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GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN INDIA—111

Compiled by

INDIAN NUCLEAR DATA GROUP

Nuclear Physics Division
ATOMIC ENERGY ESTABLISHMENT TROMBAY
BOMBAY, INDIA
1966

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PREFACE

The Third Progress Report on Nuclear Data Activities in India, being published about a year after the publication of the second report, incorporates work done upto June, 1966. We are happy to note that the response to our request for material has been increasingly better; we thank all those who have co-operated, and hope their interest in the INDG will continue.

During the last one year, the INDG has become a full fledged contributor to the CINDA (Computor Index Neutron Data) programme of the International Nuclear Data Committee (INDC) of the IAEA. All relevant Indian journals and reports are scanned regularly for nuclear data and the information is sent to the INDC.

All literature pertaining to Nuclear Data, received from the INDC, is maintained separately in the Physics Group Library at the Van de Graaff Laboratory at Trombay, and we welcome its utilization.

August 1966. Indian Nuclear Data Group

INDIAN NUCLEAR DATA GROUP

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A. ATOMIC ENERGY ESTABLISHMENT, TROMBAY, BOMBAY 74

1. The $^{16}O(n,\alpha)^{13}C$ Reaction Cross Sections from the $^{13}C(\alpha,n)^{16}O$ Reaction - A.S. Divatia, K.K. Sekharan and M.K. Mehta - Nuclear Physics Division - Total cross sections for the $^{16}O(n,\alpha)^{13}C$ reaction have been obtained from the total cross sections for the $^{13}C(\alpha,n)^{16}O$ reaction, using the principle of reciprocity. The incident neutron energy covered ranges from 3.95 to 6.50 MeV. The $^{13}C(\alpha,n)^{16}O$ reaction was studied by bombarding an enriched ^{13}C target, about 31 KeV thick for 3.1 MeV alphas, with singly charged He ions obtained from the Trombay Van de Graaff Accelerator, in the energy range 1.95 to 5.50 MeV, in steps of 5 to 8 KeV. The total neutron yield was measured by a calibrated 4π neutron detector, consisting of BF_3 counters-paraffin assembly, and the absolute cross sections were measured to an accuracy of $\pm$ 15%. About twenty resonances were observed, corresponding to energy levels in the compound nucleus ^{17}O, in the excitation energy region 7.9 - 10.5 MeV. The results are shown in Table I.

a. determined by the leading edge method of Richards

b. determined by using the formula $\Gamma_{exp}^{2} = \Gamma^{2} + T^{2}$ where T is the target thickness.

2. Binary and Ternary Fission Fragment Angular Distribution in 3 MeV Neutron Fission of U-235 - D.M.Nadkarni - Nuclear Physics Division - Angular Distribution of fission fragments in binary and ternary fission of U-235 induced by 3 MeV neutrons have been measured using 2 method. In the first method a gridded ionization chamber was used to detect fission fragments and the long range alpha particles were detected with a CSI crystal, the angular distribution being measured with the grid-pulse method. In the second method solid state detectors were used to detect the long range alpha particles and the fission fragments emitted at 0° - and 90° - difections with respect to the incident 3 MeV neutron beam. Calibration was achieved using tuermal neutron induced fission. 3 MeV neutrons were obtained with $T(p,n)^{3}He$ reaction using the 5.5 MeV Van de Graaff generator. These measurements show that the anisotropy of angular distribution in ternary fission is different both in magnitude and sign from that in binary fission. Cross section of 3 MeV neutron induced ternary fission was found to be: 1.96 ± 0.29 mb. These measurements are helpful in understanding the mechanism of ternary fission.

TABLE I

The integrated peak Cross Sections of $^{16}O(n,\alpha)^{13}C$ Reaction and widths of the levels in ^{17}O nucleus.

Incident alpha Energy E (lab) MeV	Corresponding Neutron Energy E (lab) MeV	Excitaion Energy E_x MeV	Integrated peak cross section, mb ± 15%	Total width KeV	Partial Alpha width KeV C.M.	Partial Neutron width KeV C.M.
2.10	4.05	7.94	63	79 ± 10 b		
2.27	4.18	8.07	107	71 ± 8 b		
2.43	4.32	8.19	102	71 ± 5 b		
2.62	4.47	8.34	67	9 ± 3 a		
2.70	4.53	8.40	71	4 ± 3 a	0.31	3.69
2.78	4.60	8.47	60	7 ± 3 a		
2.83	4.64	8.50	132	5 ± 3 a	0.82	4.18
3.08	4.84	8.69	88	50 ± 3 b		
3.34	5.05	8.89	183	101 ± 3 b		
3.44	5.13	8.96	164	21 ± 3 b		
3.67	5.32	9.14	12	4 ± 3 a		
3.73	5.38	9.19	43	4 ± 3 a	0.22	3.78
4.13	5.71	9.50	33	8 ± 3 a	0.26	7.74
4.44	5.95	9.73	149	15 ± 3 a	2.73	12.27
(4.50)	--	(9.78)	--	--		
4.63	6.11	9.88	134	5 ± 3 a	0.63	4.37
(4.78)	(6.23)	(9.99)	(47)	--		
(4.86)	(6.29)	(10.05)	47	--		
5.06	--	10.20	--	50 ± 3 a		
5.30	--	10.39	--	--		
5.42	--	10.49	--	--		

3. Kinetic Energy Distribution of Fission Fragments in the Fission of U-235 induced by neutrons in the Energy region E_n = Thermal to 2 MeV. - D.M. Nadkarni - Nuclear Physics Division - Average Kinetic energy of fission fragments in the fission of U-235 induced by neutrons in the energy region: thermal to 2 MeV have been measured using a gridded ion chamber and a 100 ug/cm^2 U-235 foil.

