotopes.

(L. Satapathy and S. C. Gujrathi, 'Studies of Odd Mass Co Isotopes in the Unified Model', to be published in *Nuclear Physics*.)

L. Satapathy and S. C. Gujrathi

1B.4 *A DWBA Calculation in ^{12}C (n, α) ^{9}Be Reaction*

A DWBA calculation for the angular distribution in ^{12}C (n, α) ^{9}Be reaction was taken up as a programme. But due to some technical difficulties the programme remained postponed till the middle of 1967, when it was revived. The calculation procedures have been much improved by using Runge-Kutta method of numerical solution and the computer programming has been made versatile enough to handle simultaneously the pick-up and knock-on mechanisms. By varying the optical well depths rationally, reasonable fits have been obtained for both the mechanisms. Some more calculations are yet to be done to complete this work. Few of the results obtained so far are shown in Fig. 1B.1 and

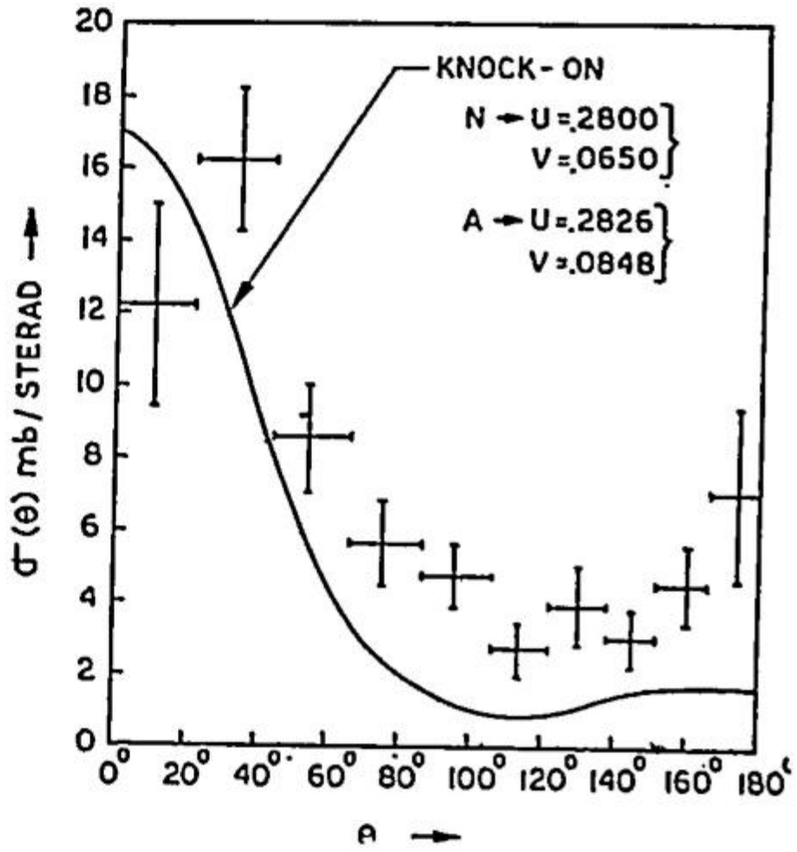

Fig. 1B.1

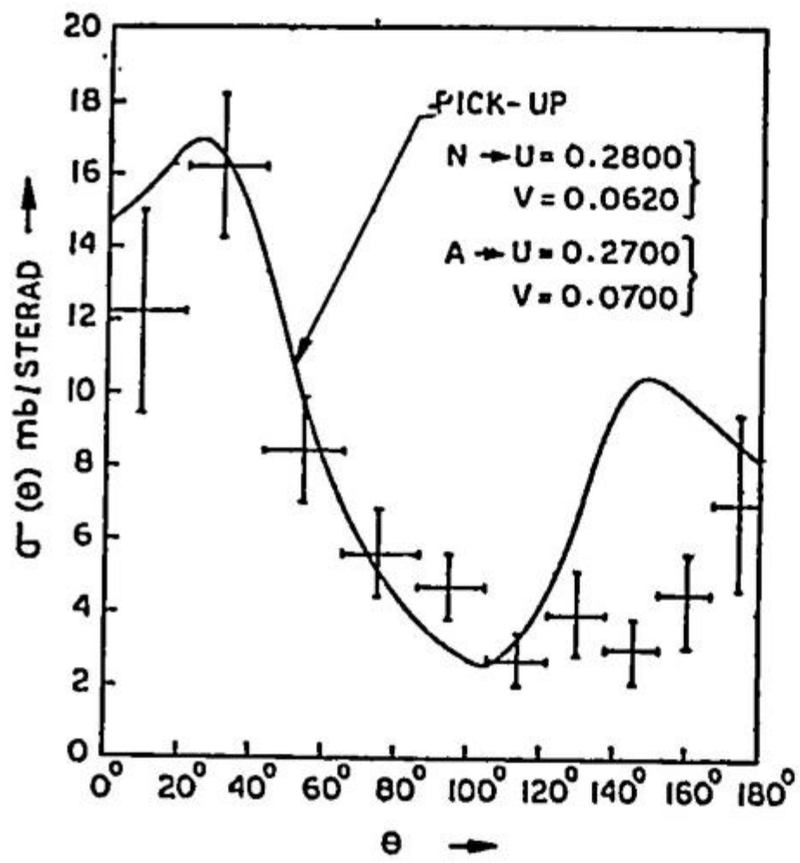

Fig. 1B.2

Fig. 1B.2. U and V represent the real and imaginary parts of the optical potential. N and A refer to neutron and alpha, respectively. Effects of cut-off in the radial integral are also being investigated.

M. L. Chatterjee and T. De.

1B.5 *Analysis of the (d, p) Reaction Data in the Rare Earth Region with the Modified Nilsson Wave-functions.*

The cross-section for the (d, p) reactions on an even even target nucleus is given by

$$d\sigma = 2C_{jl}^2 \quad \phi_l$$

where

$$C_{jl} = \sum_{\Lambda} \begin{bmatrix} l & y_2 & j \\ \Lambda & \xi & \Omega \end{bmatrix} a_{l\Lambda}$$

$a_{l\Lambda}$ being the amplitudes tabulated by Nilsson. Thus, within a particular rotational band, the relative intensities will be simply related by the different C_{jl} values corresponding to the particular Nilsson orbitals. During the last few years considerable data have been accumulated on the (d, p) reactions of rare earth nuclei. It has been found that the C_{jl}^2 calculated from the Nilsson's tabulated wave-functions gives a rather poor fit with the experimental yields. This has led us to modify the Nilsson wave-functions in such a way that the starting zero-deformation s.p. spectra correspond to the actual experimental data. In order to get this agreement it has been found that $\chi = 0.033$ and $\mu = 0.35$ are a better set of parameters for the $N = 5$ and 6 shells. With this choice of the parameters the C_{jl}^2 are extensitively tabulated for all the orbitals in the $N = 5$ and 6 shells and for different deformations. An extensive comparison of the (d, p) experimental data with these C_{jl}^2 has been made for various rare earth isotopes. One such comparison is shown in Table 1B.1 for the $[510\frac{1}{2}-]$ band in ^{177}Yb.

Table 1B.1

C_{jl}^2 for the [510 $\frac{1}{2}$ −]state of ^{177}Yb.

j	C_{jl}^2 (ours)	C_{jl}^2 (Expt.)	C_{jl}^2 (Nilsson)
1/2	0.007	0.017	0.067
3/2	0.351	0.336	0.430
5/2	0.275	0.400	0.308
7/2	0.222	0.164	0.164
9/2	0.118	—	0.080
11/2	0.026	—	0.010

G. Ramakrishna and P. Mukherjee

1B.6 *Bound States in a Wood-Saxon Well*

In DWBA calculations of stripping cross-sections it is customary to use harmonic oscillator wave-functions for the bound proton or neutron. It has been recognised for some time that this imposes considerable uncertainties in the value of the cross-sections, mainly because the actual bound state wave-functions near the nuclear surface is very much different from that given by H.O., although the overlap within the nuclear matter is better than 90%. Since the interactions in such reactions is mainly confined to the surface of the nucleus, a better choice for the wave-functions will be that given by the realistic Wood-Saxon well. For these reasons we have set to evaluate the wave-functions in such a potential well, first by fixing the parameters so that the actual binding energies of the neutron (or proton) are well reproduced. Calculations are in progress for the N=5 and 6 shells, which are of interest to us. Preliminary results indicate that while the bound state energies for the s, p, d, f and g states are fairly insensitive to the diffuseness parameter 'a' of the well, both the h and the i levels are very sensitive to it. Thus, a change of 'a' from 0.6 to 0.7 fermi pushes the i level by as much as 1 MeV. This may account for the anomalous spin-orbit splitting of the i-state.

G. Ramakrishna and P. Mukherjee

1B.7 *Estimation of (t, p) Reaction Reduced-widths with Shell Model Wave-functions*

Ratios of the (t, p) cross-sections of the first two O^+ states in the nuclei ^{18}O, ^{30}Si, ^{44}Ca, ^{50}Ca and ^{58}Ni are calculated using both the surface-delta interaction and

more realistic residual interactions between the two neutrons. These are tabulated in Table 1B.2

Table 1B.2

(t,p) cross-section ratios for the first two 0^+ states

Reaction	σ exc. $/\sigma$ gnd.	
	S.D.I.	Finite Range
^{16}O (t,p) ^{18}O	2.633	—
^{28}Si (t,p) ^{30}Si	0.899	0.652
^{42}Ca (t,p) ^{44}Ca	0.092	—
^{48}Ca (t,p) ^{50}Ca	0.006	—
^{56}Ni (t,p) ^{58}Ni	0.083	0.063

K. V. Chalapati Rao and P. Mukherjee

1B.8 *Intermediate-Coupling Model for Odd-Cadmium Isotopes*

A phonon-particle model is applied to study the excitations of the even-parity states in the reactions ^{114}Cd (d,p) ^{115}Cd. Phonons upto N = 3 are admixed and the residual states are identified with the available experimental data. Simultaneously, attempts are being made to correlate these states with those arising from the band mixing calculations, to see if such isotopes can be represented as rotational nuclei.

K. V. Chalapati Rao and P. 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 uptake through mixed crystal formation and its application, (3) study of separation chemistry on the laboratory scale and (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. These are : (i) Necessary arrangements and preparations for measuring low level radioactivity with reference to products of spontaneous fission. Techniques have been improved to recover the product of spontaneous fission from large amount of uranium with satisfactory recovery yield and decontamination. (ii) Simplified procedures in some interesting systems for working out chemical analysis through activation. The procedure in some cases has met with success. (iii) Developing radiation chemistry. We have not yet been able to get our own radiation source. We are very thankful to our workshop and to Prof. B. D. Nagchaudhuri for taking steps in order to have a X-ray unit for our purpose. We hope that within a few months it will be in operation. We are hopeful of a better prospect as soon as this handicap is over. (iv) To construct, fabricate and assemble simple apparatus which are used in the laboratory.

It has been a principle to avoid foreign exchange as far as practicable. With this object in view we always try to construct apparatus of our own. As an example, we can mention the name of a simple and reliable automatic fraction collector which will find extensive application in the field of research.

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

B. C. Purkayastha

Analytical Chemistry

1C.1 *Radiometric Micro Estimation of Palladium, Silver and Iodide with the help of ^{131}I and of Hafnium with the help of ^{32}P in presence of Interfering Ions*

In the previous year the estimation of palladium or iodide, using iodine-131, has been reported. Micro estimation of hafnium as hafnium pyrophosphate

using ^{32}P as a measuring indicator was also the subject matter of study during the year 1966. During the year 1967 micro estimation of silver, iodide and palladium in presence of interfering ions has been studied by raliometric procedure. Estimation of hafnium in microstate with ^{37}P as indicator in presence of interfering ions has also been the subject matter of study. Some of the interesting findings are given in Table 1C.1, 1C.2 and 1C.3.

It has been found that in presence of cations which interfere in traditional method, iodide can be estimated as silver iodide. Iodide or silver has been estimated by silver iodide procedure in presence of 10,000 times its weight of lead and 500 times its weight of copper (ous). Estimation of iodide as palladous iodide can be done in the presence of 30 times its weight of chlorine and 5 times its weight of bromine. Palladium can also be estimated in the presence of about 750 times its weight of nickel and about 12 times its weight of gold and platinum.

Estimation of hafnium as pyrophosphate with ^{32}P as measuring indicator has also been investigated in presence of interfering ions. It has been possible to estimate micro amount of hafnium in presence of 250 times its weight of titanium by complexing titanium with hydrogen peroxide. It will be observed from Table 1C.3 that hafnium can be estimated in presence of near about 1200 times its own weight of cerous cerium and 600 times its weight of aluminium.

Table 1C.1

Micro estimation of palladium and iodide with ^{131}I

Amount of foreign elements, mg		Palladium taken, mg	Palladium found, mg	Iodise added as potassium iodide, mg	Iodine found, mg	Standard deviations of activity measure-ments, %
Chloride	2.200	0.01003	0.00973	0.07600	0.07830	± 3.2
	2.290	0.01003	0.00988	0.07600	0.07706	± 1.6
Bromide	0.370	0.01003	0.00979	0.07600	0.07781	± 2.7
	0.740	0.01003	0.00880	0.07600	0.08652	± 4.1
Nickel	0.5540	0.001138	0.001111	0.01099	0.01125	± 2.6
	0.8310	0.001138	0.001148	0.01099	0.01089	± 1.2
Platinum	0.0078	0.001138	0.001152	0.01099	0.01086	± 1.4
	0.0156	0.001138	0.001121	0.01099	0.01116	± 1.7
Gold	0.0050	0.001138	0.001115	0.01099	0.01121	± 2.2
	0.0127	0.001138	0.001149	0.01099	0.01089	± 1.2

Table 1C.2

Micro estimation of silver and iodide with ^{131}I

ount of foreign elements, mg		Silver taken, mg	Silver found, mg	Iodine added as potassium iodide, mg	Iodine found, mg	Standard deviations of activity measure-ments, %
Lead	24.380	0.01179	0.01145	0.02743	0.02820	± 3.1
	48.760	0.01179	0.01215	0.02743	0.02661	± 3.1
	97.520	0.01179	0.01217	0.02743	0.02655	± 3.4
Cuprous	0.0154	0.01179	0.01158	0.02743	0.02790	± 3.2
	2.3430	0.01179	0.01144	0.02743	0.02821	± 3.1
	4.6860	0.01179	0.01140	0.02743	0.02834	± 3.5

Table 1C.3

Micro estimation of hafnium in presence of foreign ions with ^{32}P

Amount of foreign ions, mg		Hafnium taken, mg	Hafnium found, mg	Standard deviations of activity measurements, %
Titanium	4.00	0.03256	0.03186	± 3.3
	8.00	0.03256	0.03218	± 1.4
Cerium(ous)	8.61	0.03256	0.03105	± 4.9
	42.60	0.03256	0.03264	± 0.5
Aluminium	11.09	0.03256	0.03269	± 0.7
	22.18	0.03256	0.03109	± 5.1

Usha Purkayastha and H.P. Maity

1C.2 *Separation and Determination of Oxyacids of Sulphur ($S_2O_8^=$, $SO_1^=$, $SO_3^=$, $S_2O_3^=$ and $S_2O_6^=$) in a Mixture*

A systematic study of separation and estimation of the above species is being made using Dowex 2×8 anion exchange resin (column size—18cm long, 1.2cm dia) with varied concentration of NaCl as the eluting agent. In the first attempt quantitative separation of $SO_4^=$, and $SO_3^=$, $S_2O_3^=$, $S_2O_6^=$, $S_2O_8^=$ has been

achieved (Fig. 1C.1). 0.5M NaCl solution elutes $SO_4^=$ and $SO_3^=$ simultaneously; sulphate is estimated in the mixture by the method of turbidimetry as $BaSO_4$ and sulphite by titration with standard iodine solution. $S_2O_3^=$ is eluted with 1.OM NaCl

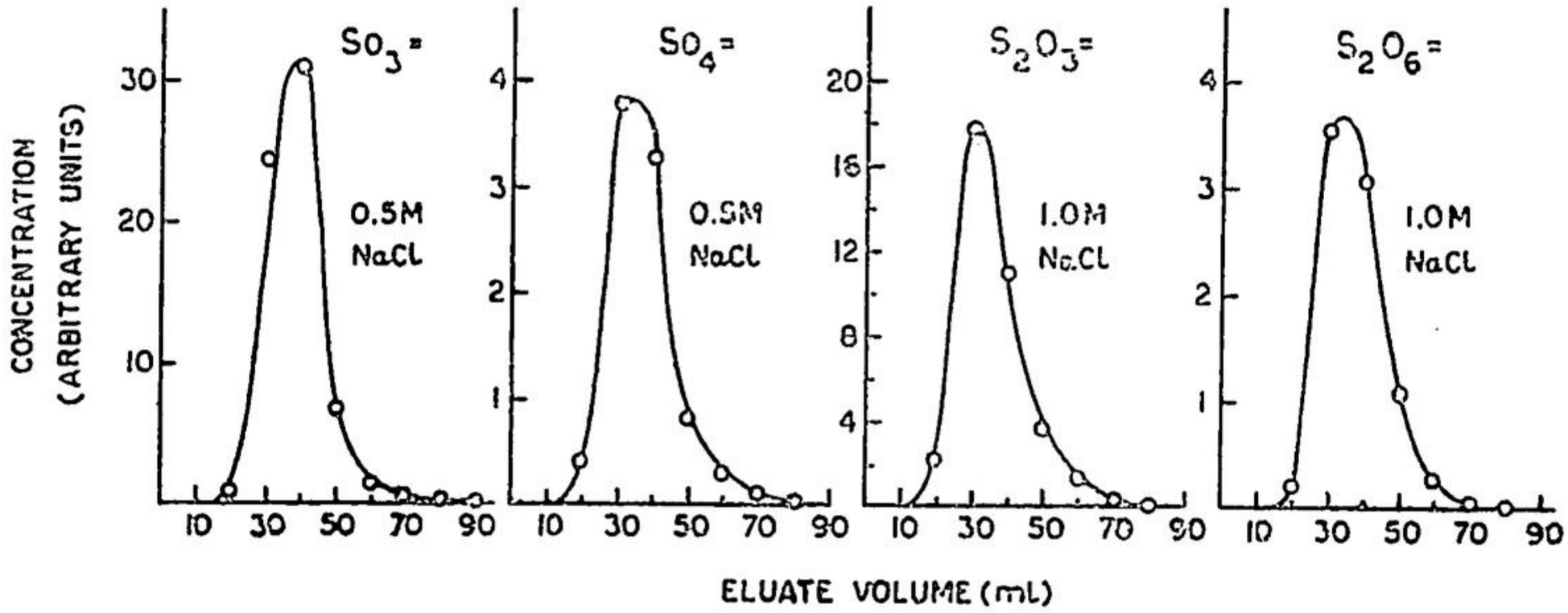

Fig. 1C.1

This figure shows no diagram of elution of $S_2O_3^=$ although referred to in the text.

and estimated iodometrically. $S_2O_6^=$ is eluted with 2.OM NaCl and oxidised to sulphate with H_2O_2 and estimated as above. Finally, persulphate is reduced on the bed itself and subsequently the sulphate formed is eluted with 0.5M NaCl. Detailed study as regards the validity of the method with varied proportions of the constituents in the mixture is under progress.

The object of this analysis is to study the radiation induced decomposition of persulphates, which requires thorough investigation.

K. N. Dutta

Study of Uptake Through Mixed Crystal Formation and its Various Applications

1C.3 *A New Method for Determining Transition Temperature through Mixed Crystal Formation. Determination of Transition Temperature in the System : $MnSO_4$, $7H_2O - 6H_2O$*

It has been previously reported by us (*J. Inorg. Nucl. Chem., 28*, 347, 1966) that a new method has been developed in 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 temperatures of the

guest component. This new method of approach has been applied in the present investigation to the study of transition temperatures of orthorhombic and monoclinic $MnSO_4$, $7H_2O$-$6H_2O$. Ferrous sulphate ($FeCO_4$, $7H_2O$) was taken as host for monoclinic variety and $MgSO_4$, $7H_2O$ was the host for orthorhombic variety. Homogeneous distribution factor at different temperatures was studied with these two hosts and ^{54}Mn as guest at tracer level. Transition temperatures of orthorhombic and monoclinic variety of $MnSO_4$, $7H_2O$—$6H_2O$ have been found respectively to be 10°C ± 0.5°C (Fig. 1C.2) and 10.5°C ± 0.5°C (Fig. 1C.3). Orthorhombic $MnSO_4$, $7H_2O$ is metastable with respect to monoclinic

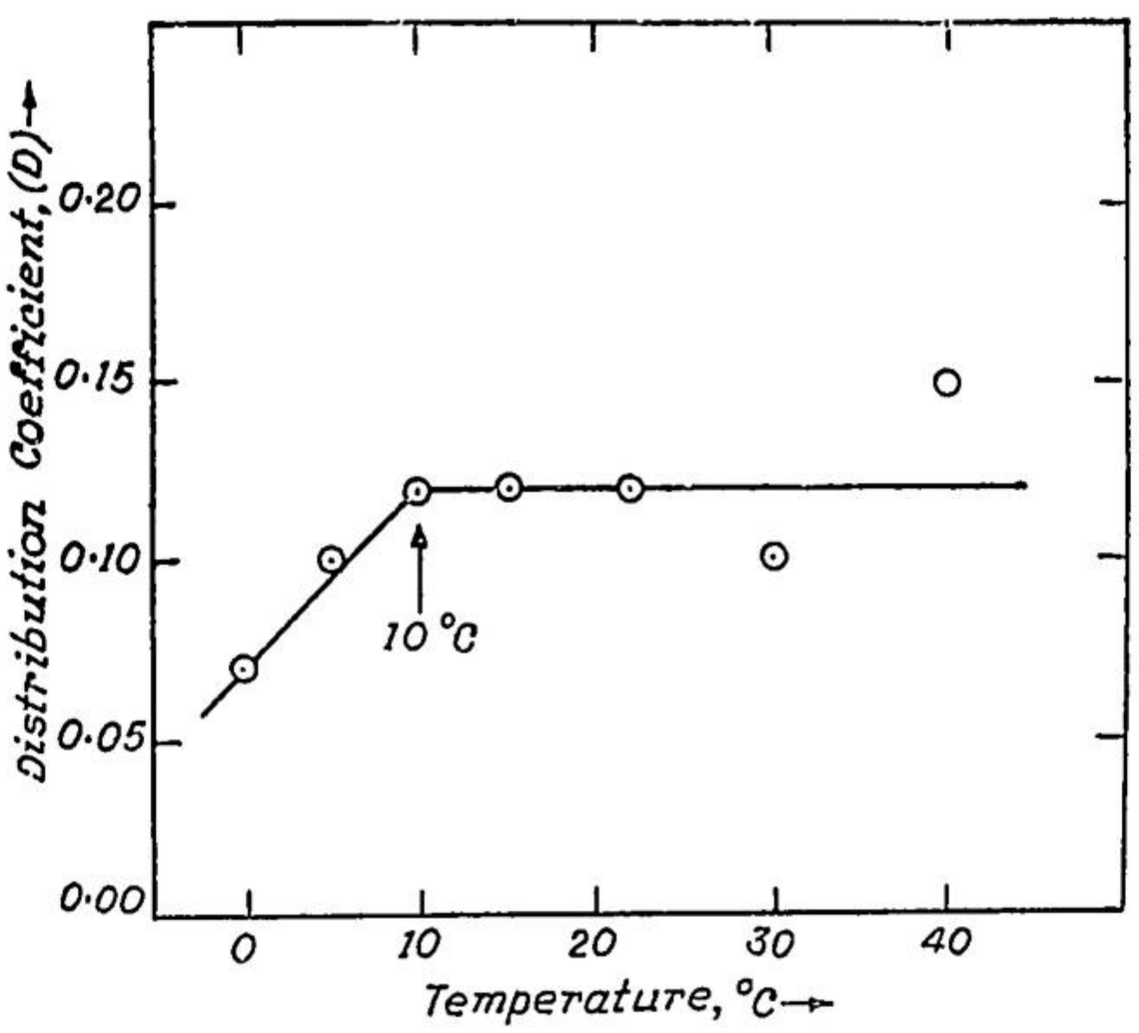

Fig. 1C.2 Study of the transition temperature of orthorhombic manganous sulphate. The transition temperature of orthorhombic manganous sulphate through mixed crystal formation between $MgSO_4$, $7H_2O$ as host and ^{54}Mn as guest.

variety. The transition temperatures of these two varieties are near about the same and similar to $ZnSO_4$, $7H_2O$, which has been previously reported.

It has been argued by Gordon (*Anal. Chem., 30,* 1605, 1958) that mixed crystal formation can be looked upon as an ionic exchange equilibrium and on certain assumptions an expression for the standard change in free energy can be written as: $\triangle F^\circ = RT \ln D$. With this expression $\triangle F^\circ$ has been calculated from the D-values where the data were taken for determining transition point of orthorhombic cobalt sulphate with ^{60}Co as tracer and orthorhombic $MgSO_4$, $7H_2O$ as host. Fig. 1C.4, where $\triangle F^\circ$ and D-values are plotted against temperature will show that the standard free energy change, $\triangle F^\circ$, is minimum at the transition point.

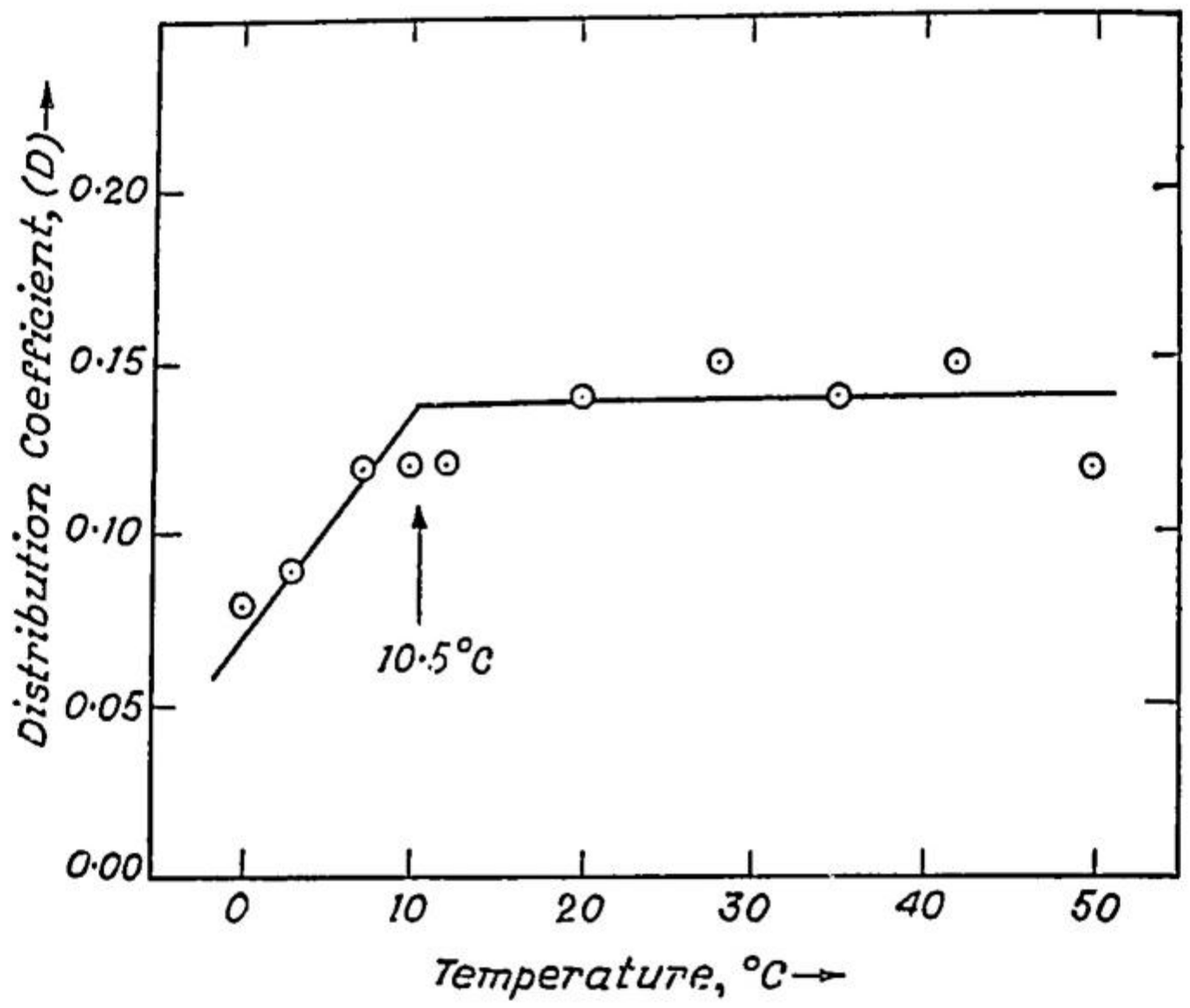

Fig. 1C.3 Study of the transition temperature of monoclinic manganous sulphate. The transition temperature of monoclinic manganous sulphate through mixed crystal formation between $FeSO_4$, $7H_2O$ as host and ^{54}Mn as guest.

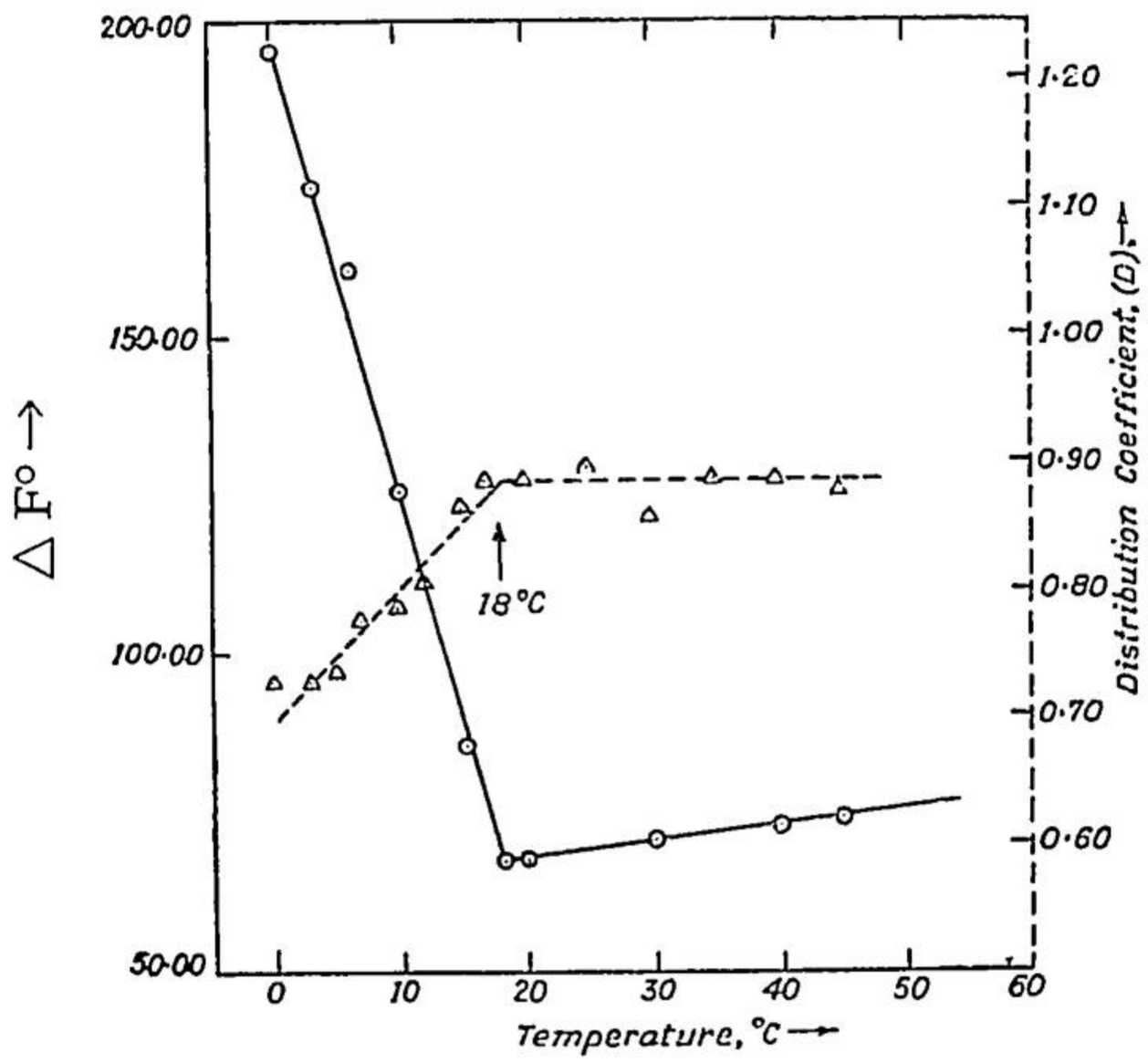

Fig. 1C.4 Variation of standard free energy change, $\triangle F,^{\circ}$ and distribution coefficient, D, with temperature in case of uptake of Co^{60} by $MgSO_4$ $7H_2O$ (Orthorhombic).

B. C. Purkayastha and Samir Sarkar

C.4 *A Critical Review on Coseparation Process including its Application during the Separation of Radioactive Isotopes*

It is well known that Doerner and Hoskins formulated their heterogeneous distribution law in connection with the uptake of radium by barium compounds. The law was established on the assumption that along with the growth of each plane of the host layer there is an equilibrium between the ions in solution and the ions in the crystal layer. Thus the crystal as a whole turns out to be heterogeneous. The expression derived by the author is as follows :

$$\log \frac{\text{Initial tracer}}{\text{Tracer in solution}} = \lambda \log \frac{\text{Initial carrier}}{\text{Carrier in solution}}$$

This has all along been used both in normal and anomalous mixed crystal formation. The law as a whole does not account for the equivalence of charge replacement in anomalous mixed crystal formation, which is not essentially necessary for the validity of the law. In recent years Gordon points out that the simple expression for λ should be written in terms of equivalence of charge displacement in case of anomalous mixed crystal formation. Thus according to this conception, λ_g, in the uptake of lanthanum tracer by thorium iodate, comes out as follows:

$$\log \frac{La_i}{La_f} = \lambda_g \left(\frac{4}{2.303}\right)\left(\frac{1}{V^{1/4}}\right)\left(Th_i^{\frac{1}{4}} - Th_f^{\frac{1}{4}}\right)$$

where La_i, Th_i, and La_f and Th_f represent the initial and final concentrations of lanthanum and thorium in solution, in terms of moles and V is in liters. This new expression of λ_g became the subject matter of considerable interest during the year. As a matter of fact, both λ and λ_g will be constant in case of ionic reaction but they will differ in magnitude. λ gives a clearer conception of separation factor than g. Both λ and λ_g have been computed from the data obtained in our laboratory in the following systems. λ_g is calculated from the following expression:

$$\log \frac{M_{initial}}{M_{final}} = 0.8686\ \lambda_g \left(Ca^{-\frac{1}{2}}_{final} - Ca^{-\frac{1}{2}}_{initial}\right)$$

where $M_{initial}$ and M_{final} represent the initial and final concentrations of the tracer in question in the solution and $Ca_{initial}$ and Ca_{final} represent initial and final concentrations of calcium (carrier) in solution.

Table 1C.4

Initial conc. of the guest component	% of calcium salt in question separated	% of the guest component carried	λ	λ_g
(i) Coprecipitation (*J. Ind. Chem. Soc., 41,* 69, 1964) of yttrium (^{91}Y) with calcium oxalate, precipitated by conventional precipitation method in acetic acid medium at 35°C.				
	Initial concentration of calcium = 8.725×10^{-1}M			
Conc. of Y =	1.05	18.5	19.3	20.45
1.72×10^{-4} M	1.77	27.1	17.6	17.57
	2.20	36.8	20.5	20.85
	3.94	49.9	17.3	16.46
	6.16	67.8	17.8	16.63
			Av. 18.5	Av. 18.39
(ii) Coprecipitation (*J. Ind. Chem. Soc., 40,* 759, 1963) of ^{152,154}Eu with calcium sulphate at 35°C.				
	Initial concentration of calcium = 3.49×10^{-1}M			
Conc. of Eu =	23.6	15.7	0.63	0.35
5.68×10^{-7} M	44.5	29.7	0.60	0.30
	51.9	33.6	0.56	0.27
	69.4	50.1	0.59	0.25
			Av. 0.59	

A glance at Table 1C.4 will show that both λ and λ_g are constant in the case of uptake of ^{91}Y by CaC_2O_4, $2H_2O$. Constancy of λ_2 disappears in case of uptake of ^{152,154}Eu by gypsum. Disagreement in the constancy of λ_g has been explained on the basis that gypsum takes up europium tracer through double salt formation. Evidence of the double salt formation in this system has been gathered through other sources (*J. Ind. Chem. Soc., 40,* 759, 1963) as well. In anomalous mixed crystal formation there are a large number of cases where uptake takes place through double salt formation. In such cases constancy of λ_g is unexpected; λ_g, therefore, gets a limitation in its application. However, the expression can be utilised to study whether the uptake is through equivalence ionic replacement or through double salt formation.

In addition to this a critical review on coseparation with special reference to its application in separaton and analytical chemistry has been undertaken. It will not be out of place to mention that Hahn reviewed this interesting aspect in 1936. Further extension of the work has been carried out by A. Bonner and M. Kahn in the year 1951. Since then a large number of data have been published and many interesting findings have been derived. Even it may have impact upon the very idea of the mechanism of coseparation as was conceived by earlier workers. All these findings, scattered in the literature, are under collection. A review work on this issue is likely to be completed during the next year.

B. C. Purkayastha and Shyamoli Sen

IC.5 *On the Study of Tetrahydrated Double Sulphate of Tervalent Elements with Radioactive Indicators*

In continuation of our study with tetrahydrated double sulphate of thallic thalium as host and radioactive isotopes of tervalent elements like ^{46}Sc, ^{116}In and $^{55, 59}Fe$ as guests, it has been observed that just like ^{46}Sc (Annual Report, 1966) both $^{55,59}Fe$ and ^{114}In tracers are taken up by the host lattice through mixed crystal formation. It is of interest to comment that the distribution value does not undergo any change when concentration of the tracer component is increased by addition of natural elements in question in case of scandium and indium, whereas in case of iron, prominent change takes place by changing the concentration of the tracer component by the addition of natural elements. Values of the distribution factor are given below in Table IC.5.

Table IC.5

Distribution of ^{46}Sc, ^{114}In and $^{55,59}Fe$ with preformed $(NH_4)Tl(SO_4)_2\,4H_2O$ crystal and its saturated solution in 9N H_2SO_4, medium at different concentration of the guest in question at 15°C.

