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GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

PROGRESS REPORT ON NUCLEAR DATA MEASURING ACTIVITIES IN INDIA - I

Compiled by

INDIAN NUCLEAR DATA GROUP

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good, indicating compound nuclear levels in Si^{28}. It is proposed to measure angular distributions on a number of resonances and an attempt at analysing this data in terms of compound nuclear reaction mechanism will be made. The level density is large but not large enough for a statistical model analysis to be valid.

3. <u>4π Neutron Counter</u> - K.K.Sekharan, A.S.Divatia and M.K. Mehta - A 4π high efficiency neutron counter has been constructed for the study of total (integrated) cross sections for (p, n) and (α, n) reactions. This consists of twelve $B^{10}F_3$ counters arranged in two circles of diameter 6" and 8", embedded in a 18" cube of paraffin. The target is mounted at the center. The efficiency of this counter is studied by measuring the yield from $Li^7(p, n)Be^7$ reaction from the threshold upto 4 Mev proton energy. A preliminary study of $F^{19}(\alpha, n)Ne^{22}$ and $B^{11}(\alpha, n)N^{14}$ reaction upto 4 Mev bombarding energy has just been completed.

4. <u>$Cl^{37}(p, n'\gamma)Ar^{37}$ Reaction</u> - K.V.K.Iyengar*, S.K. Gupta* and E. Kondaiah* - The angular correlation of the neutron group to the 1.42 Mev level in Ar^{37} produced in the reaction $Cl^{37}(p, n'\gamma)Ar^{37}$ with the subsequent coincident gamma to the ground state has been measured in the reaction plane at a proton energy of 5 Mev at the three neutron emission angles of 0°, 30° and 60°. The angular correlation is isotropic at all these three angles and is consistent with a spin assignment of 1/2 to the 1.42 Mev level in Ar^{37}.

It is now known that there exists a level at 1.61 Mev in Ar^{37} and is excited in $Cl^{37}(p, n)Ar^{37}$ reaction though its intensity of excitation is < 15% of the 1.42 Mev level. The resolution of our neutron time-of-flight spectrometer used in the above measurement was not sufficient enough to resolve the two neutron groups to the 1.42 and 1.61 Mev levels. The resolving time of our neutron time-of-flight spectrometer is therefore being improved to resolve these two groups of neutrons of nearly the same energies, to allow measurement of the (n, γ) angular correlation of the individual neutron groups to obtain information of the spins of these levels.

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5. <u>Electric Quadrupole Lens System</u> - K.V.K. Iyengar*, S.K. Gupta* and T.P. David - An electrostatic quadrupole lens system has been designed for use with the Van de Graaff Accelerator at the Atomic Energy Establishment Trombay to transport the ion beam from the present target position to the centre of the neutron pit for performing neutron scattering experiments under conditions of reduced background. Preliminary tests conducted on the performance of the lens system reveal the following features:

(i) The lens system is capable of focussing the beam.

(ii) There is a shift in the position of the beam which increases with the increase of focus voltage. This is undesirable and is found to be due to imperfect machining of the lens system.

The lens system will be tested after realignment of electrodes to minimize the shifting of the beam with variation of focus voltage when time is again available on the accelerator.

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6. <u>Investigations on the Fission of U^{235} Induced by 4 Mev Neutrons</u> - S.S. Kapoor, D.M. Nadkarni, R.Ramanna and P.N. Rama Rao - The correlation between the angular anisotropy and the mass asymmetry of the fragments has been investigated in the fission of U^{235} induced by 4 Mev neutrons generated by $T(p, n)He^3$ reaction using the 5.5 Mev Van de Graaff Accelerator at Trombay. The kinetic energies of the pair fragments emitted parallel and perpendicuaar to the incident beam direction are measured by solid state detectors and recorded by a three dimensional analogue to digital converter incorporated with a print out arrangement. The variance σ_M^2 of the observed mass distributions of the 0° and 90° fragments are found to be same and equal to 65.3. The anisotropy N(0)/N(90°) has been found to increase with the asymmetry in the region of mass ratios 1.2 to 1.7. From this the effect of the saddle point quantum numbers on the mass division is inferred. The average values $\bar{E}_k$ of the total kinetic energies of the fragments are found to be as follows:

$$\bar{E}_k(0°) = (165.5 \pm 1.1) \text{ Mev}; \quad \bar{E}_k(90°) = (166.0 \pm 1.1) \text{ Mev}$$

This shows that the scission configurations of the fissioning nucleus in the two cases are the same. The variation of $\bar{E}_k$, and the mean square deviations $\sigma_{E_K}^2$ with the fragment mass ratios are found to be different than that for the thermal fission. The symmetric fragments are found to be formed with about 16 Mev more excitation energy in thermal fission, than in 4 Mev neutron induced fission, showing that the fissioning nucleus is more stretched in the thermal fission.