Neutrons in this energy region were obtained with $T(p,n)^3He$ reaction using the 5.5 MeV Van de Graaff generator and the measurements were made at 22 different neutron energies. Analysis of data is in progress; however preliminary results indicate a definite structure in the variation of average kinetic energy with excitation energy of fissioning nucleus.

4. Study of Neutron Resonance Parameters Using slowing down time lead spectrometer - K. Chandramoleswar, M.P. Navalkar, M.R. Phiske, J.V. Ramana, D.V.S. Ramakrishna and S.K. Sadavarte - Nuclear Physics Division - A slowing down time lead spectrometer set up in connection with an I.A.E.A. research project has been used for the measurement of neutron resonance parameters. The results for Ag, Au, Ho and Ta have been compared with published BNL values and are presented in Tables I to IV.

Because of the large energy range of lead spectrometer, it is ideally suited for resonance analysis. The possible use of this type of analysis to determine average fission cross section over resonances of uranium in the 1 -- 10 eV energy range for samples of various dimensions is suggested.

TABLE I

$^{109}Ag(E_o = 5.2\ eV)$

Resonance Parameters	Experimental Values		BNL Values	
	Minimum	Maximum	Minimum	Maximum
Γ_n in eV	0.011	0.0116	0.0122	0.0128
$\sigma_o\Gamma$ in barns eV	2050	2090	1784	2111
Γ_n in eV	0.149	0.160	0.1502	0.1608
σ_o in barns	12848	14027	11875	13125

(for assumed error on σ_o of $\pm$ 5% on BNL Values)

TABLE II

$^{197}Au(E_o = 4.9\ eV)$

Resonance Parameters	Experimental Values		BNL Values	
	Minimum	Maximum	Minimum	Maximum
Γ_n in eV	0.012	0.0133	0.0152	0.0160
$\sigma_o\Gamma$ in barns eV	3960	4360	3882	4505
Γ in eV	0.133	0.1403	0.1362	0.1430
σ_o in barns	28235	32782	28500	31500

(for assumed error on σ_o of $\pm$ 5% on BNL Values)

TABLE III

$^{165}Ho(E_o = 3.92\ eV)$

Resonance Parameter	Experimental Values		BNL Values	
	Minimum	Maximum	Minimum	Maximum
Γn in eV	0.00137	0.00150	0.002	0.003
$\sigma_o\Gamma$ in barns eV	390	426	342	593

Resonance Parameter	Experimental Values Minimum	Maximum	BNL Values Minimum	Maximum
Γ in eV	0.07137	0.1115	0.072	0.113
σ_o in barns	3498	5969	4750	5250

(for assumed error of σ_o, $\pm$ 5% on BNL Values)

TABLE IV

$^{181}Ta(E_o = 4.28$ eV)

Resonance Parameter	Experimental Values Minimum	Maximum	BNL Values Minimum	Maximum
Γ_n in eV	0.0031	0.0040	0.0033	0.0043
$\sigma_o \Gamma$ in barns eV	820	1050	563	800
Γ in eV	0.0461	0.059	0.0463	0.0595
σ_o in barns	13898	22776	12160	13440

(for assumed error on of σ_o, $\pm$ 5% on BNL Values)

5. Isomeric Cross-Section Ratios in the (n,γ) Reactions on ^{76}Ge and ^{82}Se - R.S. Iyer, M.B. Ramaniah, C.L. Rao and Satya Prakash - Radiochemistry Division - The cross section ratios for the formation of the isomeric pairs $^{77, 77m}Ge$ and $^{83,83m}Se$ in the (n,γ) reaction by reactor neutrons were measured by a radiochemical method involving the estimation of their daughter activities ^{77}As and ^{83}Br respectively. The values of $\sigma g/(\sigma g + \sigma m)$ obtained are tabulated below along with the values of others and those calculated by Huizenga et al. The ratios were also determined for epicadmium

neutrons and were found to be 0.31 and 0.08 respectively for ^{77}Ge and ^{83}Se isomers.

Target	Experimental Values		Calculated Values			
	Present work	Other data	Huizenga & Vandenbosch(5) N = 3, N = 4, N = 5 ρ = 3, ρ = 3, ρ = 5			Bishop et al (6)
^{76}Ge	0.23 ± 0.02	0.47 ± 0.14 (1); 0.04 (2)	0.26	0.37	0.54	0.16
^{82}Se	0.07 ± 0.01	0.07 ± 0.05 - (3) (4)	0.13	0.23	0.38	0.10

N = number of gamma rays emitted in the de-excitatiom of the compound nucleus

ρ = spin density parameter

(1) E. der Mateosiam and M. Goldhaber, Phys. Rev.,108 (1957) 766

(2) W.S. Lyon and J.S. Eldridge, Phys. Rev.,107 (1957) 1056

(3) J.R. Arnold and N. Sugarman, J.Chem. Phys., 15,(1947) 703

(4) D.J. Hyghes and R.W. Schwartz, U.S.A.E.C Report BNL-325 (1958)

(5) J.R. Huizenga and R. Vandenbosch, Phys. Rev., 120,(1960) 1315

(6) C.T. Bishop, H.K. Vonach and J.R. Huizenga,Nucl. Phys.,, 60, (1964) 214

6. Isomeric Cross-Section Ratios in the (n,γ) reactions on ^{130}Te and ^{110}Pd - M.N. Namboodiri, M. Rajagopalan, N. Ravindran,

K. Rengan and M.V. Ramaniah - Radiochemistry Division - Isomeric Cross Section ratios $\sigma_m / \sigma_m + \sigma_g$ in the (n,γ) reactions on ^{130}Te and ^{110}Pd have been determined using radiochemical techniques. The measurements were carried out by isolating and assaying the daughter activities ^{131}I and ^{111}Ag from solutions of neutron-irradiated telluric acid and palladium chloride respectively. In each case, the amount of the longer-lived isomer and the sum of the amounts of both the isomers (formed) during irradiation, were measured separately making use of the different in the half lives of the isomers. The Cross Section ratios calculated from these data are given in Table I. A detailed account of this work is given in J. Inorg. Nucl. Chem. 28, 1, (1966).