Guest in question	Initial conc. of the guest ion	Thallium in solid phase %	Tracer in solid phase %		D
(i) ^{46}Sc	1.5×10^{-7} M	44.2	56.4		1.63
		37.4	49.3		1.62
		28.0	41.2		1.80
		17.9	27.8		1.76
				Av.	1.70

Table IC.5 (*Continued*)

1	2	3	4	5
,,	3.6 × 10^{-3} M	42.7	58.9	1.92
		39.2	52.9	1.75
		29.0	43.5	1.88
		25.1	36.6	1.72
			Av.	1.82
(ii) ^{114}In	1.01 × 10^{-1} M	48.60	11.75	0.1408
	..	42.05	9.70	0.1481
		36.70	7.50	0.1402
		28.30	5.80	0.1561
			Av.	0.1463
,,	1.74 × 10^{-4} M	47.84	11.6	0.142
		44.00	9.2	0.130
		34.10	7.1	0.148
		22.40	4.0	0.144
			Av.	0.141
(iii) ^{55,59}Fe	5.7 × 10^{-4} M	48.84	11.30	0.1325
		44.14	8.70	0.1207
		36.00	7.36	0.1431
		26.26	4.50	0.1320
			Av.	0.1321
,,	1.43 × 10^{-2} M	44.73	11.8	0.1653
			Av.	0.1536
		25.04	5.0	0.1576
		30.30	6.3	0.1546
		39.50	8.2	0.1370
,,	1.1 × 10^{-1} M	48.38	21.2	0.2870
			Av.	0.2805
		23.15	7.9	0.2847
		35.45	13.1	0.2794
		43.20	17.1	0.2711

A glance at Table IC.5 will show that the values of the distribution factors in case of scandium and indium as guests remain near about the same, both at finite and tracer concentrations, whereas a prominent change is observed in case of iron as guest when the guest ion concentration is changed. Fractional isolation of ammoniumdiferrisulphate by breeding on thallic ammonium sulphate tetrahydrate has been made. Chemical composition of the guest in question constituting about 11.4 mole percent of the guest corroborates with that of the host. This fractional isolation gives an evidence that it is a case of normal mixed crystal formation though there is change in distribution factor with change in concentration of the guest. Discrepancy in case of iron has been explained in terms of solution complexities at tracer concentrations whereas the same value at tracer and finite concentrations in case of indium and scandium gives an indirect evidence that disulphato thallic thallium can stabilise analogous ionic species of scandium and indium. Ionic radii of these four elements are also in favour of such a picture.

B. C. Purkayastha and D. K. Bhattacharyya

1C.6 *On the Study of the Uptake of Strontium Tracer by Different Forms of Calcium Sulphate*

It was reported previously (Annual Report, 1966) that an apparatus has been devised to isolate the solid phase and wash it free from the mother liquor at the temperature at which the solid phase is crystallised and to dry the product in question at the same temperature. Our preliminary study on the coseparation of strontium tracer was based on physical data collected by us and by other workers. From these observations (*J. Ind. Chem.Soc., 43,* 687, 1966) we assumed that any phase precipating in between 45° and 72°C would be anhydrite. With the apparatus as mentioned, we crystallised calcium sulphate at 55°C and on analysis of the solid phase we found that it was not anhydrite but the composition corroborated with that of gypsum, $CaSO_4$, $2H_2O$. This observation is, however, contrary to all previous studies. We prepared gypsum at a lower temperature and it was subjected to dehydration at different tmperatures and found that up to 65°C it did not lose any water, though the sample was continuously heated at the temperature in question for a period of seven hours. From these observations it became clear that the transition from gypsum to anhydrite does not take place at 42°C. But the physical evidence as described by us refers to a transition at about 40°C (*J. Ind. Chem. Soc., 43,* 687, 1966). A preliminary X-ray study shows that the structure above 45°C is different from that of gypsum though the chemical compositions are the same. The solid phase crystallising in between 45°C and 65°C has different structure from that already

known for gypsum though the chemical compositions are the same. This particular characteristic of gypsum was thus far unknown and the study in details about this interesting aspect is still in progress.

Publication :

B. C. Purkayastha and Anita Chatterjee, *J. Ind. Chem. Soc., 44,* 130, 1967.

B. C. Purkayastha and Anita Dutta

Separation Chemistry

1C.7 *On the Study of Concentrating Rare Elements from the Mineral, Zircon*

In our previous communication (Annual Report, 1966) it was reported that about 90% of trace amount of pure scandium can be recovered from beryl and monazite. The study during the year was concentrated to the recovery of scandium from zircon of Indian origin. It has been found that the recovery of scandium is of the same order of magnitude as in the case of two other minerals mentioned above. The treatment consists mainly of the following procedure. A weighed amount of the mineral was taken in a silver crucible. A few drops of a solution containing ^{46}Sc was added. It was then subjected to fusion treatment by NaOH. After the fusion was over, the mass was treated with HCl, and SiO_2 was finally removed by $HClO_4$. Tetravalent ions were removed by precipitating as iodate in the conventional procedure. Scandium was taken up by using ceric pyrophosphate as carrier. Ceric pyrophosphate was then decomposed and ceric cerium was reduced and scandium was extracted out by TBP. Scandium was recovered from TBP in the usual way and the final yield was about 90%.

The main object of this study was to estimate scandium in the complex minerals through neutron activation. Extraction of scandium from other minerals will form the subject matter of further studies.

B. C. Purkayastha and N. R. Das

1C.8 *On the Study of the Recovery of Cesium from Molasses*

Study on the recovery of cesium from potassium salts was reported in the previous communication (Annual Report, 1966). The technique has been applied

to the recovery of cesium from molasses of Indian origin. The molasses contain about 5% potassium. ^{134}Cs has been used as an indicator for studying the extent of recovery of cesium. A typical procedure will specify the procedure adopted. 50 gms. of molasses were taken and ^{134}Cs was added. The molasses was decomposed in the wet way by nitric acid. Cesium from the clear solution was taken up by ammonium phosphomolybdate. The phosphomolybdate containing ^{134}Cs was as such dissolved in ammonia and cesium together with ammonium was recovered by passing through anion exchanger. The recovery is about 95%. The object is to estimate cesium by neutron activation in natural substances rich in potassium.

B. C. Purkayastha and Sunanda Aditya

1C.9 *Technical Development in Studies on Separation Chemistry*

Importance of a fraction collector in separation chemistry is well known. Description of different varieties are found in scientific literature. In view of the fact that fraction collectors can no longer be imported from abroad, we took recourse to design and construction of such an instrument in our laboratory. The instrument has been designed to operate automatically by electronic-mechanical devices. Most of the electronic circuits are transistorised.

The instrument consists of the following main units :

(i) electronic assembly,
(ii) rotating table which accommodates 144 test tubes, and
(iii) an assembly which runs a micro-pump for collecting the eluting solutions at a regular rate.

It has been found by experience that the instrument is very smooth running. Each part can be separated from the others in case of any repair. In case of a repair, it does not give us any trouble and in these respects this instrument is much more convenient than any variety of its kind purchased from abroad. A section of the assembly is shown in Fig. 1C.5 (*vide* p. 32).

M. N. Chandra

RADIATION CHEMISTRY

1C.10 *Radiation Chemistry of Aqueous Solution of Potassium Periodate*

In continuation of our studies on the radiation induced reduction of oxidising agents, the radiolysis of aqueous solution of potassium periodate was studied. Aerated aqueous solution of potassium periodate in neutral medium

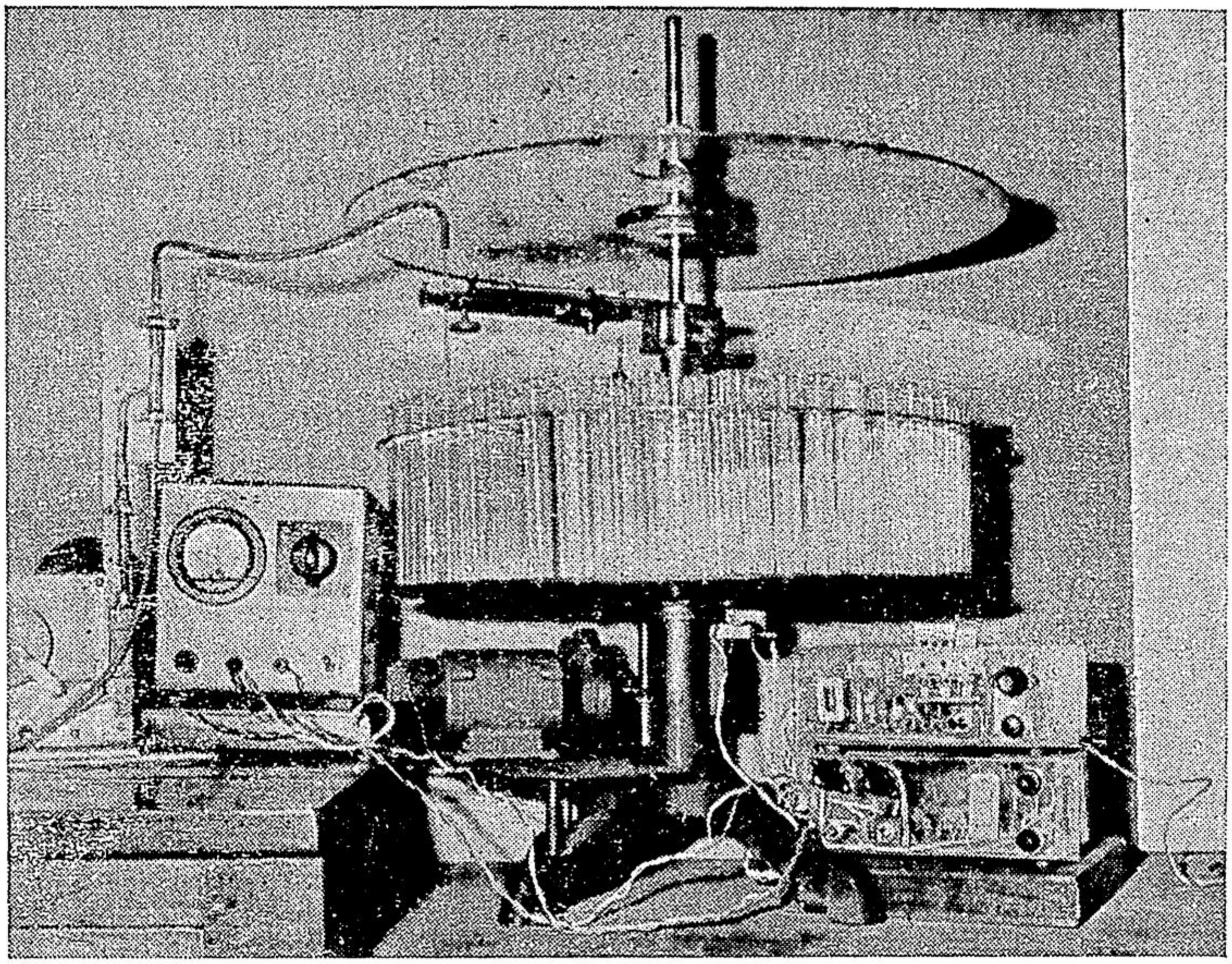

Fig. 1C.5 A photograph of the fraction collector.

was irradiated with ^{60}Co gamma-rays at the MARC. It was observed that the periodate on radiolysis is reduced only to iodate and no other reduction product was, however, detected. No H_2O_2 could also be detected in the medium after radiolysis. $G(-IO_4^-)$ was determined. Further studies are in progress to find more evidences in support of a proposed model on the mechanism of radiolysis of potassium periodate in aqueous solution.

S. N. Bhattacharyya and D. K. Bardhan

1C.11 *Chemical Dosimetry*

A critical survey of the work done on chemical dosimetry till recent days has been made. The characteristics that make up an ideal dosimeter have been discussed. The scope and limitations of the most popular Fricke dosimeter have been discussed at length. Several other systems that are used or are being tried for both low and high-dose measurements have been described. The prospects

of various systems of being good dosimeters have been discussed and it has been assessed that chemical dosimeters may in future replace the present day monitoring devices since they are simple, cheap and easy to handle.

Publication :

S. N. Bhattacharyya and K. N. Dutta, *J. Scient. Ind. Res.*, *26*, 147, 1967.

S. N. Bhattacharyya and K. N. Dutta

1C.12 *Radiolysis of Ferric Ethylenediaminetetraacetate*

It has been observed that ferric ethylenediaminetetraacetate on radiolysis in aerated aqueous solution in 0.1N H_2SO_4 is reduced and the chelate decomposition yield and the yield of ferrous iron formed in terms of molecules per 100 eV of energy adsorption were determined. Formaldehyde was also detected and analysed amongst the radiolytic products when aqueous solution of ferric ethylenediaminetetraacetate is irradiated with X-rays or gamma-rays. The appearance of formaldehyde amongst the radiolytic products may arise as a result of initial radical attack on the legand molecule of the metal chelate. This may bring forth an interesting evidence that in the metal chelate in question the legand molecule has a powerful shielding effect on the central metal ion and the chelate is decomposed as a result of preferential radical attack on the legand molecule rather than on the central metal ion. Work is in progress to arrive at a detailed mechanism to explain the mode of radiation induced decomposition of ferric ethylenediaminetetraacetate in aqueous solution.

S. N. Bhattacharyya and K. P. Kundu

1D. MASS SPECTROSCOPY AND OTHERS

1D.1 *Sputtering Experiments with Silver Single Crystals*

In continuation of our previous studies on sputtering phenomena, we measured the sputtering yields of a silver (110) bombarded by krypton ions in the energy range 4-10 keV at various angles of incidence. The results show definite minima in the yields at certain angles. This shows the effect of channeling of ions in certain axes in which they are focussed without much interaction with the lattice atoms, causing an appreciable sputtering effect. The results are compared with the theoretical model based on the work of Lindhard.

Experimental results are also obtained with ions produced with vapours of the solids as charge materials loaded in the oven of the ion source. Solids used were lithium sulphate, Pr-chloride, uranyl nitrate, etc. The former one shows no sputtering effect on silver. The latter two have also much less sputtering efficiency than the noble gas ions.

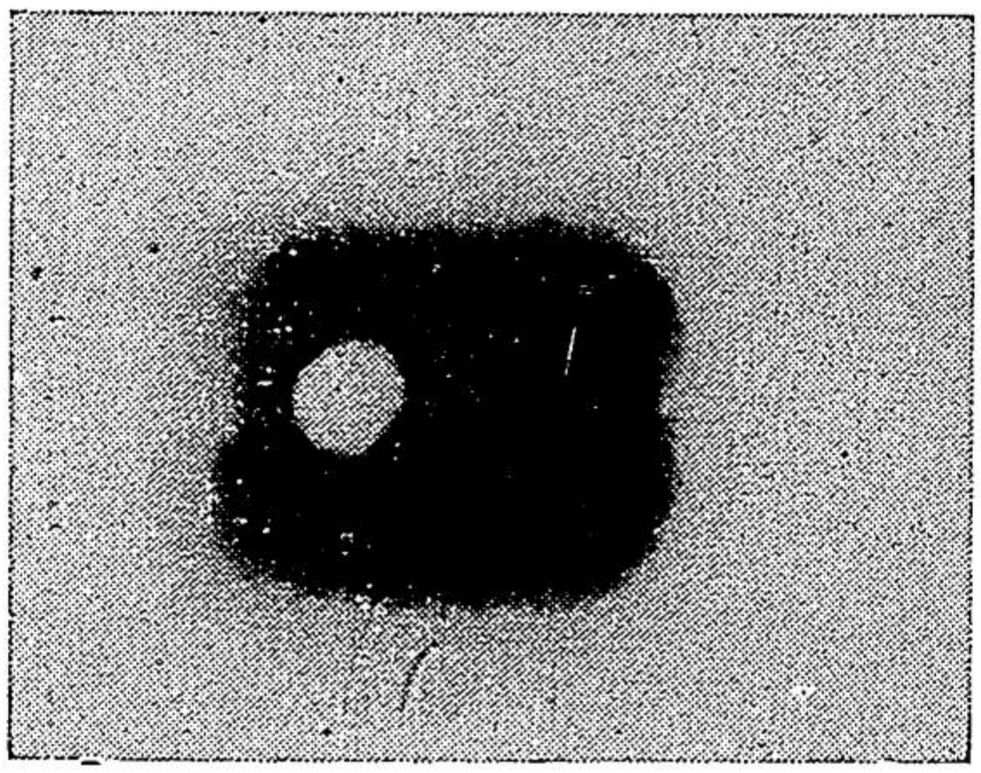

Fig. 1D.1 An autoradiograph of the deposit pattern of a silver (110) monocrystal bombarded by 5 keV krypton ion showing the preferential ejection in the closely packed directions.

Autoradiograph of the deposit pattern of the sputtered atoms from a silver (110) crystal was taken. The orientation shows similarity with the earlier observations at lower energy with the exception that at this higher energy the <110> spots are more intense (Fig. 1D.1).

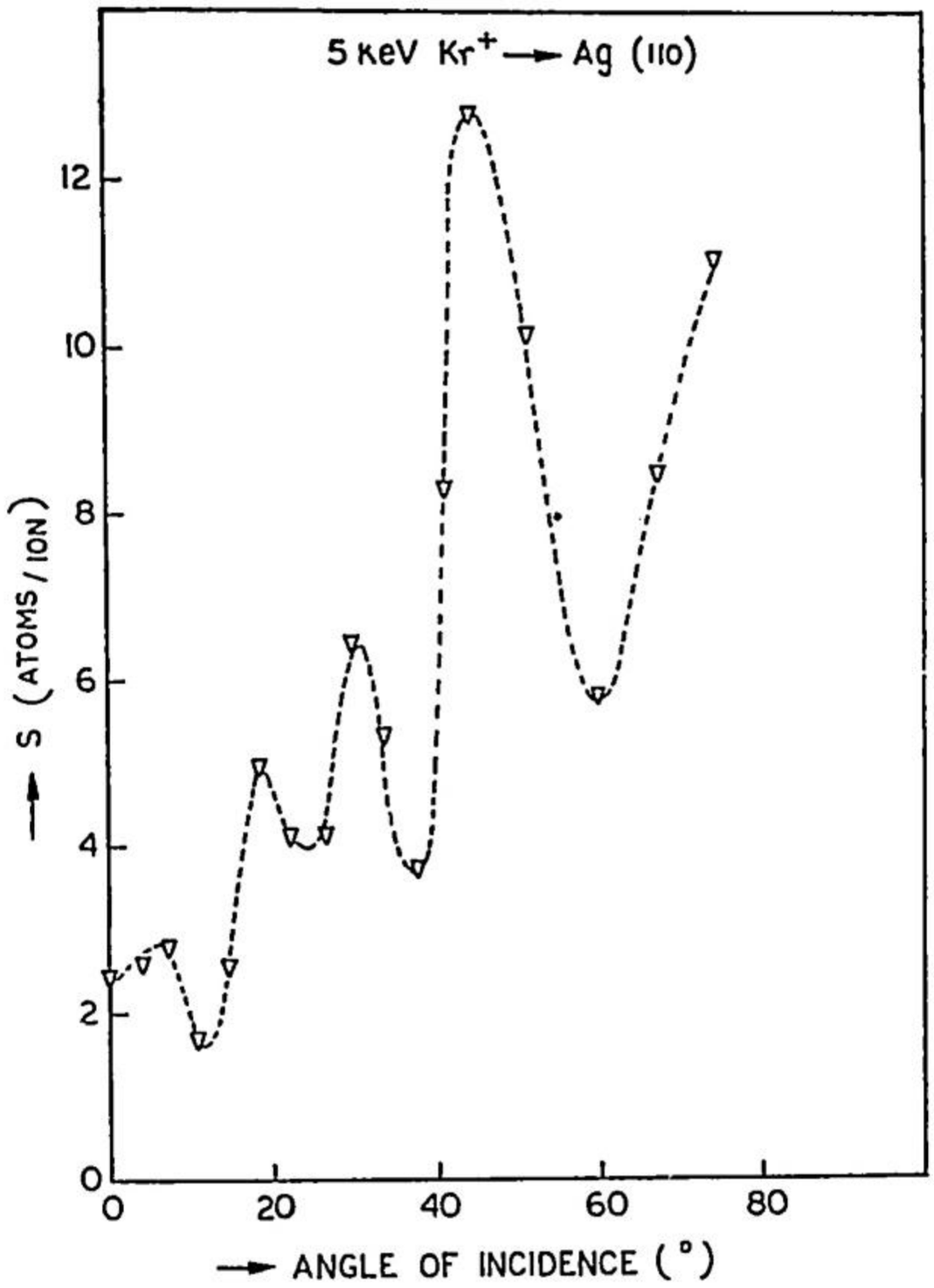

Fig. 1D.2. Variation of the sputtering yield with the angle of incidence shows the channelling effect of ions in the directions parallel to some axes of the silver (110) monocrystal bombarded by 5 keV krypton ions. The normal beam is perpendicular to the (110) plane and the angle of incidence is changed by rotating the crystal through an axis parallel to the (110) plane.

S. D. Dey and S. B. Karmahapatro

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

For studies on negative ions and ions produced as rare phenomena, a high sensitivity mass spectrometer has been designed. The magnetic analyser with 60° angle of deflection is constructed. The magnetic analyser produces B=6500 Gauss at 1.5 A with a stability of 0.5% in a magnetic field for a fairly long time.

The chamber, the electron multiplier detector and the vacuum system are under construction.

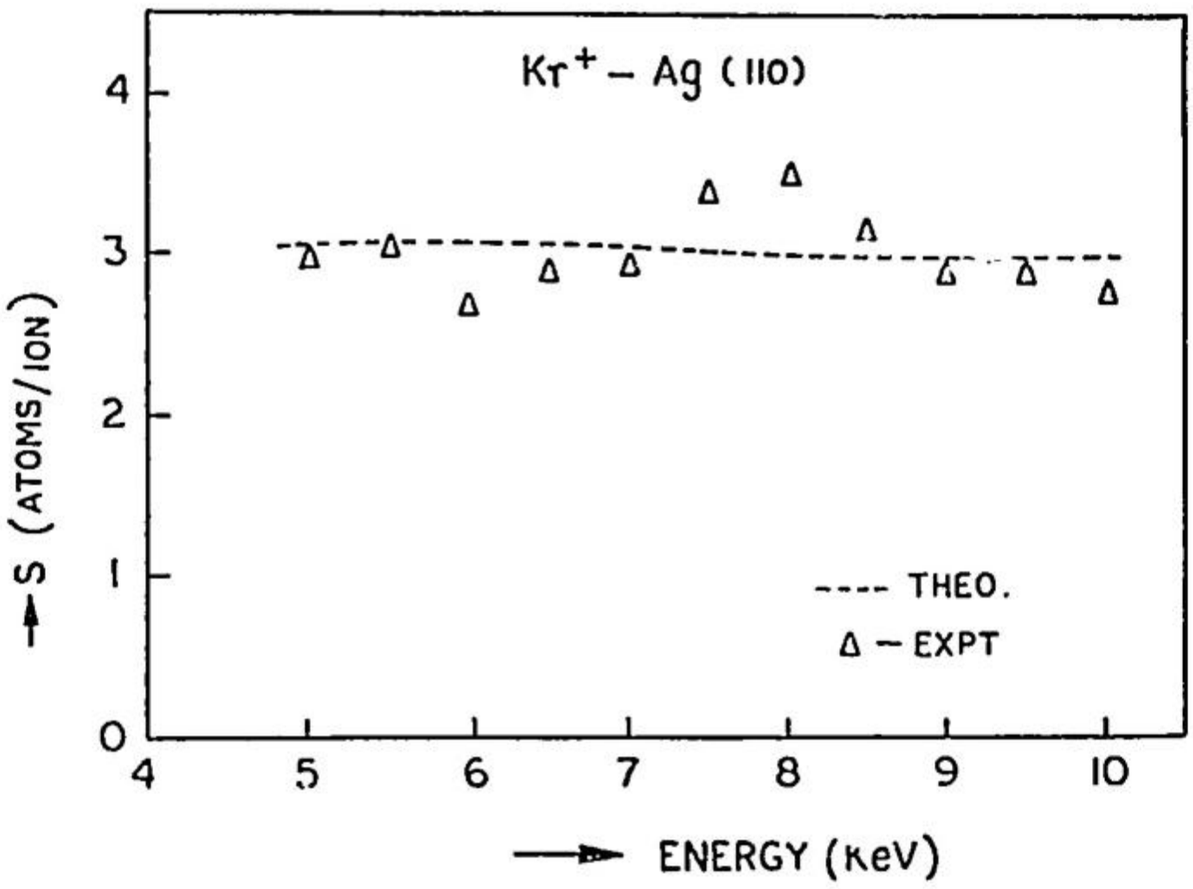

Fig. 1D.3. Sputtering yield of silver (110) at normal incidence of krypton ions for the energy 5 - 10 keV. Theoretical and experimental results are compared.
(*vide* Sec. 1D.1)

The thermal emission ion-source has been constructed. The ion-source has been tested with lithium and the rare earth elements which give a minimum 10^{-8} A unanalysed ion current.

Publication :

S. D. Dey and S. B. Karmohapatro, *J. Phys. Soc.* (*Japan*), *22*, 682, 1967.

S. D. Dey and S. B. Karmohapatro, *Proc. Int. Conf. Spectroscopy, Bombay, 1*, 38, 1967.

S. D. Dey and S. B. Karmohapatro, *J. Phys. Soc.* (*Japan*), *23*, 418, 1967.

S. D. Dey and S. B. Karmohapatro

1D. 3 *Design and Development of the Magnetic Shielding for Improving the Performance of the High Intensity Mass Spectrometer*

The performance of the high intensity mass spectrometer used for experiments in atomic collisions has to be improved for using the duoplasmatron ion-source from which the boundary of the magnetic field is nearly 28 cm and the stray magnetic field deviates the path of the ion beam before it enters the magnetic field. A magnetic field shielding iron structure is designed and developed for improving the performance of the instrument.

A cooling water tank is installed with a circulating system for proper cooling of the diffusion pumps and the duoplasmastron ion-source.

S. D. Dey and S. B. Karmohapatro

1D. 4 *Isotope Separator*

The high voltage supply for ion acceleration had a few breakdowns during this year. Certain components were repaired and some replaced. In spite of the above improvements, resolution was less than the desired value. Deterioration in the current regulation was found to be the cause. Effort has been directed to achieve the maximum possible degree of regulation and thereby attain a fairly high resolution even for closely spaced isotopes in the heavy-mass region of the periodic table.

D. Basu

1D. 5 *Decay of ^{92}Nb and ^{180}Lu*

A source of ^{92}Nb produced by ^{93}Nb (γ, n) ^{92}Nb reaction at the Yale University was available for studying some of the weak gamma-rays, indications of which have been found. Further confirmation is needed. Decay of ^{180}Lu produced by ^{180}Hf (n, p) ^{180}Lu reaction has also been studied. It seems to decay with two different half lives, one $\approx$ 4 min, another $\approx$ 11 min. Further work is in progress.

D. Basu

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

Studies on thermal neutron fission of ^{235}U with the help of a low pressure cloud chamber have been initiated. The instrument has been operated in conjunction with a back-to-back double ionisation chamber installed within the active volume of the cloud chamber. The counter acts as a primary detector of the fission events and the fission pulses after suitable amplication have been utilised to trigger the expansion mechanism of the cloud chamber and record the fission events photographically.

Several binary and ternary fission events have been photographed. The long range particles associated with the ternary events have been found to be consistent with the picture of alpha particle emission during the process of fission phenomena. More data is needed to make a detailed analysis of such long range alpha emission processes. Work is in progress in this field.

M. Rama Rao

1D. 7 *Studies on a Delay Line Oscillator*

Characteristics of oscillation of an oscillator with a lumped delay line in the feedback path have been studied under free and forced conditions. It has been found that, only odd harmonic frequencies are excitable in the oscillator along with the fundamental frequency when executing self-oscillation. The characteristics of the oscillation have also been studied when a forcing signal is introduced externally in addition to the self-oscillation. It has been found that when the forcing signal frequency is synchronised to one of the possible harmonic frequencies of the oscillator, the amplitudes of the fundamental and of the forcing signal frequency oscillation show hysteresis and jump phenomena. Some of these synchronisation techniques have been suggested for the construction of multimode frequency memory. Theoretical results have been verified experimentally by constructing model oscillators.

(D. N. Basu Mallik and B. R. Nag, 'Free and Forced Oscillations in a Delay Line Oscillator', to be published in *International J. Electronics*.)

D. N. Basu Mallik

2A. NUCLEAR PHYSICS DIVISION

2A.0 *Introductory Remarks*

An important event in the current year is the creation of a new division named the division of crystallography and molecular biology, which has been put under the leadership of Prof. N. N. Saha. The report of the work done by this division has been separately given by Prof. N. N. Saha. The services of Prof. P. Mukherjee have been transferred to the Accelerator Division.

A brief report of the work of this division is given here. The group of Dr. R. L. Bhattacharyya working on nuclear spectroscopy has made a detailed performance study of the pair spectrometer whose construction was reported last year. This group is also making regular g-factor measurements using magnetically perturbed angular correlation studies. They have also developed converters for electron conversion studies. There has also been some nuclear shell structure calculations on ^{116}Sn and ^{4}He. Prof. D. K. Roy's group was primarily interested in the application of the double time Green's function technique to various problems of solid state physics, particularly relaxations and self-energies of spins interacting with lattice phonons, and thermal conductivity of magnetic systems. Some realistic calculations based on neutron scattering data in MgO have been carried out by them using this formalism. This group has also studied the effect of crystalline electric field on magnetic and thermal properties of rare earth metals and some work for symmetrisation of the orbitals for these systems have been carried out. Dr. A. Mukherjee's group has continued the self-consistent calculation of dynamic polarisability of some light atoms. They have also carried on self-consistent calculations of Van der Waal force constant in a number of systems. They have also developed a method of estimating excited p-state wave-function from dynamic polarisabilities of some simple atoms. They have continued their calculations of electrostatic polarisability and nuclear shielding in a number of closed shell ions. Dr. A. Chakravarty has continued the work on octahedral complexes of transition metal ions by calculating the oscillator strengths of magnetic dipole transitions. He has calculated a theory of magnetic anisotropy and susceptibility of cubic $^{5}T_2$ term in transition metals. A review is being prepared of the absorption spectra of complexes of rare earth ions with the object of determining the effect of vibronic interactions. Dr. S. K. Sinha has further applied a gauge variation method to study diamagnetic susceptibility and proton chemical shift of H-atom in external uniform electric field. Prof. D. K. Ghosh's group reported last year on the measurement of the microwave absorption spectra of ethylamine in the range 18 kMc – 26 kMc (barring the range 20.5 kMc – 21.5 kMc). A detailed theoretical analysis of the spectra is still being carried out. The micro-wave spectra of thioacetic acid in the same frequency range has been completed, which is now being interpreted theoretically. The micro-wave spectra of trichloroethylene has been worked out theoretically in this range and is being compared with experimental observations.

In view of the effect that infra-red spectroscopy is supplementary to micro-wave spectroscopy, a feasibility report is being drawn up for the construction of a suitable high resolution IR spectrometer in our Institute. Prof. R. N. Ray's group in collaboration with Dr. S. K. Sinha has continued analysis of ESR spectra of polycrystalline samples of $CuSO_4$, $5H_2O$ and Cu-complexes of onithine chloride and lysine hydrochloride. They have also planned to detect variations of J-coupling at two non-equivalent sets of the Cu^{++} ions in $CuSo_4$, $5H_2O$. The development work of this group regarding the construction of a UHF ESR spectrometer in the range 300 Mc and a K-band superheterodyne ESR spectrometer has been severely handicapped due to lack of foreign exchange. This group reported the construction of 3-rotation goniometer for NQR studies. This has been used with a NQR spectrometer presenting second derivative spectrum to study a number of Cl – containing systems. Morino and Toyama's method is also being used to determine η. values from powdered samples. The values so obtained are checked against values obtained for single crystals by the method developed by this group. Dr. S. K. Sinha has made further progress in setting up his instrument for the study of acoustic magnetic resonance. Prof. M. Bose has written a review article on "Nuclear Magnetic Resonance in Magnetic Materials". Her group has continued high resolution NMR studies by examining the effect of solvent interaction on 2-amino-pyridine. They have also measured T_1 in methyl pyridine. They have continued their ^{31}P resonance work in a number of solid samples of rare earth phosphates and Co-phosphates. Efforts are being made to make the high resolution NMR spectrometer available for analytical purposes for workers outside the Institute.

Due to continuance of severe foreign exchange shortage all through the current year it was not possible to take up major constructional programmes of instruments. For next year it is planned that a start would be made in the construction of an infra-red spectrometer and a K-band superheterodyne electron spin resonance spectrometer. Attempts are also being made to obtain a multichannel analyser for the division and a liquid-He plant for the Institute. If these attempts succeed, a Mössbauer spectrometer will be constructed next year.

A. K. Saha

2A.1 *Nuclear Structure Calculations on Low-lying Levels of ^{116}Sn*

Nuclear structure calculations on low-lying levels of ^{116}Sn have been done in the hole-particle model. In these calculations the proton excitations have been neglected and only neutron excitations have been considered. Recent experimental findings also support this assumption. The ground state neutron configuration is taken to be $(1g_{7/2})^8(2d_{5/2})^6(3s_{1/2})^2$. Excited states are formed by exciting a particle from these levels to higher levels in the same shell or in the next major shell. Calculations for the first 2^+ and second 2^+ states were carried out, using a δ-function interaction and considering three possible hole-

particle configurations. Agreement between theoretically calculated level positions and E2 and M1 transition probabilities and the experimental values are quite satisfactory.

Calculations for the 3^- and 5^- states have also been undertaken, using a δ-function interaction. For the 3^- and 5^- states we have considered 14 and 11 possible configurations, respectively. A computer programme for diagonalising the 14×14 and 11×11 matrices, in connection with these calculations, has been prepared and the calculations will be completed shortly.

Publication :

S. Sen, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 281.

S. Sen and B. K. Sinha

2A.2 *On the Odd-parity States in ^{4}He*

Taking one-hole one-particle configurations up to 2p shell and employing various exchange mixtures the odd-parity states $J = 1^-$ $(T = 1)$ and 0^-, 2^- $(T = O)$ in ^{4}He have been calculated. The ratio $B(E1')_{1'^- \to 0^+} / B(E1)_{1^- \to 0^+}$ is found to be 0.312 for the Serber-Yukawa force, compared to the exjerimental value 0.5.

Publication :

S. Shastry and M. L. Rustgi, *Phys. Letters, 25B*, 391, 1967.

S. Shastry

2A. 3 *g-Factor Measurements on ^{187}Re and ^{125}Te*

The 686 keV $5/2^-$ state of ^{187}Re decays as a pure E2 479 keV γ-transition to the 206 keV state having a half-life of 535 ns. The g-factor of the 206 keV level was measured by perturbed angular correlation technique using the differential delay constant angle method at a magnetic field of 3100 Gauss. Coincidences between the 479 and 72 keV γ-rays were observed at 135° with field up and down positions. The value of g was found to be 1.15.

Preliminary measurements on the 462 keV state of ^{125}Te were made by observing the coincidences between the 175 and 427 keV γ-rays at a magnetic field of 21,000 Gauss. The half-life of this state was measured to be 0.45 ns in a separate set-up using plastic phosphors. The estimated value of g in these measurements was 2.1 with large error. Further experiments are in progress.

A. K. Nigam and R. Bhattacharyya

2A.4 *Performance Studies on Pair Electron-spectrometer*

The performance of the pair electron-spectrometer was standardised with the help of conversion electron and β-spectra of several isotopes. In the course of such studies it was found that 100% detection efficiency of the spectrometer is obtained at an electron energy of 125 keV. The electron detector system, now consisting of RCA 6655 photomultipliers, coupled to plastic phosphors with the help of logarithmetic spiral type light guide needs replacement by better photomultipliers and anthracene phosphors to improve the S/N ratio and to push the energy of 100% transmission down. The effect of magnetic field on the detectors corresponding to maximum current allowable in the magnet coils (corresponding to 1.5 MeV electron energy) was found to be negligible.

Coincidence studies with these spectrometers have shown encouraging results. However, improvements are being incorporated to obtain shorter resolving time with the detector pulses up to 100 mV amplitude. To this end, transistorised limiter circuits capable of limiting pulses of minimum 100 mV amplitude and coincidence circuits having $2\tau = 10$ ns are being used.

These spectrometers are being used for investigations on ce-β, ce-γ, etc., coincidences. Studies on ce-γ and β-γ angular correlation have also been undertaken.

S. Sen and R. Bhattacharyya

2A.5 *Internal-external Conversion Studies at Low Energy*

For IEC studies at low energies with the magnetic β-spectrometer very thin GM counter windows are necessary. To reduce straggling and consequent degradation in energy within the converter which is used for external conversion of γ-rays, we also need very thin converters. To meet these requirements,

(a) we have been able to prepare mylar films of thickness down to 250 μgm/cm^2 by dissolving mylar sheets in carbolic acid, spreading it on a known area and evaporating the acid away; polythene films of similar thickness have also been prepared in the same way by dissolving it in dekalin, and

(b) thin U-converters have been prepared from uranium loaded colloidion by spreading it on water. Thickness of such films can be controlled easily. A 1 mg/cm^2 converter has been tested for external conversion efficiency with satisfactory results upto γ-energies of 662 keV.

B. K. Sinha and R. Bhattacharyya

2A. 6 *Fast Coincidence Devices*

Transistorised limiters and coincidence circuits referred to in 2A.4 was developed using RCA 2N828 pnp transistors constructed on printed boards. The limiter has a sensitivity of 250 mV normally. When preceded by a fast amplifier of nominal gain, this sensitivity can be pushed down below 100 mV. A resolving time of 10 ns was obtained with this arrangement.

For measurements of the g-factor of levels having half-lives upto 0.5 μ sec, referred to in 2A.3, a time-to-amplitude converter was constructed. The time scale was generated by a suitable transistorised sweep circuit. A resolving time of 5 ns for ^{60}Co gamma rays detected in NaI (Tl) phosphor was obtained.

S. Sen, B. K. Sinha and A. K. Nigam

2A.7 *Theoretical Investigations into Various Aspects of Spin-lattice Relaxation in Paramagnetic Crystals*

(i) In order to explain the unusual behaviour of spin-lattice relaxation at very low temperature, generalized expression for the life-time of spins in cubic crystals have been obtained by using the double time Green's function technique.

D. K. Ray

(ii) For spin $s>1/2$, solutions of rate equations combined with perturbation calculation give multiple relaxation times for cubic crystals. Green function treatment of the life-time of spins has been done and this shows a phonon averaging process resulting in a single relaxation time.

D. K. Ray

(iii) Anisotropy of the spin-lattice relaxation in cubic crystals due to the orientation about the Zeeman field has been investigated for a number of ions in MgO crystal. The results will have interesting bearing on the maser operation of certain ions.

(D. K. Ray, T. Ray and S. K. Gupta, 'Theoretical Investigations on the Anisotropy of the Spin-Lattice Relaxation in Paramagnetic Crystals', to be pub-

lished in *J. Appl. Phys.*, also reported in *International Congress on Magnetism*, Boston, 1967.)

Publication :

T. Ray and D. K. Ray, *Phys. Rev.*, *164*, 420, 1967.

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

(iv) The temperature dependence of two phonon spin-lattice relaxation in MgO crystal has been worked out on the basis of phonon distributions as rcently obtained from neutron scattering experiments.