The work is being sent for publication.

7. Structure of Potassium Oxalate Monohydrate - Lone Pair Co-ordination of the Hydrogen-bonded Water Molecule in Crystals - R.Chidambaram, A.Sequeira and S.K.Sikka - A single crystal neutron diffraction study of the structure of potassium oxalate monohydrate (space group C2/c) was made. Zero layer data were collected about the b- and a- axes. The intensities of 79(hol) and 55(Okl) reflections within the limit $\sin \theta/\lambda \leqslant 0.75$ were examined at a wavelength of 1.029 Å. The unit cell constants were determined to be a = 9.236, b = 6.190, c = 10.694 Å, $\beta = 110°47'$. Starting from the heavy atom positions given by the earlier X-ray work[1] and the proton positions suggested by N.M.R. investigation[2] the structure was refined by Fourier, difference Fourier and least square methods. The final structure gives an overall R factor of 13.1%.

There are significant shifts in the positional parameters of all the atoms from Hendrick's values. The agreement with a recent re-investigation of the X-ray structure by S. Ramaseshan et al.,[3] is satisfactory. The hydrogen bonds between the water molecules and the oxalate ions lead to infinite $-C_2O_4-$ H_2O_4- C_2O_4- H_2O - chains parallel to the $[10\bar{1}]$ direction, the chains being held together by electrostatic interaction with the potassium ions. The oxalate ion is planar and the H-O-H angle of the water molecule is $108.3 \pm 4.3°$. The O-H distance is 0.974 ± 0.028 Å in a hydrogen bond of length 2.745 ± 0.016 Å and the O-H---O angle is $169.2 \pm 2.6°$.

The co-ordination of the water molecule in this structure is unusual with the two hydrogen atoms and the two potassium ions lying almost in a plane around the water oxygen atom. Now the electronic structure of a water molecule consists of two O - H orbitals and two lone pair orbitals directed approximately tetrahedrally away from the oxygen atom. In hydrates, where hydrogen bond donar groups are available, the O - H orbitals are generally used in the formation of hydrogen bonds. We have examined the structures of a large number of hydrogen-bonded hydrates reported in the literature and find that the lone-pair co-ordination of the water molecules in these hydrates can be broadly classified into several types. Each lone pair is usually specifically directed toward a metal ion or a hydrogen bond donor group. The bisector of the lone pairs is directed toward a polyvalent ion in another common type; recently a few examples have been found in which the bisector is directed toward a hydrogen bond donor group. We have also found instances in which one of the lone pairs is specifically directed toward a metal ion or toward a hydrogen bond donor group while the other is not. But $K_2C_2O_4 \cdot H_2O$ may be the only reported structure of the type in which neither of the lone pairs of the water molecule is specifically directed.

1. S.B. Hendricks, Zeit Krist. 91, 48 (1935)
2. R.Chidambaram, Ph.D. thesis, Indian Institute of Science, Bangalore, (1961).
3. S.Ramaseshan et al., private communication.

8. Configuration of the Cyanide Ion in Metallic Cyanides - A.Sequeir - The aim of these studies has been to see whether the cyanide ion is rotating or not and in the latter case to see whether the carbon or the nitrogen atom co-ordinates with the divalent metal ion. The advantage of using neutrons as compared to X-rays in these studies stems from the fact that the neutron scattering amplitudes of C and

N are significantly different and further are comparable to and often exceed these of the metal atoms.

Elliott and Hastings[1] studied the neutron diffraction powder pattern of KCN and concluded from the intensities of a few low angle reflections that the cyanide ion in this cubic crystal is rotating. But there would appear to be some errors in their calculation of the diffraction intensities on the basis of the static model. The powder pattern has been recorded again in this study and the observed intensities (nF^2) are compared with the calculated ones in Table 1. It is clear that low angle polycrystalline data is insufficient for any distinction to be made between the two models. Before proceeding to a single crystal study of KCN, which is highly deliquescent and difficult to handle, a study of $K_2Zn(CN)_4$ which has a cubic spinel structure and is stable at room temperature was started.