TABLE I

(a) Isomeric Cross-Section ratio for (n,γ) reaction on ^{130}Te

Experiment	1	2	3	4	5	6	7
$\sigma_m/\sigma_g + \sigma_m$	0.057	0.054	0.063	0.063	0.058	0.061	0.059

Mean: 0.059 ± 0.003

(b) Isomeric Cross Section ratio for (n,γ) reaction on ^{110}Pd

Experiment	1	2	3	4
$\sigma_m/\sigma_g + \sigma_m$	0.044	0.045	0.046	0.047

Mean: 0.045 ± 0.001

7. Prediction of Neutron Cross Sections on the basis of optical and statistical models. - S.B. Garg, K.Balasubramanian

and V.K. Shukla - Reactor Physics Division - Optical model and Hauser-Feshbach's statistical theory of compound nucleus have been used to compute the total, elastic and inelastic cross sections of Ni and Cr in the energy range 0.1 to 4.0 MeV. Angular distributions of both elastically and inelastically scattered neutrons have also been predicted in the centre of mass and laboratory systems. Out of the six local optical model parameters U, W, V, r, a and b we have varied only r and w to obtain best fits to the measured total cross-sections. Saxon-Wooks form of central potential has been used both for the real and imaginary parts. Spin-orbit part of the potential has been taken as zero in all these calculations. The parameters used in different energy regions are given below and the results compared in Table I.

Ni-58

(i) $(0.1 \leq E \leq 0.5$ MeV) U = 45.0 MeV; W = 18.0 MeV; r = 1.45 fm
a = b = 0.5 fm

(ii) $(0.5 \leq E \leq 1.5$ MeV) W = 5.0 MeV; others same as for (i)

(iii) $(1.5 \leq E \leq 4.0$ MeV) r = 1.35; W = 5.0 MeV; others same as for (i)

Cr-52

(i) (0.5 MeV) U = 45.0 MeV; W = 6.0 MeV; r = 1.45 fm
a = b = 0.5 fm.

(ii) $(0.5 < E \leq 4.0$ MeV) " = 4.0 MeV; others same as for (i)

TABLE I

Comparison of calculated and measured total cross sections

E_n (MeV)	Element	Calculated σ_t (b)	Measured σ_t (b) KFK-120
0.5	Cr	3.27	3.27
	Ni	3.91	3.83
0.8	Cr	3.01	2.80
	Ni	3.50	3.42
1.0	Cr	3.11	2.80
	Ni	3.38	3.34
1.5	Cr	3.38	3.10
	Ni	3.24	3.24
2.5	Cr	3.55	3.60
	Ni	3.32	3.20
3.0	Cr	3.54	3.70
	Ni	3.34	3.33
3.5	Cr	3.49	3.76
	Ni	3.36	3.39
4.0	Cr	3.43	3.80
	Ni	3.47	3.45

8. The $^{51}V(p,n)^{51}Cr$ Reaction Cross Sections - K.K. Sekharan, A.S. Divatia and M.K. Mehta - Nuclear Physics Division - Using a vanadium metal target 45 KeV thick for 3 MeV protons, the integrated cross-section of $^{51}V(p,n)^{51}Cr$ reaction was determined for the incident proton energy range 2.8 to 5.5 MeV, in steps of 50 KeV, with a 4π neutron detector consisting of a BF_3 counters-paraffin assembly. For 1.9 to

2.8 MeV range a thin target yield was averaged and normalized with the thick target yield. The cross section rises from about 10 mb at 2 MeV to more than 600 mb at 5.5 MeV.

9. "Proton Induced Reactions on ^{51}V" - N. Sarma Nuclear Physics Division, A.E.E.T. and V.K. Deshpande, G.K. Mehta and D. Sood, Indian Institute of Technology, Kanpur.

A measurement of the differential yield of (p,p), (p,p'), (p,α) and (p,α') reactions has been made by proton bombardment of ^{51}V. The data was obtained at backward angles where the groups were well separated. The bombarding energy was varied from 2.5 to 5.5 MeV in 10 KeV steps, corresponding to a range of excitation energy in the compound nucleus ^{52}Cr from 12.88 MeV to 15.82 MeV. The excitation curves show a strong dependence of the cross section on the bombarding energy. Appreciable enhancement of the cross-section is observed at some energies and there is some evidence that the different excitation curves are correlated. Analysis of data to determine level properties of ^{52}Cr is being attempted.

10. Reaction Induced by Proton Bombardment of Aluminium - M.K. Mehta, Joseph John*, S.S. Kerekatte and A.S. Divatia - The reactions $^{27}Al(p,p_0)^{27}Al$, $^{27}Al(p,p_3)^{27}Al^*$ and $^{27}Al(p,\alpha_0)^{24}Mg$

are studied in the proton energy range 3.5 to 5.5 MeV with energy steps of about 5 KeV using thin ($\approx$ 3 KeV) natural aluminium targets. The differential cross sections are measured as a function of bombarding energy to an accuracy of $\pm$ 15% at laboratory angles of 90° and 150°. The excitation curves exhibit sharp maxima of 10 to 50 KeV widths superimposed on broad 150 to 200 KeV wide structure. A fluctuation analysis of the data in terms of auto correlations yields a coherence energy varying from 15 $\pm$ 3 KeV to 22 $\pm$ 3 KeV depending upon the excitation functions and the averaging interval chosen. Non zero cross correlations between the two α_o yield curves and the p_3 yield curve indicate the presence of correlated resonance structure due to individual or groups of similar levels in the compound nucleus ^{28}Si in the region of excitation from 15.3 to 16.9 MeV.

Accepted for publication in Nuclear Physics.