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

2A.8 *Effect of Spin-Phonon Interaction on the Self-energy of Spins in Paramagnetic Crystals*

Contribution of single and two phonon processes to the self-energy and hence to the g values of Kramer's doublets in cubic crystals has been investigated using double time Green's function technique. Results indicate that for a number of rare earth ions the single phonon contribution is not negligible.

Publication :

Santosh Kumar and D. K. Ray, *Phys. Rev.*, *164*, 424, 1967.

S. K. Gupta and D. K. Ray

2A.9 *Thermal Conductivity in Magnetic Systems*

As a first step to the theory of thermal conductivity in magnetic systems, contribution to the thermal current from spin-phonon scattering in paramagnetic systems has been worked out using Green's function. The resonant behaviour of the thermal conductivity for $kT \approx \frac{h}{2\pi}\omega_0$, ω_0 being the Larmor frequency, opens up the possibility of using thermal conductivity as one of the most sensitive techniques for studying paramagnetic systems.

K. C. Das and D. K. Ray

2A.10 *Investigations into Magnetic and Thermal Properties of Rare Earth Metals*

Magnetic and thermal properties of rare earth metals are determined to a considerable extent by the crystalline electric field at the rare earth sites. Various contributions to this field are being investigated.

K. C. Das and D. K. Ray

2A.11 *Band Calculations for Rare Earth Metals*

APW method is being applied to study the energy bands in rare earth metals. Problems associated with symmetrization of orbitals are being investigated.

Aparna Ghosh, K. C. Das, T. Ray and D. K. Ray

2A.12 *Effect of the Ligand Charge Distribution on the Crystalline Electric Field of Rare Earth Ions*

The investigation on the effect of the ligand charge distribution on the crystalline electric field of rare-earth ions in $PrCl_3$ crystal was completed. The calculation shows that the usual belief that the ionic model of crystalline electric field holds better in rare earth ions does not stand close scrutiny and for proper estimation of the crystalline electric field parameters in rare earth ions, one has to make a detailed molecular orbital treatment, allowing for covalency.

Publication :

A. K. Raychaudhuri and D. K. Ray, *Proc. Phys. Soc.*, *90*, 839, 1967.

A. K. Raychaudhuri

2A.13 *Magnetic Properties of Transition Metal Ion Cubic $^5T_2$ Terms in Axial Ligand Fields*

(i) *Magnetic anisotropy and principal magnetic susceptibility*

The theory of magnetic anisotropy and susceptibility of cubic $^5T_2$ terms, whose degeneracy has been lifted by a ligand field component of axial (tetragonal or trigonal) symmetry as well as by spin-orbit coupling has been worked out using the method of Abragam and Pryce. The influence of covalency of the metal-ligand bond and its anisotropy has been incorporated. The results are presented in numerical and graphical form and compared with the experimental data available for iron (II) compounds. Molecular parameters are deduced and a change of the anisotropic part of the crystal field with temperature is confirmed although more accurate magnetic measurements are needed.

(ii) *Average magnetic susceptibility*

Results and calculations of the effective magnetic moment for d^6 ions with a cubic $^5T_2$ ground state in axial ligand fields are presented both in numerical and graphical form. The diagrams given may be used for direct comparison with experimental moments plotted as function of temperature and the molecular parameters Δ, λ and k may readily be determined.

Experimental investigations of the magnetic behaviour of high-spin iron (II)-bis (1, 10-phenanthroline) complexes are reported and the results compared

with the theory. Accordingly, the moments of compounds [Fe $phen_2$ X_2], where X = Cl^-, Br^-, $N3^-$ and OCN^-, are compatible with $\lambda = -80$ cm^{-1}, K = 0.8 and a trigonally distorted ligand field of $\triangle$–values between –800 and –2000 cm^{-1} [Fe $phen_2$ $(HCOO)_2$] is apparently tetragonally distorted, having $\triangle = 2000$ cm^{-1}.

A. S. Chakravarty

2A.14 *Magnetic Dipole Transitions in the Octahedral Complexes of the Transition Metal Ions*

The oscillator strengths of the magnetic dipole transitions in the octahedral complexes of the transition metal ions have been calculated using the strong field wave-functions.

The oscillator strength for the magnetic dipole transitions is given by

$$f = \frac{h\nu}{6mc} \sum | < n | \vec{L} | m > |^2$$

where m and e are the electronic mass and charge, c is the velocity of light, ν is the energy difference (in cm^{-1}) between the ground and the excited state and L is the angular momentum operator. $\Sigma|L|^2$ refers to the sum of the squares of the matrix element of the angular momentum (in units of $(h/2\pi)^2$ between the components of the ground state and each of the components of the excited state.

We have calculated the above matrix elements for the different ions using the determinantal wave-functions in the strong field approximation. ν has been taken from the experiment.

A. S. Chakravarty

2A.15 *Additional Contribution to the Paramagnetic Susceptibility from High Frequency Elements from outside the Ground Configuration.*

It is customary to refer to that part of χ, the susceptibility, which arises from matrix elements of $\beta H (\vec{L} + 2\vec{S})$ between states which are thermally occupied and those which are not appreciably so, as arising from high frequency elements. This is temperature independent apart from the Boltzmann factor dependence.

Let us consider first that we have a determinantal function $|\psi o>$ belonging to t_{2g}^n, then the relevant high frequency contribution to χ is

$$\chi_n = \frac{2N\beta^2}{3} \sum_n \frac{| < \psi_n | \vec{L} + 2\vec{S} | \psi_o > |^2}{E_n - E_o}$$

where the sum runs over all excited configurations. Now $\vec{L}+2\vec{S}$ is an one electron operator and therefore the only non-vanishing elements arise from $|\psi_n>$ in $t_{2g}^{n-1}\ e_g$. Further $\vec{S}$ has no matrix elements between configurations because of orthogonality of the spatial functions. Our final expression is, therefore.

$$\chi_h = \frac{2N\beta^2}{3}\sum_{-}^{\neg} \frac{|<\psi_n|\vec{L}|\psi_o>|^2}{E_n}$$

where E, the difference in energy between ground and excited state, has to be found out from experiment. We are working with octahedral complexes of the transition metal ions and strong field wave functions.

V. P. Desai and A. S. Chakravarty

2A.16 *Absorption Spectra of Complexes of Rare Earth Ions*

A study of absorption spectra of complexes of rare earth ions is undertaken, with the main emphasis being on the effects of vibronic interaction. The vibronic coupling between modes of crystalline symmetry allows certain transitions which are otherwise forbidden. The existing literature on this topic is being reviewed.

V. P. Desai and A. S. Chakravarty.

2A.17 *Self-consistent Calculation of Dynamic Polarizability*

We have developed a method for self-consistent calculation of dynamic polarizability. At present we are extending our calculation to Li^+, Be^{++}, Be, Ne and Ar (including members of their iso-electronic sequence). No quantum mechanical calculation in this line has yet been reported for Ne and Ar. As such our theoretical results will provide a check on the experimental values.

Publication :

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

S. Sengupta and A. Mukherji

2A.18 *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.

(S. Sengupta and A. Mukherji, 'Self Consistent Calculation of Van der Waals Force Constant', to be published in *Phys. Rev.*)

S. Sengupta and A. Mukherji

2A.19 *Self-consistent Excited p-State Wave-function*

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 points of discontinuity in the dynamic polarizability expression caused by the $1s^2$-1s np transition. The wave-function obtained by this procedure will still further be improved, correcting for error inherent is Koopman's theorem. At present we are studying the self-consistent 2p wave-function of helium.

P. Mukherjee, S. Sengupta and A. Mukherji

2A.20 *Electrostatic Polarizability and Nuclear Shielding*

Dipole and quadrupole polarizabilities and shielding factors for 18-electron closed shell ions from Cl^- to Ca^{++} have been calculated following the self-consistent perturbation procedure. Interpolation relations correlating these quantities to the radii of maximum electron density of the ions have been obtained. These relationships may be used to assess the true polarizabilities and nuclear shielding (or antishielding) for such ions in actual crystals.

Publication :

J. Lahiri and A. Mukherji, *Phys. Rev., 155,* 24, 1967.

J. Lahiri and A. Mukherji

2A.21 *Microwave Spectra of Ethylamine*

Detailed theoretical analysis of ethylamine molecule is still being worked out. The presence of large numbr of lines exhibited by ethylamine molecule which is an asymmetric rotor, may be attributed to the splitting due to internal rotation in the molecule and due to inversion doubling. In order to calculate bond lengths, bond angles and barrier to internal rotation a complete programme has been written.

Publication :

D. K. Ghosh, A. Chatterjee and A. K. Saha, *Ind. J. Phys, 41,* 467, 1967.

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

2A.22 *Microwave Spectra of Thioacetic Acid*

The spectrum of thioacetic acid was observed in the 18 kMc-26 kMc. The sample was purified by repeated distillation. Accurate frequencies of absorption lines were measured after calibration with methyl alcohol lines.

A preliminary theoretical computation was performed. Assuming structural parameters from electron diffraction data, various barrier lengths to internal rotation were tried and transition predicted. A value of barrier height roughly near that of acetic acid gave fairly good agreement between the theoretical prediction and experimental observation.

In the computations only second-order perturbation was used. Results show that fourth-order perturbation treatment will have to be incorporated for better agreement. The work is in progress.

A. Chatterjee and D. K. Ghosh

2A.23 *Microwave Spectra of Trichloroethylene*

The theoretical calculation of possible transitions and corresponding frequencies of this asymmetric molecule in the K-band (18 to 26 kMc) region has been done, assuming structural parameter from electron diffraction data. There are three Cl-nuclei having appreciable quadrupole moment which will yield h.f.s. to the rotational spectrum. The Stark components of the rotational levels are likely to be modified due to the coupling of the nuclear spin and total angular momentum. The experimental work is in progress.

R. Nandi and A. Chatterjee

2A.24 *Diamagnetic Susceptibility and Proton Chemical Shift of Hydrogen Atom in External Uniform Electric Field*

Using the "Guage-Variation" method, the diamagnetic susceptibility and proton chemical shift have been calculated for hydrogen atom when the latter is placed in an external uniform electric field. This formulation indicates that the value of the larger portion of the second-order paramagnetic part will remain uncertain if the calculation is performed with a ground state wave-function obtained from energy-minimization principle.

S. K. Sinha and S. K. Mondal

2A.25 *Acoustic Magnetic Resonance*

Acoustic magnetic resonance experiments reveal the details of the spin-lattice coupling, and a part of the apparatus needed for these experiments has been assembled.

To measure the acoustic properties of the samples for such experiments, the pulsed rf generator (1-14 Mc) and a pulse receiver have been set up, which forms a part of the complete pulse-echo apparatus. A suitable "probe" for holding the "sample" has been designed and constructed. The dewars necessary for low temperature measurements have also been set up.

A test sample of single crystal MgF_2 has been prepared. Two parallel faces (parallelism better than 1mm of arc) have been cut and polished optically flat (correct to $\lambda/2$). The direction perpendicular to these faces was fixed to be (111), using the X-ray black-reflection method. 8 Mc X-cut quartz transducers have been mounted onto the faces using araldite as the bonding material; the nonaq bond has also been tried. Preliminary measurements are being tried with this sample using the "Q-meter method".

Some quantum statistical analysis of the effect of the spin-phonon interaction on such experiments has also been done.

S. K. Sinha

2A.26 *ESR Spectroscopy*

The analysis of ESR spectra obtained from polycrystalline samples of $CuSO_4$, $5H_2O$ is in progress. The evaluation of the 'g' tensor components from the recorded line shapes needs programming in a computer and a process of iteration has been worked out, following Johnston and Hecht (*J. Mol. Spectroscopy, 17,* 1965). A similar analysis of the ESR spectra from Cu-complex of onithine chloride and lysine hydrochloride for the determination of 'g' tensor has also been taken up.

Recent proton NMR studies on $CuSO_4$, $5H_2O$ single-crystal (S. Wittekoek and N. J. Poulis, *Physica, 32,* 693, 1966) indicate that Cu^{++} ions occupying (O, O, O) positions behave as an antiferromagnetic linear chain below 3°K, while those occupying (1/2, 1/2, 0) positions remain paramagnetic down to very low temperatures (<0.1°K). In terms of exchange coupling this indicates that J for the above two non-equivalent positions are different and the whole assembly of Cu^{++} ions behave as two weakly interacting subsystems. Since this behaviour is not generally observed, we have planned to measure J from ESR line shape studies following the method of Anderson and Weiss (*Rev. Mod. Phys. 25,* 267, 1953).

For this experiment, $CuSO_4$, $5H_2O$ single crystals have been grown from

solution to a suitable size. The faces developed have been checked by a preliminary orientation study in a two-circle optical goniometer. These preliminary studies have been used to determine the directions of the crystallographic axes by comparison with previous structural studies of this crystal (C. A. Beevers and H. Lipson, *Proc. Roy. Soc.*, (*L*) *A 146*, 570, 1934; D. J. Fisher, *American Mineralogist*, *37*, 95, 1952). The theoretical computation of the fourth moment of tht ESR line shape, as required in Anderson-Weiss method, has also been started.

Studies of ESR in single crystals need the fabrication of a high 'Q' cavity —a cylindrical TE_{011} mode resonator with waveguide-feed from the top. A transition section incorporating a taper section from X-band dimensions to K-band dimensions, filled with styron 666 dielectric has been fabricated. However, the absorption of microwaves in the said dielectric seems to be a handicap in its utilisation in the spectrometer. Attempts are being made to use 'steatite' as dielectric in the tapered waveguide unit, which will obviate this difficulty in the feedline. The development of a 400 cps field modulation system together with the lock-in-amplifier system for the second derivative presentation of ESR signal was withheld for non-availability of a dual-channel pen recorder.

The development of an ESR spectrometer at uhf around 300 Mc is in progress. The fabrication of the tuned-plate-tuned-cathode type uhf oscillator operating at 300 Mc is complete. The Zeeman field required will be supplied by a pair of Helmholtz coils yielding 160 Gauss/Amp. This spectrometer will be useful for the detection and study of ESR in aqueous solution and specially that obtained from free radicals in biological samples.

The plan and design of a K-band superheterodyne ESR spectrometer is ready. This spectrometer will be useful for the detection of narrow absorption lines obtained from liquid samples and would give a better S/N ratio than that in the X-band system. In this system two K-band klystrons (2K33 B) will be used. The frequency of one klystron will be approximately 30 Mc off from that of the signal klystron and this 30 Mc difference will be maintained by an electronic interlock device; on the other hand, the frequency of the signal klystron will be locked to that of the resonant frequency of the sample cavity by an automatic frequency stabilization system operating at 10 kc. Magnetic field modulation and the P.S.D. system will be developed at about 80 cycles.

Publication:

A. K. Roy, R. Roy and S. K. Sinha, *Proc. Nucl. Phys. Sol. St. Phys. Symp. Kanpur*, 1967, p. 118.

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

2A.27 *NQR Spectroscopy*

Studies on nuclear quadrupole resonance on ^{35}Cl nuclei in sodium chlorate single crystal was handicapped for the dearth of a large single crystal. Recently a single crystal of $NaClO_3$ of size 1.4 cm × 1.2 cm × 1.2 cm has been grown from saturated solution with the help of a crystal plant (ref. 2A.26). Studies on the determination of crystal parameters such as η and eq. Q from Zeeman split spectra with a goniometer device, allowing rotation of the single crystal around three mutually perpendicular axes, are in progress.

Determination of the asymmetry parameter η from the Zeeman split NQR signal pattern from polycrystalline samples containing $I=3/2$ nuclei has been started. The experimental method consists of (i) the application of a low Zeeman field in the same direction as that of the rf. field (Morino and Toyama, *J.C.P.*, *35*, 1289, 1961) and (ii) the recording of the split NQR signal in the second derivative presentation.

The value of η obtained from powder samples of chloranil ($C_6O_2Cl_4$) has been found to tally with that obtained from single crystal studies. Powder samples of antimony chloride ($SbCl_3$) and frozen (polycrystalline) samples of transdichloroethylene are now being studied by the same method for the estimation of the value of η and its dependence on temperature.

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

2A.28 *Crystal Growth*

Work on growing single crystals of $NaClO_3$ by the method of slow cooling of a saturated solution, had been in progress since last year. Studies on nuclear quadrupole resonance of ^{35}Cl nuclei necessitated a single crystal of large size, because the size of the crystal dictates the filling factor in the sample coil assembly and hence the S/N ratio of the NQR signal. The crystals grown in early experiments, though looking transparent and cubical in shape, proved to be polycrystalline, since with the application of Zeeman field, the NQR resonance line broadened up and vanished ; thus it appeared that the single crystal character of the crystal will be proved only if the characteristic Zeeman field split pattern is obtained for any assigned orientation of the crystal axis with respect to the applied Zeeman field.

The design of the crystal growth plant developed during the year, follows the U-tube method of Kruger and Finke with some modifications. The container for the saturated solution is fabricated with two vertical tubes (14 cm dia. and 9.5 cm dia. and height 16.5 cm) interconnected by two horizontal tubes (3.8 cm dia. and 11.8 cm length), all the tubes being made from thin stainless steel sheet. The centres of the horizontal tubes are at the heights of 2.5 cm

and 12.7 cm from the bottom level of the container. Seed crystals of $NaClO_3$ are tied with human hair on the bottom surface of thin glass discs (dia. 1.9 cm) held by six narrow vertical glass rods. The set of glass rods is clamped on an aluminium disc of dia. 12.4 cm. The whole assembly of glass rod cum disc for holding crystal seeds rotates at a speed 14 rpm inside the wider vertical tube containing the saturated solution (Fig. 2A.1). It may be mentioned in this

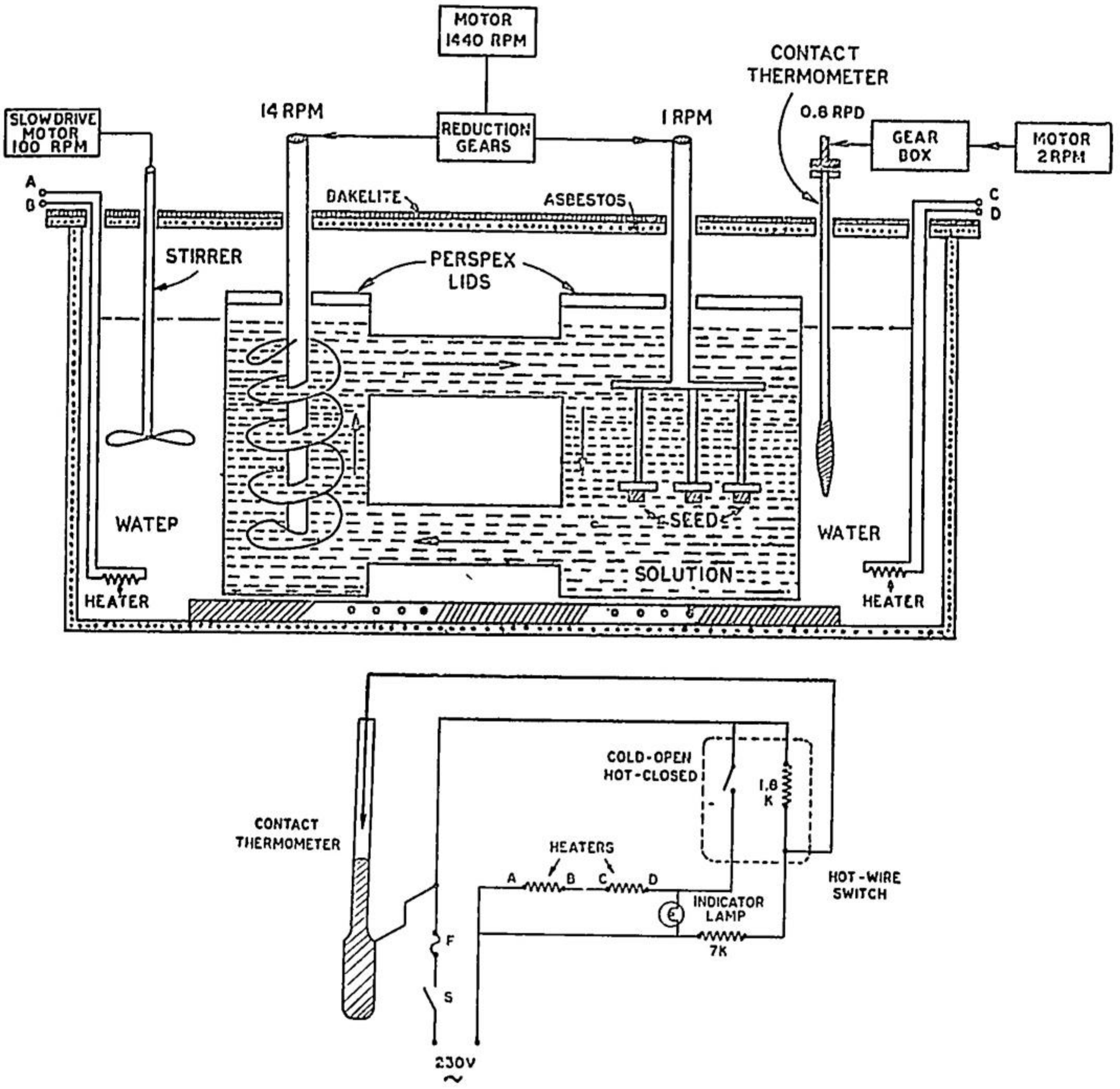

Fig. 2A.1 (Upper diagram) : Crystal growth plant.
(Lower diagram) : Control circuit for temperature regulation.

connection that the horizontal glass disc gives a distinct advantage, i.e., spurious growth of crystals (leading to twin or multiple crystal formation) on the supporting rod or hair from the upper part of the solution is avoided.

The same ac motor (1440 rpm) which rotates the crystal seeds, also drives through a set of reduction gears a helical stirrer (dia. 8.9 cm, length 14 cm) housed in the narrower vertical limb. This aluminium stirrer helps in maintaining a continuous flow of the solution through the upper horizontal tube,

down the limb for crystal growth, through the lower horizontal tube, back to the stirrer.

The container for the saturated solution is immersed in a thermostatically controlled bath of water. The outside surface and the top of this aluminium bath is lined with 1.25 cm thick asbestos sheet to prevent rapid cooling by conduction or convection in the surrounding air. Two 1,000 watt heaters are immersed in the bath; the current through the heater elements is turned on and off with the help of a contact thermometer and a Sunvic hot wire vacuum switch. The head of the contact thermometer is also rotated by a separate ac motor cum reduction gear assembly, which ultimately facilitates the lowering of the temperature of the thermostat bath at the rate of 0.4°C/day. With all the precautions for avoiding heat loss, the constancy of temperature of the bath is within $\pm$ 0.05°C only; such an on-off system of temperature control does not seem to give any better stabilization of temperature.

The procedure for crystal growth with this plant is to start the plant with a saturated solution at about 50°C and slowly cool the solution to 42°C temperature in course of 3 weeks. Single crystals of $NaClO_3$ of maximum size 1.4 cm $\times$ 1.2 cm $\times$ 1.2 cm have been grown so far. The typical Zeeman field split spectra (Fig. 2A.2) obtained with the NQR spectrometer for a field direc-

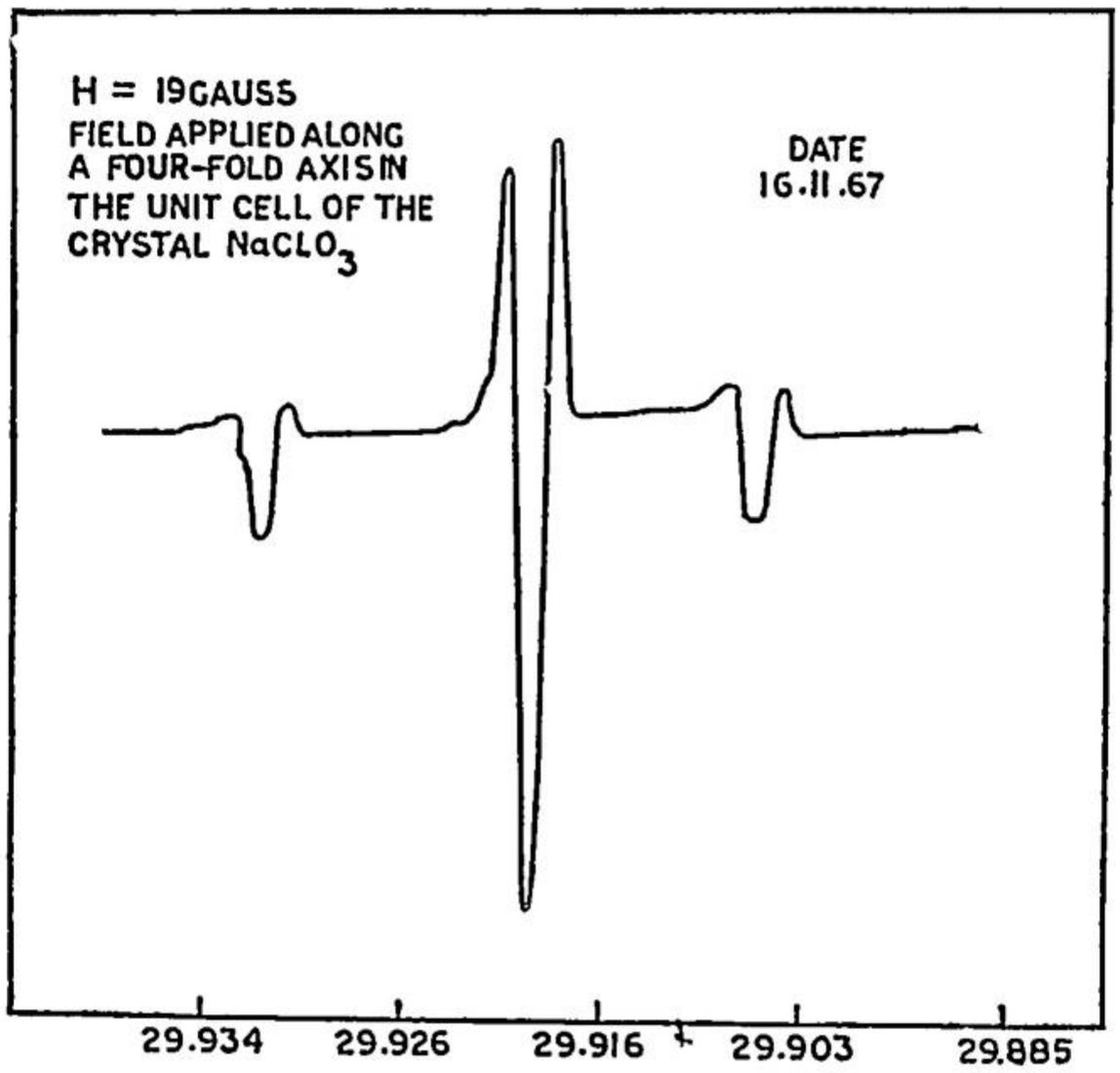

Fig. 2A.2 A typical Zeeman field split spectra obtained with the NQR spectrometer for a field direction along a four-fold axis of symmetry in the unit cell of the crystal.

tion along a four-fold axis of symmetry in the unit cell of the crystal proves it beyond doubt that the grown crystals were truly of single crystal character.

R. Roy, S. Sengupta and N. Banerjee

2A.29 *Goniometer Unit for NQR Studies*

Goniometer assembly (Fig. 2A.3) made from perspex sheets and rods, consists of a crystal holder (1) mounted inside an worm wheel W_{2B} such that the crystal holder together with the crystal X inside, can rotate freely around a vertical X axis. The worm wheel W_{2B} whose outer surface is slotted, is

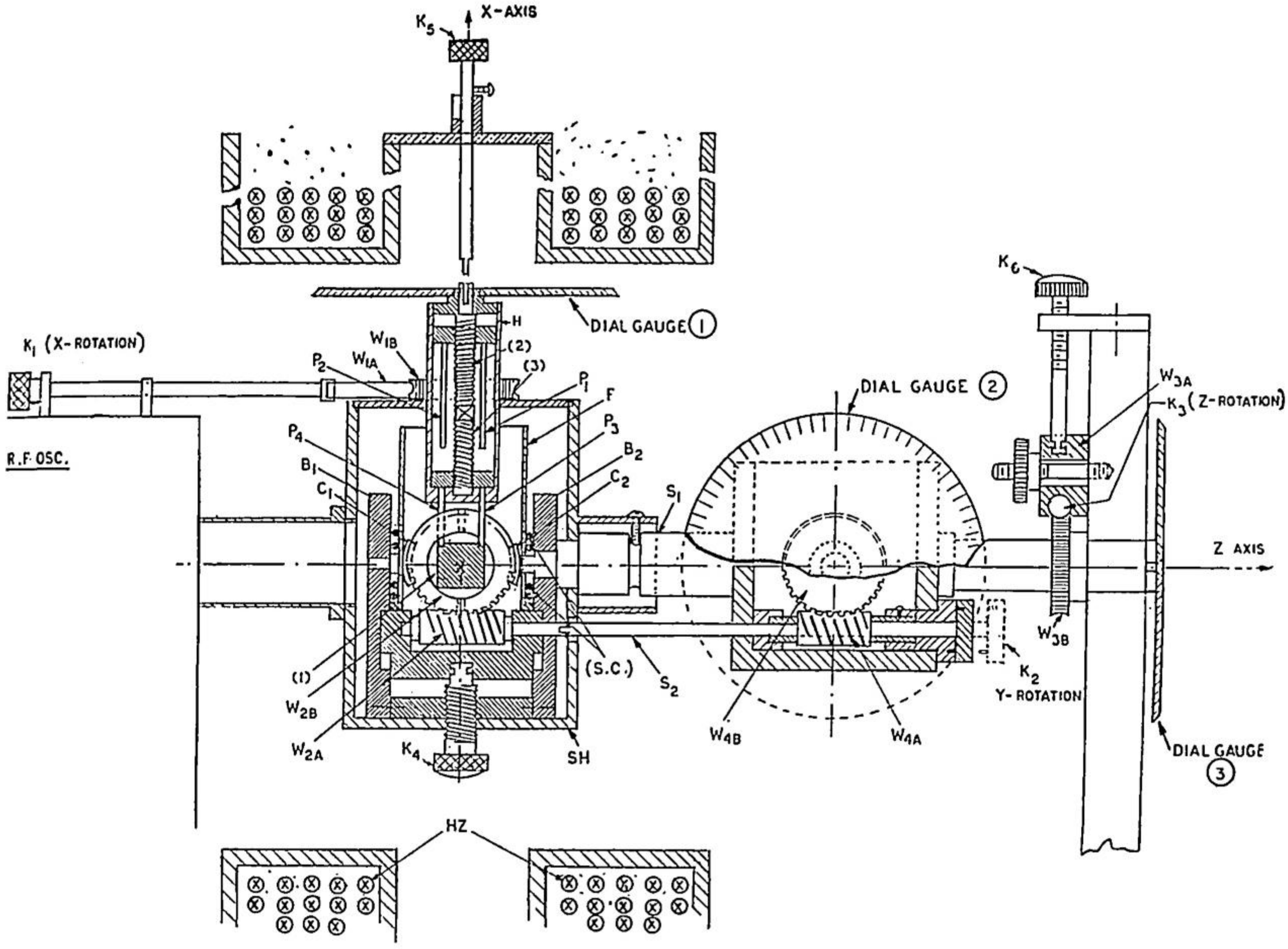

Fig. 2A.3 Goniometer for NQR studies.

Notations used in the Goniometer assembly.

X – Single crystal
(1) – Crystal holder
B_1 and B_2 – Brackets
C_1 and C_2 – Clutches
W_{1A}, W_{2A}, W_{3A}, W_{4A} – Worm
W_{1B}, W_{2B}, W_{3B}, W_{4B} – Worm wheel
P_1, P_2, P_3, P_4 – Locating pins
(2) – Left hand screw
(3) – Right hand screw
S_1 and S_2 – Spindles
K_1 – Knob for X–rotation
K_2 – „ „ Y– „
K_3 – „ „ Z– „
K_4, K_5, K_6 – Knobs
(S.C.) – Sample coil
F – Perspex former
SH – Cu-Cylinder F/F shield
HZ – Helmholtz coil.

supported on both sides by a pair of clutches (C_1 and C_2), so that the wheel can move around its axis (perpendicular to the plane of the paper – Y axis) between the clutches. One of the clutches C_1 is held in a circular groove in one bracket B_1 and is free to rotate about the Z axis; the other clutch C_2 is fixed to one spindle S_1 and at the same time supported by another bracket B_2. The sample coil (S.C.), fitted on a former F, encloses the crystal holder (1) with the crystal X and the worm wheel W_{2B} together with the pair of clutches. The procedure for impressing the three rotations to the crystal keeping it insitu inside the rf coil assembly is detailed in the following :

(i) X–rotation : The left hand screw (2) and right hand screw (3) arrangement in the housing H at the top of the crystal holder allows two pairs of locating pins (P_1, P_2 and P_3, P_4) to fit in two pairs of holes on the surface of the crystal holder. Knob K_5 is used to bring down one pair of locating pins (P_1, P_2) to fit in a pair of holes (on the surface of the crystal holders). The worm W_{1A} and worm wheel- W_{1B} system at the top gives the X–rotation with the knob K_1 and the corresponding reading is obtained from the dial gauge (1). The worm wheel W_{1B} limits this rotation to 90° for one pair of locating pins; so, after completion of a rotation of 90°, the pair of locating pins is pulled in to bring down the other pair (P_3, P_4) with the help of knob K_5 and a similar rotation of another 90° is made. In this way a full rotation of 360° around the X axis can be obtained.

(ii) Y–rotation : All the locating pins are brought to the neutral position marked in the housing H with knob K_5 so that the crystal holder gets free. The worm W_{2A} is engaged to its wheel W_{2B} using knob K_4 and the spindle S_2 is pushed in to fit in a socket on the worm W_{2A} A rotation of the spindle S_2 with knob K_2 gives the rotation around the Y axis and a similar set of worm W_{4A} and worm wheel W_{4B} records the corresponding rotation in the dial gauge (2).

(iii) Z–rotation : The worm W_{2A} is released from its wheel W_{2B} by knob K_4 whereas the worm W_{3A} is engaged to its wheel W_{3B} using know K_6, the locating pins being kept at the neutral position. With the help of knob K_3 this worm W_{3A} and worm wheel W_{3B} rotates the spindle S_1 together with the worm wheel W_{2B} and the crystal holder about the Z axis. Dial gauge (3) records this rotation around the Z axis.

Thus the rotation of a single crystal, within the rf coil around three mutually perpendicular axes, can be accomplished with the help of this goniometer assembly.

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

HIGH RESOLUTION NMR STUDIES

2A.30 *Solvent Interaction Effects on 2-Amino-Pyridine*

Attempts have been made to extend the investigation on solvent-solute interactions of 2-Amino-Pyridine in different solvents besides, acetone, ether and carbon tetrachloride.

Furthermore, work on solvent dependence of coupling constants is under progress.

N. Das and M. Bose

2A.31 *Spin-lattice Relaxation Time* (T_1) *Measurements in Methyl Pyridines*

Last year, we reported solvent effects on proton chemical shifts of different methyl pyridines. Continuing our studies on methyl pyridines, we have measured the spin-lattice relaxation times of 2–, 3– and 4–methyl pyridines by the adiabatic rapid passage technique (reversal of polarization). As in the case of toluene, the spin-lattice relaxation time of methyl protons is found to be much shorter than that of the ring protons (T_1 for methyl protons $\sim$ 10 secs and T_1 for ring protons $\sim$ 25 secs). This shortening can be logically explained on the basis of rotation of methyl group about the C–C axis. The short relaxation times of different protons (both ring and methyl) in 4–methyl pyridine as compared to 2– and 3–methyl pyridines are, in all probability, due to the extra degree of freedom provided by the torsional oscillation in 4–methyl pyridine, permitted by the C_{2v} symmetry element present in the molecule.

N. Chatterjee and M. Bose

Publication :

N. Das, N. Chatterjee and M. Bose, *Proc. Int. Conf. Spectroscopy, Bombay*, 1967, p. 484.

N. Chatterjee and M. Bose, *Molecular Physics, 12*, 341, 1967.

2A.32 *Nuclear Magnetic Resonance Studies of Solids*

(i) *^{31}P resonance in solid phosphates*

^{31}P resonances in some diamagnetic and paramagnetic polycrystalline phosphates have been investigated with a view to understanding the nature of dependence of spin-lattice relaxation time T_1 and line-width on the paramagnetic

centres present in the system. Table 2A.1 gives the measured T_1 and line width values at room temperature and at 16 Mc in different diamagnetic and paramagnetic substances.

Table 2A.1

Compound	Line width in kc	T_1 in sec	Remarks
P_2O_5		10	measured by a.r.p.
Na_3PO_4	6.6	4	modulation broadened symmetric line
$Na_4P_2O_7$	7.3	2	modulation broadened symmetric line
$LaPO_4$	2.6	0.7	
$PrPO_4$	17.3	0.08	asymmetric line
$NdPO_4$	15.2	0.024	asymmetric line
$SmPO_4$	3.1	0.009	asymmetric line

Line width measurements in these systems were rather inaccurate due to the large modulation broadening which could not be avoided. The low S/N ratio and the fact that the system saturated at comparatively low rf values necessitated the use of a large modulation amplitude. It is thus quite likely that the actual widths are less than the measured values.