Table 1

hkl	nF^2(observed)	nF^2(Calculated) Dynamic	Static
111	50.9	50	51.3
200	100	100	100
220	113.4	114.8	117.4
311	15.6	15.2	14.6
222	52.0	43.3	47.3
400	16.7	18.6	13.7

An attempt has been made to choose between the following models:

I. The cyanide ion freely rotating

II. The cyanide ion ordered with co-ordination of the type -
Zn-C-N-K-N-C-Zn-

III. The cyanide ion ordered with the inverse co-ordination
Zn-N-C-K-C-N-Zn-

IV. The cyanide ion disordered which is actually an average of models II and III.

96 (hkl) reflections were recorded within the limit $\sin \theta/\lambda \leqslant 0.73$ at $\lambda = 1.025$ Å using a cylindrical specimen 5.7 mm. long and 2 mm. in dia. with its axis along [110]. Sixteen of the strongest reflections were recorded using a smaller specimen in order to estimate the effect of extinction. Initial calculations of structure factors on the basis of the various models gave R-factor of I. 52.0%; II. 26.3%; III. 31.8%; IV. 26.2%. A Fourier projection of the scattering density along [110] was made using the signs given by the average Model IV. The very high R-factor for Model I as well as the appearance of well-defined peaks in the Fourier clearly eliminated Model I. Model III could also be rejected because of its higher R-factor and further because it gave serious discrepancies for some low angle reflections. A second structure factor calculation for Models II and IV with revised temperature factor indicated by the Fourier gave R-factors of 21.8% and 21.3%. It was difficult to choose between these two models on the basis of diffraction data alone. However, since Model IV was not expected crystallographically the refinement was continued first on the basis of Model II. A weighted least squares calculation gave the following atomic parameters (for all atoms x = y = z = u) : Zn: u = 0.125, B = 2.0 $Å^2$, K: u = 0.500, B = 2.5 $Å^2$, C: u = 0.2183, B = 3.0 $Å^2$, N: u = 0.2712,

$B = 4.1\ \text{Å}^2$. An extinction correction was also applied to the observed data and the R-factor dropped to 16.6%. Further refinement using anisotropic temperature factors is being continued.

1. Elliott and Hastings, Acta Cryst. 12, 674 (1959)

9. Fast Recording of Neutron Diffraction Intensity Data - R. Chidambaram, A. Sequeira and S.K. Sikka - Using reasonable approximations it has been shown that the recording time for a total number G of neutron Bragg reflections from a crystal of volume V and unit cell volume v using the usual '2θ - scan' technique is given by

$$T_1 = G\left\{\frac{60Cv}{I_0 V \langle b'^2\rangle_{45°}}\left\langle \beta_{\frac{1}{2}}(2\theta)\sin 2\theta\right\rangle\right\}$$

where I_0 is the incident flux of monochromatic neutrons, $\beta_{\frac{1}{2}}(2\theta)$ is the half width of Bragg peak at counter angle 2θ and C is a certain specified number of signal counts for a reflection of average intensity at an average counter angle 2θ = 45°, and $\langle b'^2\rangle$ is the mean squared scattering amplitude, including the temperature factor, of the nuclei in the unit cell. If one collects 3-dimensional data, G is roughly proportional to v so that the recording time is proportional to v^2. This shows that while the proteins for example, are clearly beyond the scope of the application of the neutron diffraction technique with the available neutron fluxes, even for a crystal of considerably less complexity like vitamin B_{12} ($v \approx 8000\ \text{Å}^3$), it may take several years to collect the neutron diffraction data.

A method of cutting down the recording time by almost an order of magnitude is suggested. Now, it has been found by us in the course of collection of zero-layer two-dimensional data from several crystals like $K_2C_2O_4 \cdot H_2O$, $K_2Zn(CN)_4$ and $BeSO_4 \cdot 4H_2O$ that the ratio of the integrated-to-peak intensity in a given zone of a given crystal is a function only of the Bragg angle. This indicates that while collecting 3 dimensional data from a crystal it should be sufficient to measure the peak intensities of most of the reflections, a few integrated intensities being measured to develop the correlation diagram. This would effect a considerable economy in the recording time.

A paper on this work has been accepted for publication in Nuclear Instr. & Methods.

10. Computer Programmes for Neutron Diffraction - S.Srikanta and B.G. Mythili* - Two programmes designed for structure factor calculations in neutron diffraction crystal structure analysis have been written for TIFRAC (Tata Institute of Fundamental Research Automatic Calculator). The first programme NC-1 is meant for all space groups and for three dimensional data using isotropic temperature factors. The second programme NC-2 is also for all space groups but for two-dimensional data and anisotropic temperature factors.