*Working at present as I.A.E.A. fellow at the Florida State University, Tallahassee, Fla.,U.S.A.

11. <u>A Search for the 1.65 and 1.83 MeV Levels in ^{21}Al</u> - A.S. Divatia, M.K. Mehta and S.S. Kerekatte - Nuclear Physics Division - A search has been made for recently reported levels in ^{27}Al, at 1.65 and 1.83 MeV, utilizing the reaction $^{27}Al(p,p')^{27}Al^*$, for incident proton energies 3.5 - 5.5 MeV. No positive evidence has been found for the existence of these

levels. An upper limit of 0.4 mb/ar has been obtained for the differential cross-section for exciting these levels in the range of proton energies covered.

Accepted for publication in the Indian Journal of Pure and Applied Physics.

12. Proton - gamma ray angular correlation Studies in the Reactions $^{26}Mg(d, p\gamma)^{27}Mg$ and $^{24}Mg(d, p\gamma)^{25}Mg$ - M.A. Eswaran, N.L. Ragoowansi and P.C. Mitra - Nuclear Physics Division - "Method II" of Litherland and Ferguson (1) has been applied to the study of the first two excited states at 0.98 and 1.69 MeV respectively in ^{27}Mg and the 1.61 MeV level in ^{25}Mg. The levels were excited in the $^{26}Mg(d,p)^{27}Mg$ and $^{24}Mg(d,p)^{25}Mg$ reaction using deuteron beam from the Trombay Van de Graaff Accelerator. The outgoing protons in the reactions feeding a particular excited state were detected at 0° to the beam in a semiconductor detector and the angular correlation of the subsequent de-excitation gamma ray was measured.

A computer program in FORTRAN was written for CDC - 3600 for the analysis of the angular correlation data. The angular correlation coefficients for different choices of the spin of the excited level were obtained from the tabulation of Smith (2). The analysis is carried out by linear least squares fitting procedure treating the magnetic substate population parameters as unknowns, The fitting is made to the measured correlation for a discreet set of fixed values of the parameter δ, the

quadrupole to diple mixing amplitude ratio of the de-excitation gamma ray.

From these angular correlation measurements the spins of the 0.98 and 1.69 MeV excited stated in ^{27}Mg have been assigned as 3/2 and 5/2 respectively. For the 1.61 MeV excited state in ^{25}Mg, the spin values of 7/2 and 3/2 give acceptable fits to the measured correlation. The value of 7/2 for the spin of this level is in agreement with the expected value from other evidences (3).

(1) A.E. Litherland and A.J. Ferguson. Candian Journal of Physics. 39 (1961) 788.

(2) P.B. Smith in 'Nuclear Reactions' Vol.II North - Holland Publishing Co. (1962).

(3) P.M. Endt and C. Van der Leun. 'Nuclear Physics' 34 (1962) 1.

13. Elastic Scattering of alpha particles from ^{6}Li - K.B. Nambiar, A.S. Divatia, M.K. Mehta and D.K. Sathe - Nuclear Physics Division - Energy levels in ^{10}B lying between 5.92 MeV and 7.01 MeV have been investigated by studying the elastic scattering of alpha particles from ^{6}Li for incident alpha particle energies from 2.4 to 4.5 MeV. The excitation curves obtained at two angles $\theta_{lab} = 56^{\circ}$ and $\theta_{lab} = 80$ corresponding to $\theta_{c.m.} = 90^{\circ}$ and $\theta_{c.m.} = 125^{\circ}$ show a number of resonance structures at E (lab) = 2.45, 2.68, 2.87, 3.11, 3.52 and 4,34 MeV corresponding to excited levels in thecompound nucleus ^{10}B at 5.93, 6.06,6.18,6.31,6.57 and 7.05 MeV. The level at

6.31 MeV has not been previously reported. The anomaly at E_{α}(lab) = 3.52 MeV corresponding to the 6.57 MeV level in ^{10}B shows an interesting behaviour at the two angles. The level appears well isolated from neighbouring ones. In order to determine the spin and parity of this level, angular distribution of the elastically scattered alpha particles were obtained over the resonance at 3.52 MeV. It is proposed to extend this work to E_{α}(lab) = 5.5 MeV, so that energy levels upto 7.78 MeV in ^{10}B could be investigated.

14. Elastic Scattering of Alpha Particles by ^{24}Mg - S.S. Kerekatte, M.K. Mehta, A.S. Divatia and K.K. Sekharan - Nuclear Physics Division - Alpha particles elastically scattered from ^{24}Mg isotope, (for incident alpha energies from 3.440 to 5.500), have been observed at the following four laboratory angles: 80°29' (all odd Legendre Polynomials are zero at this angle); 116°39' ($P_2(\cos\theta)$ is zero at this angle); 143°47' ($P_4(\cos\theta)$ is zero at this angle); and 164°. The last angle, 164°, is sufficiently backwards, so that one of the significant Legendre Polynomianls can vanish, and therefore, all the resonances appear at this angle. The excitation function at 164° reveals ten resonances at 3.520, 3.600, 3.825, 4.580, 4.640, 4.870, 5.137, 5.170, 5.205 and 5.415 MeV, indicating levels in the compound nucleus, ^{28}Si. The first three resonances have been observed in previous data from other laboratories.

From the vanishing of a resonance at an angle corresponding to the zero of a Legendre Polynomial, it will be possible to obtain the spin of the corresponding level in the compound nucleus. The data is being processed. The excitation curve at 164° shows resonances which are fairly isolated and superposed on a smooth curve due to Rutherford scattering.

15. "The two-nucleon stripping reaction, $^{40}Ca(^{3}He,p)^{42}Sc$" - B.K. Jain and N. Sarma - Nuclear Physics Division - The theory of two-nucleon stripping reactions as applied to the $^{40}Ca(^{3}He,p)^{42}Sc$ reaction is described. Using antisymmetrised wave functions for the captured nucleon pair and for the incident ^{3}He particle the differential cross-section has been estimated. The results have been applied to the $^{40}Ca(^{3}He,p)^{42}Sc$ reaction where twenty eight levels have been identified. The effect of changes in the optical potentials has also been investigated.