Fig. 2A.4 presents the resonance spectra of hydrated neodymium phosphate

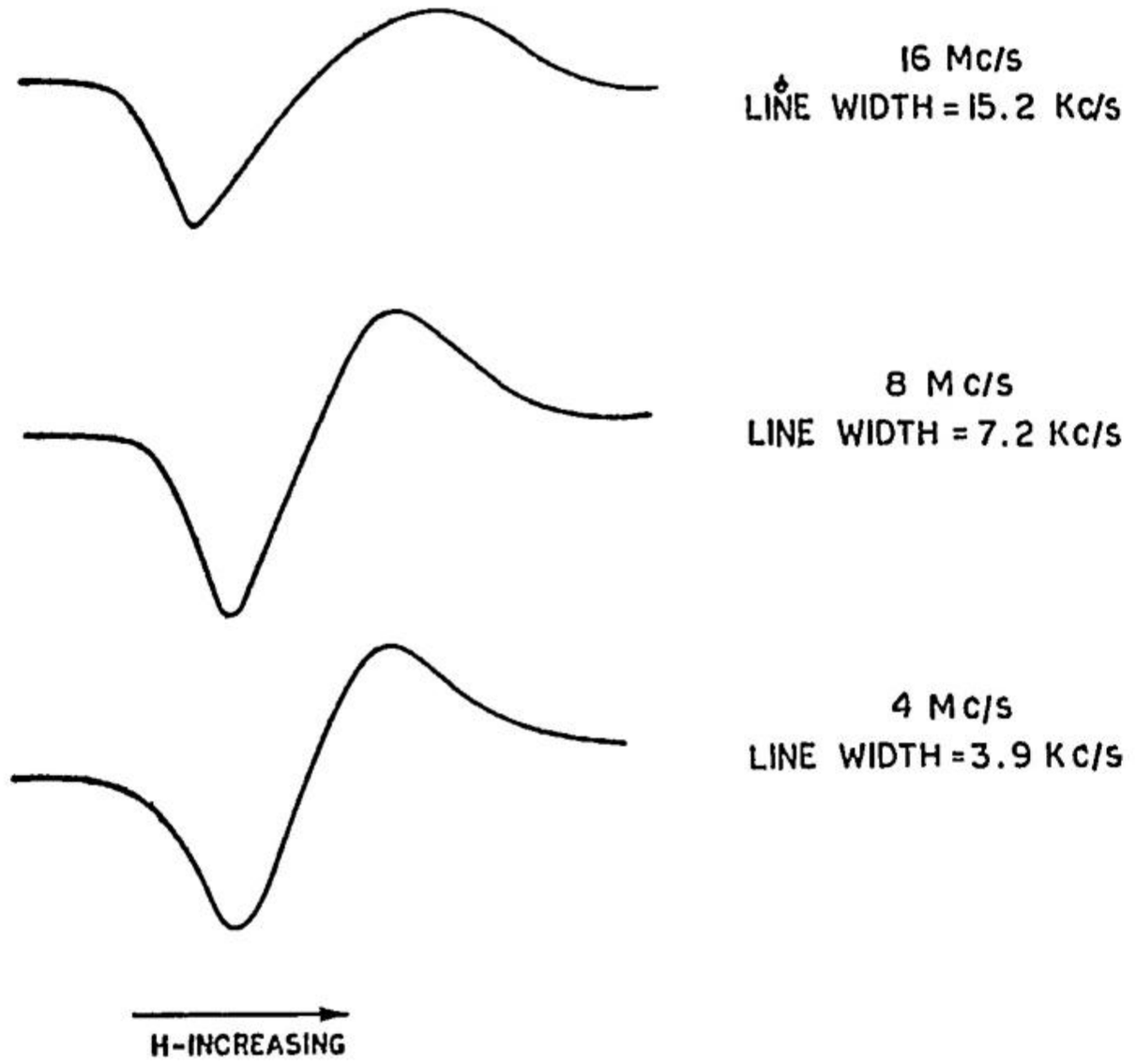

Fig. 2A.4 Derivative of ^{31}P absorption line in hydrated $NdPO_4$ at different frequencies at 300°K.

at 4, 8 and 16 Mc at room temperature. The lines are in general asymmetric and the asymmetry increases with increase of frequency, the high field wings becoming broader and flatter. Asymmetric lines have been observed in praesodymium and samarium phosphates also.

Fig. 2A.5 shows the dependence of line width on the number of 'f' electrons present in rare earths. It shows the same trend as that of the magnetic

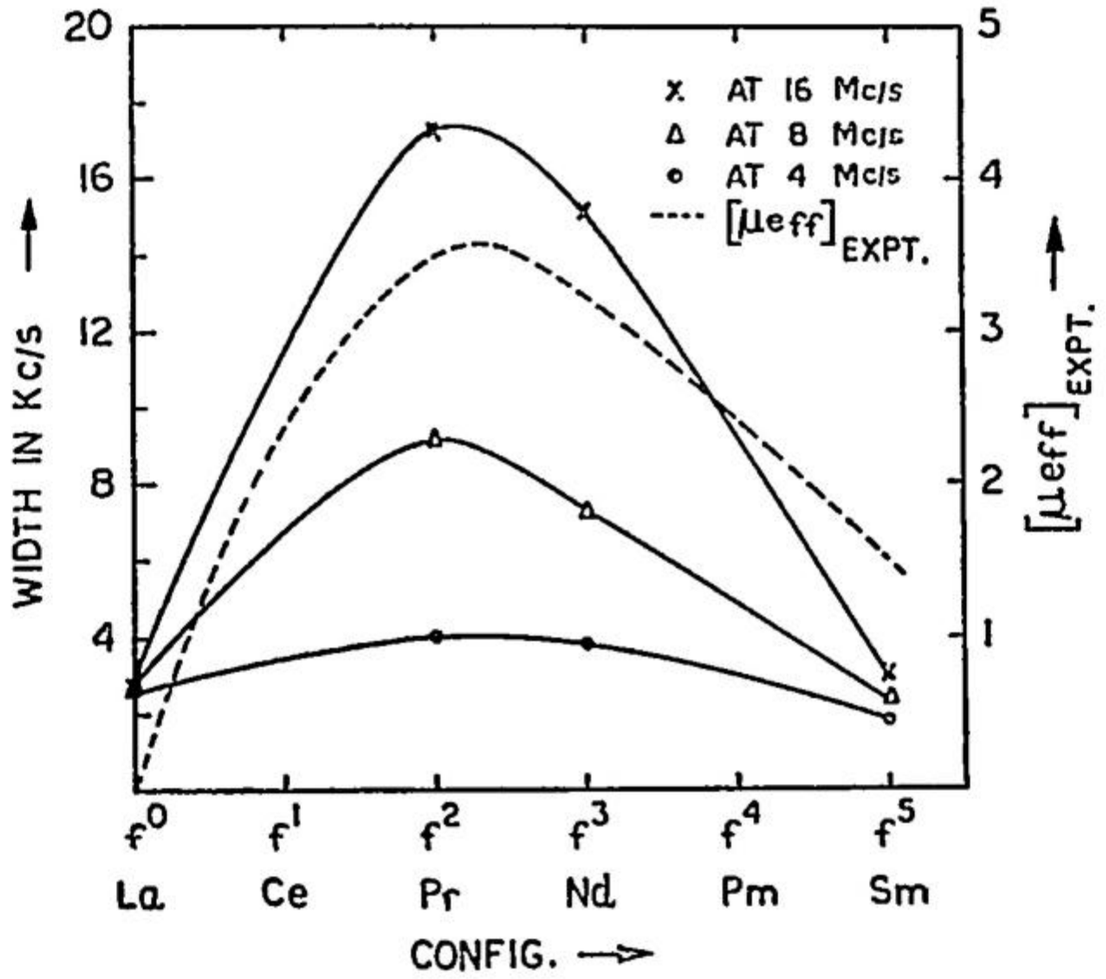

Fig. 2A.5 ^{31}P line width in hydrated rare earth phosphates at various frequencies at 300°K.

moment vs. number of 'f' electron curve. Line widths measured at different frequencies show almost a linear dependence on frequency. In the rare earths investigated, only praesodymium phosphate (hydrated) exhibited large (613 ppm high field shift. Nd-and Sm-phosphates exhibited no shift in comparison to the resonance in diamagnetic La-phosphates. The zero shift in Sm-phosphate is not unexpected rom the known magnetic properties of Sm-compounds. White and Van Vleck have pointed out that the expectation values of Sm^{3+} spin $\langle S \rangle$ should have a sign reversal at 300°K, so that at about this temperature range, it effectively behaves as a diamagnet. This is also supported by the absence of ^{19}F shift in SmF_3 (V. Saraswati and R. Vijayraghavan, *Phys. Letters, 21,* 363, 1966) at 300°K. But the zero shift in the case of neodymium phosphate is yet to be understood.

Lack of knowledge of the exact composition and crystal structure of the hydrated rare earth phosphates prevents us from obtaining further information about the samples. Hence monazite type rare earth phosphates with well-

defined crystal structure, have been prepared and are currently being investigated.

Publication :

M. Bhattacharyya, Anjali Chowdhury and M. Bose, *Proc. Nucl. Phys. Sol. St. Phys. Symp. Kanpur,* 1967, p. 59.

M. Bhattacharyya, A. Chowdhury and M. Bose

(ii) *Preliminary ^{31}P NMR investigations in monazite type rare earth phosphates*

Normal phosphates corresponding to the formula RPO_4 are prepared by adding sodium phosphate to rare earth solutions, both adjusted to a pH of 4.5, following the method of Buyers' *et al.* (A. G. Buyers, E. Guisbrecht and L. F. Audreeth, *J. Inorg. Nuc. Chem., 5,* 133, 1957).

Nuclear magnetic resonance of ^{31}P in polycrystalline monazite type gadolinium phosphate has been investigated. The resonance lines were found to be asymmetric and very wide. The asymmetry and the line width are field dependent. Due to rather short relaxation time, the resonance line could not be saturated by the available power.

M. Bhattacharyya and M. Bose

2A.33 *Temperature Variation Studies on Cobalt Phosphate*

To elucidate the nature of the exchange phenomenon as also the hyperfine interaction parameters, T_2, the transverse relaxation time from line width measurement and $\triangle\omega$, the freequency shift of ^{31}P resonance line were measured as a function of temperature from 0°C to 110°C in a solution of cobalt phosphate in 89% phosphoric acid.

Swift and Connick's (T. J. Swift and R. E. Connick, *J. Chem. Phys., 33,* 307, 1961) expression for T_{2p} (eq. 1) and $\triangle\omega$ (eq. 2) has been used for analysing the data. The relevant equations are

$$T_{2p}^{-1} = T_2^{-1} - T_{2o}^{-1} = pq \frac{1/T_{2M}\,(1/T_{2M} + 1/\tau_M) + \triangle\omega_M^2}{\tau_M\,(1/T_{2M})^2 + \tau_M \triangle\omega_M^2} \qquad (1)$$

where $T_{20} = T_2$ for pure phosphoric acid, $T_{2M} = T_2$ of bonded nuclei, $p = (Co^{2+})/(PO_4)$ and q = number of phosphate ligand attached to the molecule.

$$\triangle\omega = pq \frac{\triangle\omega_M}{(\tau_M/T_{2M} + 1)^2 + \tau_M^2 \triangle\omega_M^2} \qquad (2)$$

In the fast exchange limit, $(1/\tau_M \gg 1/T_{2M},\ \triangle\omega_M)$,

Eq. (2) becomes, $\triangle\omega = pq\triangle\omega_M = \dfrac{pq\ \omega S(S+1)\, g\,|\beta|\,A}{3KT\gamma_I}$ (3)

$$\text{or } \frac{\triangle\omega}{p\omega} = \text{constant } q/T = Y. \qquad (4)$$

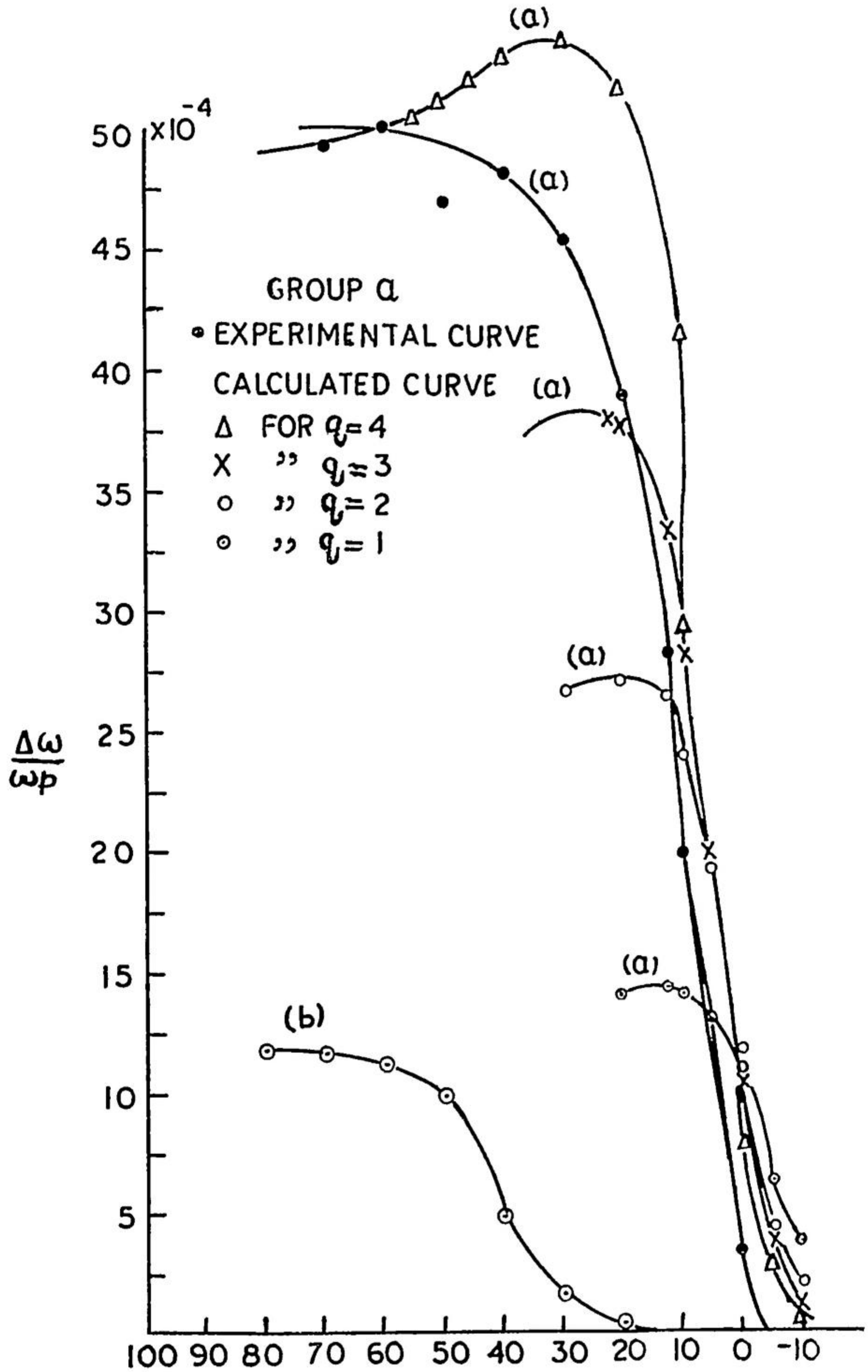

Fig. 2A.6 Variation with respect to temperature of $\frac{\Delta\omega}{\omega_p}$ in (a) cobalt phosphate solution for different values of q, (b) AMP Co^{+2} solution (taken from R. G. Shulman et al).

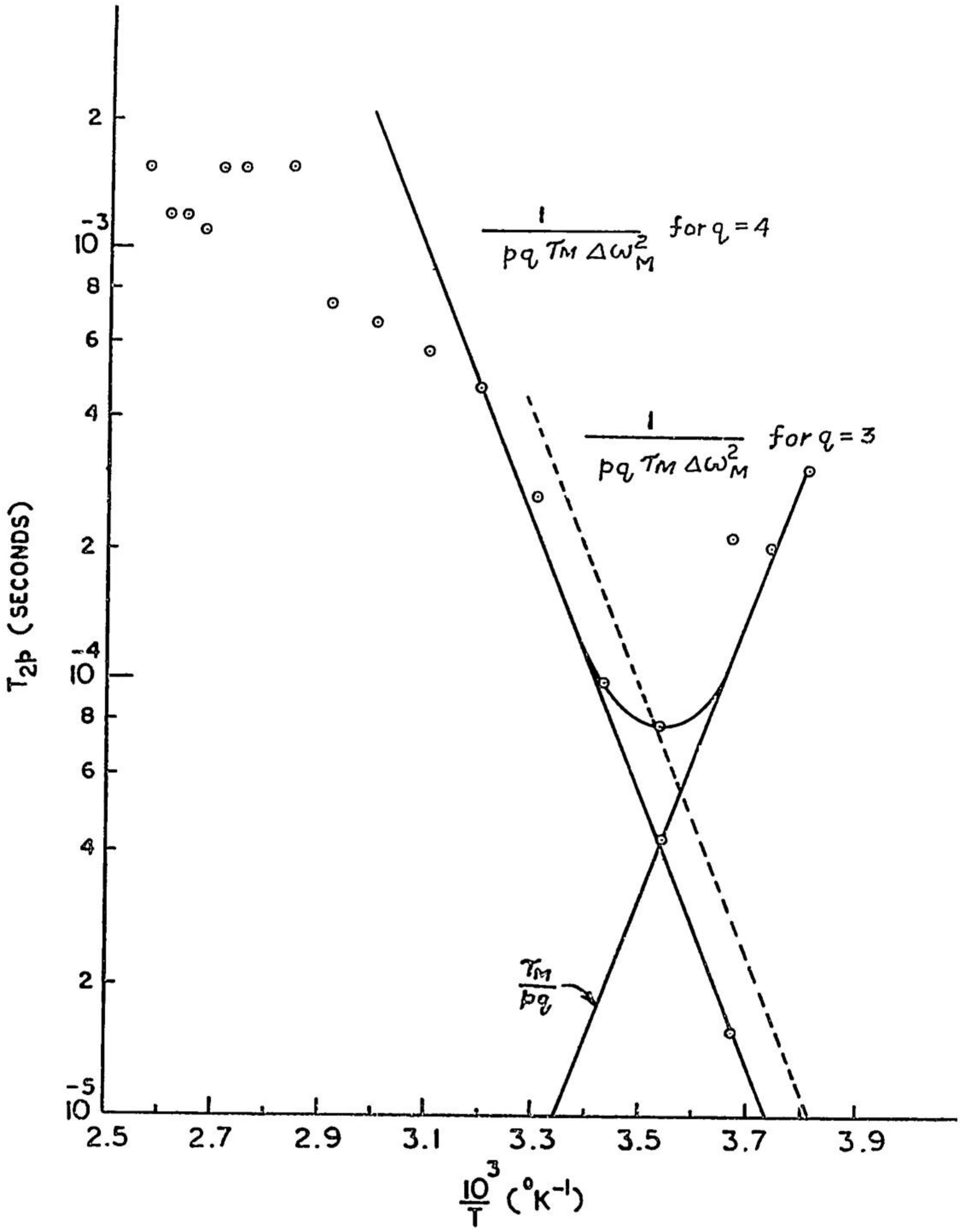

Fig. 2A.7 Measured values of T_{2p} vs (temperature)$^{-1}$ for cobalt phosphate solution.

For two samples at constant T, $Y_1/Y_2 = q_1/q_2$. (5)

For q = 4, the estimated value of $\Delta\omega_M = 1.42 \times 10^5$ rad/sec.

With rise of temperature, τ_M decreases as $\tau_M = \tau_{Mo} \exp(-\Delta H/RT)$ and one comes to a region whcre $1/\tau_M^2 \gg \Delta\omega_M^2 \gg 1/(\tau_M T_{2M})$.

so that eq. (1) becomes, $T_{2p} = 1/(pq\ \tau_M\ \Delta\omega_M^2)$.

The corresponding plot for a value of q = 4 fits the experimental points. For further increase of temperature $'\Delta'\omega_M^2 = 1/T_M T_{2M}$ and hence the deviation (the points fall below the line), ΔH, the activation energy has been estimated to be 15 Kcal. from the slope and τ_M at 20°C is found to be 2.4×10^{-6} sec. Decrease of shifts with fall of temperature (Fig. 2A.6) is caused by increase of τ_M/ Shulman *et at* (R. G. Shulman, H. Sternlicht and B. J. Wyluda, *J. Chem. Phys. 43,* 3115, 1965) found, in AMP–Co^{2+} complex, the value of q to be 1. In our results, the ordinate of experimental curve is four times that for AMP–Co^{2+} complex (Fig. 2A.6), so that the value of q can be taken as 4 (cf. eq. 5), in agreement with the value of q required for the best fit of the plot T_{2p}/vs. 1/T (Fig. 2A.7). A/h, the isotropic hyperfine coupling constant, has been estimated to be 3.7×10^6 cps.

Publication :

M. Bhattacharyya, A. Chowdhury and M. Bose, *Proc. Int. Conf. Spectroscopy, Bombay,* 1967, p. 484.

M. Bhattacharyya, A. Chowdhury and M. Bose

2A.34 *^{31}P NMR in H_3PO_4 Acid containing Rare Earth Ion*

Nuclear magnetic resonance of ^{31}P in solutions of gadolinium phosphate in phosphoric acid has been studied. The temperature dependence of line widths has been investigated and the line narrowing at high temperature has been observed.

A. Chowdhury and M. Bose

2B. CRYSTALLOGRAPHY AND MOLECULAR BIOLOGY DIVISION

2B.O *Introductory Remarks*

The research activities of this division may be broadly headlined as follows:

(1) Crystal and molecular structure of biomolecules by X-ray crystallographic methods.
(2) Ultrastructure of biopolymers by small angle X-ray diffraction and electron microscopic methods.
(3) Physico-chemical and enzymatic studies of biomolecules.
(4) Quantum biology and conformational studies of biomolecules.
(5) Radiation biology.

In our general programme of research on the role of structure at different levels of organisation on biological functions, the investigations on the structure and properties of collagen from various sources are being continued at molecular level by wide angle X-ray diffraction analysis and at higher levels of organisation by low angle X-ray diffraction, electron microscopic and physico-chemical methods. Further study on the relative orientation of crystallites and mechanism of calcification in normal bones and also the structural and functional changes due to diseases in bones is being made. It is well known that a knowledge of the molecular structure and conformation of the subunits, e.g., amino acids, their derivatives and metal complexes, is a positive step forward towards the understanding of conformations and perhaps functions of various biopolymers like collagen and other protein molecules. The crystal structures of three amino acid derivatives have been completely solved and the work on four metal complexes is nearing completion. Investigations on a few more structures have recently been undertaken.

In our programme on the structure of biopolymers at a higher level of organisation by electron microscope and low angle X-ray diffraction, an extensive study has been made on collagen from various sources. Our study of SF collagen has conclusively shown that not only the mode of aggregation of tropocollagen to form fibrils but the tropocollagen molecule itself of SF collagen also is different from those of tendon collagens. Small angle X-ray study of different collagens is also being continued with further interesting results. As before, the small angle intensity data and the band-interband fine structural details from electron micrographs have been used for the ultrastructural models of collagens from various sources and having different biological functions. In our physico-chemical study of biomolecules, a definite advance has been made in separating the components of sharkfin collagen and the subsequent isolation and characterisation of the α, β and γ chains in the acid extract component of sharkfin collagen. In

this project DNA's from different sources have been extracted. Their physico-chemical properties as well as the effect of carcinogens on them are also being studied. In our study on enzymes, some interesting results have already been published and further work on the function of inositol on the activity of an enzyme, phosphofructokinase prepared in our laboratory is being continued.

In our programme of work on quantum biology, a study is being made on the correlation of bond lengths, bond angles and other structural properties of amino acids as obtained by X-ray study with the theoretically calculated σ-electronic charge distribution by LCAO–MO method. In this programme, study is also in progress of the conformation of small biomolecules by molecular orbital calculation based on extended Huckel method.

The last but not the least in importance is our radio-biology section. With a very modest beginning a few years ago, this small unit developed into an active group under the direct supervision of Dr. B. D. Nagchaudhuri. As mentioned by Dr. Nagchaudhuri in the last year's annual report that the work in radiation biology appears to be sufficiently mature so as to consider its integration with that of crystallography and molecular biology division, this section has been transferred to this division in April, 1967. In the programme of this section, investigations on tracer study in riboflavin deficiency, haemolymph from cockroaches by radioactive tracers, etc., are being made. An exhaustive programme of study to extend the scope of this section is already in progress.

N. N. Saha

2B.1 *Crystal and Molecular Structure*

The structural study of the derivatives and metal complexes of amino acids, peptides and related compounds of biological interest forms a major part of our general long-term programme of research on the role of structure at different levels of organisation on biological functions. It may be noted that the study of crystal and molecular structure of these small units provides an understanding of their physical and chemical behaviour in different environments. It is also well known that a detailed knowledge of the dimensions and conformations of constituent amino acids and peptides is of great help in elucidating the configuration of protein molecules, particularly those of side groups associated with the main polypeptide chain. The structure of the metal complexes of the constituents of proteins will no doubt be a step forward in our understanding of the metal-protein interactions, a phenomenon of immense biological importance. The compounds whose structure determination is at different stages of progress in our

laboratory are sarcosine, glycocyamine, ornithine, arginine, lysine, benzene sulphonyl glycine, glutamyl glycine ethyl ester, EDTA, etc. Some of these structures have been completely solved and the work on some is nearing completion.

N. N. Saha

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

Single crystals of sarcosine hydrochloride are monoclinic with biomolecular unit cell of the dimensions

$a = 9.00$ Å, $b = 5.93$ Å, $c = 5.41$ Å and $\beta = 96°$

The space group has been found to be $P2_1$ with all atoms in the general positions:

$$xyz; \quad \bar{x}, \quad y+\tfrac{1}{2}, \quad \bar{z}$$

The structure was derived from two dimensional Patterson and Fourier syntheses and was refined by the three dimensional least-square method. The value of the disagreement factor (R) at this stage was $R = 18\%$. The bond lengths and bond angles of sarcosine hydrochloride are in fair agreement with those found in other amino acids. The molecules are held together by a three dimensional network of hydrogen bonds. The protonated amino nitrogen is hydrogen bonded to chlorine ions and assumes a tetrahedral configuration. The carboxyl oxygen of one molecule is hydrogen bonded to the carboxyl oxygen of the other symmetry related molecule.

A paper on the crystal structure of sarcosine hydrochloride was presented in the second annual symposium in biophysics of the Indian Biophysical Society in 1967.

(S. C. Bhattacharyya, S. K. Majumdar and N. N. Saha, 'The Crystal Structure of Sarcosine Hydrochloride', to be published in *Ind. J. Phys.*)

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

(b) *Copper sarcosine* $Cu(CH_3NHCH_2COO)_2.2H_2O$

The compound was prepared by refluxing a mixture of sarcosine and cupric carbonate taken in steichiometric proportions. Single crystals of copper sarcosine were prepared by evaporating an aqueous solution of the compound at room temperature. Blue and needle shaped 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, $\alpha = 107°45'$, $\beta = 116°1'$, $\gamma = 100°45'$. The space group is either P1 or $P\bar{1}$ and the unit cell contains two molecules of copper sarcosine. Three dimensional intensity data have been collected by multiple film equi-inclination Weissenberg photographs using CuK α radiation. The complete solution of crystal structure of copper sarcosine is in progress by making use of the three dimentional intensity data.

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

(c) *Glycocyamine hydrobromide* ($C_3H_7O_2N_3$. *HBr*)

Single crystals of glycocyamine hydrobromide belong to monoclinic system with four molecules per unit cell of dimension : a = 5.53 Å, b = 13.52 Å, c = 9.24 Å and $\beta = 92°$. The space group is $P2_1/c$ with atoms in general positions : $\pm$(xyz ; x, $\frac{1}{2}-y$, $z+\frac{1}{2}$). The positions of heavy atoms (bromine) in the unit cell were determined from two Patterson projections on (100) and (001) and those of light atoms (C, N, O) were determined from a three dimensional Fourier synthesis calculated with observed structure amplitudes (Fo's) and phases of the heavy atoms. Atomic parameters were refined by the least-square method. The bond lengths and bond angles of the molecule of glycocyamine hydrobromide are shown diagrammatically in Fig. 2B.1. The molecules are held together by a three

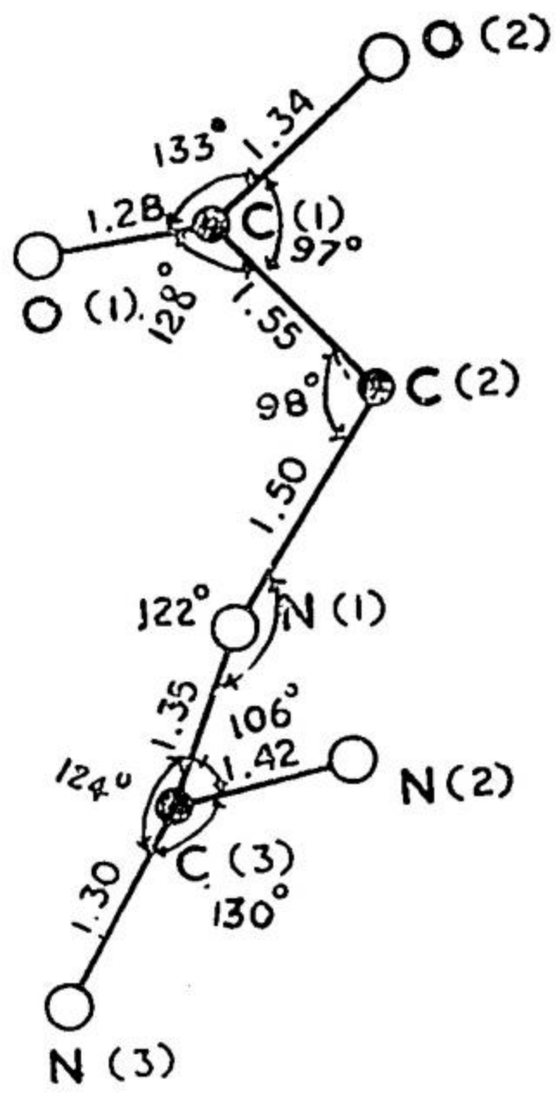

Fig. 2B.1 Glycocyamine hydrobromide : Bond lengths and bond angles.

dimensional network of hydrogen bonds (Fig. 2B.2). There are altogether six hydrogen atoms available for hydrogen bond formations, one from the carboxyl oxygen and five from the guanidyl ion. The guanidyl ion makes three hydrogen bonds with bromine ions and two with carboxyl oxygens of other symmetry related molecules. The carboxyl oxygen is hydrogen bonded to carboxyl oxygen of the other symmetry related molecules. A preliminary account of the structure was presented at the Second Annual Symposium of the Indian Biophysical Society at Calcutta in 1967.

(P. N. Roy, S. K. Majumdar and N. N. Saha, 'The Crystal Structure of Glycocyamine Hydrobromide', to be published in *Ind. J. Phys.*)

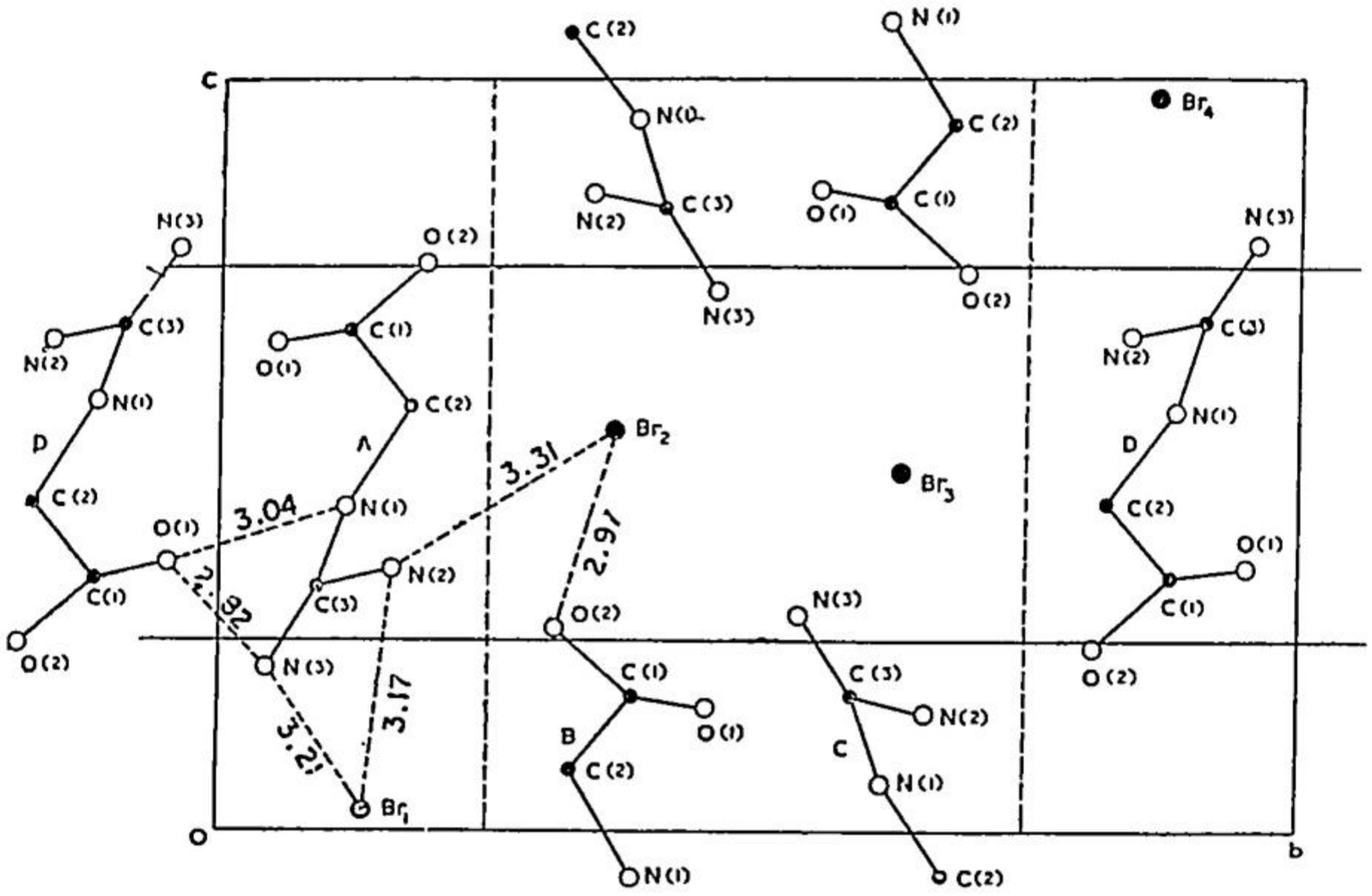

Fig. 2B.2 Glycocyamine hydrobromide : The projection of the structure along a axis.

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

(d) *Copper arginine hydrochloride*

$$Cu[(NH_2)_2CNH\ (CH_2)_3CH\ (NH_2)COO]_2Cl_2.2H_2O$$

The compound was prepared by refluxing a mixture of arginine hydrochloride and cupric oxide taken in stoichiometric proportions. Single crystals of copper arginine were prepared by slow evaporation of its aqueous solution at about 4°C. The crystals belong to the orthorhombic system and the unit cell dimensions as determined from rotation, oscillation and Weissenberg photographs taken about the c axis are :

$a = 7.25$ Å, $b = 25.69$ Å, $c = 12.84$ Å

The systematic absences of oko reflections for k odd and hoo reflections for h odd indicated that the space group is either $P2_12_12$ or $P2_12_12_1$. For unequivocal determination of the space group it is necessary to record ool reflections. The density of the crystal as determined by the method of floatation is 1.594 $g.cm^{-3}$ which was consistent with four molecules of copper arginine in the unit cell.

It has been observed that the intensities of high-angle reflections in the Weissenberg photographs are very weak. Consequently it has been decided to collect complete three dimensional intensity data at low temperature (–150°C) so that there will be a general increase in the intensities of the high-angle reflections, thus permitting a more accurate determination of atomic parameters. The work is in progress.

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

(e) *Silver benzene sulphonyl glycine*

This compound was kindly supplied by Dr. N. N. Ghosh of chemistry department, Calcutta University. The crystals belong to the monoclinic system. The unit cell dimensions as determined from rotation, oscillation and Weissenberg photographs are

$$a = 5.73 \text{ Å}, \quad b = 12.16 \text{ Å}, \quad c = 13.96 \text{ Å and } \beta = 95°.$$

The systematic absences of oko reflections for k odd and hol reflections for h + 1 odd indicate that the space group is $P2_1/n$. Three dimensional intensity data have been collected by multiple film equi-inclination Weissenberg technique using CuKα radiation. The crystal structure analysis is in progress.

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

(f) *Ca-EDTA*

Single crystals of this compound Ca-EDTA crystals grow in the triclinic system. The space group is either P1 or P$\bar{1}$, Wilson's N(z) test with intensity data, corrected for absorption (by a programme written by us), indicated the space group to be P$\bar{1}$. There are two molecules per unit cell. The cell-dimensions are :

$$a = 9.88 \text{ Å}, \quad b = 11.14 \text{ Å}, \quad c = 13.37 \text{ Å}, \quad \alpha = 131°38', \beta = 114° 13' \text{ and } \gamma = 77°2'.$$

Ca positions were determined from three Patterson projections on (100), (010) and (001). Ca-phased Fourier synthesis projected on these planes were also calculated. But these could not be interpreted due to heavy superposition of atoms in all directions.

Next, complete 3D-data was collected by the multiple film technique, using a Weissenberg camera. The intensities were estimated visually and all the correction factors were applied to them. They were brought to the same scale by cross-layer correlation method.

A 3D-Patterson synthesis was calculated, from which a minimum function was drawn. A 3D-Fourier synthesis, using the phase angles of calcium, was also computed.

But, due to the fact that calcium as a phase determining atom was not heavy enough compared to a large number of light atoms in the molecule, the structure could not be picked up from the initial Fourier. Another 3D-Fourier has been calculated, using a few more light atoms as phase determinants. This method of gradual Fourier development has been adopted to solve this structure. Further work is in progress.

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

(g) *Copper complex of lysine*

Single crystals of this compound were grown by slow evaporation method. Rotation and Weissenberg pictures showed the space group to pe $P2_1$ with cell dimensions:

$a = 5.21$ Å, $b = 16.83$ Å, $c = 11.65$ Å and $\beta = 97°$.

Density determination by floatation method shows that there are two molecules per unit cell.

Wilson N(z) test for cartrosymmetry has been carried out, using okl data. This shows that there is a centre of inversion in the molecule. Two Patterson syntheses, one sharpened and another unsharpened, have been calculated, using okl data. The y and z coordinates of the three heavy atoms i.e. one copper and two chlorine atoms have been determined from the Patterson syntheses. Three dimensional intensity data have been collected and processed, and computational work is in progress.

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

(h) *Ornithine hydrochloride*

Needle shaped crystals of this compound were grown in our laboratory. It crystallises in the monoclinic system with the space-group $P2_1$ and cell dimensions :

$a = 4.99$ Å, $b = 8.00$ Å, $c = 10.00$ Å and $\beta = 97°$.

A preliminary account of the two dimensional analysis of the structure was incorporated in the annual report of last year and was also presented at the 2nd annual symposium of the Indian Biophysical Society held in April 1967. As was mentioned in last year's report, a heavy atom phased Fourier synthesis on (010) and (100) projections together with the minimum function drawn from the unsharpened Patterson helped us to choose a few near enough but not exact molecular models of this compound. One of the difficulties in choosing the right model was the presence of a spurious mirror symmetry normal to b-axis. But this difficulty was ultimately solved and a satisfactory model of the structure could be derived by the following methods. Complete 3D-data along a-and b-axes were collected, using equi-inclination Weissenberg technique. They were corrected for spot size, Lorentz and polarisation factors and brought to the same scale by cross-layer correlation method. A 3D-Patterson synthesis was then computed. From this a Buerger superposition map was drawn, using the Cl-Cl peak in the Harker section as the second origin. The structure was ultimately solved by using the (a) minimum function and (b) a 3D Cl-phased Fourier synthesis. The difficulty of choosing the right peak due to the presence of spurious mirror was solved with the prior knowledge of bond lengths and bond angles and stereochemistry of the molecule.

Refinement of the structure was done by the least square feet, and after five cycles of refinement the disagreement factor (R) came down to 0.098, including the unobserved reflections.

The structure viewed along the b-axis is shown in the Fig. 2B.3. The bond lengths and bond angles as obtained compare well with those of related amino acids. The structure is held by three dimensional network of hydrogen bonds, as shown in Fig. 2B. 3.