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11. Hydrogen positions in Ammonium Oxalate Monohydrate by Neutron Diffraction - V.M. Padmanabhan - Using a single crystal, intensity data for 120 (hk0) reflections and 35 (0kl) reflections were collected. Detailed analysis of the data confirmed the unit cell parameters and the atomic positions of nitrogen, carbon and oxygen. From the Fourier projections on (001) and (100) plane the hydrogen atoms of the water molecule and the ammonium ion were determined.

Slight distortion in the tetrahedral nature of the NH_4^+ ion was noticed. Water oxygen occupies a special position lying on a two fold axis and the protons of the water oxygen are bonded to oxygen of the (COO) group. The position of the hydrogen atom agrees with the findings of the nuclear magnetic resonance data. The bond distances and angles are being calculated taking into consideration individual temperature factors for the atoms.

12. <u>Study of Ammonium Salts by Neutron Spectrometery</u> - G.Venkataraman, K. Usha Deniz, P.K.Iyengar, P.R.Vijayaraghavan and A.P.Roy - The study of the dynamics of the ammonium ion by slow neutron inelastic scattering which was started sometime ago is being continued. Measurements using the window filter technique are currently under way on the study of the torsional oscillations of the NH_4^+ ion in various ammonium salts. The split of the torsional frequency in NH_4Cl at room temperature previously reported by us is now being investigated carefully as a function of temperature. Measurements are also being made on NH_4Br, NH_4I, ND_4Cl, ND_4Br, $(NH_4)_2SnCl_6$ and $(NH_4)_2SnBr_6$.

The thermal cloud of the proton in these ammonium salts has been studied by observing the angular distribution of elastically scattered neutrons. The measurements were made with a triple axis spectrometer using incident neutrons of wavelength 1.085 Å (0.0695 ev) and the elastically scattered neutrons were selected by reflecting off the (111) planes of an aluminium single crystal. The energy window was 0.012 ev. The scattering from vanadium was also studied as a check, and the form factor was found to be a gaussian consistent with a Debye temperature of 349°K. In the case of NH_4Cl and NH_4Br measurements were made only at room temperature. The observed form factors are gaussians and yield mean square displacements $\overline{u_H^2}$ of 0.04 $Å^2$ and 0.042 Å in the two salts. In the case of NH_4I at room temperature the form factor departs considerably from a gaussian being sharper. The form factor is however not as sharp as free rotation or uniaxial rotation would demand. It seems therefore that the actual motion of the NH_4^+ ion is complicated lying somewhere between torsional oscillations and free rotation. Somewhat similar behaviour has also been observed with the ammonium stannous salts. When NH_4I is cooled to 318°K, the form factor becomes a gaussian corresponding to a $\overline{u_H^2}$ of 0.046 $Å^2$. This is expected since at 318°K, NH_4I is in the tetragonal phase where the $NH_4{}^+$ ion is known to be performing torsional oscillations from measurements made on the beryllium detector spectrometer.

The cold neutron scattering from the ammonium salts has also been investigated using the rotating crystal spectrometer. The scattered neutron spectrum of NH_4Cl at room temperature shows peaks at 0.047 ev and 0.028 ev arising from the torsional oscillations and optical mode. Similar peaks are observed in NH_4Br at 0.042 ev and 0.023 ev. NH_4I, $(NH_4)_2SnCl_6$ and $(NH_4)_2SnBr_6$ however do not show any structure in the scattered neutron spectra. Instead a broad bump is observed. Comparison has been made with calculations based on Krieger-Nelkin Model for these salts. In the case of NH_4I neither a uniaxial rotational model nor a free rotational model gives agreement. Partial agreement is obtained for the stannous salts with an effective mass of $\sim$ 3.3 m_H for the proton.

13. <u>Neutron Scattering from Paramagnetic MnO</u> - K.Usha Deniz, G. Venkataraman, N.S.Satyamurthy, B.A.Dasannacharya and P.K.Iyengar