16. Life time of the 1.10 and 1.29 MeV excited states in ^{59}Co - N.P.S. Sidhu and U.C. Gupta - Electronics Division - Radioisotope ^{59}Fe decays(1)by beta emission to the 1.10, 1.29 and 1.43 MeV excited states of ^{59}Co. Half life of the 1.10 and 1.29 MeV states were measured by delayed coincidence method. Plastic scintillator measuring 25mm x 1.6 mm was used for beta detection and NaI(Tl) measuring 25mm x 25 mm for gamma detection. Half life of the 1.10 MeV state was evaluated by the centeroid shift method using ^{60}Co as the source of prompt coincidences.

Half life for the 1.29 MeV state was measured by the centeroid shift method and was also confirmed from the slope of the delay-coincidence curve. The half life for this state was found to be 0.60 ± 0.05 nsec, though it was expected to be faster the 10^{-11} sec. 2,3).

(1) Nuclear Data Sheet, National Academy of Sciences, National Research Council, Washington D.C.

(2) Alkhazov et al. Izv. Akad. Nauk SSSR, Ser Fiz, 28 (1964) 1967.

(3) A.G. Blair & D.D. Armistrong Phys. Rev. 140(1965) B 1567.

17. Present Status of Neutron Source Standardization in India - M.G. Shahani, N.C. Jain, D. Sharma and U.C. Gupta - Electronics Division - In order to establish the national standards of neutron emitters, two Ra- α-Be sources were employed. One of these sources (Code No. AEE/Trombay/1) was imported from Union Minere du Haut Katanga in July 1956 and was constructed from an intimate mixture of 249.9 mgs. of radium in the form of sulphate and 2.5 gms. of beryllium. The source was doubly sealed in monel metal and stainless steel capsules (lemgth 19 mm, diameter 19 mms and wall thickness approximately 2 mm). The absolute calibration of this source was done by the activation of a manganese sulphate bath in January, 1964 and simultaneously intercompared with the Canadian neutron standard which was also calibrated in this laboratory by the manganese bath technique and absolute BF_3 chamber technique for the purpose of

International Intercomparison. Another Ra-α-Be source (Code No. TIN/250) also containing about 250 mgs. of Radium was imported from Radio-chemical Centre, Amersham in November, 1951 and was contained in a cylindrical platinum capsule (length 19 mms, diameter 19 mms and wall thickness 1 mm). The absolute calibration of this source was done by the gold foil activation technique in April, 1961.

The results of measurements made on the two Indian standards and the Canadian standard are given in Table I and II.

The work was reported at the Symposium on Radioactivity and Metrology of Radionuclides, organized by the Department of Atomic Energy, Government of India,

TABLE I

Present Status of Neutron Source Standardization in India

Sr. No.	Type of source Code No. Wt. of Radium	Calibration Technique	Q= neutrons per sec x 10^{-6}	Q_M Manufacturers value	Correction factor K	Q_M K	$\frac{Q_M K}{Q}$
1.	Ra-α-Be (TIN-250) 343 mgs	Gold foil (Absolute)	3.16 $\pm$ 0.06 (April '61)	3.1 $\pm$ 0.3 (Nov.'51)	1.036	3.21_2 $\pm$ 0.3	1.0164
2.	Ra-α-Be (AEE/Trombay-1)249.9 mgs	Manganese Bath (Absolute)	3.926 $\pm$0.08 (Jan.'64)	4.00 $\pm$0.2 (July'56)	1.03	4.12 $\pm$ 0.2	1.049
3.	Ra-α-Be (AEE/Trombay-1)249.9 mgs	Manganese Bath Ref N-200-1 (Relatvie)	3.94_9 $\pm$ 0.06 (Jan.'64)	4.00 $\pm$0.2 (July'56)	1.03	4.12 $\pm$ 0.2	1.043
4.	Ra-α-Be (N-200-1) 183 mgs.	BF_3 chamber (Absolute)	3.169 $\pm$ 0.16 (March'64)	3,245 $\pm$0.032 -0.026 (NRC Value) (July'64)	0.99876	3.241 + 0.032 - 0.026	1.023
5.	Ra-α-Be (N-200-1) 183 mgs.	Manganese Bath (Absolute)	3.22_4 $\pm$0.06 (March'64)	3.245 + 0.032 - 0.026 (July'64)	0.99876	3.24_1 + 0.032 - 0.026	1.0054

K denotes the correction factor due to the growth of ^{210}polonium in the decay of ^{226}radium.

TABLE II

International Intercomparison of the Canadian Neutron Standard by the Manganese Bath Technique

Laboratory	Date of measurement	Result obtained 10^6 n x $\bar{S}^1$	Absolute error (±)	Cross-Section value used	Normalization σ Mn=13.2 barns σ H=0.332 " σ S=0.52 " Jan.1962	Jan.66
E.T.L.,Japan	Jan.1962	3.322	0.10	x	3.289	3.328
I.K.O., Holland	July.1962	3.173	0.046	σ Mn=13.24	3.173	3.211
CENS,France	Oct.1962	3.279	0.05	x	3.271	3.310
IMM,U.S.S.R.	Jan.1963	3.26	0.05	σ Mn=13.16 σ S= 0.49	3.250	3.280
SRE,Israel	May.1963	3.242	0.06	x	3.228	3.267
BCMN,Belgium	Nov.1963	3.31	0.06	Gold foil activation	3.290	3.329
BIPM,France	April.1964	3.252	0.03	x	3.339	3.268
AEET, India	March.1964	3.208	0.08	σ Mn=13.25 σ S= 0.49	3.197	3.235
NRC,Canada	July.1965	3.215	+0.032 -0.026	x	3.221	3.260
NBS,U.S.A.	Feb. 1965	3.245	0.04	x	3.185	3.223
NPL, U.K.	June.1959	3.162	0.03	$\frac{\sigma H}{\sigma Mn}$ =0,02497)	3.197	3.235

18. International Intercomparison of $^{90}Sr - ^{90}Y$ - P.K. Srivastava and G.D. Khera - Electronics Division - A.E.E.T. is a participant in the International Intercomparison programme which is organised by the Bureau International des Poids et Mesures, France. Such an intercomparison of $^{90}Sr - ^{90}Y$ was held in February 1964 in which 24 national and international laboratories of the world participated. For this, samples of radioactive solution of 1 μc/gm and 15 μc/gm were distributed by Physikalisch-Technische Bundesanstalt, W. Germany, to each participant.