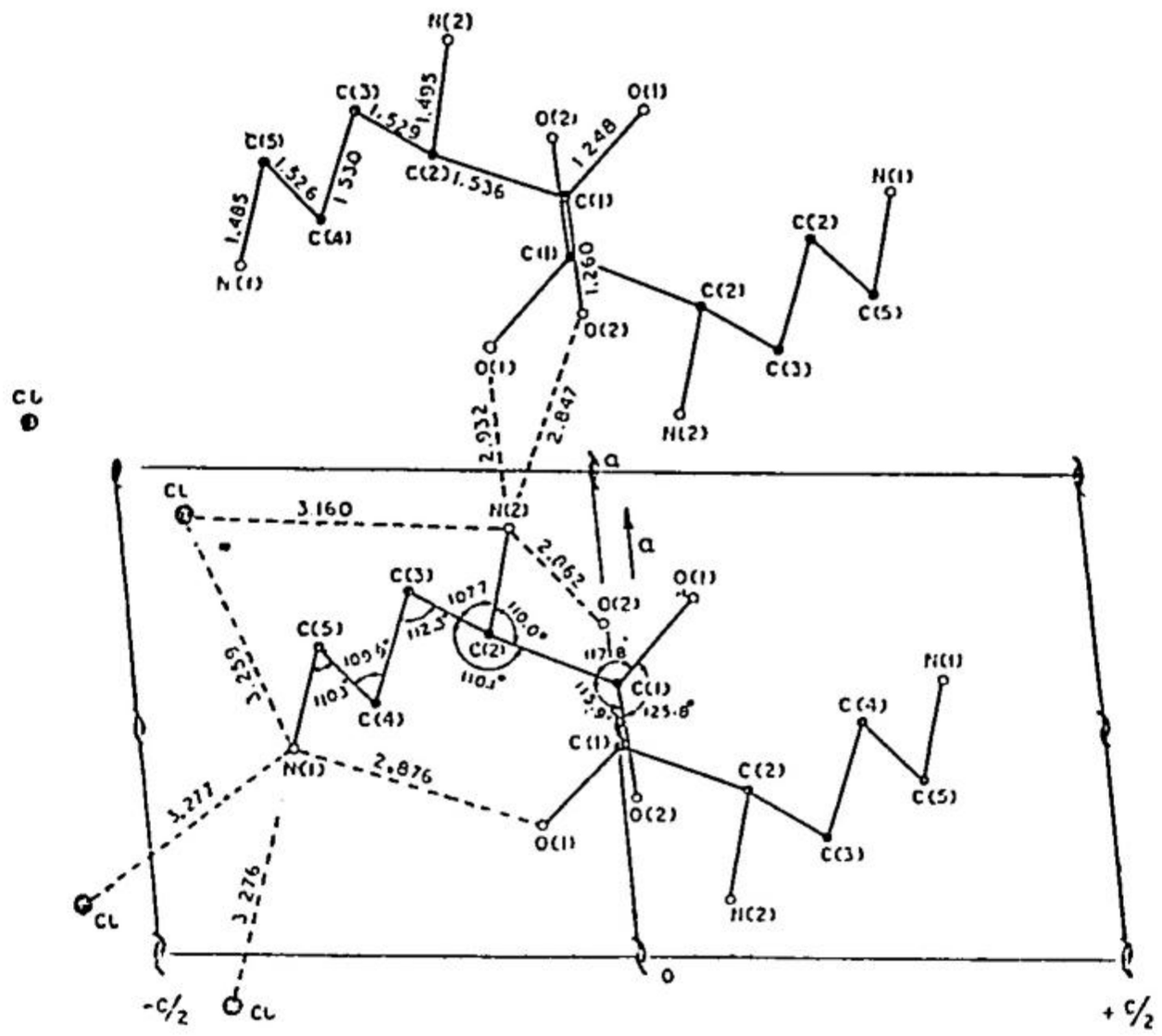

Fig. 2B.3 Ornithine hydrochloride : The projection of the structure on (010). The hydrogen bonds are marked by dashed lines.

The computations were done on IBM 1620 and CDC 3600.

Publication :

S. Guha, S. K. Mazumdar and N. N. Saha, *Ind. J. Phys.*, *8*, 624, 1967.

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

(i) *Copper complex of ornithine*

This complex was prepared by refluxing a mixture of ornithine hydrochloride and cupric oxide in stoichiometric proportions. Thin needle shaped single crystals belonging to monoclinic system were grown by slow evaporation method.

Systematic absences of oko reflections for k odd indicate that the space group is $P2_1$. The cell dimensions of this crystals are :

$a = 5.18$ Å, $b = 15.59$ Å, $c = 11.80$ Å and $\beta = 92°48'$.

A comparison of measured and calculated densities shows that there are two molecules per unit cell. A two dimensional Patternson synthesis projected on (100) was calculated. But the positions of all the heavy atoms could not be uniquely determined from this projection at this stage. Three dimensional intensity data were collected by multiple film equi-inclination Weissenberg technique and a three dimensional Patterson synthesis was computed. Out of three heavy atoms (one copper and two chlorine atoms) per molecule the peaks in the Patterson map could reveal the position of copper at 0°, 90°, 90° and one chlorine at 96°, 144°, 60°. But no relevant peaks could be obtained so as to identify the position of the second chlorine. It was, therefore, presumed that the two chlorine atoms might be centrosymmetrically related and their peaks would

naturally superpose. At this stage centrosymmetric test, i.e., N(z) test was made and the experimental curve indicates that the copper ornitnine molecule is centrosymmetric. The structure factors computed with these heavy atoms of this centrosymmetric molecule shows a reasonable agreement between $|F_o|$ and $|F_c|$ Further work is in progress.

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

(j) *Low temperature crystallography*

Low temperature crystallography is used (a) to study compounds which crystallise at low temperatures but are not stable at room temperature, (b) to study thermal vibrations, to locate hydrogen or other light atom positions accurately in the presence of heavy atoms and (c) to study phase transition.

The method of cooling employed in the present arrangement is simple gas cooling. The technique used is a modified version of that developed by Fankuchen (1951) and Lipscomb (1950). In this method nitrogen gas (free from carbon dioxide and water vapour) is passed through a copper coil immersed in liquid air, thereby bringing the temperature of the gas to the temperature of the liquid air. The stream of the cold gas is allowed to pass through a Dewar tube and to fall on the crystal sealed inside a capillary and mounted on the goniometer head of a Weissenberg or rotation camera. The experimental arrangement is shown in a schematic diagram in Fig. 2B.4.

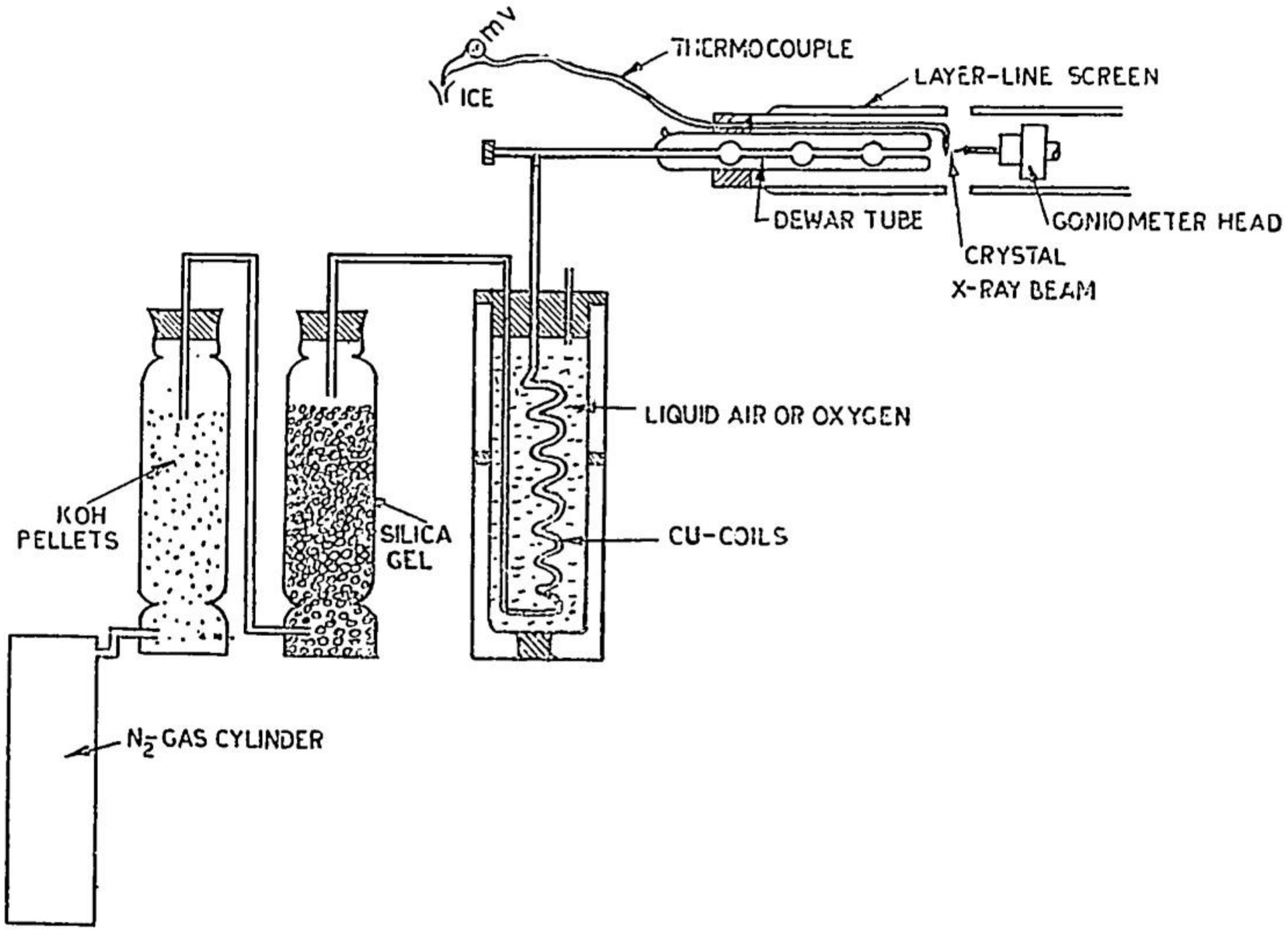

Fig. 2B.4 A schematic diagram showing the low temperature attachment to Weissenberg goniometer.

J. K. Dutta Gupta, S. K. Mazumdar and N. N. Saha

2B.2 *Ultrastructure of Biomolecules by Electron Microscopy and Small Angle X-ray Diffraction.*

In this programme collagen from various sources, normal and diseased bones, DNA from various sources, e.g., sponge, hydra, rat liver, etc. are being studied. Our previous programme on ultrastructural models is also being continued.

N. N. Saha

(a) *Electron microscopic study of collagen*

The band-interband structure of sharkfin collagen has been studied under electron microscope after staining the specimen positively with PTA. The member of ridges and furrows per repeat period was found to be in exact conformity with the earlier electron microscopic observations made on this collagen by shadowing or by negative staining PTA. The above observation supports the conclusion made earlier by us (*Proc. 6th Int. Cong. Elec. Micro.* Kyoto, *2*, 129, 1966) that the tropocollagen molecule of sharkfin collagen has in it a distribution of polar sites different from that in tendon collagens, e.g., rat tail tendon or chicken leg tendon.

For further confirmation of the distribution of polar sites in fin tropocollagen, attempts have been made to produce the SLS crystallites by addition of ATP to an acetic acid solution and also to a tryptic digested solution of SF collagen in varied environmental conditions. This resulted into aggregated but non-striated forms only. The SLS-like crystallites showed filamentous units within them and were supposed to be the traces of tropocollagen units. Their measured lengths were about 2800 Å-3000 Å indicating that the length of the fin tropocollagen molecule is of the same order as that for tendon tropocollagen.

The fact that SLS could not be produced by our method indicates that the exact condition for SLS formation of fin collagen is perhaps very critical. It may be noted that fin collagen has a high content of hexose and hexosamine loosely bound to it. These carbohydrate moietics may have some inhibiting effect on the matching of polar sites of the tropocollagens during the formation of SLS crystallites from collagen solution. Attempts are now being made to break the carbohydrate links by some suitable enzyme and to produce the SLS forms.

S. Das

(b) *Ultrastructural model of collagen*

It may be mentioned that an ultrastructural model for wet sharkfin collagen has already been proposed by us using the results of small angle X-ray diffraction and electron microscopic data. An attempt is now being made to postulate a satisfory ultrastructural model for dry SF collagen. But an exposure

of even 75 hours from an X-ray tube running at 35 kV and 20 mA could not produce a reproducible small angle pattern of dry SF collagen. It was, therefore, decided to collect intensity data from small angle patterns of SF collagen at different humidities and to propose a model for dry collagen. It may be noted that the rectangular density distribution used for wet collagen has been found unsuitable for dry collagen. Consequently, a Gaussian distribution of density has been assumed for working out an ultrastructural model for the latter.

Theoretical calculation for the exact relationship between the observed integrated intensity and the structure factor F_n is being made to account for the intensity distribution in sharkfin collagen which is different from that of rat tail tendon.

S. C. Bhattacharya and N. N. Saha

2B.3 *Physico-chemical and Enzymatic Study of Biomolecules*

(a) *Physico-chemical studies on the molecular subunits of sharkfin collagen*

In our general programme of research on the separation and study of the various components of sharkfin collagen, an elaborate study is being continued on the gelatinous component obtained by treating the formic acid extract of sharkfin collagen by ether. The spectrophotometric study of this gelatine fraction showed that it did not contain any tyrosine—an amino acid which this particular collagen contains in an appreciable amount. It has been found that the portions left insoluble in formic acid contains almost all the tyrosine present in this collagen. This finding of ours is in conformity with the observations of previous workers who failed to solubilize the tyrosine-rich component in this collagen even after autoclaving at 15 lb pressure for 16 hrs.

Although paper electrophoresis of the gelatine in acetate buffer (pH 4.8; $\mu = 0.05$) at 300 volts for 4-5 hours apparently showed its homogeneity, it appeared to be heterogenous when the experiments were carried out in alkaline buffers (borate buffer, pH 9.00; veronal buffer, pH 8.6). The heterogeneity of the material was corroborated also from the ultracentrifuge experiment in phosphate buffer (pH 6.8; $\mu = 0.1$).

An attempt has been made to seperate the components in the gelatine fraction by column chromatography. The absorbent used was carboxymethyl cellulose (BIORAD). The protein sample was dissolved in starting buffer (0.04M acetic acid; 0.06M sodium acetate; pH 4.8) and dialysed against the same overnight before being passed into the column. Elution was made with a linear salt gradient increasing from ionic strength 0.06 to 0.14 over a 600 ml volume. The limiting buffer was of pH 4.8 and of ionic strength 0.2 (0.04M acetic acid; 0.06M sodium acetate; 0.14M sodium chloride). The column was developed at a rate of 220 ml per hour and aliquots of 10-12 ml was collected

in each tube. The effluent from the column was monitored with a Hilger U-V spectrophotometer at 230 mμ. Only two components (A and B) could be separated by this system. Elution was then continued with a straight 0.06 ionic strength buffer of pH 4.8 containing 0.44 M sodium chloride. By this method two more components (C and D) have been separated. The rest of the protein still absorbed in the column was eluted out with the same buffer solution of pH 4.8 but containing 6M urea and 1M sodium chloride, which gave three components (E, F, G). Thus as many as seven components have so far been detected in the sharkfin gelatine. Starch-gel electrophoresis for the identification of these components has been thought of and the apparatus required for this purpose is under construction in our workshop.

Work is in progress to elucidate the molecular nature of these components and also their relation to the parent macromolecule.

S. K. Ghosh and N. N. Saha

(b) *Physico-chemical properties of DNA and protein extracted from sponge and hydra cells*

In the evolutionary scale of living beings from unicellular to multicellular organisms sponge and hydra occupy unique positions. In fact, these two systems bridge the gap between unicellularity and multicellularity. Hence it will be of immense interest to have some insight into the molecular basis of such cell substances as DNA and proteins.

Series of experiments have been done to determine the melting temperature T_m of hydra DNA. From preliminary data a T_m of 88°C (approx) has been obtained. T_m is related to the base content of DNA by the equation

$$T_m = 69.3 + 0.41 \text{ (G.C.)}$$

So, by determining T_m, the base proportions of an unknown DNA may be found out.

Preliminary experiences have been carried out to isolate the proteins from sponge and hydra cells. When isolating DNA the denatured protein layer obtained after centrifugation has been collected to test for collagen and other proteins. The collected mass was insoluble in conc. acid but soluble in conc. alkali. Analysis by electrophoresis and paper-chromatography is being tried.

Anjali Mookerjee

(c) *Studies on the functions of inositol in PFK activity*

It was earlier observed that inositol deficiency caused an effect in S. Carlbergensis similar to "Crabtree effect" namely cells harvested from the long phase showed respiratory inhibition during the aerobic utilization of glucose and ethanol. Cells harvested from the saturated phase, however, regained most of their normal respiratory characteristics. It was shown that during aerobic glucose utilization by the deficient cells, glucose, 6-phosphate had increased tremendously and fructose di-phosphate concentration had fallen considerably. Therefore, it is believed that the enzyme phosphofructokinase (PFK) activity is somehow affected by inositol deficiency.

A detailed programme of study on the function of inositol in PFK activity has been undertaken. To do this, PFK has been isolated by lysing the protoplasts made by treating the cells with enzymes from snail gut juice prepared in our laboratory. A 150-fold purified enzyme has been made by salt fractionation and absorption techniques. Enzyme activity was assayed by fluorimetric methods. The kinetic study of PFK is in progress. It has been found that the enzyme is strongly inhibited by adenosine 5′-triphosphate (ATP) in presence of low concentration of fructose 6-phosphate (F6–P). But, if a very low concentration of ATP is maintained, rise in F6–P concentration can overcome this inhibitory effect of ATP on the enzyme. It has also been seen that Mg^{++} concentration is not critical, though absolute activity has been found to decrease at the low Mg^{++} levels. With low levels of F6–P and high ATP, both Pi and 5′-AMP can stimulate activity of this enzyme. The effects of 3′, 5′-AMP, FDP, etc. on the activity of this enzyme are being studied now. Attempts are also being made to find out if inositol is in any way connected with enzyme activity. Some of the techniques used for these studies are (i) fluorescence fluorimetry, (ii) polarographic method for oxygen utilization, (iii) U-V spectrophotometry and (iv) colorimetry.

Publication :

A. Ghosh and S. N. Bhattacharyya, *Biochim. Biophys. Acta, 19,* 136. 1967.

S. N. Bhattacharyya and A. K. Ghosh

2B.4 *Quantum Biology*

(a) σ – *electronic charge distribution in amino acid derivatives*

Our earlier programme on the study of the electronic properties of α – amino acids and their derivatives is being continued. The LCAO – MO method suggested by G. Del Re has been used in calculating the electronic charges in sarcosine and glycocyamine, both in neutral and cationic forms, and has been compared with the bond lengths and bond angles of those amino acid derivatives obtained by X-ray study. The σ – electronic charges of N–acetyl glycine, N–acetyl alanin, citrulline and ornithine have been calculated for the neutral forms. The study of the ionic forms and the σ – bond energies of these compounds are in progress. The data would be used to study the bond-properties and biophysical properties of the compounds. A large number of related compounds has been included in our programme of study.

The σ – electronic charge distribution of two of the compounds already studied, e.g., N – acetyl alanine and citrulline is shown in Fig. 2B.5 and Fig. 2B.6, respectively.

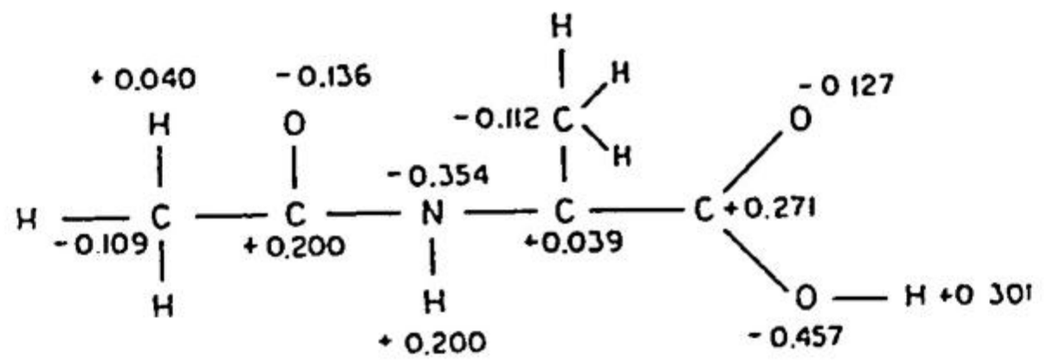

Fig. 2B.5

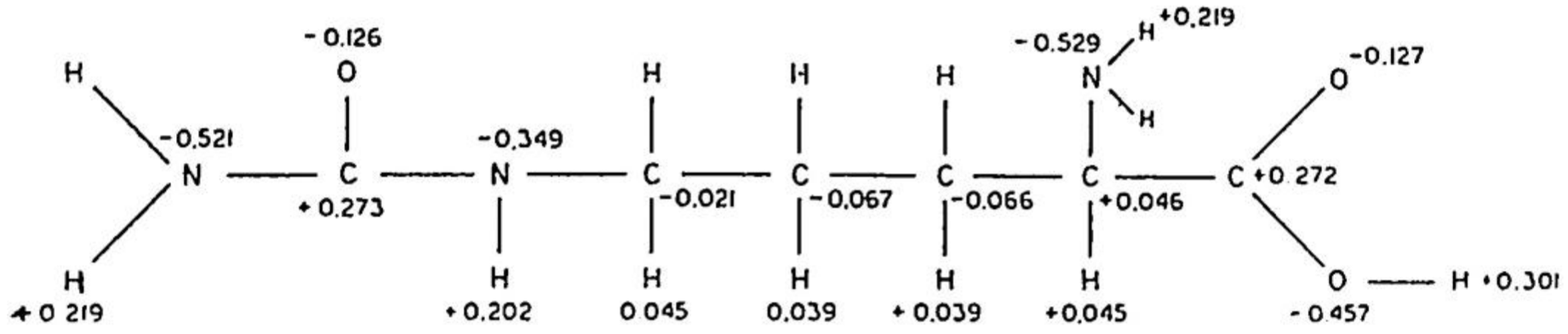

Fig. 2B.6

(N. N. Saha, S. K. Mazumdar and S. Guha, 'Structure and Electronic Charge Distribution of Amino Acid Derivatives', presented at the *International Conference on Chemical Bonds* held at Minsk, USSR, May 1967).

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

(b) *Conformational studies of biomolecules by molecular orbital calculations*

It is well known that biological functions depend to a great extent on conformations. A programme of research has been undertaken to correlate the molecular dimensions and conformations as obtained by X-ray crystallographic analysis with the theoretical molecular orbital calculation on some amino acids and peptides with an ultimate object of elucidating the conformations of biomolecules for which experimental data are lacking or inadequate. The first few molecules chosen for our investigation are histidine, hydroxyproline, phenylalanine, proline, tryptophan and tyrosine on which X-ray data are already at our disposal. The study of polypeptide chains built up of these amino acids will be taken up later. The above mentioned amino acids on which work has already been started have both $\pi-$and $\sigma-$bonds. The calculations based on the extended Huckel method of Hoffmann are in progress (*J. Chem. Phys.*, *39*, 1963). The extended Huckel method is very efficient in establishing the structure of large molecules consisting mainly of $\pi-$bonds (R. Hoffmann, *J. Chem. Phys.*, *40*, 1964). The $\sigma-$orbitals of the molecules are also explicitly taken into account in this method. It must be mentioned that this method is ideally suited for studing the geometry of bent molecules.

Jayanti Lahiri, S. K. Mazumdar and N. N. Saha

2B.5 *Radiation Biology*

(a) *Low background 4 π counter*

A windowless 4 π counter has been constructed and its characteristics have been studied. The background has been lowered, in addition to the material shielding, by the anticoincidence operation of two halves of it. The lower limit of the background reached by it on an average is 2.61 ± 0.38 cpm. The sample changing of this counter has been facilitated by having a circular rotatable sample changer. The duration of the counting is shortened by having a preflush position for the sample before introducing it into the active volume of the counter.

The counter is being used in the low level tracer study of the fibrous protein present in paramecium using ^{14}C– proline. The presence of hydroxyproline has been confirmed in this protein. It may be mentioned that hydroxyproline is mostly concentrated in the fibrous lines of the organism. The extraction of both acid and alkali soluble protein contained in the fibrous lines solution and its characterization are in progress.

(K. B. Udupa, '^{14}C-proline Incorporation and its Turn-over in Paramecium —a Tracer Study', to be published in *Proc. Symp. Biophys.* (*Ind. Biophys. Soc.*), *Calcutta.*)

K. B. Udupa

(b) *Tracer study in riboflavin deficiency*

The incorporation of ^{32}P into different fractions of adrenals and in plasma has been studied under riboflavin deficiency. The distribution of radioactive phosphorus in the inorganic P and lipid P fractions of adrenals indicates the stimulation of adrenal cortical function in riboflavin deficiency.

Publication :

S. C. Jamdar and K. B. Udupa, *Endokrinologie, 51,* 175, 1967.

K. B. Udupa and S. C. Jamdar

(c) *Studies in haemolymph from cockroaches by radioactive tracer*

Tracer study on the haemolymph of cockroaches is being continued. It has been observed that the haemolymph inside and outside the heart carries different concentrations of inorganic ions like sodium, chloride, phosphate, iodide and iron. The difference in anionic concentration is more pronounced.

The study is extended on the protein composition of the fluids. Use of paper electrophoretic technique indicated that the composition of the two fluids are different. The nature and extent of this difference with the possible physiological consequences are under investigation.

Publication :

S. K. Lahiri, A. Roy, D. Banerjee, S. C. Jamdar, S. R. Basu and B. D. Nag, *Ind. J. Exp. Biol., 5,* 27, 1967.

Sandwip Bose, S. K. Lahiri 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 the thyroid function was carried out on rats earlier. Further studies are undertaken to understand the nature and extent of these changes.

A limited range of tracer doses of ^{131}I is found to have specific effect on thyroid function. Electrophoretic and chromatographic work is under progress in this range of tracer doses to find the reason of this effect.

S. R. Basu and S. K. Lahiri

(e) *Investigation on collagen degradation by radiation*

A few samples of hide powder were subjected to ultraviolet irradiation for different known periods. The irradiated samples thus obtained were tanned with different tanning materials. It has been found that the uptake of tanning materials by irradiated samples increases progressively with the irradiation period indicating thereby the increase in the number of bonding sites. The possible mechanism is the breakage of hydrogen bonds and creation of some bond-forming sites due to irradiation.

A water soluble fraction was obtained from the U. V. irradiated hide powder which was otherwise an insoluble material. The physico-chemical properties of the irradiated samples and their water soluble fractions have been studied.

X-ray diffraction study of the irradiated samples has also been made. Some beneficial effects of U. V. irradiation have been noted.

N. N. Guha and N. N. Saha

2C. TEACHING DIVISION

2C.0 *Introductory Remarks*

The fourteenth session of the post-M.Sc. associateship course continued till the end of May, 1967. A series of colloqui were also started for the students on every working Saturdays. There was very good co-operation from the research staff of the Institute who took active part in the programme.

Excellent co-operation was received from members of the research staff of the Institute in taking various classes for the students. Besides regular members of the staff of the Institute, many pool officers and research assistants and associates took part in the teaching programme of the 14th session. Towards the end of the 14th session of the post-M.Sc. course, Dr. M. K. Mehta of BARC was invited to give a series of talks on experiments with electrostatic accelerator to the post-M.Sc. students.

The post-M.Sc. diplomas were distributed on the last day of the 14th session. Prof. B. D. Nag Chaudhuri handed over the diplomas.

Out of the fifteen students of the 14th session six have been absorbed in various research groups in the Institute, five have gone abroad and the rest have settled in various other institutes and universities in the country.

The fifteenth session of the post-M.Sc. associateship course for training in nuclear physics and solid state physics started in July, 1967. Of about 180 applications received, ninety three students were selected for admission test. Twenty five students were offered admission. Twenty two students joined the course. Several meetings of the teaching committee took place and a balanced programme for teaching both nuclear physics and solid state physics were drawn up, which took effect from the fifteenth session. For the fifteenth session it was decided not to ask research assistants to take classes as it demands too much of their time. However, a system of paying honorarium to non-members was introduced. Rules and regulations for examination were also formulated which will be applicable from the sixteenth session.

A new series of colloqui will start for the fifteenth session from January 1968. It is proposed that this year the students will also participate.

In the present academic year, Dr. Krishnadas Banerjee, a pool officer in the biophysics division of the Institute gave an interesting course of lectures on "computers and programming". Dr. S. N. Goswami of Maulana Azad College has been delivering a series of lectures on "plasma physics".

Serious thought is also being given to the introduction of biophysics as a topic of specialisation in the post-M.Sc. course.

A summer school on physics sponsored by the NCERT for the B.Sc.

students, was conducted in the Institute during May and June. A large section of the staff took part in the programme. About 27 students from different parts of northern India attended the course.

Research report of the staff of the teaching division is given under the nuclear physics division.

B. B. Baliga

2C.1 *Teaching programme for the 14th session, 1966-67*
(January - May)

Many body aspects of nuclear models ..	Dr. S. C. K. Nair
Two body problem	Dr. B. B. Baliga
Introductory elementary particle physics ..	Prof. T. Pradhan
Nuclear structure and nuclear models ..	Dr. J. Mahalanabish
Nuclear spectroscopy	Dr. R. Bhattacharya
Neutron physics	Dr. S. K. Mukherjee
Experimental measurements of the properties of the elementary particles	Dr. B. Basu
Solid state devices	Dr. J. K. D. Verma
Molecular spectra	Dr. D. K. Ghosh and Dr. G. Das
Mathematical methods & group theory ..	Shri P. Rudra
Mathematical methods	Shri A. Roy Chaudhuri
NMR, etc.	Prof. M. Bose
Structural crystallography	Prof. N. N. Saha
Magnetic properties of solids	Dr. A. Chakraborty
Crystal field theory	Shri S. K. Gupta
Resonance methods	Prof. R. N. Roy
Nuclear reactions	Dr. P. N. Mukherjee
Band theory of solids	Shri K. C. Das
Superconductivity	Dr. T. Roy
Statistical mechanics	Dr. S. K. Sinha
Nuclear reactions	Dr. S. Mukherjee
Some problems in β-decay theory	Dr. S. C. K. Nair
Plasma physics	Prof. B. D. Nag

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

R. N. Chaudhuri	..	Approximate methods of solving potential scattering
Jadunath De	..	A study of isobaric analogue states from direct (p, n) reactions
* V. P. Desai	..	Paramagnetic susceptibilities and resonance of ion group and rare earth complexes of octahedral symmetry
Vijay V. Dixit	..	One pion exchange model in peripheral interaction with form factors and absorptive corrections
* Aparna Ghosh	..	NMR studies in paramagnetic solids
A. V. Khare	..	Current algebra
Nanda Mukherjee	..	Measurement of nuclear g-factor of excited levels of nuclei
* Prasanta K. Mukherjee	..	Self consistent field approach to many electron problem
Ashesh Nandy	..	N/D perturbation theory and applications to simple and double pole models
* R. N. Nandy	..	Determination of the space-group of sarcosine
J. R. Saraf	..	B. B. G. K. Y. kinetic theory of plasma physics
* Papiya Sengupta	..	The Bohm-Pines approach to many body problem applied to dense electron gas
Srikrishna Singh	..	Radiative μ-capture in nuclei
T. N. G. Tiwari	..	Procedures for investigations of decay schemes of nuclei and some experimental studies on the decay of ^{46}Sc
* S. N. Toke	..	The study of internal rotation by gaseous microwave spectroscopy

* Students with solid state physics specialisation

2C.3 *Teaching Programme for the 15th Session, 1967-68*

(*July-December*)

Quantum mechanics ..	..	Dr. B. Dutta Roy
Basic mathematics ..	..	Dr. S. Mukherjee
Advanced nuclear physics ..	..	Dr. J. Mahalanabish
		Dr. S. C. K. Nair
Advanced quantum mechanics ..	..	Dr. A. Roy Chaudhuri
Nuclear physics ..	..	Dr. R. Bhattacharyya
Advanced solid state physics ..	..	Dr. S. Sinha
Solid state physics, numerical analysis	..	Dr. A. Mukherjee

Nuclear physics	.. .. ..	Dr. B. B. Baliga
Quantum mechanics	.. .. ..	Prof. T. Pradhan
Solid state physics	.. .. ..	Dr. A. Chakravarty
Nuclear physics	.. .. ..	Dr. D. Pal
		Prof. M. K. Pal
		Dr. I. Mukherjee
Plasma physics	.. .. ..	Dr. J. Basu
		Dr. S. N. Goswami
Experimental physics	.. ..	Dr. J. K. D. Verma
		Dr. N. K. Majumder
		Dr. A. K. Sengupta
		Dr. K. S. Patel
		Dr. R. Bhattacharyya
		Dr. S. Nath
		Prof. R. Roy
		Dr. J. Basu
		Dr. S. B. Kar
		Dr. R. Bhattacharyya
		Shri B. K. Sinha
		Shri S. Sen
Computer and programming	.. ..	Dr. K. D. Banerjee

2C.4 *Special Lectures*

Speaker	*Subject*	*Date*
Academician V. M. Glushkov, Soviet Scientist	1967-M. N. Saha Memorial Lecture Data processing in physical science and engineering	January 13, 1967
Academician A. M. Prohorov, Soviet Scientist	Multi-quantum processes of quantum electronics	January 13, 1967
Prof. Mareos Meshinsky	Group theory and the four nucleon problem	January 16, 1967 and January 17, 1967
Dr. C. H. Carlisle, Brieback College, London University	Some aspects of X-ray work in the crystallographic deptt.	January 25, 1967

Speaker	*Subject*	*Date*
Prof. Eigi Hirota, Tokyo University	Microwave spectum of sulphur monoxide	January 30, 1967
	Determination of the equilibrium structure by microwave spectroscopy	January 31, 1967
	Internal rotation of asymmetric tops	January 31, 1967
Prof. David Falkoff, Brandeis University	Theory of coherent photon states and experimental applications	January 31, 1967 and February 1, 1967
Dr. P. Gregass, Hungarian Scientist	Ultrasonic research and application in Hungary	February 23, 1967
Prof. L. S. Stermen, Head, Thermoelectric Power Station, Moscow Inst. of Energetics	Informal talk	March 3, 1967
Mr. D. J. Mathias, IBM	Systematic programming system for IBM 1620	August 1, 1967 to August 4, 1967
Dr. (Miss) D. F. Jackson, University of Surrey	Nuclear structure studies with knock-out reactions	September 15, 1967
	Overlap integrals for the excitation of hole states	September 16, 1967
Prof. P. G. D. Freund, University of Chicago	Superconvergence relations	September 26, 1967
Dr. M. Rho, France	Migdan's Green function approach to nuclear structure	October 5, 1967
Prof. T. P. Das, University of California	Many body theory of hyperfine interactions in atoms	October 24, 1967
Prof. Samuel Devones, F.R.S., Columbia University	Muonic nucleus and nuclear structure	November 20, 1967
Dr. P. P. Divakaran, TIFR, Bombay	Construction of composite particles field operation	December 7, 1967
	Criteria for compositions of particles	December 8, 1967
Dr. B. Mishra, Geneva University	Asymptotic condition scattering theory	December 22, 1967

A symposium on biophysics was held on 17th and 18th April, 1967, under the auspices of the Indian Biophysical Society.

2C.5 *Colloqui*

Speaker	*Subject*	*Date*
Shri M. L. Chatterjee	Study of energy and angular distribution in (n, α) reaction	January 7, 1967
Shri S. D. Dey	Measurement of ionization potential by surface ionisation studies	January 21, 1967
Shri K. V. Chalapati Rao	Interpretation of (t, p) reaction data using surface data interaction wave-functions	February 4, 1967
Dr. S. N. Sengupta	Probe studies of a cold cathode PIG discharge	February 18, 1967
Prof. B. D. Nag Chaudhuri	Plasma physics	March 27, 1967
Dr. G. Das	Electron correlation in metals	April 1, 1967
Prof. B. D. Nag Chaudhuri	Plasma physics	April 20, 1967
Shri A. K. Nigam	Measurement of gyromagnetic ratio of nuclear levels	April 29, 1967

3. BIOPHYSICS DIVISION

3.0 *Introductory Remarks*

From the reports of the research workers given below, it will be seen that the biophysics division made satisfactory progress during the year under review. A serious difficulty has been felt by the research workers due to the remoteness of the library which is located in the main building of Saha Institute. Some capital grants are immediately necessary for construction of additional space for library and reading rooms.

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

Theoretical and practical teaching in biophysics special paper of the M.Sc. course of Calcutta University has been continued and 7 students got their M.Sc. degree in 1967 with biophysics as a special subject of study. If the funds for equipments and for the construction of additional space are available, teaching and research facilities in biophysics may be improved during 1968.

The *electron microscope section* has continued investigations on the fine structure of macromolecules like haemoglobin, DNA, etc. The changes produced in the ultrastructure of these molecules under different conditions have also been examined. Investigations on the interaction of proteins with electron stains have been continued and the sedimentation and ultraviolet absorption characteristics of DNA have been studied. Continuous efforts are also being simultaneously made to improve the quality of specimen preparation and electron microscopy techniques.

In the *ultrastructure research section*, studies have been made on the ultrastructure of bacterial, protozoan and metazoan cells, either with intact cells or after ultrathin sectioning. Attempts have also been made to investigate the changes in the sub-cellular organisations of diseased human cells. Researches on nuclear structure and on chromosomal organisations of different microorganisms have also been carried out. Investigations on the nucleohistone complexes from the amphibian and reptilian erythrocytes are under progress with an aim to find out the orientation of these fibrous elements inside the chromosome.

In the *radiation biology section*, experiments have been carried out on the effect of previous thymineless incubation, on the ultraviolet sensitivity of bacteria and *vice versa*. How the presence or absence of RNA and/or protein syntheses during the thymineless incubation influences the susceptibility of the cells to such incubation, is under investigation. Studies with X-irradiated cells have shown that some of the radiation-killed cells could be reactivated, if instead of immediately plating them on agar plate, they are incubated for suitable time in the presence of non-irradiated cells, prior to plating. The investigations on the

synergism of X-rays and ultraviolet radiation have been further extended with different strains of bacteria. Simultaneously with the studies on the bacterial cells, experiments have been initiated with the X-ray sensitivity of bacteriophage T2, previously treated with ultraviolet rays.

The *molecular genetics section* continued its work on the molecular biology of bacteriophage ϕX174. Study of the influence of the viral genome on the synthesis of different RNA moietics, has revealed that phage infection severely inhibits the ribosomal RNA. Photodynamic inactivation of free ϕX174 and infected *E. coli* cells in presence of acridine dyes has been undertaken to bring out any possible difference in the mode of action of such mutagens with single- and double-stranded DNA. Isolation and purification of free ϕX–DNA and its double-stranded replicative form (RF) is being carried out so as to corroborate by *in vitro* experiments the results of earlier *in vivo* study on the relative biological importance of the two strands of a DNA molecule. Work on the isolation of temperature sensitive *E. coli* mutants to be used in studying the contribution of host cell on the growth of bacteriophage ϕX174 is in progress. Attempts are being made to isolate a new phage smaller than ϕX174.