The energy spectra of cold neutrons scattered by paramagnetic MnO have been studied using the rotating crystal spectrometer. The Neel temperature of MnO is 122°K and the paramagnetic Curie temperature is about 500°K. At room temperature it exhibits a considerable degree of short range ordering as seen from a broad peak in the diffraction pattern centred round the position of the first antiferromagnetic reflection (Q_o = 1.18 Å^{-1}). The energy distributions have been studied at various scattering angles (Q_o = 0.45, 0.8, 1.1, 1 1.18, 1.44 and 1.72 Å^{-1}) which cover the range of the short range ordering peak. At Q_o = 1.1 Å^{-1} distributions have also been taken at 220°K and 480°K. Each of the room temperature spectra is characterised by a distinct inelastic peak, the position of which is Q-dependent. The energy transfer corresponding to this peak is a minimum for Q_o= 1.18 Å^{-1} and increases as Q moves away from this value. The maximum energy transfer of 5.5 Mev has been obtained for Q_o= 0.45 Å^{-1}. The results of Iyengar and Brockhouse[1] show only a spectrum broadened about the incident energy. The inelastic components cannot be seen distinctly owing to the poor resolution. The spectrum at Q_o= 1.35 Å^{-1} which has been analysed on the triple axis spectrometer, using a wavelength 1.74 Å confirms the results of Iyengar and Brockhouse.

Attempts are being made to calculate the energy spectrum using the cluster model given by Van Vleck[2]. This theory treats the neutron-ion magnetic interaction in the incoherent approximation and hence holds good only at high Q.

1. P.K.Iyengar and B.N.Brockhouse, Bull. Am. Phys. Soc. 3, 195 (1958).

2. J.H.Van Vleck, Phys. Rev. 55, 924 (1939).

14. Slow Neutron Scattering from Liquid Methane - B.A.Dasannacharya, G.Venkataraman and K. Usha Deniz - A theoretical model for slow neutron scattering by the protons in liquid methane has been constructed. The model assumes (1) that internal vibrations in the CH_4 molecule being of high frequency are excited neither thermally nor by the neutron, (ii) that the rotations of CH_4 molecules are free and (iii) that the translations are described by simple diffusion. Calculations are then made in the Zemach and Glauber formalism using the so called intermediate scattering functions consistent with above assumptions. The rotations are treated as in the work of Griffing[2]. The final expression for the cross section is a sum of several lorentzians each associated with a particular rotational transition. This is to be contrasted with the single lorentzian expected for a simple diffusion model. Detailed computations for neutrons of 4.1 Å scattered at 30° and 90° are now in progress. A system for liquefying methane has been built and is being tested. A cryostat and sample holder have also been fabricated. It is hoped to use the rotating crystal spectrometer and make detailed measurements of cold neutron scattering in the near future.

1. A.C.Zemach, and R.J. Glauber, Phys. Rev. 101, 118 (1956).
2. G.W.Griffing, Phys. Rev. 124, 1489 (1961).

2. BOSE INSTITUTE, CALCUTTA

1. Nuclear Physics Investigations with Neutron Generator in the Bose Institute, Calcutta - A.M. Ghose and B. Mitra - (n, p) cross sections for the following isotopes have been measured - O^{16}, F^{19}, Na^{23}, Mg^{25}, Al^{27}, Si^{28}, Ga^{71}.

Preliminary data has been reported previously[1]. An end window counter was used for the β counting from short lived products. As statistics are necessarily poor, very careful determination of various correction factors are now being made. For experimental determination of i) self absorption and ii) self scattering factor a new method of extrapolation is being followed. Work is expected to be completed soon.

Developments are in progress of a simple, absolute method for monitoring flux of fast neutrons with organic scintillators. Semiempirical relation have been developed to correlate pulse height with neutron flux.

Design and construction of a simple multichannel analyser is in progress.

Non-elastic cross section measurement of 14 Mev neutrons by sphere transmission method are also in progress.

1. A.M.Ghose and B.Mitra, Proc. of Nuclear Phys. Symposium, Bombay (1963), (Department of Atomic Energy, Bombay, 1963)

3. INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

1. Nuclear Data Activities in Indian Institute of Technology, Powai, Bombay - P.P. Kane - We are planning to study various aspects of gamma ray scattering, including the rotation of a resonance fluorescence pattern in the presence of a magnetic field and the possibility of measuring magnetic moments of excited nuclear states. Radioactive sources, scintillation detectors and associated electronic circuitry have been assembled and tested during the last six months or so. We will be starting the actual experiments during the coming months.

4. SAHA INSTITUTE OF NUCLEAR PHYSICS, CALCUTTA

1. The (n,α) Reaction on C^{12} at 14 Mev - M.L. Chatterjee and B.Sen - The $C^{12}(n,\alpha)Be^{9}$ reaction leading to the ground state of Be^{9}, has been studied using nuclear emulsions. The angular distribution of the emitted group of alphas is found to be asymmetric about 90° c.m. and indicates the presence of direct interaction. The distribution shows a prominent forward peak at about 30° and a comparatively slow rise in the background direction. The total cross-section for the ground state transition is 69 ± 13 mb. The theoretical fits to the experimental angular distribution have been discussed in terms of direct and exchange effects.