Four independent dilutions by a factor 15 were performed by weight on the 15 μc/gm solution, while the other was used without dilutions. Sources were prepared by using Ultramicro-buret and were counted in a $4\pi\beta$ - proportional counter. The self absorption and the film absorption were determined by the "efficiency tracing technique" using ^{82}Br as a tracer with a $4\pi\ \beta$-γ coincidence set-up. The results of measurements of all the participating laboratories are given in the following Table L. A paper describing this intercomparison was presented at the Symposium on Radioactivity and Metrology of Radionuclides, organised by the Department of Atomic Energy, Government of India, Bombay (1966).

TABLE I

Laboratory	Low sp. Ac.		High sp. Ac.	
	Activity dps/mg	Accuracy %	Activity dps/mg	Accuracy %
AAEC, Australia	73.09	0.13	1100.9	0.16
AECL, Canada	73.30	0.08	1097.0	0.08
AEET, India	73.00	0.082	1102.1	0.19
AIEA, Austria	--	--	1108.0	0.70
BCMN, Belgium	73.597	0.27	1104.2	0.18
BIPM, France	73.111	0.095	1099.7	0.06
CENS, France	73.6	0.07	1100.4	0.14
CNAM, France	73.00	0.06	1097.0	0.19
ETL, Japan	72.88	0.13	1079.1	0.96
GWI, Sweden	73.143	0.094	1088.8	0.10
IAR, E.Germany	73.82	0.20	1100.4	0.50
IBJ, Poland	72.353	0.236	1087.5	0.174
IKO, Holland	73.58	0.52	1089.5	0.48
IMM, U.S.S.R.	73.45	0.08	1096.0	0.20
IPA, Rumania	72.640	0.40	1084.3	0.62
ISN, Yogoslavia	74.44	0.08	1101.1	0.049
JEN, Spain	73.51	0.05	1100.3	0.04
NBS, U.S.A.	73.05	0.14	1090.5	0.18
NPL, U.K	72.48	0.13	1087.5	0.09
NPRL, South Africa	--	--	1077.4	0.26
NRC, Canada	73.066	0.083	1095.9	0.02
OMH, Hungary	--	--	1087.8	1.42
PTB, W.Germany	73.35	0.06	1106.0	0.11
UVVVR, Czechoslovakia	73.15	0.12	1096.5	0.13
Weighted Mean	73.315	0.085	1097.2	0.067

19. Intensity of 1.114 MeV gamma transition in the decay of ^{65}Zn - P.S. Rao - Electronics Division - The intensity of 1.114 MeV gamma transition in the decay of ^{65}Zn has been found to be (51.3 ± 1.5)% using a calibrated 4π gamma ionization chamber. The chamber response was calculated in the energy range 0.3 - 3.0 MeV by Dale's method (1). Standard sources of ^{60}Co and ^{22}Na were used to normalize the response curve.

A standard sample of ^{65}Zn (98.4 ± 2 uc) obtained from IAEA gave a current of (2.33 ± 0.01 pA) when introduced in the chamber. The contribution due to the annihilation of positrons was estimated to be (0.065 ± 0-01 pA)· Capture x-rays and conversion electrons had negligible effect on the current due to the 1 gm/cm^2 thick wall of the chamber.

(1) J.W.G. Dale, Int. J. Appl. Rad. Isotopes 10 (1961) 72.

20. $4\pi\beta$ -γ Coincidence Technique For The Standardization of Radionuclides - P.K. Srivastava and G.D. Khera - Electronics Division - National standards of radioactivity have been prepared by using the $4\pi\beta$-γ coincidence system, which has been developed at A.E.E.T. for the absolute standardization of most of the radionuclides of interest and for participating in the international intercomparison. This technique offers a very powerful tool for standardization. An accuracy of ± 0.2% has been achieved for ^{60}Co by using this system.

The advantages of the coincidence system lies in the fact

that the disintegration rate of the sample is obtained from directly observable quantities and the detector efficiency does not appear in the final calculations. The only few correction factors applicable are small because of the high beta efficiency of the system. The set-up has been used for the standardization of the beta-gamma emitters with complex decay scheme as well as pure beta emitters by "efficiency tracing technique". Some typical results of standardization are given in Table I

TABLE I

Radionuclide	Activity	Overall accuracy
^{60}Co	2564 dps	0.18%
	4167 dps	0.19%
	4917 dps	0.20%
	4578 dps	0.24%
^{35}S	25.93 μc/gm	0.73%
$^{144}Ce - ^{144}Pr$	1.156 μc/gm	1.5%

A paper describing the technique in detail has been presented at the Symposium on Radioactivity and Metrology of Radionuclides, arganized by the Department of Actomic Energy, Government of India, Bombay (1966).

21. Standardization of Radionuclides at A.E.E.T.- U.C. Gupta, P.K. Srivastava, S.C. Misra, N.P. Sidhu, K.C. Dhingra, G.D. Khera, H.K. Sahoo and P.S. Rao - Electronics Division - The standards of radioactivity are produced and maintained at A.E.E.T. by using the various methods of standardization. The choice of the method of measurement depends on the type of radiations (α, β, γ, e or X-ray), their energy and the decay scheme of the nuclide.