N. N. Das Gupta

3.1 *Negative Staining of Human Haemoglobin Molecules with Uranyl Acetate*

Normal human adult haemoglobin (Hb–A) molecules have been electron micrographed after negative staining with uranyl acetate. The effect of the stain on the protein molecules has been investigated by the techniques of sedimentation and spectrophotometry. The electron micrographs have shown many particles with characteristic ultrastructure and having the mean dimension of 66 ± 8 Å, a number of dimers of average length 57 ± 5 Å and overall width 33 ± 3 Å, and many globular blobs of average size 33 ± 6 Å. These particles have been interpreted to be whole, half and quarter haemoglobin molecules respectively. The dimension and the ultrastructure of the intact molecules have been found to agree with those of the Perutz-model of haemoglobin. The sedimentation and the spectrophotometric results, however, have indicated an interaction between the protein and the UO_2^{++} ions, resulting in the formation of loose aggregates of the protein molecules. Nevertheless, staining with uranyl acetate has revealed high resolution structural details of this haem protein. Usefulness of uranyl acetate compared to other stains in high resolution studies of these small macromolecules has been discussed.

(D. N. Misra and P. Ganguly, 'Negative Staining of Human Haemoglobin Molecules with Uranyl Acetate', to be published in *Arch. Biochem. Biophys.*)

D. N. Misra

3.2 *A Comparative Study on the Interaction of Sodium Tungstate and Potassium Phosphotungstate with Haemoglobin*

The interaction of sodium tungstate with haemoglobin has been studied by spectrophotometry and ultracentrifugation. The influence of various parameters such as the pH of the electron stain, relative concentration of the stain and the substrate reversibility on the interaction characteristics has been investigated. It has been observed that with decreasing pH, the interaction of sodium tungstate with haemoglobin increases, as indicated by an increase in the sedimentation coefficient and a decrease in the absorbance at the absorption peaks of the molecules, concomitant with their shift towards lower wave-length. These effects were found to be dependent on the relative concentration of the protein and the stain. As the protein concentration was decreased or the stain concentration increased, the effects were more prominent. These results have been compared with those obtained for the interaction of potassium phosphotungstate with haemoglobin. It has been concluded that under comparable conditions sodium tungstate is less injurious to haemoglobin than potassium phosphotungstate. Finally, a method has been proposed for avoiding pH variation problems in sample preparation procedures in electron microscopy, by mixing sodium tungstate and potassium phosphotungstate in suitable proportions.

Publication :

A. B. Sanyal and P. Ganguly, *Biochim. Biophys. Acta, 133,* 535, 1967.

A. B. Sanyal and P. Ganguly

3.3 *Spectrophotometric Investigations of DNA in the Ultraviolet*

The ultraviolet absorption spectra of a number of DNA's in the helical and random forms have been studied. A short wave-length absorption band has been observed with a maximum near 200 mμ. This band is more intense, as well as much more variable with changes of ionic strength of the suspending medium, than that centred at 258 mμ. Also, the hyperchromism due to heat denaturation at this

band is greater than that at 258 mμ. Other phenomena accompanying thermal denaturation of DNA have been described.

Publication :

S. Basu, *Biopolymers, 5*, 319, 1967.

S. Basu and N. N. Das Gupta, *Biochim. Biophys. Acta, 145*, 391, 1967.

S. Basu and N. N. Das Gupta

3.4 *Conformational Changes in Denatured DNA*

Results of recent studies on the denatured DNA molecule with the help of ultracentrifugation, electron microscopy and ultraviolet absorption techniques have been reviewed. Some new investigations carried out in this laboratory with the help of these techniques, on *E. coli B* DNA denatured by heat and prolonged storage are also reported. The observed sedimentation co-efficients have been compared with the electron micrographs and with the ultraviolet absorption data. An attempt has been made to obtain a definite picture of the conformational changes brought about by different methods of denaturation.

Publication :

N. N. Das Gupta, S. Basu, B. Bagchi and D. N. Misra, *International Symposium on the "Conformation of Biopolymers"*, Ed. G. N. Ramachandran, Vol. *2*, p. 663, 1967, Academic Press (London).

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

3.5 *Some Observations on the Food Vacuole of Paramecium Auralia*

Fully fed *Paramecium auralia*, cultured in this laboratory, have been examined under the electron microscope after ultrathin sectioning. In these organisms, the food vacuoles are full of partly digested and partly undigested bacteria. During the process of digestion, the nuclear matter of bacteria is disintegrated first and that region becomes vacuolated. Then the cytoplasm shows the sign of absorption which is ultimately digested leaving only the cell wall. During this stage, the pinocytic vesicles appear by the evagination of the wall of the food vacuole, which finally cuts off from the main body and moves to the cytoplasmic stream. As this process of digestion goes on further, the accumulation of the pinocytic vesicles increases in number. At this stage, the rounded nature of the food vacuole is not retained which becomes somewhat amoeboid

when most of the bacteria have been digested. Then the maximum accumulation of pinocytic vesicles takes place around the food vacuole. In many places these are visible in the remote parts of the cytoplasm, where they become smaller and smaller are ultimately absorbed.

Publication :

J. Chakraborty and P. Sadhukhan, *Zeits. fur Naturforschg.*, *22*, (*b*), 558, 1967.

J. Chakraborty and P. Sadhukhan

3.6 *Electron Microscopy of the Hypotrich Ciliate, Oxytricha Platystoma, with Consideration of its Macronuclear Organization*

The body of *Oxytricha platystoma* has been found to be covered with 2 membranes, the outer or pellicular membrane and the inner or cytoplasmic membrane. Each cirrus consists of a bundle of 25-50 cilia. The macronuclei are elongated bodies surrounded by 2 unit membranes. Some larger bodies found inside the nucleus may be nucleoli. There is a single re-organization band in each macronucleus. It consists of a solution plane and a reconstruction plane, and has a total thickness of 1.5μ. This re-organization band helps in the DNA synthesis. The movement of this band from one pole of the macronucleus to the other pole has also been noticed.

Publication :

J. Chakraborty, *J. Protozool.*, *14*, (*1*), 59, 1967.

J. Chakraborty

3.7 *Ultrastructure of the Parasitic Ciliate, Conchophthirius Anodontae*

The morphology of the parasitic ciliate, *Conchophthirius Anodontae*, obtained from the two large gill-places of fresh water mussel (Unio.) have been studied. Body of this holotrich ciliate is laterally compressed. Macronucleus is large and takes very deep stain with feulgan. The cilia show typical "9 + 2" pattern. Mitochondria are specially arranged near the cell surface, also many are visible in the cytoplasm. A special type of rounded bodies are scattered all over the cytoplasm at random which resemble the mitochondria. The results have been reported at the Annual Conference of the Electron Microscope Society of India, Kharagpur, 1967.

J. Chakraborty

3.8 *Electron Microscopic Studies of a Pathogenic Bacillus, Pseudomonas Pyscyanea*

The morphological details of a human pathogenic bacillus, *Pseudomonad pyocyanea* have been investigated. No electron microscopy has so far been done of this organism. The bacillus, collected from patients was cultured in the laboratory, fixed in buffered osmium tetroxide, sectioned with the ultramicrotome and observed under Siemens Elmiskop I at 60 kV.

Ps. pyocyanea is a rod shaped organism about 1-3μ long and 0.3-0.5u wide. It is found in the literature that this organism is actively motile by virtue of 1 to 3 polar flagella. However, both in the section or in the intact organism, no such flagellum was visible.

In the ultrathin sections, the surface structure of the cell appears to consist of two components : cell membrane and the cytoplasmic membrane. Each of these in turn, is observed to have a double aspect. The nuclear matter covers the entire central region of the cell, which is composed of fibrillar material. In some sections a few rounded unidentified bodies are present. The preliminary observations have been reported at the Annual Conference of the Eleceron Microscope Society of India, Kharagpur, 1967.

P. Sadhukhan

3.9 *Electron Microscopy of Nucleohistone and other Fibrillar Elements from Vertebrate Erythrocytes*

Conformational studies on the nucleohistone obtained from vertebrate erythrocytes were made by spreading a drop of blood on an air-water interface. The spread material was picked up by touching carbon-coated grids on the water surface. The grid was next fixed, stained, dehydrated and dried before observation under the electron microscope. Cells and nuclei in various stages of disruption were observed. In an well extended nucleus, it was clearly seen that its entire mass consisted of network of fibres. Where the network was unentangled, the fibre diameter varied within 200 and 320 Å. But in certain ill-spread network, the fibres appeared twisted and knobby. The diameter then measured around 500 Å. It is not yet clear, whether this thickening arises due to an artifact during specimen preparation or in the result of multiple folding of thinner 200 Å fibres. No substructure within the 200 Å fibre was visible. These results were presented at the Annual Conference of the Electron Microscope Society of India, Kharagpur, 1967.

D. K. Chattoraj and P. Sadhukhan

3.10 *Thickness Variation in Vacuum Evaporated Carbon Film*

The properties of vacuum evaporated films are being investigated. The pattern of the variation of the thickness of carbon films deposited on a flat surface by the usual evaporation technique has been investigated.

A flat circular glass plate with a centre mark was horizontally placed in the evaporation chamber containing carbon electrodes. The centre of the plate was positioned vertically below the electrode tips, and carbon film was deposited on the glass surface in the usual way. The optical density of the film was measured along a certain radius from the plate-centre to the circumference. Similar measurements were made along other radii spaced at $22\frac{1}{2}^{\circ}$ interval around the centre. The optical densities along the various radii were plotted on a circular graph paper and points of equal density joined together.

In the evaporation of carbon from the electrodes (spherically symmetrical around the tips), the loci of equal optical density on the graph would have been circles. The experimental pattern indicated a rather pear-shaped form. Since the optical density is directly proportional to the film thickness, the pattern in the graph also indicated the nature of the variation of the film thickness on the surface of the glass plate. These results were reported at the Annual Conference of the Electron Microscope Society of India, Kharagpur, 1967.

H. P. Mitra and M. L. De

3.11 *Sedimentation Studies on Denatured DNA*

DNA prepared from *E. coli* cells were neat-denatured in two solvents namely, 0.15M-NaCl and 0.013M-Na^{+} phosphate buffer. In both cases, renaturation was checked by the addition of 1% formaldehyde in neutral solution. From the measured sedimentation co-efficient of denatured DNA, the following different forms have been proposed :

(i) single stranded DNA in either stretched or collapsed condition,
(ii) single stranded DNA folded on itself,
(iii) double stranded DNA but united at short regions either intra- or intermolecularly,
(iv) double stranded DNA still hydrogen bounded but with interstrand coiling lost.

The relative S-values in each case have been discussed.

B. Bagchi

3.12 *Effect of In-vitro X-irradiation on the Ribosomes of Yeast Cells*

The effect of *in-vitro* X-irradiation on purified ribosomes, contained in 0.01M-Tris + 0.005M-$MgSO_4$, pH–7.2 buffer, was studied. The ribosomes showed following types of changes when examined in the analytical ultracentrifuge:

(i) the ribosomal distribution of control and irradiated samples did not differ, but the S-values of the 80S component of irradiated sample decreased,

(ii) when Mg^{++} ion concentration of the samples were slowly reduced by dialysis, in both the cases dissociation of 80S into 60S + 40S and conversion of 60S to 50S occured; but in the irradiated sample the processes were enhanced,

(iii) when the samples having low Mg^{++} concentration were dialysed back to high Mg^{++} concentration, the association process took place at the same rate in both the cases.

The following conclusions were made from these observations. The decrease in S-value was probably caused by breaks produced by X-rays in the exposed RNA portions of the ribosomes producing loosening of structure. The faster conversion of 80S to 60S + 40S was due to action of X-rays on the Mg^{++} ions binding places of the sub-units. It also supports the hypothesis that 60S to 50S conversion is a conformational change of structure.

Nandini Ghosh

3.13 *Physical Studies of T7 DNA*

T7 bacteriophage has been cultured in this laboratory, using *E. coli B.* as the host. The phage was purified and concentrated by the method of Davison and Freifelder. The concentration of the titre has been increased by the $(NH_4)_2SO_4$–precipitation method. The DNA was extracted with phenol and its molecular weight is under investigation.

R. K. Sinha and S. Basu

3.14 *Influence of Protein and RNA Syntheses on Thymineless Death of E. coli* $15_{T^-A^-U^-}$

E. coli $15_{T^-A^-U^-}$ cells are incapable of synthesizing protein and RNA in the absence of arginine and uracil in the growth medium. Thus, if these requirements are individually withheld, one can then study the effect of absence of such

syntheses on the susceptibility of cells to thymineless incubation. It has been found that when the cells are held in a medium where protein and RNA syntheses are allowed, the slope of the thymineless survival curve is 2.1×10^{-2} per minute. This value of the slope does not change even when the cells are held in media in which thymine-arginine, thymine-uracil and thymine-arginine-uracil are respectively absent. This indicates that the presence or absence of protein and/or RNA syntheses is immaterial so far as the sensitivity of the cells to thymineless incubation goes. To confirm these preliminary results, experiments with specific inhibitors of protein and RNA syntheses, during thymineless incubation are in progress.

S. B. Bhattacharjee and Nati Ganguli

3.15 *Sensitivity of E. coli to Thymineless Incubation and U.V.-irradiation*

Experiments have been done to study the influence of previous thymineless incubation on the U.V. sensitivity of a thymine requiring strain of *E. coli*. It has been found that the sensitivity of the cells to U.V. rays increases with the increasing periods of previous thymineless incubation. The sensitivity reaches a maximum saturation value after which further increase in the previous thymineless incubation does not increase the U.V. sensitivity any more. Experiments have also been done to study the influence of previous U.V.-irradiation to later thymineless incubation. It has been observed that previous U.V.-irradiation sensitizes the cells to thymineless incubation only upto a dose of 300 ergs/mm^2; beyond this dose, the cells become gradually resistant to thymineless incubation and ultimately a stage is reached when they are immune. The process to reach this immunity to thymineless incubation is a gradual one, the resistant population increasing with the increase in the dose of previous U.V.-irradiations. These results have been explained from the assumption that due to previous ultraviolet irradiation, at low doses, some nuclear disturbance occurs which sensitizes the cells to thymineless incubation and at high doses, the cells are incapable of synthesizing DNA and so are immune to thymineless incubation.

S. B. Bhattacharjee and Nati Ganguli

3.16 *Synergism between X-rays and Ultraviolet-rays in Cell Killing*

In the further extension of the work that has been reported earlier (Annual Report, 1966), the interaction of X-rays and U.V.-rays in cell killing have been studied for the bacteria, *E. coli* $15_{T^-A^-U^-}$, *E. coli B*, *E. coli* B_{S^-1} and *E. coli* B/r. For each of these bacterial strains, it is found that pre-ultraviolet irradiation is

capable of sensitizing the cells to later X-irradiation. There is a maximum sensitivity which is reached at a particular pre-U.V. dose depending on the strain of bacteria. Pre-irradiation beyond this dose does not increase the X-ray sensitivity any further. For the cells which are pre-treated with X-rays, no general increase in U.V. sensitivity is observed. It is found that only *E. coli* 15_{T-A-U-} shows genuine increase in U.V.-sensitivity due to pre-X-ray treatment. Results for other strains of bacteria could simply be explained from the destruction of the repair mechanism.

S. B. Bhattacharjee and G. Bhaumik

3.17 *X-ray Sensitivity of Pre-U.V.-irradiated Bacteriophage T2*

Experiments have been done to determine the X-ray sensitivity of bacteriophage T2, exposed to various doses of U.V., previous to X-irradiation. It has been found that the effect of previous U.V. irradiation is to make the bacteriophage resistant to later X-ray treatment. This resistance to X-rays gradually increases with the increase in the previous U.V. exposure dose upto the level studied (200 ergs/mm). This result is in contrast with the results obtained for the interaction of X-rays and U.V.-rays in the case of bacterial killing. Further experiments are in progress to elucidate the phenomenon.

S. B. Bhattacharjee and K. Banerjee

3.18 *Recovery of X-irradiated Bacteria*

It has been found that when X-irradiated bacteria are held at 37°C in phosphate buffer, instead of being immediately plated, their viable number decreases with the increase in time of incubation. Ultimately this action reaches a saturation value. If during this incubation period, non-irradiated cells are present, the decrease in viability is checked. Furthermore, the incubation of X-irradiated cells in presence of non-irradiated cells promotes recovery of the radiation killed cells, the degree of recovery depends on the time of incubation, upto a saturation value. That this is a genuine recovery is established from the fact that the total number of cells remains constant during experimental period, indicating that there is no division of the non-irradiated cells.

S. B. Bhattacharjee, G. Bhaumik and P. Mukherjee

3.19 *Influence of the Viral Genome on RNA Synthesis in E. coli Infected with Bacteriophage ϕX174*

Gross RNA synthesis in log-phase *E. coli* cells growing in trisglucose medium was not altered as a result of infection with bacteriophage ϕX174. But in presence of 50 γ/ml chloramphenicol, significant difference was observed in the mode of RNA synthesis in the infected and uninfected cells; in the latter case, there was until about 100 min an increase in the rate of synthesis, whereas such a stimulatory effect was absent in the former case. This was found to be due to excessive inhibition of synthesis of ribosomal RNA, especially its 23s component, in the infected cells when protein synthesis was blocked by chloramphenicol. If the log-phase cells growing in absence of chloramphenicol were first given a 90 sec pulse of $^{32}PO_4^{-}$ $^{-}$, then infected with ϕX174 and finally allowed to grow in non-radioactive medium (i.e., "chased"), the rate of turnover of breakdown products of pulse-labelled RNA into ribosomal RNA especially into its 23s component, was found to be slower when compared to the corresponding uninfected control cells. RNA from such pulsed and infected cells was relatively riched in pyrimidine content, implying serious inhibition of 23s ribosomal RNA synthesis and uninhibited accumulation of soluble RNA and ϕX-specific messenger RNA in these cells.

(S. R. Palchowdhury and R. K. Poddar, 'Influence of the Viral Genome on RNA Synthesis in *E. coli* Injected with Bacteriophage ϕX174', to be published in *J. Molecular Biology* (*Cambridge*).)

S. R. Palchowdhury and R. K. Poddar

3.20 *Photodynamic Inactivation of Free Bacteriophage ϕX174 and Infected E. coli Cells in Presence of Acridine Dye*

Acridine dyes are potent mutagenic agents for bacteria and viruses. These are supposed to intercalate between adjacent layers of base pairs of a regular DNA double helix and thus produce "frame-shift" mutations. Present study has been undertaken to reveal the difference, if any, in the mode of interaction of these dyes with single and double stranded nucleic acids. Preliminary experiments showed that incubation at 35°C for as long as 60 min, of free phages in 0.05M phosphate buffer, pH 6.7, containing 2γ/ml acridine orange did not produce any significant lethal action since the survival was about 90%. Visible light inactivation study at 0°C of ϕX174 in presence of 2γ/ml of acridine orange was made. Prior to irradiation ϕX was incubated at 35°C for 10 min with 2γ/ml of acridine orange. A control ϕX sample was similarly irradiated without

acridine orange. This study showed that after 10 mins of irradiation, only 0.01% of the ϕX survived. The percentage of survival for the control was 95.

Cells of *E. coli* were infected with ϕX in presence of 30γ/ml of chloramphenicol. After 40 min of incubation at 37°C they were centrifuged and resuspended in 0.01M tris buffer (pH 7.5). The complexes were incubated for 10 min at 35°C with 2γ/ml of acridine orange and then irradiated by visible light at 0°C. The surviving fraction for 10 min complex fell to 70% after 5 min of irradiation and then became constant. But there was 100% survival for 40 min complex upto 10 mins of irradiation. After 15 min, the surviving fraction fell to 70% and then became constant. This study revealed that although there was a strong binding of acridine orange with free ϕX, host cells somehow protected the phage genome very efficiently from photodynamic inactivation in presence of acridine. Mechanism(s) of this protection will be further investigated.

U. Choudhury and R. K. Poddar

3.21 *Effect of Replacement of Thymine by Bromouracil (Bu) on the Parental Strand of ϕX-RF DNA*

To get Bu-labelled ϕX174, *E. coli* CR was grown in TG medium containing 18γ/ml Budr and 2γ/ml thymidine. After 4 hr growth bacteria were infected with ϕX174 and grown until lysis. The lysate was centrifuged. To check whether ϕX174 was labelled uniformly with Bu, CSC1 density gradient centrifugation was carried out at 36,000 rpm for 30 hr. A single peak was obtained, which shows that ϕX174 was labelled uniformly.

The strands of the RF DNA of bacteriophage ϕX174 was labelled differentially with Budr or thymidine as required. Experiments of last year were repeated and it was observed that (C+ϕX) complex was more sensitive towards X-ray and U.V., when infecting strand was Bu labelled than when it was thymine labelled, the medium in which the complex grown having practically no effect on the radiation sensitivity. To check radiation sensitivity of RF DNA *in vitro*, work is in progress on the extraction of RF DNA from (C+ϕX) complexes grown in presence of chloramphenicol and on its subsequent fractionation into 16s and 21s components on 5-20% sucrose density gradient.

B. Datta and R. K. Poddar

3.22 *Isolation of a Temperature Sensitive E. coli Mutant Susceptible to ϕX174*

Since sudden change of growth-temperature can be used to switch "on" or "off" some specific metabolic process in a suitable strain of bacteria, we have

been trying to isolate a mutant of ϕX-sensitive, thymine-requiring *E. coli* strain which will grow at 37°C but not at 41°C and then use such a strain to investigate the contribution of the host cell towards the intracellular maturation of ϕX174. Our attempts with hydroxyalamine, ethylmethane sulphonate and ultraviolet irradiation have so far been infructuous. Success is expected with the very potent mutagen, N-methyl-N^1-nitro-N-nitrosoguanidine which is being currently employed.

A. Chatterjee and R. K. Poddar

3.23 *Attempt to Isolate a New Bacteriophage Smaller than ϕX174*

ϕX174 s one of the smallest-sized bacteriophages isolated so far. It probably contains 7 genes. Now any phage should have at least 3 genes : one required for infective DNA synthesis, the second for coat protein synthesis and the third one for lysing the host bacterial cells. It may be possible therefore that there exists a phage which is smaller in size than ϕX174. The U.V. sensitivity of a phage depends to a large extent on its DNA content. So by measuring U.V. sensitivity of an unknown phage and comparing the same with that of ϕX174, one can possibly find out if the former contains less DNA than ϕX174.

So far two different phage isolates from Calcutta sewers have been tested for their U.V. sensitivity, but none of them appears to be smaller than ϕX174.

S. Mukherjee and R. K. Poddar

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 students.

The division brings out regularly reports on research work done by members of the staff and students in the form of pre-prints which are distributed to all active centres of research in theoretical physics inside as well as outside India. The following preprints were brought out during 1967 :

SINP-TH/67—1 : Positive parity mesonic states and unitary symmetry—B. Dutta-Roy and S. Baba Pundari.

2 : Leptonic decays of baryons and T-violation—B. Dutta-Roy and S. Baba Pundari.

3 : Structure of Pr-isotopes—Y. K. Gambhir and Ram Raj.

4 : Two- and four-quasiparticle states in spherical vibrational nuclei—M. K. Pal, Y. K. Gambhir and Ram Raj.

5 : Remarks on calculations of mass-shifts by the N/D method—Haridas Banerjee.

6 : Modified Regge representation—Suprokash Mukherjee.

7 : Low energy π-N scattering—H. Banerjee and B. Dutta-Roy.

8 : Conductivity of a plasma in a steady magnetic field—T. Pradhan and B. Dasgupta.

9 : Reggeization of elementary particles—T. Pradhan and J. N. Passi.

10 : Suppression of strangeness-changing leptonic decays of hadrons—T. Pradhan and M. Pattnaik.

11 : Leading Laudau curves for a larger class of Feynman diagrams—Mamata Pattnaik.

12 : Calculation of the levels of Ni and Sn-isotopes by the quasi-particle method—Ram Raj, Y. K. Gambhir and M. K. Pal.

13 : Positronium formation by the passage of positrons through a dense electron gas—T. Pradhan and D. N. Tripathy.

14 : One-and three-quasiparticle states of odd-mass Ni-isotopes—Y. K. Gambhir, Ram Raj and M. K. Pal.

15 : Exact shell-model calculation of ^{58}Ni and ^{60}Ni—Y. K. Gambhir and Ram Raj.
16 : Axial-vector renormalisation constant from SU(4) algebra of current—Mamata Pattnaik.
17 : Low energy kaon-nucleon scattering—S. Baba Pundari and B. Dutta-Roy.
18 : A model for π-π scattering in the $I = J = 0$ channel—Haridas Banerjee, B. Dutta-Roy and V. J. Menon.
19 : Dielectric constant of a dense electron gas containing a fixed point charge—D. N. Tripathy.
20 : Validity of Hartree-Fock calculations before angular momentum projection—a test in ^{20}Ne—L. Satpathy and S. C. K. Nair.
21 : Weak axial-vector coupling constant in the static Chew-Low model—T. Pradhan and M. Pattnaik.
22 : Studies of odd mass Co-isotopes in the unified model—L. Satpathy and S. C. Gujrathi.
23 : Axial-vector renormalisation constant from algebra of currents II—Mamata Pattnaik.
24 : Schwinger terms—T. Pradhan (Invited talk for tenth symposium on Cosmic Rays, Elementary Particle Physics and Astrophysics held at Aligarh, 1967).

As part of the research activities the division invites active workers in theoretical physics from different research centres in India and abroad to deliver special lectures, the details of which are given under the teaching division.

T. Pradhan

4.1 *Reggeization of Elementary Particles*

Except in the scattering of vector bosons by spin $\frac{1}{2}$ nucleons, elementary particles of conventional field theory correspond, in general, to Kronecker delta singularities in the complex angular momentum plane of the scattering amplitude, and if there is a Regge trajectory, it does not pass through the elementary particle pole. However, this Regge trajectory induces a pole in the vertex function and a zero in the propagator of the elementary particle. These induced effects are such that under certain conditions on the renormalization constants, all the Kronecker delta singularities cancel each other and the Regge trajectory moves to the elementary particle pole. We demonstrate this reggeization of elementary particles in a soluble model field theory.

Publication :

T. Pradhan and J. N. Passi, *Phys. Rev. 160*, 1336, 1967.

T. Pradhan and J. N. Passi

4.2 *Modified Regge Representation*

A new Regge-type representation for the scattering amplitude is proposed, which has correct asymptotic behaviour for small K and large λ and small background integral.

Publication :

Suprokash Mukherjee, *Phys. Rev., 160,* 1546, 1967.

Suprokash Mukherjee

4.3 *Low Energy Kaon-nuclear Scattering*

The success of the current algebra method and the vector-meson dominance approach for s-wave kaon-nucleon scattering lengths are taken to suggest an anatz that in the absence of t-channel singularities, low energy s-wave kaon-nucleon scattering is absent. This leads to certain sum rules which enable us to determine kaon-baryon coupling constants which agree very well with other estimates. These values of the coupling constants are then found to give a satisfactory fit to low energy kaon-nucleon s- and p-wave phase-shifts.

(B. Dutta Roy and S. B. Pundari, 'Low Energy Kaon-Nucleon Scattering,' to be published in *Phys. Rev.*)

B. Dutta Roy and S. B. Pundari

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

By properly defining weak currents so as to include the mesonic contributions and thereby have them satisfy the Chiral SU(2) (×) SU(2) albegra, it is shown that axial-vector coupling constant is renormalised by a factor $|(G_A/G_V)| = 1.12$ due to static pion-nucleon interaction. It is also shown that $1 \leqslant (G_A/G_V)^2 \leqslant 3/2$ in this model.

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

T. Pradhan and M. Pattnaik

4.5 *Axial-vector Renormalisation Constant from SU(4) Algebra of Currents*

A set of relations among the reduced matrix elements of current operators are 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 renormalisation constant $g_A = 1.22$, which is quite close to the experimental value $g_A = 1.18$.

(Mamata Pattnaik, 'Axial-Vector Renormalisation Constant from SU(4) Algebra of Currents', to be published in *Annals of Physics*).

Mamata Pattnaik

4.6 *Axial-vector Renormalisation Constant from Algebra of Currents II*

A general sum rule, relating the matrix elements of the SU(4) current operators, taken between any arbitrary physical states of zero momentum, is derived using SU(4) current commutation relation and Racah algebra. These are a set of infinite number of coupled equations involving reduced matrix elements which can be solved by truncation and the value of (G_A/G_V) is obtained from these solutions.

(Mamata Pattnaik, 'Axial-Vector Renormalisation Constant form Algebra of Currents', to be published in *Annals of Physics*).

Mamata Pattnaik

4.7 *Conductivity of a Plasma in a Steady Magnetic Field*

We derive expressions for the complex conductivity tensor of a homogeneous classical plasma in an external uniform magnetic field, in terms of electric field correlations using the Kubo theory of transport phenomena. The main aim is to bring out explicitly the magnetic field dependence of the conductivity tensor. Exact relations between the conductivity tensor in the presence of the magnetic field and the same tensor in the absence of the magnetic field have been obtained.

Publication :

T. Pradhan and B. Dasgupta, *Phys. Rev. 160*, 184, 1967.

T. Pradhan and B. Dasgupta

4.8 *Dielectric Constant of a Dense Electron Gas containing a Fixed Point Charge*

An expression for the dielectric constant of a dense electron gas containing a positive point charge Ze with a neutralizing positive background is obtained by employing the diagram technique of quantum field theory. The present derivation leads to some more terms in addition to those obtained in the self-consistent field approximation. Besides, our derivation rigorously takes into account the Pauli exclusion principle. The simplest evaluation of the dielectric constant is made in the region where collective effect dominates, and the results are compared with those obtained in the self-consistent field approximation.

(D. N. Tripathy, 'Dielectric Constant of a Dense Electron Gas Containing a Fixed Point Charge', to be published in *Phys. Rev.*)

D. N. Tripathy

4.9 *Two- and Four-Quasiparticle States in Spherical Vibrational Nuclei*

Expressions are derived in the modified Tamm-Dancoff (TD) approximation which take into account the mixing of zero-, two- and four-quasiparticle states for the description of the collective vibrational states of spherical nuclei. The proposed method is free from two very important defects, inherent in higher random-phase-approximation (HRPA), namely non-orthonormality and redundancy of the four-quasiparticle basic states. The relative merits of the present method over the existing one (HRPA) are discussed.

Publication :

M. K. Pal, Y. K. Gambhir and Ram Raj, *Phys. Rev., 155*, 1144, 1967.

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

4.10 *One- and Three-quasiparticle States of Odd Mass Nickel Isotopes*

Modified Tamm-Dancoff approximation (MTDA) has been used to study the states of odd Ni-isotopes as the superposition of one- and three-quasiparticle states. The three-quasiparticle basic states are classified according to the well known seniority scheme and are expressed in an equivalent second quantized form. These three-quasiparticle states form an orthonormal and non-redundant set. The effect of the spurious 0^+ two-quasiparticle state has also been removed from these basic wave-functions. Several different kinds of two-body residual

interaction have been used in the calculation. A fairly decent agreement is obtained in the energy spectra between our results and the exact shell model results using the effective interaction of Cohen *et al.* Various approximate methods like the perturbation theory and a phonon approximation are discussed in the context of the present method. The effect of the ground state correlation is also studied. The admixture of the three-quasiparticle states in the lowest few levels causes very little change in the magnetic moment, and the Ml transition rates calculated on the basis of a single-quasiparticle structure of these states. The E2 transition rate is fairly sensitive to the admixture and the type of interaction used.

Publication :

Y. K. Gambhir, Ram Raj and M. K. Pal, *Phys. Rev., 162,* 1139, 1967.

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

4.11 *Leading Landau Curves for a Larger Class of Feynman Diagrams*

The leading parts of Landau curves for a larger class of Feynman diagrams is found to give no singularities, on the physical sheet provided certain conditions are imposed upon the external and internal masses. The number of such masses involved is found to be fixed, no matter how complicated a member of this class is considered.

Publication :

Mamata Pattnaik, *J. Math. Phys., 8, No. 5,* 1155, 1967.

Mamata Pattnaik

4.12 *The Alpha-alpha Interaction Potential*

The phase-shift data for $\alpha - \alpha$ scattering upto c.m. energies $\leqslant$ 12 MeV has been fitted by a phenomenological $\alpha - \alpha$ interaction potential. A potential with a strongly l-dependent repulsive core and an outside l-independent attractive square well is considered in fitting the phase-shifts. The repulsive core radius is smaller for higher l. With a suitable choice of necessary parameters this potential is seen to give reasonable results in the energy region considered.

Publication :

Rajagopal Shanta, *Proc. Nucl. Phys. Sol. St. Phys. Symp, Kanpur,* 1967, p. 106.

Rajagopal Shanta

4.13 *On the Question of Adequacy of the N/D method in Mass-shift Calculations*

Sawyer has recently pointed out that the N/D method of Dashen and Frautschi, when applied to an extended version of the Lee Model, leads to the paradoxical result that less attraction gives stronger binding. It is demonstrated in the present note that if the no ghost condition ($0 \leqslant Z \leqslant 1$, where Z is the wave-function renormalisation constant) is introduced as an input constraint as in the off-shell method recommended by Sawyer, the anomalous N/D result disappears.

Publication :

H. Banerjee, *Nuovo Cimento, 50,* 992, 1967.

H. Banerjee

4.14 *Analysis of Inelastic Scattering of 156 MeV Proton by ^{7}Li*

The differential cross-section and polarisation in the inelastic scattering of 156 MeV protons by ^{7}Li has already been calculated, using impulse approximation and LS coupled shell model wave-functions constructed from the lowest configuration. The wave-functions for the ground state (3/2) and the first excited state ($\frac{1}{2}^{-}$) at 0.478 MeV, which are the members of the $^{2}2p[3]$ doublet are then constructed using the fractional parentage method. The shell-model calculations failed to fit the experimental data for the cross-section for the scattering to the 0.478 MeV state. Analysis of the experimental data suggests the application of the rotational model for ^{7}Li nucleus. We have repeated the calculations using the seven-nucleon wave-function for the $^{2}2p[4+3]$ states of ^{7}Li, obtained by the generating procedure from the deformed single particle orbitals, which has been shown by Kurath to reproduce the observed quadrupole moment and the B(E2) strength between the two lowest states in ^{7}Li fairly well. The results obtained are discussed in this paper.

Publication :

J. Mahalanabis, *Proc. Nucl. Phys. Sol. St. Phys. Symp, Kanpur,* 1967, p. 50.

J. Mahalanabis

4.15 *Low Energy Pion-nucleon Scattering*

On the basis of the dynamical assumptions implicit in the recent derivations of the s-wave π–N scattering lengths we obtain sum rules for the π–N coupling constant and the subtraction constant in the π–N forward dispersion

relations. Our estimates for these quantities are in excellent agreement with their recent experimntal determination.

Publication :

H. Banerjee and B. Dutta Roy, *Phys. Letters, 24B,* 413, 1967.

H. Banerjee and B. Dutta Roy

4.16 *Analytical Studies in Charged Particle Wave Amplitude*

Analytical properties of the charged particle partial wave amplitude is discussed for positive energy. Asymptotic behaviour for large values of angular momentum in the right half plane are examined and the validity of Regge representation is discussed.

Publication :

S. Mukherjee and C. S. Shastry, *Nuclear Physics, B3,* 1, 1967.

S. Mukherjee and C. S. Shastry

4.17 *Scattering Amplitudes generated by Pole Terms and Regge Type Representations*

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

(S. Mukherjee and C. S. Shastry, 'Scattering Amplitudes Generated by Pole Terms and Regge Type Representations', to be published in *Phys. Rev.*)

S. Mukherjee and C. S. Shastry

4.18 *Second-order Contribution to the Binding Energy of Closed-shell Nuclei with the Tabakin Potential*

Hartree-Fock calculations have been performed previously on the binding energy of closed-shell nuclei using the separable non-local two-nucleon potential of Tabakin. In this paper, we report on an evaluation of the second-order corrections to the binding energy of ^{16}O and ^{40}Ca. In cluding the second-order terms we obtain a binding energy of 6.7 and 10.9 MeV, respectively, for these two nuclei.

Publication :

A. K. Kerman and M. K. Pal, *Phys. Rev., 162, No. 4,* 970, 1967.

M. K. Pal

4.19 *Low Energy Scattering of Neutrons from Nuclei*

The usefulness of Regge type representations for the partial wave amplitude in fitting the low energy scattering of neutrons from various nuclei are studied in the energy range 0 – 4 MeV.

Publication :

S. Mukherjee and C. S. Shastry, *Proc. Nucl. Phys Sol. St. Phys. Symp., Kanpur*, 1967; p. 28.

S. Mukherjee and C. S. Shastry

4.20 *Optical Well Scattering of Neutrons from Nuclei*

The validity of Regge type representations in analysing the optical model of elastic scattering of neutrons from various nuclei in the energy range 6 – 14 MeV is studied for different nuclei.

Publication :

S. Mukherjee and C. S. Shastry, *Proc. Nucl. Phys Sol. St. Phys. Symp., Kanpur*, 1967, p. 39.

S. Mukherjee and C. S. Shastry

4.21 *Optical Well Scattering of Protons from Nuclei*

Elastic scattering of protons from various nuclei in the energy range 4 to 20 MeV are analysed with the use of a modified Regge representation. The role of background integral in various representations is discussed.

Publication :

S. Mukherjee and C. S. Shastry, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 49.

S. Mukherjee and C. S. Shastry

4.22 *Hartree-Fock Calculations with Realistic Hard Core Potential*

The effective matrix elements of the two-nucleon Yale potential have been used in doing Hartree-Fock calculations in $N=Z$ even nuclei ($8 \leqslant A \leqslant 40$). The ground state energy and single particle energies and wave-functions have

been calculated as a function of two deformation parameters. The calculated equilibrium shapes and binding energy per nucleon are found to be reasonably good. The difficulties in the HF formalism due to the state dependence on the reaction matrix have been discussed and methods suggested for doing a fully self-consistent calculation of the reaction matrix elements and the HF energy and states.

Publication :

M. K. Pal and A. P. Stamp, *Phys. Rev., 158, No. 4,* 924, 1967.

M. K. Pal

4.23 *Pairing Effects in Nuclei described by the Hartree-Fock Theory*

The amount of energy gap between occupied and unoccupied single particle states determines the reliability of a Hartree-Fock (HF) calculation. If the gap is comparable to the residual pairing interaction, the sharp Fermi surface corresponding to the HF state is smeared out through mixing with pair-excited configurations. In heavy and medium heavy nuclei, it is believed that such mixing with configuration having several pairs are important. In the light 2s, 1d shell nuclei, where the energy gap is 6–8 MeV, it is a fairly good approximation to calculate the correction to the HF state by mixing only the two hole (h)–two particle (p) type excited configurations. Such corrections represent a genuine pairing correlation present in the intrinsic state. Formulae have been worked out for diagonalising the residual interaction between the HF state and the 2h-2p states. Explicit numerical results are presented for ^{20}Ne using the two-body, effective matrix elements of the Yale potential. The corrected ground state is found to contain about 8% admixture of excited configurations, thus showing that the pairing corrections are not very important in 2s, 1d shell nuclei. The reason for this finding is analysed.