The full report will be found in a forth-coming issue of Nuclear Physics. Similar work ~~on~~ O^{16} is in progress.

2. Decay of Cu^{68} - H. Bakhru and S.K. Mukherjee - Decay of Cu^{68} was studied by bombarding Zn and Ga of spectroscopic purity with 14 Mev neutrons, using standard scintillation counter techniques. The beta and gamma measurements showed the presence of four gamma rays of 810 ± 8 kev(18), 1080 ± 3 kev(100), 1240 ± 10 kev(3) and 1880 ± 10 kev(5) energies and three beta group of maximum energies 3.5 ± 0.06 Mev(75%), 2.7 ± 0.08 Mev(22%) and 2.25 ± 0.08 Mev(3%) decaying with a half life of 30 ± 1 sec. Coincidence and sum spectrum studies showed that the 1080 kev gamma ray was in cascade with 800 kev and 1240 kev gamma rays, and that the 1080 kev gamma ray was in coincidence with 3.5 Mev, 2.7 Mev and 2.25 Mev beta particles. A decay scheme is proposed, and Cu^{68} - Zn^{68} mass difference of 4.58 Mev is obtained.

The full paper will soon come out in an issue of Nuclear Physics.

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

A paper on this work has been accepted for publication in Nuclear Physics.

4. <u>The Decay of Sr^{93} and the Gamma Spectrum of Y^{93}</u> - H. Bakhru and S.K. Mukherjee - Sr^{93} is produced by the Zr^{96} reaction with 14.5 Mev neutrons, and is studied by means of standard spectroscopy techniques. A quick and efficient method for radiochemical separation of Sr from Zr and Y, has been developed. The beta and gamma measurements show three beta groups of maximum energies 2.9 $\pm$ 0.05 Mev (65%), 2.6 $\pm$ 0.05 Mev (10%) and eight gamma rays of energies 0.305, 0.400, 0.600, 0.800, 1.10, 1.50, 1.70 and 2.1 Mev. Coincidence studies show that 0.600 Mev gamma ray is in coincidence with 0.305, 0.400, 0.800, 1.1 and 1.5 Mev gamma rays; 0.800 Mev gamma rays with 0.305, 0.400 and 0.600 Mev gamma rays; 1.1 Mev gamma ray with 0.400 and 0.600 Mev gamma rays and 1.7 Mev gamma ray with 0.400 Mev gamma ray only. Also with 0.600 and 0.800 Mev gamma rays in gate, all the three beta groups are observed; with 1.1 and 1.7 Mev gamma rays, two beta groups of maximum energies 2.6 and 2.2 Mev, are observed; and with 1.5 and 2.1 Mev gamma rays only the beta group of the energy 2.2 Mev appears. Based on the above observations, a decay scheme of Sr^{93} is proposed.

A paper on the above work has been communicated to Nuclear Physics for publication.

5. <u>Decay of Tc^{96}</u> - S. Shastry, B.B. Barman Roy and R. Bhattacharyya- The decay of 4.3 d Tc^{96} has been studied with the help of scintillation gamma spectrometer using a 4" x 4" well type NaI (Tl) Phosphor and a Siegbahn-Slatis beta ray spectrometer. The multipolarities of different gamma rays from the internal conversion coefficients were measured. The 317.2 kev and 1115 kev gamma rays have been found to be of M1 and E2 characters respectively. Gamma-Gamma angular correlation measurements were made using two 1½" x 1½"

NaI (Tl) phosphors employing the summing technique. The spin of all the levels and multipolarity of all the gamma rays were fixed. From the well spectrum analysis the energy of the highest excited state was found to be 3184 kev. Evidence of a new 460 kev gamma rays also was found.

6. On the Spin of 2.73 Mev Level of Mo^{96} - B. Barman Roy, S.Shastry and R. Bhattacharyya - Recently Born et al., have assigned 5^+ to the 2.73 Mev level. The spin values of the next low-lying states and the fact that 315 kev gamma ray is of E1 multipolarity according to an early beta-spectrometric measurement suggest the spin as 5^-. The spin-parity was therefore ascertained by measuring the internal conversion coefficient of the 315 kev gamma ray by the Siegbahn-Slatis beta ray spectrometer which gave the 315 kev gamma ray to be M1 character leading to a value 6^+ for the spin of the 2.73 Mev level. The knowledge of this spin value helps to find the spin of the ground state of Tc^{96} by determining the log ft-value of the corresponding electron capture transition.