The instruments set up at Trombay for the standardization of radionuclides include the NaI(Tl) spectrometer, the $4\pi\beta$ proportional flow counter, the $\beta-\gamma$, X-γ and $\gamma-\gamma$ coincidence counting system, the $4\pi\beta-\gamma$ coincidence counting system, the high pressure 4π X-ray counter, the $4\pi\gamma$ ionization chamber, the end windo β flow proportional counter, the well type scintillation counter and the liquid scintillation counter. An internal gas counting system for low energy β emitters is also being set up. Normally more than one method is employed to ensure reliability of the results. For making use of the different counting systems, source samples of different activity are usually required depending on the background, sensitivity, and the counting capacity of the system. Table I gives the best specifications for the solution to be standardized and the accuracy of the different methods.

To check the standardization techniques, the A.E.E.T. results of measurement were compared with those of the other national and international laboratories of the world issuing

standards of radioactivity. For this we participated in the international intercomparison of ^{198}Au, ^{60}Co (solid sources) and ^{90}Sr - ^{90}Y. Standards of ^{198}Au, ^{131}I and ^{32}P from IAEA were also measured. Our results were in good agreement with those of the leading laboratories of the world.

TABLE I

Method of mea -sure -ment	Gamma Ioniz -ation Chamber	End window count -er	Gamma spectro -meter	β - γ X-γ & γ-γ Coinci -dence	$4\pi\beta$ Propor -tional counter	$4\pi\beta$-γ Coinci- dence
Speci -fic Acti- vity range	10 uc to curies per ml	10-100 μc/ml	10-to 200 μc/ml	1 to 10 μc/ml	0.1 to 5 μc/ml	0.1 to 5 μc/ml
Solid content	Any	20-100 μg/ml	20-1000 μg/ml	20-1000 μg/ml	20-500 μg/ml	20-100 μg/ml
Support	Glass vial	10 μg/ cm^2 VYNS film	1 mg/ cm^2 plastic film	1 mg/ cm^2 plastic film	10 μg/ cm^2 VYNS film with 30 ug/cm^2 gold	10 μg/cm^2 VYNS film with 30 ug/cm^2 gold.
Accuracy of stan -dardi- zation	$\pm$ 10%	$\pm$ 10%	$\pm$ 5% to $\pm$ 10%	$\pm$ 3% to $\pm$ 5%	$\pm$ 2% to $\pm$ 3%	$\pm$ 0.2% to $\pm$ 1%

22. Standard Thermal Neutron Flux-Density (STAG) - D. Sharma and M.G. Shahani - Electronics Division - A standard of thermal neutron flux density has been established by distributing six $^{241}Am - \alpha - Be$ neutron sources (Emission rate of each source approx. 1.1×10^6 neutrons/sec.) inside a graphite stack (5' x 5' x 4'). The stack contains a cavity, centrally situated with respect to these sources, for the calibration of foils and small detectors. A preliminary measurement of the thermal neutron flux density has been made by $4\pi\beta\text{-}\gamma$ coincidence counting of irradiated gold foils. The thermal neutron flux density below cadmium cut-off energy is estimated to be 6522 $\pm$ 3% neutrons/cm^2.sec.

The flux standard is being directly compared with the standards maintained at the National Bureau of Standards, U.S.A. and the Electrotechnical Institute, Tokyo. In this way, the standards maintained by eleven international laboratories will be intercompared under a programme organised by the International Bureau of Weights and Measures (1), (2).

(1) E.R. Mosburg and W.M. Murphey Res. Sci. & Tech.14 (1961) 25

(2) T. Michikawa et al., Bull. Electrotech. Lab. 25 (1961) 843

23. Thermalisation and Thermal Diffusion Parameters of Lead using a Pulsed Neutron Source - K. Chandramoleshwar, M.P. Navalkar, M.R. Phiske, J.V. Ramana, D.V.S. Ramkrishna and S.K. Sadavarte - Nuclear Physics Division - Using a 400 KeV D-T accelerator and forty channel time analyser, the thermal

diffusion parameters (Σav, Do, τ_{cs} & L) for lead have been determined from the decay constants of two assemblies.

The temperature relaxation time constant (τ_t) and thermalisation time constant (τ_{th}) have been measured from the time dependent capture gamma intensities for a thick Cd sample as normalised by neutron density measured with 1/v detector. The experimental data has been analysed both on classical temperature difference concept and also as an eigen value problem to yield the above parameters.

Thermalisation power (M2) and diffusion cooling coefficient (C) have been calculated using both the experimental data. The mean free path (λ_s) has been measured in the energy range of 1 ev and is found to be independent of energy.

All the experimental values are in fairly good agreement with the calculated values for lead at 300^0 K and p=11.24 gms/C.C. Mocroscopic absorption and scattering cross-section of 170 mb and 11 bams respectively have been used in the calculations of thermal diffusion parameters. Thermalisation studies confirm that in case of lead, heavy gas model can be used.

The experimental and calculated results are shown in Table I.