Publication :

M. K. Pal, Y. K. Gambhir and Ram Raj, *Phys, Rev., 155,* 1144, 1967.

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

4.24 *Calculation of* $\sigma(\vec{k}, w)$ *for a Plasma in a Uniform Magnetic Field*

The frequency and wave number dependent conductivity for a plasma within a uniform magnetic field is calculated, extending the previous calculation of conductivity of a plasma for zero wave number. The conductivity is calcu-

lated upto first order in k. The first order k correction terms appear negligible in a high magnetic field and contain gradient of (internal) electric field. Although magnetic field dependence cannot be exactly ascertained, certain sum rules are derived. This work is still in progress.

T. Pradhan and B. Dasgupta

4.25 *Vlassov Eigenfunctions for Plasma in a Magnetic Field*

The linearised Vlassov equation for a plasma in a (uniform) magnetic field has been solved, treating this as an eigenvalue problem. This is an extension of the work by Van Kampen. The eigenfunctions of the 'Vlassov operator' and its adjoint were calculated, and completeness and orthogonality properties of this set of eigenfunctions have been established.

P. Dasgupta and B. Dasgupta

4.26 *Positronium Formation in Metals*

On the basis of an improved numerical solution of the Bethe-Goldstone equation, it has been shown that positronium formation in an electron gas is possible at metallic densities.

D. N. Tripathy

4.27 *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.

T. Pradhan and D. N. Tripathy

4.28 *Validity of Hartree-Fock Calculations before Angular Momentum Projection—A Test in ^{20}Ne*

A variational calculation after angular momentum projections for the first three even-parity states of ^{20}Ne ($J=0$, 2 and 4) 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.

L. Satapathy and S. C. K. Nair

4.29 *Suppression of Strangeness-changing Leptonic Decays of Hadrons*

By making simple assumptions about the weak hadron currents, a fairly satisfactory explanation of the suppression of the $\triangle C=1$ relative to $\triangle S=0$ coupling is given in the frame work of universal Fermi interaction.

T. Pradhan and Mamata Pattnaik

4.30 *A Model for π-π Scattering in the $I=J=O$ Channel*

It is shown that the recent data on Ke_4 decay and the 3 π-decay modes of η and K°_L admit of satisfactory interpretations in terms of a model for π-π scattering in the $I=J=0$ channel suggested by an analysis of the backward π-N dispersion relations.

H. Banerjee, B. Dutta Roy and V. J. Menon

4.31 *Calculation of the Levels of Ni and Sn Isotopes by the Quasiparticle Method*

Modified Tamm-Dancoff approximation, developed in a previous paper, has been applied to even Ni and Sn isotopes. Detailed spectra, E2 transition strengths connecting various levels and the quadrupole moment of the first excited 2^+ level have been calculated and the trends of the results compared with experimental values. The method appears to be fairly satisfactory. It points to the necessity of more reliable information on the effective interaction, active single-particle

orbitals and single-particle radial functions in order that a dependable quantitative fit to the data can be achieved.

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

4.32 *Possible Parity Violation in N-D Capture*

The effect of known weak interaction in the parity impurity of nuclear states has been estimated by studying the polarization of γ-rays in the radiative capture of 100 keV neutron by deuteron. Calculations are carried out with two forms of parity nonconserving internucleon potentials derived by Blinstoyle (R. J. Blinstoyle, *Phys. Rev., 118,* 1605, 1960) and Curtis Michel (F. Curtis Michel, *Phys. Rev., 133,* B329, 1963). The degree of circular polarization δ comes out to be 1.08×10^{-6} with Blinstoyle's force and 4.42×10^{-5} with Michel's force.

D. Pal

4.33 *Core Excitation in Stripping Reactions*

The possiblity of excitation of the 2^+ states of a vibrational even-even target in a stripping reaction is included in the DWBA $^{44}Ca(d, p)^{45}Ca$ and $^{58}Ni(d, p)^{59}Ni$. The theoretical proton angular distributions have the right trend but the theory does not explain the experimental situation completely. It seems that the inclusion of core excitation due to proton core residual interaction (which we have neglected in the present theory) might improve the situation a lot.

D. Pal

4.34 *Universal Theory of Strong Interactions*

Pion-nucleon s-and p-wave scattering lengths are calculated from a theory of strong interactions in which nucleons have Yukawa couplings with vector and axial-vector bosons only. Pions do not interact directly with nucleons. The results are in excellent agreement with experiment.

T. Pradhan

4.35 *Relation between HNZ Construction and Vanishing of Renormalisation Constant*

We are investigating, in Lee Model, the nature of restrictions put to the theory due to the existence of local composite-particle field operator. The equivalence $\phi = \phi_c$ and $Z_3 = 0$ for divergent self-energy and finite self-energy of V-particles is under investigation.

J. N. Passi

4.36 *Current Algebra Calculation of Mass Ratio N* and N*

Pion-nucleon interaction is taken to be

$$H = \frac{g_o}{\mu} \overset{\alpha}{a}_{\mu} \delta_{\mu} \overset{\alpha}{\phi}$$

with $\overset{\alpha}{a}_{\mu} = g_A \bar{\psi} \gamma_{\mu} \gamma_s \frac{\overset{\alpha}{\tau}}{2} \psi + \lambda (\Psi^{+}_{\mu} \overset{\alpha}{\eta} \psi + \text{h.c}) + \lambda^* \Psi^{+}_{\delta} \overset{\alpha}{\Theta} \gamma_{\mu} \gamma_s \Psi_{\delta}$

$\overset{\alpha}{\eta}_{\mu}$ being 4×2 matrics, Ψ being N* field, λ is determined from current commutator

$$\left[\int d^3x \, \overset{\alpha}{a}_o (x), \int d^3x' \, \overset{\beta}{a}_o (x') \right]_{x_o = x'_o} = i \epsilon_{\alpha\beta\gamma} \int d^3x \, \overset{\gamma}{v}_o (x)$$

with $\overset{\alpha}{v}_{\mu} = \Psi \gamma_{\mu} \frac{\overset{\alpha}{\tau}}{2} \psi + \Psi_{\delta} \overset{\alpha}{\Theta} \gamma_{\mu} \Psi_{\delta}$

Imposition of unitarity on the resulting pion-nucleon scattering amplitude gives

$$\frac{m^*}{m} = \frac{8\pi\lambda^2}{9 g_A^2} \, 1.28,$$

which is to be compared with the experimental value of 1.32.

T. Pradhan

4.37 *Studies in Coulomb Nuclear S-Matrix and Analysis of Nuclear Scattering based on Regge Pole Hypothesis*

Regge trajectories for coulomb-nuclear S-matrix is being calculated for a Yukawa type nuclear potential and comparison will be made with those of the pure

nucleon S-matrix case. Improvements in Regge type representation is being done to calculate optical model calculations of elastic scattering. More explicit asymptotic behaviour of S-matrix for optical potential is being studied for this purpose.

C. S. Shastry and S. Mukherjee

4.38 *Fast Convergence of t-Matrix*

Brueckner t-matrix, which is used for saturation calculations and structure studies, is represented by a series similar to modified Born series of Bethe-Brandow-Petschek. Using the idea of S. Weinberg, this expansion is made in powers of the difference of two potentials. A non-local separable potential of Tabakin type is used for subtraction. By actual calculation, the parameters of this potentials have been found for fast convergence. The calculation of binding energy and single particle energy in nuclear matter is in progress.

Rajkishore Satapathy and S. Mukherjee

4.39 *Collective Oscillations of a Dense Electron Gas containing a Fixed Point Charge Ze*

An attempt is being made to obtain a single-particle Schrodinger equation to described the collective oscillations in a dense electron gas containing a fixed point charge Ze.

D. N. Tripathy

4.40 *Nuclear Scattering Resonances and Pology*

The excited states of ^{16}O which decay by α are categorized in terms of Regge trajectories. Unitarity was used to obtain the residues and with a Khuri type representation angular distribution for $^{12}C-\alpha$ was computed at 11.74 MeV. The results are in quantitative agreement with experiment over a wide range of backward angles. An extensive calculation is being planned, using superior representations.

Rajagopal Shanta

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

The uncoupled integral equation for three body transition operator has non-compact kernel. But it is found that, if the scattering amplitude is terminated by intermediate bound and resonance states, then the integral equation obtained for the transition matrix has compact kernel. This formalism and Faddeev's original formalism with Lovelace modification are being applied to study stripping and pick-up reactions.

S. Mukherjee and S. Samaddar

4.42 *A Dynamical Calculation of Low Energy $\pi-\pi$ Scattering*

With a view to explaining dynamically the features of $\pi-\pi$ scattering in the $I=J=0$ state as suggested by Lovelace *et al*, we have taken the leading Regge trajectories in the t-channel of $\pi-\pi$ problem and obtained the t-channel equivalent potential by the Balazs' technique. Solution of the resulting Schrödinger equation is expected to give a large (negative) scattering length and zero of the S-wave phase shift provided the Regge pole parameters are properly chosen.

H. Banerjee, P. Dasgupta and V. J. Menon

4.43 *A New Approach to the N/D Method of π-N Scattering in the p-Wave*

Pion-nucleon scattering is treated in the N/D formalism, where the input singularities are constructed through current algebraic methods. The contribution from the singularities turns out to be qualitatively and quantitatively different from the usual ones obtained from lowest order. Feynman diagrams, e.g., the p-meson exchange contribution involves electromagnetic form factors. Calcula- ρ-meson exchange contribution involves electromagnetic form factors. Calculations of amplitudes have been carried out using earlier fits to form factor and calculations using the most recent fits are now under progress.

H. Banerjee and S. N. Mallik

4.44 *Relaxation Processes in Plasma*

Relaxation of an electron plasma having an arbitrary initial isotropic distribution towards Maxwellian is studied by numerically integrating the Balescu-Lenard kinetic equation. This equation takes into account the collective effect

within a plasma. It is expected that collective effects will be observed in the process of relaxation. Although the work is not fully completed, the following results are obtained. A generalised Fokker-Planck equation has been derived for a test particle, starting from Balescu-Lenard equation and taking a two-component plasma background with equilibrium Maxwellian distribution. (The calculation is extended to the case when the test particle has an isotropic velocity distribution). Then assuming the initial distribution to be a delta-function, the initial slope of the energy relaxation curve and the energy relaxation time are calculated. These results show predominant collective effects when compared with those obtained from ordinary Fokker-Planck equation.

B. Dasgupta and P. Dasgupta

4.45 *Complex Angular Momentum Approach to Optical Model of Elastic Scattering*

Analytical properties of the partial-wave amplitude for a complex potential with Saxon-Woods radial form are studied. The Regge and Khuri representations are discussed for the case of scattering of particles with $\frac{1}{2}$ spin from spin zero target taking into account the spin-orbit interaction. Various other representations are studied and the application of complex angular momentum approach to charged particle scattering is discussed. A set of typical calculations are presented in order to estimate the validity of various representations.

S. Mukherjee and C. S. Shastry

4.46 *Calculations of Core Excitations*

Calculations on (two holes-four particles) are completed for both ^{42}Ca and ^{42}Sc. Good results are obtained for the two $J = 0^+$ levels and the two $J = 2^+$ levels in both isotopes.

B. H. Bye

4.47 *Projecting Good Angular Momentum States from Non-axial Band Wave-function for ^{25}Mg*

Hartree-Fock calculations performed by M. K. Banerjee and L. Satapathy have shown that a non-axial structure is energetically more favourable for ^{25}Mg. Now we are using the computer code developed here for angular momentum

projections to get a wave-function of the form $\Sigma_k a_k P\ \phi_k$. The band mixing coefficients a_k's are obtained by a diagonalisation of the effective interaction (in the above P^j is the projection operator).

L. Satapathy and S. C. K. Nair

4.48 *Calculation of the Asymmetry of Neutrons Emitted after the Capture of Muons in ^{40}Ca*

Some experiment on the neutron asymmetry has produced a result which is impossible to understand in terms of what is known to date about the weak interaction coupling constant. Since nuclear structure effects do influence the theoretical estimate of the asymmetry, the effort in this work is to take care of this as best as the present day knowledge of nuclear structure enables us, and thus it is hoped that a reliable number for the asymmetry will emerge soon.

S. K. Singh and S. C. K. Nair

4.49 *Application of PCAC to Photo Production of Pions from Nuclei*

In collaboration with M. Rho of Saclay, the cross-section for the photo-production of charged pions from nuclei at energies close to the threshold is being calculated with the aid of the PCAC hypothesis. Both an "elementary particle treatment" (due to Kim and Primakoff) of the initial and final nuclei and the more conventional way of putting in the nuclear wave-functions are being attempted.

S. C. K. Nair

4.50 *Stripping Calculation including Core Excitation due to Proton-core Residual Interaction*

We have done stripping calculation including contribution from the excited core of the residual nucleus. However, the effect of proton core residual interaction has not been investigated properly. We are persuing the stripping calculation including that interaction. So far, in all stripping theories, the proton-core residual interaction (unbound pair interactions) has been neglected in comparison with the deuteron binding interaction. We doubt very much the soundness of this approximation and are trying to estimate the effect of proton-core interaction on stripping processes.

D. Pal

4.51 *Estimation of Exchange Effect in ^{14}N (p,p') $^{14}N^*$ Reaction in a Coupled Channel Calculation*

We have planned to carry out a coupled channel calculation for the specific reaction ^{14}N (p, p') $^{14}N^*$, for the purpose of estimating the exchange effect. The reason for choosing this example is that here the direct scattering is forbidden and therefore, the study of this reaction will add to our knowledge of possible exchange effects in inelastic scattering.

D. Pal

4.52 *Co-variant Perturbation Theory Calculation of Vector and Axial-vector Renormalisation Constant in Hadron-decay*

An attempt to understand the lack of renormalisation of the weak $\triangle S=O$ vector current and the difference between the renormalisations of $\triangle S=O$ and $\triangle S=1$ weak vector and axial-vector currents within the framework of co-variant perturbation theory of meson-baryon interaction is being attempted.

A. V. Khare and T. Pradhan

4.53 *Jacobi Identity, C-number and Q-number Schwinger Terms in a Realistic Model*

Bucella, Gatto, Okubo and Venezian have pointed out that it is necessary to have both C-number and Q-number Schwinger terms in equal time current commutators if Jacobi identity is to be fulfilled. Johnson and Low have tried to verify this in perturbation theory.We attempt to verify this for axial vector currents which are bilinear in nucleon fields and linear as well as trilinear in meson fields.

T. Pradhan

4.54 *Study of the Isobaric Analogue States in Light Nuclei by (p, n) Reactions*

We have analysed the (p, n) reactions in several light nuclei (^{6}Li, ^{7}Li and ^{9}Be), using the impulse approximation and the two-body scattering matrix which includes the i-spin formalism. We have used the shell model and the oscillator radial functions for our calculations. The theoretical predictions for the angular

distributions are compared with the experimental results at 92 and 152 MeV incident energies of the proton. The results are discussed and the validity of the shell model is questioned.

J. Mahalanabis

4.55 *Quasi-free Electron Scattering on Nuclei and Investigation of Nuclear Structure*

The quasi-free electron scattering is an important tool for studying the nuclear structure. The ^{12}C (e, e′, p) ^{11}B reaction has been investigated by Ciofi Degli Atti using single particle wave-functions in the harmonic oscillator well which is not in very satisfactory accord with experimental data. We propose to study these reactions using the single particle functions of Elton and Swift generated in an energy dependent Saxon-Woods well with adjustable parameters, which has been shown to fit the (p, 2p) and (p, d) reactions fairly well.

J. Mahalanabis

4.56 *Study of s-d Shell by Self-consistent Methods*

An exhaustive investigation of the properties of the s-d shell nuclei is made by HF and HFB self-consistent methods. The effect of the pairing force is assessed by calculating the overlaps of the HF and HFB wave-functions. The spectra of the excited states and the electromagnetic properties have been predicted by projecting out good angular momentum states from the HF wave-functions.

M. K. Banerjee and L. Satapathy

4.57 *Properties of the Projected TDA Spectra of ^{20}Ne and ^{29}Mg*

The TDA formalism has been applied to study the intrinsic excited bands of ^{20}Ne and ^{29}Mg. The energy levels corresponding to the excited bands are predicted by projecting out good angular momentum states from the TDA wave-functions.

L. Satapathy and M. K. Banerjee

4.58 *Analysis of Nuclear Scattering Data by the Application of Regge Pole Method*

Two specific cases of α scattering are being treated in this work; the cases correspond to ^{4}He and ^{12}C targets.

M. K. Pal and R. Shanta

4.59 *Nuclear Structure Calculations in the Latter Half of the 2s-1d Shell*

Although nuclei in the range $^{20}Ne - ^{28}Si$ show clear cut evidence of permanent deformation, the heavier ones in the 2s-1d shell do not conform to any well defined rotational or vibrational pattern. All the available data are being compiled with the aim of eventually developing a comprehensive theory.

M. K. Pal and J. N. De

5. INSTRUMENTATION DIVISION

5.0 *Introductory Remarks*

Good propress was made in the development of systems, facilities and techniques in the ultra-high frequency band. 750 Mc amplifiers have been designed and fabricated round the RCA 5876 tube—a cheap pencil triode. As power amplifiers operating in class B mode, these supply 700 mW with an effective input of 100 mW. As class A amplifiers, these are estimated to deliver about 10 db gain. A doubler raising the frequency from 500 Mc to 1000 Mc have also been perfected. This employs the same 5876 tube, delivers 250 mW output with 90 mW input and so provides power gain. The doubler that raises the frequency from 1000 Mc to 2000 Mc and delivers 130 mW output, uses the same tube but provides negligible gain. Preliminary results (80 mW output) have also been obtained with a doubler that raises the frequency from 2000 Mc to 4000 Mc. The outputs available from these systems are small as the unit oscillators employed to drive these systems could not supply adequate inputs It is, therefore, planned to develop a 500 Mc amplifier, which is expected to deliver one watt. The sequence of doublers can then be driven adequately hard and larger outputs are expected from all of them. At the same time, another sequence of doublers, H 750 Mc to 1500 Mc and 1500 Mc to 3000 Mc, using tubes, will be developed.

Transistors available now appear to have superior capabilities compared to tubes upto about 1000 Mc. Transistorised systems will, therefore, be developed in the coming year with a view to producing uhf and microwave sources of extremely stable and accurately known frequency.

A transistorised oscilloscope for general work, with a frequency range extending to 5 Mc, has been developed. This uses the ordinary and inexpensive RCA 5ABP cathode-ray tube. If a more sensitive CRT becomes available, a faster model will be developed.

The handling systems and computer techniques have been under study and a transistorised pulse-height to time converter has been planned.

A transistorised current amplifier to produce very low frequency rectangular sweeps of magnetic field for a high resolution NMR spectrometer has also been developed

B. M. Banerjee

5.1 *High Amplitude Square-wave Field Sweep for NMR Spectrometer*

The circuit uses transistors and supplies a low frequency square wave with very fast rise and fall times of the order of a microsecond, and with a very flat top so that the line shape is faithfully reproduced.

Sneha Chowdhury

5.2 *Construction of a Transistorised Oscilloscope*

A fully transistorised oscilloscope has been developed and constructed. The main technical data of the oscilloscope are given below :

Cathode-ray tube	5ADP1
Useful screen area	10 × 10 cm
Total accelerating voltage	1500 volts
Deflection factor	vertical : 10 volts/cm
	horizontal: 13 volts/cm
Vertical amplifier	Freq. response : dc to 5 Mc at 3 db
	Rise time : 80 ns.
	Input impedance > 1 M
	Nominal gain : 1800
Horizontal amplifier	Freq. response : dc to 1 Mc at 3 db
Time base	10 calibrated times : 1, 2, 5, 10, 20, 50, 100, 200, 500 μs/cm and 10 ms/cm
Mode of operation	Triggered and self running

Duplication of the same oscilloscope is taken up.

Transistorised vedio amplifier and sweep circuits for a TV receiver which forms a part of closed circuit television system has been developed.

Santosh Chandra Nath

5.3 *750 Mc Amplifiers*

Two 750 Mc amplifiers were constructed using RCA 5876 pencil triodes. To facilitate heat dissipation, the tube is mounted at the anode, on the central conductor of a so-called $\lambda/4$ coaxial resonator, designed for and built around the tube. The input signal is applied to the tunable cathode resonator of this grounded grid circuit. The system as developed is basically a fixed frequency arrangement in the interest of simplicity of fabrication, although the cathode resonator is tunable over a range of 50 Mc (adjustable length) and the anode resonator over a range of 20 Mc (tuning screw).

The systems were tested and tuned to 750 Mc, by being driven from a

variable frequency (250-920 Mc) unit oscillator—a GR 1209B—rated for a nominal output of 200 mW into a 50 ohm resistive load. Coupling power to the cathode of 5876 and matching impedances posed problems of some difficulty. Simple loop coupling was found very inefficient. A double stub matching network, comprising two tees and two adjustable shorts, between the unit oscillator and the cathode loop, was found necessary. However, this makes a rather cumbersome arrangement that occupies a lot of space. Besides, shielding between input and output becomes poor and the system has a tendency to self-oscillate.

To facilitate improved coupling, it was decided to neutralize the inductive reactance of the loop, by interposing a variable capacity. A co-axial capacitor, variable from 0.2 pF to 2 pF, was therefore designed. Fabricated so as to be placed integrally in series with the coupling loop, as a continuation of the cable feeding power from the unit oscillator, it proved very convenient and effective. The power feed into the cathode is less than that with double stub matching, but the voltage feed proved adequate. The adjustment for maximum drive is easy compared to that for double stub matching.

An output power of 700 mW, excluding resonator losses, was obtained from this amplifier, and the power feed to the cathode was 100 mW. The units may also be used as class A signal amplifiers. However, the two units built could not be cascaded for maximum gain, as this leads to self-oscillation.

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

5.4 *Doubler for 500 Mc to 1000 Mc*

This unit is also built round the 5876 tube. The design is similar. The anode is mounted on the central conductor of a 1000 Mc resonator operating in the $\lambda/4$ mode. The cathode forms the capacitive load of a 500 Mc line resonating again in the $\lambda/4$ mode. Adjustable capacitive probe coupling was tried for the input resonator and was found convenient and satisfactory. Large drive voltages needed for efficient doubler operation are readily obtained in such an arrangement. The cathode resonator has a broad resonance and could be tuned from 460 Mc to 530 Mc by adjustment of the line length. The anode resonator tunes sharply and could be adjusted over a range of 20 Mc. Power available at the output frequency of 1000 Mc is 250 mW. The input power is estimated as only 90 mW, and the drive voltage obtained is 15 volts. It may be mentioned that a doubler needs a voltage drive twice as much as that for amplifier operation. The optimum operating condition was realised by an increased cathode bias and this limited the amplitude of the peak current. Reduction of power output in a doubler is theoretically inevitable. The best that could be realised is half of that for amplifier operation. In the system developed, output is limited

to the low figure of 250 mW, because the drive available from the unit oscillator is inadequate.

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

5.5 *Doubler for 1000 Mc to 2000 Mc*

This follows a similar design and is also built round the 5876 tube. The cathode resonator operates at $\lambda/4$ mode, the adjustable short playing over the cathode cylinder itself. The anode resonator uses a $3\lambda/4$ line. Power is fed into and extracted out of the system through adjustable capacitive probes. Output available at 2000 Mc is only 130 mW. Power gain in the system is inappreciable because the limiting frequency of the tube has been reached. The system was tuned and tested with a GR 1218A unit oscillator.

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

5.6 *Doubler for 2000 Mc to 4000 Mc*

The system has been built around a better high frequency tube, the Siemens RH7C. It consists of a $3\lambda|4$ line at the cathode (2000 Mc), as well as at the anode (4000 Mc). As before, the input is applied and the output extracted through variable capacity probes. Preliminary data available now indicate a power output exceeding 80 mW.

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

5.7 *Transistorised Pulse-height to Time Converter*

During the year 1967, the plan for the design of transistorised pulse-height to time converter of discharge type was undertaken. In the absence of available literature on the subject, considerable time was spent before arriving at a tentative practical design of the circuit. The design follows the conventional technique and consists of a gated window amplifier, a capacitor charging emitter follower, a linear rundown circuit and a gated multivibrator clock. The experimental work, however, could not be executed as planned because of the non-availability of fast switching transistors needed for the work. Some high speed switching transistors have recently been received, and experimental work is now in progress.

K. S. Patel

6. DIRECTOR'S RESEARCH GROUP

6 (i). PLASMA PHYSICS

6 (i).0 *Introductory Remarks*

The major emphasis in this field is on plasma diagnostics and on understanding the behaviour of plasma under various conditions. A duoplasmatron ion source and a Penning discharge have been investigated with standard Langmuir probes. RF technique has also of late been introduced as a diagnostic tool. The electrical and thermal properties of thallium selenide habe been studied with a view to correlating these to the characteristics of a semiconductor plasma.

The development programme covers the following items : duoplasmatron ion source, ion extraction system, induction heating of plasma, growth of single crystals, automatic zone refiner, etc.

B. D. Nagchaudhuri

6(i).1 *A New Method Of Ion Extraction from High Density Plasma Source*

A method of ion extraction from a high density plasma source suitable at low extraction kV is being investigated. The ion source used is a duoplasmatron type source which has a characteristic high density plasma. Usually to obtain a useful beam, about 60 kV acceleration voltage is necessary in a 4 mm gap with this source. At lower extraction voltages the beam is highly diverging and the major portion of the beam is lost to the extractor. The secondary electrons ejected from the extractor cause damage both to the source and to the high voltage power supply. One method for producing an ion beam of low divergence is to reduce the plasma density by allowing it to dilate in an expansion chamber with a large opening. In our system we have replaced the expansion chamber by a ring electrode which we call pre-focussing electrode (PFE). The PFE has the dimensions 3/4″ I.D., 1″ O.D. and 1/8″ thickness, and it was placed about 7 mm from the anode opening. The extractor was about 6 mm from the PFE. The ion current was measured in a biased Faraday cage.

It has been found that the PFE has a good control over the extracted beam. Above a particular value of the positive voltage to the PFE, depending on the arc current and the extraction voltage, the extracted ion current reaches a maximum, where the whole ion beam is transmitted through the extractor and the extractor loss becomes zero. The PFE has the following advantages : 1) it acts like a plasma expansion electrode without collecting positive ions, and 2) the positive

voltage applied to the PFE produces a focussing action on the ions before they are accelerated to full velocity. Because the PFE can prevent extractor loss even at low extraction voltages, this method is suitable when an ion beam of low energy is required.

Publications :

B. D. Nagchaudhuri, D. K. Bose and S. N. Sengupta, *Proc. 8th Int. Conf. on Phenomena in Ionised Gases, Vienna,* 1967, p. 539.

D. K. Bose, B. D. Nagchaudhuri and S. N. Sengupta, *Proc. Nucl. Sol. St. Phys. Symp., Kanpur,* 1967, p. 8.

D. K. Bose, B. D. Nagchaudhuri and S. N. Sengupta

6(i).2 *Dependence of the Properties of Duoplasmatron Plasma on Magnetic Field*

Presently the study of the instabilities and diffusion of charge carriers of the high density plasma in a duoplasmatron has been undertaken. It has been observed that the diffused electron current which comes out axially through the anode shows a number of peaks with the variation of the magnetic field. The electrons are also found to carry rf signals of about 100 kc. These types of behaviour are thought to be related to the oscillations in the plasma; ion saturation currents received by probes placed inside the source, show that the diffusion after a certain critical H behaves anomalously. Marked variation of the rf signals (of about 100 kc and 5 Mc) with H is also observed from preliminary probe data.

D. K. Bose and B. D. Nagchaudhuri

6(i).3 *Constructional Scheme for a Duoplasmatron*

Following the principle of Von Ardenne a scheme is taken to make duoplasmatrons in our workshop. Two such pleces are being constructed ; the first one which will be supplied to DAE is nearly complete. The sources are intended for about 80 mA of proton current at 2A arc.

D. K. Bose and B. D Nagchaudhuri

6(i).4 *Study of a Low Pressure PIG Discharge*

The following characteristics of a cold cathode ring-anode PIG discharge (pressure $\sim 10^{-5}$ Torr) have been investigated.

1. Striking characteristics.
2. Voltage-current characteristics as a function of the magnetic field

Further study of certain abrupt changes observed in voltage-current characteristics is contemplated.

Publication :

C. Dutta, S. N. Sengupta, J. Basu and B. D. Nagchaudhuri, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 24.

C. Sen (*nee* Dutta), S. N. Sengupta, J. Basu and B. D. Nagchaudhuri

6(i).5 *Fluctuation Phenomena and Diffusion of Plasma across a Magnetic Field*

In course of a study of the properties of a cold cathode PIG plasma, it has been found that there exist strong oscillations in the plasma in magnetic fields above about 500 Gauss. Below this value of the magnetic field the oscillations disappear and the plasma becomes fairly steady. Similar fluctuations have also been observed by a number of other investigators who have found the fluctuations causing an enhanced diffusion of charged particles across the magnetic field. In order to determine the influence of the observed oscillations on the transverse diffusion of plasma in our case, a probe study has been undertaken by using two identical Langmuir probes. The two probes are made to record the fluxes of charged particles inside (N_{int}) and outside (N_{out}) the plasma at different values of the magnetic field. A preliminary analysis of the data obtained so far indicates that the ratio of the fluxes, N_{out}/N_{int}, is about 30% more in the oscillating mode of the discharge than that in the stable mode.

D. K. Bose, A. K. Chatterjee and S. N. Sengupta

6(i).6 *RF Study of a Plasma*

An rf method has been developed for determining the sheath thickness of a plane probe immersed in a plasma and biased with a dc voltage. The method is free from the limitation of the usual technique of electron beam probing, which is confined to comparatively thick sheaths. Expressions have been derived giving the sheath thickness in terms of the rf impedance of the probe for different regions of the V-i_e characteristic. Preliminary experiments with a glow discharge plasma show that the measured sheath thickness is of the right order.

Work is in progress for developing an rf impedance method for determining the electron density and collision frequency in a plasma.

Publication :

J. Basu and C. Sen, *Proc. IEEE, 55*, 1767, 1967.

J. Basu and C. Sen

6(i).7 *Coaxial Probe for Plasma Diagnostics*

The applicability of a coaxial probe for determining plasma parameters has been investigated. The probe, open at both ends and with the external surface of the outer conductor insulated, is suitable for both dc and rf measurements. It is assumed that the dimensions of the probe are such that the plasma can penetrate fully inside and can be considered to have a uniform annular shape, bounded by the sheaths at the inner conductor and at the internal surface of the outer conductor.

The electron temperature and charge density can be obtained by using the coaxial conductors as a dc double probe system with the advantage over the conventional double probe that the results pertain not only to high energy electrons but also to low energy ones.

The coaxial geometry is an obvious choice for avoiding stray capacitances in rf measurements. The charge density and electron collision frequency in a plasma can be derived by measuring the impedance of the coaxial probe, placed in the plasma, at two radio frequencies.

Publication :

J. Basu, C. Dutta and S. N. Sengupta, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 26.

J. Basu, C. Sen (*nee* Dutta) and S. N. Sengupta

6(i).8 *RF Heating of a Cylindrical Plasma*

The rf heating of a uniform cylindrical plasma by the standard induction and dielectric heating methods has been studied. The plasma is considered either as a conductor with a finite amount of reactance or as a lossy dielectric, and results are given, relating the power absorbed by the plasma to the operating frequency and the plasma parameters, viz., its dimensions, the electron density and electron collision frequency.

The study is being extended to cover non-uniform cylindrical plasmas.

Publication :

J. N. Maiti and J. Basu, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 17

J. N. Maiti and J. Basu

6(i).9 *Design and Construction of a Shock Tube*

An electromagnetic shock tube has been designed and constructed for studying shock wave phenomena and MHD problems. The tube made of pyrex glass is 5 cm in radius and 60 cm in length. Arrangements have been made for producing shock waves by a high voltage condenser discharge between two tung-

sten electrodes (diameter ~ 4 mm) placed within the tube and separated by about 5 mm. Two brass electrodes (area ~ 25 sq. cm, each) flush with the inside wall of the tube have been provided to collect the MHD power. Diagnostic tools are, at present, being developed.

J. Basu, J. N. Maiti and B. D. Nagchaudhuri

6(i).10 *Solenoid Magnet for Plasma Studies*

To facilitate our studies of the behaviour of gaseous plasma in presence of a magnetic field, the construction of a large solenoid magnet was undertaken in July 1967. The magnet is expected to produce an uniform field of 5-6 kilogauss in a region of length 45 cm and cross sectional area 7.5 sq. cm. It would consist of 8 coils of No. 12 SWG super-enamelled copper wire wound in 4 water-cooled brass spools of outer diameter 22 inches each. It would be possible to arrange the coils for both uniform and inhomogeneous mirror magnetic fields. The construction of the magnet is progressing in our workshop and is expected to be complete in a few months.

D. K. Bose, A. K. Chatterjee and S. N. Sengupta

6(i).11 *Determination of Electron Distribution Function and Transport Coefficients in Weakly Ionised Argon in Parallel Electric and Magnetic Fields*

Electron energy distribution function has been calculated for weakly ionised argon in parallel electric and magnetic fields by solving Boltzmann transport equation. In order to solve the equation we have taken approximate expressions for the collision cross-sections for different energy ranges for both the elastic and inelastic scatterings. These approximate expressions have been suggested and used by Golant. Energy distribution functions have been plotted for different values of E/p.

The distribution functions so obtained are used for the calculation of transport coefficients—ionisation coefficient, mobility, first Townsend coefficient, mean velocity of the directed component. These transport coefficients have been plotted against different values of E/p. These are in good agreement with those of Golant

A. K. Chatterjee

6(i).12 *Semiconducting Properties of Thallium Selenide*

Investigations on the transport properties of thallium selenide (Tl Se), grown by Bridgman technique in the laboratory, have been carried out. These

properties are electrical conductivity, Hall coefficient, Hall mobility and thermal conductivity. A study of different techniques for the measurement of thermal conductivity as applicable to semiconductors has also been undertaken. Measurement of thermoelectric power of Tl Se is also in progress.

(i) *Electrical properties of Tl Se*

Measurement of electrical conductivity and Hall coefficient has been carried out by conventional dc potentiometric method in the temperature range between 100°K and 540°K. The intrinsic activation energy obtained from conductivity measurements is 0.574 eV. The carrier concentration in the samples, as estimated from Hall coefficient measurements, ranges from 1.2×10^{17} cm^{-3} to 14.4×10^{15} cm^{-3}. It is found that Hall mobility obeys $T^{-3/2}$ law at high temperatures, indicating the presence of lattice scattering. The ratio of electron to hole mobility, as obtained from conductivity plot, is 0.398. The observed higher hole mobility may be explained partly on the basis of dual valence band theory.

Publication :

P. S. Nayar, J. K. D. Verma and B. D. Nag, *J. Phys. Soc. Japan, 23,* 144. 1967.

(ii) *Thermal properties of Tl Se*

(a) Though measurement of thermal conductivity appears to be a simple one, in actual practice one finds that the problem is more complex. The fact that accurate measurements of thermal conductivity are difficult is also evidenced by frequent disagreement found in the results for the same material by different workers. Therefore, a comprehensive study of the different techniques for the measurement of thermal conductivity, as applied to semiconductors and various practical considerations affecting accurate measurement, has been undertaken. It concluded that a prior knowledge of the order of thermal conductivity of the sample is quite useful in selecting a suitable method for the measurement of thermal conductivity.

(P. S. Nayar, J. K. D. Verma and B. D. Nag, 'Thermal Conductivity Measurement Techniques for Semiconductors', to be published in *Semiconductor Products & Solid State Technology*).

(b) The thermal conductivity of thallium selenide crystals has been measured by series comparison method in the temperature range between 300°K and 520°K. A rough measurement of thermal conductivity of Tl Se by the method of Haacke and Spitzer indicated that Armoc iron is quite suitable to be used as a standard with thallium selenide. The observed thermal conductivity shows nearly a $T^{-1.1}$ dependence. The electronic contribution to thermal conductivity is less than 0.5% of the measured thermal conductivity. The Debye characteristic temperature of Tl Se is estimated to be about 300°K. Therefore, the temperature ranges in which measurements have been made, are above the Debye temperature. The point imperfection scattering is very small and, hence, it is concluded that phonon-phonon scattering is the only dominant mechanism in the limitation of thermal conductivity above the Debye temperature.

An interesting feature of the experimental arrangement is the construction of a very stable low drift thermocouple reference function. It is found that the drift in this function is less than 0.01°C for a temperature change of several degrees in the ambient. This facilitates very accurate measurement of extremely small temperature differences potentiometrically. In addition, several other techniques such as low thermal resistance junctions, have been developed.

(P.S. Nayar, J. K. D. Verma and B. D. Nag, 'Thermal Conductivity of Thallium Selenide', to be published in *J. Appl. Phys.*)

(c) The effective masses of carriers, the temperature coefficient 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 sample. The set-up is complete, and the measurements are in progress.

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

6(i).13 *Semiconducting Properties of Naphthalene*

Investigations on the semiconducting properties of naphthalene have been continued. Studies have also been continued on the effect of various factors on the growth of large single crystals.

(i) A study of temperature gradient in a Bridgman-Stockbarger type furnace indicated that a very large temperature gradient at the solid-liquid interface (diaphragm) would give good quality single crystals. Various other parameters affecting the growth are the purity of the material, the grow rate and the shape of the crystal container.

(S. C. Datt and J. K. D. Verma, 'Temperature Gradient for the Growth of Large Single Crystals of Naphthalene', to be published in *Ind. J. Pure Appl. Phys.*)

(ii) Although a number of methods exist for the growth of single crystals of organic solids, it is generally advantageous to grow them from melt as this method yields large single crystals. Hence a comprehensive study of the mechanism of single crystal growth from melt has been made. Some salient features of the morphology of the solid-liquid interface, origin of different types of imperfections in the crystals grown from the melt and the requirements for growing single crystal have been reviewed.

(S. C. Datt and J. K. D. Verma, 'Crystal Growth of Organic Solids and Mechanism of Single Crystal Growth from Melt', to be published in *J. Scient. Ind. Res.*)

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

6(i).14 *Studies on Radiation Damage*

Studies on radiation damage in semiconductors and other devices are gaining importance in recent years. The effect of nuclear radiations on temperature

measuring devices such as thermocouples, resistance thermometers and thermistors have been discussed. The effect of radiation on resistance thermometers is to increase the resistance and thus record higher temperatures than the actual values. This little overestimation of actual temperature is a desirable feature and is utilized for safety control purposes in many nuclear environments such as reactors.

Publication :

J. K. D. Verma and B. D. Nag, *Thermometry,* edited by T. D. Bansal, National Physical Laboratory, New Delhi, 1967.

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

6(i).15 *Automatic Zone Refiner*

An automatic four-zone refiner has been constructed in the laboratory for purification of organic semiconductors. The zone heaters consist of 0.6 cm thick aluminium discs of diameter 10 cm with spiral grooves into which nichrome heater wires insulated by means of ceramic heads are embedded. The spacing between zone heaters is about 10 cm. The sample tube of about 1.5 cm in diameter is pulled up by means of a geared motor at a rate of 1.5 cm per hour through central holes in the disc heaters. When the tube has completed this distance, it automatically drops back to its starting position by means of suitably designed cams. The zone refiner is suitable for materials with melting point upto 300°C.