7. On the levels of Sr^{88} - S. Shastry - Recently the decay of Y^{88} was studied in a 4" x 4" NaI (Tl) phosphor in which two levels at 3.22 and 3.52 Mev were identified in the electron capture decay of Y^{88} [1]. The spin of the 3.22 Mev level was also determined by gamma-gamma angular correlation experiments. However, since Sr^{88} is a magic number nucleus with N = 50 and Z = 38, a theoretical calculation has also been made to assign the spins of these levels theoretically and to scan the entire spectrum of Sr^{88} taking single hole and single particle picture.

1. S.Shastry, to be published in Nuclear Phys. 55, (1964).

8. Decay of Sn^{125} - Previous measurements on Sn^{125} with the help of scintillation spectrometers suggested the possible spin assignment to all the levels of Sb^{125} on the basis of the log ft-values of the beta transition to these levels. We have measured gamma-gamma angular correlation between five cascades, viz. 0.91 - 1.07 Mev, 0.81 - 1.07 Mev, 0.34 - 1.07 Mev, 0.47 - 1.41 Mev, and 1.16 - 1.07 Mev to assign the spins of the levels of Sb^{125}; the results are 2.23 Mev levels as $11/2^+$, 1.98 Mev level as $13/2^+$, 1.88 Mev levels as $13/2^+$, 1.41 Mev level as $11/2^+$, and 1.07 Mev level as $7/2^+$. The Siegbahn-Slatis beta-ray spectrometer was used to determine the end-energies and log ft-values of the beta groups. These results were found to be in agreement with the previous reports.

The above is only a preliminary report of the work.

5. TATA INSTITUTE OF FUNDAMENTAL RESEARCH, BOMBAY

1. Magnetic Moment of the First Excited State of I^{127} - P.N.Tandon, S.H. Devare and H.G. Devare - The magnetic moment of the 59 kev first excited state of I^{127} has been measured by observing the rotation of the angular correlation pattern of the 365-59 kev Cascade in a magnetic field using the integral method. The value of $\omega\tau$ was found to be 0.93 ± 0.014 radians in the field of 12.78 kgauss. The A_2 and A_4 coefficients for the angular correlation of the 365-59 kev cascade as obtained by studying the correlation at seven angles are $A_2 = 0.296 \pm 0.012$ and $A_4 = 0.007 \pm 0.015$. From these measurements the value of 'g' was found to be $g = 0.56 \pm 0.08$ assuming the mean life $\tau = 2.68 \pm 10^{-9}$ sec. The magnetic moment of the 59 kev state is then, $\mu = 1.96 \pm 0.28$ n.m. since the spin of the state is 7/2.

2. <u>Decay of Pt^{197m}</u> - K.G. Prasad, K.P. Gopinathan and M.C. Joshi - The decay of the 86 m Pt^{197m} has been investigated with scintillation coincidence spectroscopy using a 512 channel pulse height analyser. Pt^{197m} was produced by neutron irradiation of enriched Pt^{196}. The 346 kev isomeric transition has been found to be in coincidence with a new gamma ray of energy 50 $\pm$ 3 kev. This established the presence of an intermediate level between the $13/2^+$ isomeric state and the $1/2^-$ ground state of Pt^{197}. The K-conversion coefficient, of the 346 kev transition has been estimated to be 4.8 $\pm$ 1.5 which agrees with an M4 multipolarity for that transition and $5/2^-$ assignment for the intermediate level. The total conversion coefficient of the 50 kev transition shows it to be E2 in character. A beta branching to the well known 409 kev isomeric level in Au^{197} has been established by milking the 7 s Au^{197m} from Pt^{197m}. The branching ratio of beta transition is estimated to be 4% from the relative intensities of the 346 kev gamma ray of Pt^{197m} and the 297 kev gamma ray of Au^{197m}.

3. <u>Angular Correlation Measurements in the Decay of Cd^{115m}</u> - V.R. Pandharipande, R.P. Sharma and Girish Chandra - Levels in In^{115} at 650, 930, 1125, 1285, 1420 and 1540 kev are populated in the decay of Cd^{115m} (43d.). The experimentally determined coefficients of the gamma-gamma angular correlation function for the cascades 485-930 and 160-1125 kev are $A_2 = -0.023 \pm 0.005$, $A_4 = 0.013 \pm 0.012$; $A_2 = -0.107 \pm 0.011$, $A_4 = 0.021 \pm 0.017$, respectively. The coefficient of the angular correlation function between the unique first forbidden beta transition and the following 930 kev gamma ray is found as $A_2 = 0.0088 \pm 0.0076$. Spin assignments for the excited states in In^{115}, which are consistent with the experimental results

are 7/2 (930 kev), 11/2 (1125 kev), 9/2 (1280 kev) and 9/2 (1420 kev) The quadrupole dipole mixing has been determined for the cascading gamma rays. From delayed coincidence measurements the half lives of 930 and 1420 kev levels were found to be shorter than 3×10^{-10} sec. and 1.1×10^{-9} sec. respectively.