J. K. D. Verma

6(ii). Electrostatic Generator

6(ii).1 *Design Study of a Small Van de Graaff Accelerator*

(a) A survey study of different types of insulating and belting materials was made in connection with their mechanical and electrical properties.

(b) A model machine with a 50 cm dia. dome was erected ; its detailed load and charging characteristics are now under study. The maximum sphere gap terminal voltage measured is ~ 290 kV with conduction charging with a newly contructed $\pm$ 28 kV supply.

(c) Ion-beam current > 100 μA has been extracted from the dc ion-source into a drift tube at 10 cm with -4.0 kV focussing voltage.

(d) The rf ion-source studies with a newly constructed Hartley type oscillator are under way, the aim being directed towards the development of the maximum focussed beam (> 100 μA) with minimum of input power (< 150 W).

(e) The gas generation and regulation systems are under construction and test. A few power supply and test systems have been constructed.

(f) The pressure vessel design has been finalised, and engineering and fabrication drawings have been completed.

(g) A Pirani type vacuum gauge system to measure 10^{-2} to 10^{-3} Torr was perfected and calibrated for use in low vacuum measurements with the acquision of a number of vacuum units. Circuits for high vacuum measurements are also being constructed.

(h) Transistor converter units to deliver power from a 12V generator inside the high voltage terminal are being designed, assembled and tested.

A. Chatterjee, S. Chatterjee, A. Ganguli, S. K. Ghosh,
N. K. Majumdar and R. Sarkar

6(ii).2 *Statistical Model Studies*

Statistical model calculations wilth a level density defined in terms of the Rosenzweig – shifted ground states are being continued to study the (a) single particle behaviour, (b) diffuseness of the Fermi surface in non-magic nuclei in the framework of the single particle and pairing gap models and (c) reformulation of the level density parameter A of the interacting two nuclear system for application in problems of fast neutron reactions and fission.

(S. Chatterjee and A. Chatterjee, 'Single Particle Behaviour in fast (n,2n) reactions', to be published in *Nuclear Physics*.)

A. Chatterjee, S. Chatterjee and R. Sarkar

6(ii).3 *Hauser-Feshbach Calculations*

The Hauser-Feshbach formalism for the discrete non-elastic neutron reaction channels is being extended to the case of the continuum regions where the statistical considerations apply. It is also proposed to develop a formalism to treat the isobaric anologue states and extend the formalism to other particle and cluster channels.

A. Chatterjee and S. K. Ghosh

7. TECHNICAL PHYSICS DIVISION

7.0 *Introductory Remarks*

Research apparatus, machines and techniques that would be useful to other laboratories of the Institute are being developed by this division. A 3 kW induction heating machine has been built up with surplus stores and it is now ready to be used in vacuum melting. The X-ray machine, though not yet has reached its target of 60 kV, 125 mA, is being used by the radiation chemistry group of the nuclear chemistry division. Fabrication of X-ray cameras has been undertaken. One Debye-Scherer powder camera has been completed. Preliminary investigations on the construction of getter-ion and molecular seive pumps have been carried out with encouraging results. It is hoped to take up the construction of larger units of getter-ion and molecular-seive pumps that would be very useful to the laboratories. A study on the construction of Root's pump that is used as booster pump in vacuum practice has also been undertaken.

G. N. Sarkar

7.1 *High Intensity Rotating Target X-ray Tube*

The defects in the rotating seal that were observed and mentioned in the last report have been corrected. With a speed of 400 rpm of the shaft, the pressure within the chambers could be reduced to 1×10^{-5} mm of mercury without any cold trap and the pressure fell to 2×10^{-6} mm of mercury with a liquid air trap. After about 1000 hours of working, the oil seals used in constructing the rotary high vacuum seal had to be changed. The arrangement for biasing the cathode cup negatively with respect to the filament with a resistance did not succeed. The beam current appreciably increased with a one kiloohm bias resistor, but only with a voltage of 20 kV on the gun there was a discharge between the high voltage terminal and the insulated terminal connecting the bias resistance to the insulated cathode cup. This break down is supposed to be due to lack of proper insulation between the cathode cup and the filament terminals that are connected to the transformer high voltage. Suitable insulating materials are being tested and a re-design of the gun is being contemplated. The construction of the control panel has been completed. There are adequate provisions for protecting the transformer against all possible eventualities such as low vacuum, high current, etc.

The tube at present can be run at 30 mA, 60 kV for 15 minutes only due to deterioration of the vacuum in the mild steel chamber whose walls become heated and evolve copious gases. The target used is commercial copper which

is also a source of evolution of gases when heated. The chamber is being reconstructed with arrangements for cooling the walls and we are attempting to replace the target with molybdenum. With these modifications, we hope to reach our target of 125 mA, 60 kV in a short time.

G. N. Sarkar, B. D. Nagchaudhuri and A. Sen Gupta

7.2 *High Frequency Induction Heating Equipment*

A 3 kW rf induction heating equipment operating at 400 kc has been designed, constructed, tested and is ready for use. The essential features of the equipment are as follows :

(i) The dc high voltage supply unit of the equipment has three mercury vapour rectifiers connected in a three phase half-wave circuit and can deliver 2A (max) to the oscillator tubes with 300 V at the plates. The dc plate voltage can be varied from zero to any desired value by connecting a three phase variac in between the supply mains and the primary of the three phase transformer. The variac also prevents the possibility of drawing higher surge current from the supply mains due to change in load conditions.

(ii) The high power radio frequency oscillator at 400 kc has been constructed with three RCA 833A tubes connected in parallel in a Colpitts circuit and operated undtr class C condition. It is a self-excited oscillator and the grid bias is provided with five 250 V, 75 W lamps connected in series. The tank circuit of the oscillator is coupled to the load inductively and the mutual coupling is kept variable over a small range for matching rf power under different load conditions. The overall efficiency of the oscillator has been measured and is found to be about 50% at the load.

(iii) A master oscillator has been constructed to use the equipment as a separately excited MOPA system. This would ensure stability of oscillation under varying load conditions. It can also be used to provide a feedback control to ensure constant power output.

(iv) The work-coil is detachable and work-coils of different designs can be connected according to the user's convenience.

D. N. Basu Mallik and T. Vijayendra

7.3 *Getter-ion Pump*

The construction of the getter-ion pump of the Penning discharge type is now completed and has been tested partially. The magnet used is an electromagnet producing a field of 2500 Gauss in an 1″ gap in which the pump is placed. The voltage on the anode is 2.5 kV. In conjunction with a liquid air trap, it

produced a vacuum better than 1×10^{-6} mm of mercury in a chamber having volume of one litre in 10 minutes. It maintained this vacuum for hours after the mechanical pump was shut off. Arrangements are being made to measure the speed and the order of vacuum with Bayard-Alpert type gauge. The design of a larger unit is being made.

G. N. Sarkar and A. Sen Gupta

7.4 *Molecular Sieve Pump*

This is another name of a pumping method by the pumping action produced by the phenomena of adsorption of gases on a refrigerated surface. This process was first observed by C.W. Scheele (Glasstone, *Text Book of Physical Chemistry*, p. 1194). Dewar in 1875 carried out some experiments on the absorption properties of charcoal. Langmuir (I. Langmuir, *J. Am. Chem. Soc., 38,* 2267, 1916) and others made a systematic investigation in this subject.

The recent interest in adsorption or molecular sieve pumps has revived due to the development of ionisation pumps, which have the following three features in common (R. R. Bannock, *Vacuum, 12,* 101, 1962). Molecular sieve pumps are used as fore-pumps with these pumps.

(i) A vacuum of only 10^{-2} mm of mercury is required to initiate the ion pump.

(ii) Once the ion pump is started, the rough pump may be valved off from the main system and then switched off, i.e., a continuously operating fore-pump is not required.

(iii) The molecular sieve pump is free from hydrocarbons, which is essential for the operation of an ion pump.

Although the alumino silicates (zeolites) are generally used as molecular sieve material, activated charcoal has still its field of use. Its adsorption properties are poor compared to that of the zeolites but it is cheaper and can be produced in the laboratory under certain controlled conditions. The adsorping properties of coconut charcoal depend much on the temperature and on the way in which it is activated, i.e., on the temperature and on whether it is heated in vacuum or in air or in an inert gas. The activation treatment may remove the impurities from the charcoal and the surface area may be increased.

Considering the great usefulness and potentialities of the molecular sieve pump, a preliminary investigation with commercially activated charcoal has been made with an apparatus after R. R. Bannock. It was observed that 40 cc of a thin walled tube loosely packed with charcoal and cooled by liquid oxygen reduced the pressure of a one litre vessel to 0.4 mm of mercury. An apparatus for preparing activated charcoal under controlled conditions has also been set up.

G. N. Sarkar and A. Sen Gupta

7.5 *Powder Camera for X-ray*

The construction of the Debye-Scherer powder camera is complete. A film cutter and perforator has also been designed and constructed. This camera is now ready with detailed drawings and operating instructions, to be supplied to one CSIR laboratory.

G. N. Sarkar

7.6 *High Vacuum Pumps*

(i) Root's pump : This type of pump has been used in industries for handling large gas flows in the pressure range of 1/2 to 1 atmosphere (*Hand Book of Vacuum Physics*, vol. I, edited by A. H. Beck). It was realised some years ago that this pump could be applied to pumping in the medium high vacuum range, provided the pump was backed to maintain the discharge at a few millimeters pressure. The lack of internal sealing fluid and the clearance of the rotors from the walls allow for high rotational speeds upto 4000 rpm for small pumps. This gives a very high displacement in relation to size. These pumps are suitable in vacuum coating and melting units, where large volumes of gases have to be removed. Commercial units in combination with suitable mechanical pumps are available abroad, giving speeds as high as 4000 litres/sec at 10^{-3} mm of mercury, but its cost would entail a heavy foreign exchange. So, it is thought expedient to develop this pump in our laboratory and as a trial a small Root's pump, having a displacement of 250 litres/sec, has been designed and is under construction.

(ii) Diffusion pump : A modern oil diffusion pump must have the following characteristics : (a) low back streaming, resulting in a high order of vacuum, (b) high jet velocity, giving high pumping speed and (c) ability to pump from high fore-pressure. Keeping an eye to all the above requirements a 6″ oil diffusion pump has been designed and is under construction.

G. N. Sarkar

8. WORKSHOP

During the year under review, the workshop completed 450 jobs. The glass blowing shop fabricated 126 jobs as per specifications from the different laboratories. The electrical shop has completed 1000 feet of three phase power wiring and 150 feet of dc wiring for fans and lights. It has repaired 7 pieces of fans and 9 pieces of motors. The jobs that called for the ingenuity and skill of the workshop staff are :

1. Emulsion plate camera
2. Duo-plasmatron ion-source
3. 4π counter
4. Beam bending arrangement
5. Microwave cavity plunger
6. Cathode resonators
7. Helmholtz coils with translational movement
8. Sputtering chamber
9. Taper travel system of cyclotron ion-source
10. Parts of Root's blower
11. Remote control table for DD generator
12. Storch-Zel electrophoresis apparatus
13. Gate valves
14. Liquid air traps
15. Liquid air traps with inside silve
16. Continuous hydrogen apparatus
17. Mercury diffusion pumps

A small turret lathe has been put into operation. The workshop can now supply screws from 1/4″ to 1/2″ dia. on a production basis. A small three feet lathe and a 12″×1″ wheel pedestal grinder have been installed in the workshop. A three dimensional pantograph milling machine has been ordered, and we expect to get it by March, 1968.

Arc welding that was introduced last year, has proved successful. We are now able to weld mild steel parts that can be used in vacuum plumbing.

The problem of space for the workshop is not yet solved and hence we cannot install new machines that are essential to the growing plans and programmes of the Institute.

G. N. Sarkar

GENERAL

As on 1st March, 1967, the total staff strength of the Institute was 357. Out of this, 135 were scientific, 93 technical, 39 administrative and 90 auxiliary/ maintenance staff.

Prof. B. D. Nagchaudhuri, Director of the Institute, on being appointed a Member of the Planning Commission of the Government of India, is on leave from the Institute. He, however, continues to keep close contact with the workers in plasma physics.

Prof. D. N. Kundu has taken over charge as the Acting Director during the absence of Prof. Nagchaudhuri.

Prof. S. Chatterjee has been participating in the VEC project of the Department of Atomic Energy on deputation from the Institute.

The research activities of the Institute are sub-divided under the following groups and divisions/sections :

1. Accelerator Group : Cyclic Accelerator Division
   Electrostatic Generator Division
   Nuclear Chemistry Division
   Mass-spectrometer Section
   Isotope Separator Section
2. Nuclear Physics Group : Nuclear Physics Division
   Crystallography and Molecular Biology Division
   Post-M.Sc. Teaching Division
3. Biophysics Division
4. Theoretical Nuclear Physics Division
5. Instrumentation Division
6. Director's Research Group : Plasma Physics Section
   Electrostatic Generator Section
7. Technical Physics Group

The other activities of the Institute are concerned with the Workshop, Library, General Administration and Medical Unit.

There were 13 DAE Fellows, 7 CSIR Scholars, 3 Research Training Scheme Scholars (Ministry of Education, Government of India) and 1 Government of India Reciprocal Scholarship Scheme Scholar during the year under report.

During this period representatives from the Institute participated in the following International Conferences/Congresses/Symposia :

(i) International Conference on Bonds in Semi-conductors, held at Minsk, USSR.

(ii) Theoretical Physics Conference on Particles and Field, held at Rochester, USA.
(iii) 8th International Conference on Phenomena in Ionised Gases, held at Vienna, Austria.
(iv) International Congress on Magnetism, held at Boston, USA.
(v) Symposium on Confirmation on Bio-polymer, held at Madras, India.
(vi) International Conference on Spectroscopy, held at Bombay, India.

In addition to the above, scientists from the Institute participated in the following Annual Congresses/Symposia/Conferences held in India :

(i) Indian Science Congress.
(ii) Low Energy Nuclear Physics and Solid State Physics Symposium.
(iii) Annual Symposium of the Indian Biophysical Society.
(iv) Annual Conference of the Electron Microscopic Society of India.

Five research workers of the Institute, Sarvashri M. L. Chatterjee, N. Chatterjee, S. C. Mukherjee, D. K. Bhattacharyya and D. N. Misra, were admitted to the D.Phil. (Science) degree of the Calcutta University during the year under reference.

The following is the Audited Statement of Accounts for the year 1966-67 :

Statement of Accounts from 1.4.1966 to 31.3.1967

Receipts		Rs. P.	Payments	Rs. P.
(i) Opening Balance		2,453.43	(i) Salary	18,53,081.79
(ii) Grant from Calcutta University		58,890.00	(ii) Maintenance	13,05,090.99
(iii) Grant-in-aid from DAE		38,21,000.00	(iii) Equipment	6,26,109.37
			(iv) Building	1,16,563.86
(iv) Income from Misc. sources :			(v) Advance for Custom Duty, Staff Salary, etc.	1,478.52
Sale of Books	439.24			
Hostel Rent	4,947.50		(vi) Balance	2,325.56
Caution Money	350.00			
Misc. Income	13,187.42			
Medical Aid Fund	3,382.50	22,306.66		
		39,04,650.09		39,04,650.09

The present holding of the Institute's library is 14,907 books and bound volumes, and that of the reports and reprints is 11,262.

The library membership number is 403, out of which 111 pertain to students (M.Sc. and post-M.Sc.).

The library subscribed to 240 periodicals, and received 247 in exchange and as gifts from various sources during the period.

The inter-library loan facility which has proved to be very useful is on the increase.

The photo-copying service has covered 1800 pages in 1967, as against 1400 pages in the previous year.

The medical service scheme of the Institute is not yet in the final shape. At present 285 members of the staff of the Institute have joined the scheme. During the year under report, the number of medical attendances together with prescriptions, served were nearly 4,700. Members were vaccinated against small-pox and inocculated against cholera, typhoid and para-typhoid during this period. There was no case showing radiation effect.

H. K. Basu

Note :

While going to the press, it came as a matter of great encouragement to the Institute that the Government of West Bengal were pleased to sanction the funds needed for the purchase of the plot of land in the Salt Lake area adjoining the site of the AVF Cyclotron project of the DAE, as referred to in the Introduction by the Director.

Registrar.

AUTHOR INDEX

LIST OF PUBLICATIONS, 1967

1. Banerjee, H., 'On the Question of Adequacy of the N/D Method in Mass-Shift Calculations', *Nuovo Cimento, 50,* 992, 1967.
2. Banerjee, H. and Dutta Roy, B., 'Low Energy Pion-nucleon Scattering', *Physics Letters, 24B,* 413, 1967.
3. Basu, J., Dutta, C. and Sengupta, S. N., 'Co-axial Probe for Plasma Diagnostics', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 26.
4. Basu, J. and Sen, C., 'RF Method for Determining the Sheath Thickness in a Plasma', *Proc. IEEE, 55,* 1767, 1967.
5. Basu, S., 'Ultraviolet Absorption Studies on DNA', *Biopolymers, 5,* 319, 1967.
6. Basu, S. and Das Gupta, N. N., 'Spectrophotometric Investigation of DNA in the Ultraviolet', *Biochim. Biophys. Acta, 145,* 391, 1967.
7. Bhattacharyya, S. N. and Chettia, P. K., 'Spectrophotometric Determination of Periodate in Presence of Iodate using Aluminium Hydroxide', *Annal. Chem., 39,* 369, 1967.
8. Bhattacharyya, S. N. and Dutta, K. N., 'Chemical Dosimetry', *J. Scient. Ind. Res., 26,* 147, 1967.
9. Bhattacharyya, M., Chawdhury, A. and Bose, M., 'Nuclear Magnetic Resonance Studies of Solid Phosphates', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 59.
10. Bhattacharyya, M., Chowdhury, A. and Bose, M., 'Nuclear Magnetic Resonance Studies of Paramagnetic Phosphates', *Proc. Int. Conf. Spectroscopy, Bombay, I,* 484, 1967.
11. Bose, D. K., Dutta, C., Maiti, J. N., Sengupta, S. N. and Nagchaudhuri, B. D., 'Time Varying Phenomena in a PIG Plasma', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 7.
12. Bose, D. K., Nagchaudhuri, B. D. and Sengupta, S. N., 'Extraction of Positive Ions and Electrons Simultaneously from a Duoplasmatron, *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 8.
13. Chakraborty, J., 'Electron Microscopy of the Hypotrich Ciliate *Oxytricha Platystoma* with Consideration of its Macronuclear Organization', *J. Protozool., 14, (1),* 59, 1967.
14. Chakraborty, J, and Sadhukhan, P., 'Some Observations on the Food Vacuole of Paramecium Auralia', *Zeit. für Naturforsch, 22B,* 558, 1967.
15. Chakravarty, A. S., 'On the Electric-quadrupole Transitions of the Octahedral Complexes of the Transition Metal Ions', *Ind. J. Phys., 41,* 602, 1967.
16. Chalapati Rao, K. V. and Mukherjee, P., 'Estimation of the (t, p) Reaction Widths from Surface-delta Interaction Wave-functions', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 93.
17. Chatterjee, N. and Bose, M., 'Solvent Effects in the NMR Spectra of Aza-aromatics', *Molecular Physics, 12,* 341, 1967.
18. Das, N., Chatterjee, N. and Bose, M., 'Analysis of Complex 3- and 4-Spin Systems', *Proc. Int. Conf. Spectroscopy, Bombay,* 1967, p. 478.
19. Das Gupta, N. N., Basu, S., Bagchi, B. and Misra, D. N., 'Conformational Changes in Denatured DNA', *Proc. Int. Symp. on Conformation of Biopolymers,* Ed. G. N. Ramachandran, *2,* 663, 1967, Academic Press (London).
20. Dey, S. D. and Karmohapatra, S. B., 'Surface Ionisation of some Rare Earth

Elements on Hot Polycrystalline Tungsten Surface,' *J. Phys. Soc. (Japan)*, *23*, 418, 1967.

21. Dey, S. D. and Karmohapatra, S. B., 'Measurement of the Ionisation Potential of the Rare Earth Elements by Surface Ionisation Method', *Proc. Int. Conf. Spectroscopy, Bombay, 1*, 38, 1967.
22. Dey, S. D. and Karmahapatra, S. B., 'First Atomic Ionisation Potentials of Dysprosium and Praseodymium', *J. Phys. Soc. (Japan)*, *22*, 682, 1967.
23. Dutt, S. C., Verma, J. K. D. and Nagchaudhuri, B. D., 'Growth of Single Crystals of Naphthalene by Bridgman-Stockbarger Technic', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 258.
24. Dutt, C., Sengupta, S. N., Basu, J. and Nagchaudhuri, B. D., 'Characteristics of a Low Pressure PIG Discharge', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 24.
25. Feldman, L., Baliga, B. B. and Nessin, M., 'Proton Capture Gamma-rays from ^{8}Be, ^{12}C, ^{24}Mg and ^{40}Ca in the Giant Resonance Region', *Phys. Rev., 157*, 921, 1967.
26. Gambhir, Y. K., Ram Raj and Pal, M. K., 'One- and Three-Quasiparticle States of Odd Mass Ni-Isotopes', *Phys. Rev., 162*, 1139, 1967.
27. Ghosh, A. and Bhattacharjee, S. N., 'Changes in the Respiratory and Glycolytic Behaviour of Saccharomyces Carlsbergensis due to Inositol Deficiency', *Biochim. Biophys. Acta., 136*, 19, 1967.
28. Ghosh, D. K., Chatterjee, A. and Saha, A. K., 'Microwave Spectra of Ethylamine Molecule', *Ind. J. Phys., 41*, 467, 1967.
29. Guha, S., Mazumdar, S. K. and Saha, N. N., 'The Crystal and Molecular Structure of L-Ornithine-hydrochloride', *Ind. J. Phys., 41*, 624, 1967.
30. Gujrathi, S. C., Bakhru, H. and Mukherjee, S. K., 'Decay of ^{162}Tb and Excited States of the ^{162}Dy', *Phys. Rev., 153*, 1262, 1967.
31. Gujrathi, S. C. and Mukherjee, S. K., 'Excited Levels in ^{61}Co from the Decay of ^{61}Fe', *Phys. Rev., 159*, 909, 1967.
32. Jamdar, S. C. and Udupa, K. B., 'Incorporation of ^{32}P in the Adrenals of of Riboflavin Deficient Rats', *Endokrinologie, 51*, 175, 1967.
33. Kerman, A. K. and Pal, M. K., 'Second-order Contribution to the Binding Energy of Closed-shell Nuclei with the Tabakin Potential', *Phys. Rev., 162, No. 4*, 970, 1967.
34. Lahiri, J. and Mukherjee, A., 'Electrostatic Polarizability and Shielding Factors for Ions of Argon Configuration,' *Phys. Rev., 155*, 24, 1967.
35. Lahiri, S. K., Roy, A., Banerjee, D., Jamdar, S. C., Basu, S. R. and Nag, B. D., 'Ionic Distribution Studies in Haemolymph from Different Parts of Periplaneta Americana by Radioactive Tracers', *Ind. J. Exptl. Biol., 5*, 27, 1967.
36. Mahalanabis, J., 'Analysis of Inelastic Scattering of 156 MeV Proton by ^{7}Li', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpour*, 1967, p. 50.
37. Maiti, J. N. and Basu, J., 'RF Heating of a Cylindrical Plasma', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur*, 1967, p. 17.
38. Mukherjee, S. and Shastry, C. S., 'Analytical Studies in Charged Particle Wave Amplitude', *Nuclear Physics, B3*, 1, 1967.

39. Mukherjee, S. and Shastry, C. S., 'Low Energy Scattering of Neutrons from Nuclei', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 28.
40. Mukherjee, S. and Shastry, C. S., 'Optical Well Scattering of Neutrons from Nuclei,' *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 39.
41. Mukherjee, S. and Shastry, C. S., 'Optical Well Scattering of Protons from Nuclei', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 49.
42. Mukherjee, Suprokash, 'Modified Regee Representation,' *Phys. Rev., 160,* 1546, 1967.
43. Nagchaudhuri, B. D., Bose, D. K. and Sengupta, S. N., 'Ion Extraction at Low Voltage', *Proc. 8th Int. Conf. on Phenomena in Ionised Gases, Vienna,* 1967, p. 539.
44. Nayar, P. S., Verma, J. K. D. and Nag, B. D., 'Some Properties of Stoichiometric Thallium Selenide', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 10.
45. Nayar, P. S., Verma, J. K. D. and Nag, B. D., 'Semiconducting Properties of Thallium Selenide', *J. Phys. Soc. (Japan), 23,* 144, 1967.
46. Nigam, A. K. and Bhattacharyya, R., 'The Gyromagnetic Ratio of the 379 keV Level of ^{169}Tm', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 10.
47. Pal, M. K., Gambhir, Y. K. and Ram Raj., 'Calculation of the Levels of Ni- and Sn-isotopes by the Quasiparticle Method, *Phys. Rev., 163,* 1004, 1967.
48. Pal, M. K. Gambhir, Y. K., and Ram Raj, 'Two- and Four-quasiparticle States in Spherical Vibrational Nuclei', *Phys. Rev., 155,* 1144, 1967.
49. Pal, M. K. and Stamp, A. P., 'Hartree-Fock Calculations with Realistic Hard Core Potential', *Phys. Rev., 158, No. 4,* 924, 1967.
50. Pattnaik, Mamata, 'Leading Landau Curves for a Larger Class of Feynman Diagrams', *J. Math. Phys., 8, No. 5,* 1155, 1967.
51. Pradhan, T. and Dasgupta, B., 'Conductivity of a Plasma in a Steady Mag netic Field', *Phys. Rev. 160,* 184, 1967.
52. Pradhan, T. and Passi, J. N., 'Reggeization of Elementary Particles', *Phys. Rev. 160,* 1336, 1967.
53. Purkayastha, B. C. and Chatterjee Anita, 'On the Study of the Uptake of Calcium Tracer by Strontium Oxalate', *J. Ind. Chem. Soc., 44,* 130, 1967.
54. Purkayastha, B. C. and Dutta, K. N., 'Radiometric Analysis of Scandium', *J. Ind. Chem. Soc., 44,* 907, 1967.
55. Purkayastha, B. C. and Sen, Shyamoli, 'On the Behaviour of Bismuth Fluoride as a Guest Component in the Study of Uptake by Calcium and Rare Earth Fluorides', *J. Ind. Chem. Soc., 44,* 1067, 1967.
56. Ramakrishna, G. and Mukherjee, P., 'Modified Nilsson Orbitals and their Applications in the Analysis of (d, p) Reactions on Even-A Rare Earth Nuclei', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 99.
57. Ray, T. and Ray, D. K., 'Dynamical Spin Hamiltonian and the Anisotropy of Spin-lattice Relaxation for the Kramer's Doublets, I—General Considerations', *Phys. Rev., 164,* 420, 1967.
58. Raychaudhuri, A.K. and Ray, D. K., 'Effect of the Ligand Charge Distribution on the Crystalline Electric Field', *Proc. Phys. Soc. (London), 90,* 839, 1967.

59. Roy, R., Sinha, S. K. and Roy, A. K., 'The Determination of g-Tensor from the ESR Studies on Polycrystalline Samples', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 118.
60. Rudra, P., 'A Group Theoretical Analysis of Ferromagnetic Green's Function', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 168.
61. Saha, N. N., Mazumdar, S. K. and Guha, Sephali, 'Structure and Electronic Charge Distribution of Amino-acid Derivatives', *Proc. Int. Conf. on Chemical Bonds, Minsk, USSR,* May, 1967.
62. Santosh Kumar and Ray, D. K., 'Anisotropy of the Spin-lattice Relaxation for the Kramer's Doublets in Cubic Crystals, II—Analysis of Specific Cases', *Phys. Rev., 164,* 424, 1967.
63. Sanyal, A. B. and Ganguly, P., 'Comparative Study on the Interaction of Sodium Tungstate and Potassium Phosphotungstate with Haemoglobin', *Biochim. Biophys. Acta., 133,* 535, 1967.
64. Sen, P. and Patro, A. P., 'Development of a Fast Time-to-amplitude Converter System for Life-time Measurement', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 504.
65. Sen, S., 'Collective Nature of the 1.29 MeV State of ^{116}Sn', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 281.
66. Sengupta, S. and Mukherjee, A., 'Self-consistent Calculation of Dynamic Polarisability of Helium', *Proc. Nucl. Phys. Sol. St. Phys. Symp, Kanpur,* 1967, p. 184.
67. Sengupta, S. and Mukherjee, A., "Self-consistent Calculation of Dynamic Polarizability", *J. Chem. Phys., 47,* 260, 1967.
68. Sethi, B. and Mukherjee, S. K., 'Life-time Measurements of the Excited States of ^{46}Ti, ^{84}Rb, ^{99}Tc, ^{162}Dy, ^{164}Er, and ^{196}Au', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 462.
69. Shanta, Rajagopal, 'The Alpha-alpha Interaction Potential', *Proc. Nucl. Phys. Sol. St. Phys. Symp., Kanpur,* 1967, p. 106.
70. Shastry, S. and Rustgi, M. L., 'On the Odd Parity States in ^{4}He', *Physics Letters, 25B,* 391, 1967.
71. Shastry, S. and Saha, A. K., 'On the Collective Octupole State of ^{88}Sr', *Nuclear Physics, A97,* 567, 1967.
72. Sinha, S. K., 'Acoustic Free Induction in a Quadrupolar Spin System in a Cubic Crystal', *Ind. J. Phys., 41,* 453, 1967.
73. Sinha, S. K. and Mondal, S. K., 'Guage-variation Calculation of Diamagnetic Susceptibility and Nuclear Magnetic Shielding in Hydrogen Molecule', *Proc. Int. Conf. Spectroscopy, Bombay, II,* 457, 1967.
74. Verma, J. K. D. and Nag, B. D., 'Nuclear Radiation Effects in Semiconductor and Temperature Measuring Devices', *Thermometry,* Ed. T. D. Bansal, National Physical Laboratory, New Delhi, 1967.

Although it is mentioned in the Introduction by the Director that the number of publications from the Institute in 1967 was 64, a few more publications have been brought to our notice while this Report has been in press. These publications are also included in the above list.—Editors

STAFF OF THE INSTITUTE

ADMINISTRATION

B. D. Nagchaudhuri, *Director (on leave)*
D. N. Kundu, *Director (Acting) and Head, Accelerator Group*
H. K. Basu, *Registrar*
A. K. Saha, *Head, Nuclear Physics Group*
N. N. DasGupta, *Head, Biophysics Division*
B. M. Banerjee, *Head, Instrumentation Division*
B. C. Purkayastha, *Head, Nuclear Chemistry Division*
T. Pradhan, *Head, Theoretical Nuclear Physics Division*
N. N. Saha, *Head, Crystallography and Molecular Biology Division*
S. K. Mukherjee, *Head, Electrostatic Generator Division*
A. P. Patro, *Head, Cyclic Accelerator Division*
S. Chatterjee, *Head, Teaching Division (on leave)*
B. B. Baliga, *Head (Acting), Teaching Division*
G. N. Sarkar, *Workshop Superintendent*
K. P. Chaudhury, *Medical Officer*
N. K. Moorty, *Chief Accountant*
A. N. Banerjee, *Establishment Officer*
B. K. Chakraborty, *Purchase and Stores Officer*

SCIENTIFIC PERSONNEL

Professors

B. M. Banerjee
N. N. Das Gupta
D. N. Kundu
B. D. Nagchaudhuri
T. Pradhan
B. C. Purkayastha
A. K. Saha

Associate Professors

H. D. Banerjee
B. Basu
Monisha Bose
S. Chatterjee
B. Dutta Roy
D. K. Ghosh
S. B. Karmahapatro
P. N. Mukherjee
S. Mukherjee
S. K. Mukherjee
M. K. Pal
A. P. Patro
D. K. Ray
R. N. Roy
N. N. Saha

Readers

B. B. Baliga
J. Basu
R. Bhattacharyya
S. N. Bhattacharyya

A. S. Chakraborty
M. L. Dey
S. K. Majumdar
A. Mukherjee
Ila Mukherjee
S. C. Nath
K. S. Patel
R. K. Poddar
Tuhina Ray
S. K. Sinha
J. K. D. Verma

Tarini Charan Sur Reader

A. Chatterjee

Lecturers

S. B. Bhattacharyya
S. D. Bhattacharyya
Jyotsna Chakraborty
Sneha Chaudhury
R. K. Das
S. Das
A. K. Ganguly
S. K. Ghosh
S. K. Ghosh Roy
Jayanti Mahalanabis
N. K. Majumdar
S. K. Majumdar
Dipti Pal
P. Sadhukhan
B. B. Sen
S. N. Sen Gupta
S. Shastry

Research Associates

S. C. K. Nair
A. K. Sengupta

Senior Research Assistants

Amala Chatterjee
M. L. Chatterjee
S. D. Dey
S. C. Gujrathi
D. N. Misra
M. Rama Rao
A. K. Raychaudhury

Research Assistants

D. Basu
S. C. Bhattacharyya
D. K. Bhattacharyya
A. Chatterjee
N. Chatterjee
N. C. Das
N. R. Das
Anita Dutta
K. N. Dutta
M. N. Ghatikar
A. K. Nigam
B. P. Pathak
A. K. Roy
P. N. Roy
Ratna Sarkar
S. Sarkar
P. Sen
Shyamoli Sen
S. Sen Gupta
Sankar Sen Gupta
B. Sethi

Teaching Assistants

S. Sen
B. K. Sinha

Research Fellows

D. K. Bose
K. V. Chalapati Rao
Harish Chandra
C. K. Chatterjee
K. C. Das
P. Das Gupta
J. N. De
V. P. Desai

Research Fellows

Bani Dutta
S. C. Dutta
Aparna Ghosh
N. Guha
S. Guha
Sephali Guha
P. K. Gupta
S. K. Gupta
R. Handa
A. V. Khare
K. P. Kundu
V. J. Menon
A. Mukherjee
P. K. Mukherjee
K. S. N. Murthy
P. S. Nayar
R. N. Nandi
S. R. Pal Choudhury
J. N. Passi
Mamata Pattnaik
S. Baba Pundari
Ram Raj
G. Ramakrishna
S. K. Samaddar
R. K. Satapathi
L. Satapathi
Chitra Sen
Rajagopal Shanta
C. S. Shastry
D. N. Tripathi
K. B. Udupa

Sr. DAE Fellows

S. Basu
M. Bhattacharyya
B. Das Gupta
Y. K. Gambhir
S. N. Mallik

CSIR Sr. Research Fellows

B. Bagchi
Nati Ganguli
J. N. Maiti
Sheela Mukherjee
H. S. Singh

CSIR Jr. Research Fellow

Nandini Ghosh

Biophysics Research Training Scholarship

G. Bhowmick
D. K. Chattoraj
U. C. Chaudhuri
P. Mukherjee

Government of India Reciprocal Scholarship Scheme

B. H. Bye

Scientific Man Power Committee Scholar

S. K. Ghosh

POST-M.SC. STUDENTS

V. A. Managoli
B. N. Rao
S. K. Sharma
D. P. Dewangan
P. N. Sen
S. K. Ghatak
A. Ramakanta
D. Bhowmick
B. K. Das Mahapatra
D. Chakravarty
R. Pal
R. K. Moitra
Ramesh Kumar
N. C. Bhattacharyya

J. K. Dutta Gupta
Y. M. Sengupta
R. G. Aul
Ahmed Ansari

S. K. Basu
Arati Lahiri
K. C. Shah

TECHNICAL PERSONNEL

Technical Associates

Sunanda Aditya
D. N. Basu Mallick
M. N. Chandra
Anjali Chaudhury
S. C. Mukherjee

Engineers

S. B. Dutta
R. Roy
D. K. Sen

Assistant Engineer

S. C. Daw

Sr. Technical Assistants

N. Banerjee
Philip Banerjee
B. Bhowmick
K. K. Bose
M. K. Chakravarty
A. Chatterjee
S K. Ghosh
H. Maity
T. N. Misra
J. C. Mondal
A. Mukherjee
P K. Mukherjee
D. Roy
M. K. Sen Gupta

Sr. Glass Technician

M. N. Saha

Glass Blower

S. C. Saha

Technical Fellow

T. Vijayendra

Supervisor

A. Das

Technicians

H. P. Banerjee
C. K. Bose
B. K. Roy

Junior Technical Assistants

D. K. Banerjee
A. Chakraborty
S. K. Das
N. M. Ghosh
Anita Majumdar
S. C. Saha
A. Sen Gupta
D. R. Sikdar

Senior Laboratory Assistants

S. Banerjee
S. K. Banerjee
D. K. Bardhan
S. Bhattacharyya

Senior Laboratory Assistants

K. C. Chakraborty
Purnima Chaudhury
S. C. Das
J. Dasgupta
S. Dasgupta
S. K. Guha
M. K. Karmakar
B. P. Mukherjee
S. Mukherjee
D. K. Pal
J. N. Roy
N. C. Saha
R. Sen
A. N. Sinha

Junior Laboratory Assistants

S. K. Banerjee
A. Chakraborty
S. Chakravarty
K. Chatterjee
K. P. Choudhury
P. C. Das
J. Mukherjee

Operators

P. C. Saha
S. C. Saha

Sr. Mechanics

N. C. Adhikary
N. C. Bose
M. M. Das
N. N. Das
R. B. Das
S. L. Dutta

Mechanic-cum-Welder

S. C. Majumdar

Tool Room Mechanic

R. K. Das

Sr. Electrician

R. K. Midday

Electrician

S. N. Samanta

Jr. Electrician

H. L. Saha

Draftsman

S. K. Roychaudhury

Tracer

S. B. Chakravarty

Fitter

G. M. Mondal

Jr. Mechanics

N. C. Adhikary
K. P. Bagh
M. M. Das
B. N. Dey
G. C. Dey
J. G. Mondal

Carpenter

K. M. Dhar

Plumber

P. Singh

ADMINISTRATIVE PERSONNEL

Accountant

T. K. Das

Assistant Librarian

S. C. Mukherjee

P.A. to Director

N. K. Sinha

Senior Assistants

R. K. Banerjee
B. B. Chakraborty
A. K. Ghosh
M. K. Sarkar
B. N. Sinha

Cashier

B. M. Roy

Assistants

N. R. Chaudhury
R. N. Chaudhury

Sr. Library Assistant

Monorama Sen

Language Teachers

T. Bhosal
D. Rej

Steno-Typists

M. K. Basak
S. K. Manna

U. D. Clerks

D. K. Dutta Biswas
D. N. Majumdar

Typists

Maya Chanda
A. T. Das
S. P. Dutta
D. Ghosh
S. C. Mitra

Clerks

P. K. Banerjee
N. K. Chowdhury
G. Mazumdar
R. B. Mondal
M. K. Mukherjee
J. C. Saha
S. C. Saha Chowdhury

Jr. Library Assistants

S. K. Bhattacharyya
Maitrayee Dutta
Nupur Dasgupta
G. Goswami
B. Sen

Compounder

L. G. Chakravarty

Nurse

Doli Arati Mondal

Jr. Assistant

J. Dutta
G. R. Kahar

Telephone Operator-cum-Filing Clerk

H. N. Mukherjee

Telephone Operator-cum-Receptionist

T. D. Ganguly

Drivers

S. C. Maity
K. N. Pal
A. Simpson