4. <u>Decay of Ce^{143}</u> - K.P. Gopinathan, E.A.S.Sarma and M.C. Joshi - The decay of Ce^{143} has been investigated with scintillation and coincidence spectrometers in conjunction with a 512 channel pulse height analyser. The analysis of the singles gamma ray spectrum of a chemically purified source showed 36 (X-ray); 57-, 142-, 232-, 293-, 351-, 440-, 493-, 590-, 668-, 725-, 815-, 940-, 1045-, 1100- and 1340- kev gamma rays. All the gamma rays except the 142 kev were found to decay with the same half-life of 33 hours. The 142 kev gamma ray which was thought to be entirely due to Ce^{141} was also shown to be present in Ce^{143} by gamma-gamma coincidence. Extensive gamma-gamma coincidences showed the presence of new weak transitions of energy 220, 374, 436, 448, 455, 815 and 1045 kev. The level at 493 kev has been confirmed and evidence for a new level at 1395 kev has been obtained. A revised decay scheme consistent with these observations and the previous beta ray measurements has been prepared with levels in Pr^{143} at 57, 351, 493, 725, 940, 1160 and 1395 kev.

5. <u>Decay Scheme of the Isomers of Te^{129}</u> - S.H. Devare and H.G. Devare - The decay of the 70 min. activity of Te^{129} and the 33 d activity of Te^{129m} has been studied using a beta ray spectrometer, scintillation spectrometers and coincidence techniques. The 70 min. activity, studied in equilibrium with Te^{129m} and also independently, was seen to emit gamma rays of energies 27, 205, 245, 275, 350, 455,

550, 625, 755, 810, 960, 1080 and 1235 kev. From coincidence relationships among these gamma rays, it was concluded that levels at 27, 275, 350 or 755, 482, 550, 810, 1150 and 1235 kev are excited in the decay of the 70 min. activity. Te^{129m} was observed to decay by the emission of gamma rays of energies 550, 695, 720 and 830 kev in addition to the 106 kev isomeric transition. These gamma rays were attributed to the excitation of levels at 695, 830, 1385 and 1415 kev. The Fermi-plot of the beta spectrum of Te^{129m} studied with the Siegbahn-Slatis spectrometer showed beta groups with end-point energies 1595, 1452, 976 and 690 kev. From beta-gamma coincidence measurements it was concluded that 1595 kev is the end-point energy of the beta transition from Te^{129m} to the ground state of I^{129} while 1452 kev is the end point energy of the beta transition from the 70 min. activity to the 27 kev level. Comparison of the total intensities of the beta transitions from Te^{129m} and Te^{129} showed that the isomeric transition takes place with the branching ratio 0.64. The log ft values for the various beta groups were found from their relative intensities and spin assignments to various levels were made on this basis.

6. Levels in La^{140} from the Beta Decay of Ba^{140} - Y.K. Agarwal, C.V.K. Baba* and S.K. Bhattacharjee - Some properties of the low-lying levels in the odd-nucleus La^{140} as populated by the beta decay of Ba^{140} have been studied by beta-gamma and gamma-gamma directional correlation experiments. The multipole orders and the E2/M1 mixing ratios of the prominent gamma rays have thus been measured. On the basis of these measurements the following spin assignments to the La^{140} levels have been made: 30 kev (2^-), 162 kev (2^-), 466 kev (1^-) and 566 kev (1^-). The 162 kev gamma ray is

predominantly of E2 character with the reduced transition probability at least 90 times that due to single particle estimate.

* Member of the Atomic Energy Establishment Trombay.

7. <u>Measurement of Magnetic Moments of Excited States in Ta^{181} and Cs^{133}</u> - Y.K. Agarwal, C.V.K. Baba* and S.K. Bhattacharjee - The magnetic moments of 482 kev (5/2) level in Ta^{181} and 80 kev (5/2) level in Cs^{133} have been measured by azimuthal shift method. The result obtained are:

$\mu = 3.23 \pm 0.05$ n.m. and $\mu = 3.25 \pm 0.15$ n.m. for the 482 kev level in Ta^{181} and 80 kev level in Cs^{133} respectively.

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