TABLE I

Thermalisation and Thermal Diffusion Parameters of lead (ρ = 11.24 gms/c.c) at 300°K

Parameters	Calculated from microscopic nuclear cross section	Experimental values
1) Absorption probability ($\leq$aV)	1222 sec^{-1}	1128 $\pm$ 168 sec^{-1}
2) Mean life time (τcs)	818 μsecs	891 $\pm$ 150 μsecs
3) Thermal Diffusion Coefficient (Do)	2.31 x 10^5 cm^2 sec^{-1}	(2.78 $\pm$ 1.8) x $10^5 cm^2 sec^{-1}$
4) Diffusion Length (L)	13.75 cms	15.75 $\pm$ 5.5
5) Mean free path (λ_s)	2.78 cms	2.61 $\pm$ 0.02 cms
6) Temperature Relaxation time constant (τ_t)	875 μsecs	730 $\pm$ 160 μsecs
7) Thermalisation Time and Constant (τ_{th})	875 μsecs(ℓ=2)	799 μsecs
8) Thermalisation power (M2)	0.01347 cm^{-1}	0.01656 $\pm$ 0.0036 cm^{-1}
9) Diffusion cooling coefficient (C)	7.87 x 10^6 cm^4 sec^{-1}	(9.4 $\pm$ 2.06) x 10^6 cm^4 sec^{-1}

24. Evaluation of the Coefficient of B^6 Term in the Decay Constant of Fundamental Mode for BeO - M.P. Navalkar and D.V. S. Ramakrishna - Nuclear Physics Division - The neutron flux in case of pulsed finite moderator assemblies has been expanded in powers of B^2, following the method of Nelkin and Beckurts. Expressions for the diffusion cooling coefficient and the coefficient of B^6 term have been derived both on diffusion and transport theory. Using the Nelkin kernel in the incoherent approximation and transport cross sections as given by Singwi, these parameters have been evaluated for BeO moderator. Numerical calculations have been done with energy mesh of 0.9 MeV and cut off energy of 0.3 eV.

The theoretical value of 3.4×10^5 cm^4 sec^{-1} for the diffusion cooling coefficient is on the lower side of the experimental value which lies between $(3.5 - 6) \times 10^5$ cm^4 sec^{-1}. In view of the large experimental errors on F coefficient, no conclusion could be drawn.

On the basis of theoretically calculated negative F value, one comcludes that the thermalisation power in case of BeO decreases with decrease in neutron temperature.

25. Lattice Vibrations of Vanadium by Inelastic Scattering of Slow Neutrons - A.P. Roy, C.L. Thaper and P.K. Iyengar - Nuclear Physics Division - Measurements on inelastic scattering of slow neutrons from Vanadium have been made at room temperature

using the Beryllium detector spectrometer. These measurements were carried out with a resolution better than that employed by earlier workers using energy-gain techniques. In the energy region covered, we observe a peak at 21.5 MeV, consistent with the previous measurements, but the high energy peak reported earlier at 28 MeV is resolved into two peaks located at 27 MeV and 30 MeV. respectively. This splitting of the high energy peak is observed at scattering angles of 70 as well as 100 degrees. This may not be surprising if one expects some similarities between the vibrational spectra of the transition elements V and Nb. In fact, the peak positions derived in the case of Nb, if scaled by the factor $\sqrt{M_{Nb}/M_V}$, lead roughly to the peaks observed in the present measurements.

26. Anisotropic refinement of the single-crystal neutron diffraction data on potassium oxatate monohydrate - R. Chidambaram, S. Srikanta, S.K. Sikka and A. Sequeira, Nuclear Physics Division - Chidambaram et.al. (1) published a neutron diffraction study of $K_2 C_2 O_4 . H_2O$ based on the intensities of 79 h0l and 55 0kl reflections. The structure was refined using isotropic temperature factors. In view of the interest in this crystal, as revealed by a three-dimensional x-ray study and a recent detailed treatment of the thermal motion of the water molecule based on proton magnetic resonance results, we have collected now the intensities of about 150 hkl reflections. The data were collected on the diffractometer SAND, which has

an electromechanical system of automation for scanning upto 20 reflections in one setting (2). The combined data have been refined using the least-squares method with anisotropic temperature factors. The R-factor is now 0.089. The structure is being examined in relation to the parameters given by the x-ray and proton magnetic resonance studies.

References:

(1) R. Chidambaram, A. Sequeira and S.K. Sikka, Chem. Phys., 41, (1964) 3616.

(2) R. Chidambaram, A. Sequeira and S.N. Momin, Ind. Jour. Pure & Appl. Phys. (1966)(to be published).

27. Cold Neutron scattering from Liquid CD_4 - G. Venkataraman and B.A. Dasannacharya - Nuclear Physics Division - A cold neutron investigation of liquid CD_4 has been made on the rotating crystal spectrometer. Data has been obtained at several angles covering the first liquid diffraction peak. At all angles, the spectra show a quasi-elastic peak associated primarily with the translational motions and an inelastic hump arising out of the rotational motions. Unlike in CH_4, the quasi-elastic peaks in CD_4 are very prominant. The width of the quasi-elastic peak displays an oscillatory behaviour. A model has been proposed which satisfactorily explains the observed oscillations.

28. The Hydrogen Bond System and Molecular Packing in Tetrachlorohydroquinone - a Neutron Diffraction Study - S.K. Sikka and R. Chidambaram - Nuclear Physics Division - The

crystal structure of tetrachlorohydroquinone, $C_6Cl_4(OH)_2$, - space group $P2_1/c$ - has been studied using the single-crystal neutron-diffraction technique. 261 independent reflections with $(\sin\theta)/\lambda \leq 0.75$ were recorded in three zones (hOl, Okl and hkO). Starting with the heavy-atom parameters obtained in an earlier x-ray study of the crystal, the structure has been refined using Fourier and least-squares methods. Anisotropic temperature factors have been used for all the atoms in the later stages of the refinement and a final R-factor of 0.094 has been obtained.

While the heavy-atom positions obtained by us are in agreement with those given by the x-ray data, the hydrogen positions postulated on the basis of a difference x-ray Fourier map has been found displaced from the correct position be more than 1A°. Consequently, the type of O-H ⋱ O / Cl 'bifurcated' hydrogen-bond interaction between neighbouring $C_6Cl_4(OH)_2$ molecules, proposed on the basis of the x-ray study is not existent. There are close-packed layers of molecules parallel to the (100) plane, with six-fold coordination of each molecule. The layers are connected to one another by O-H---O hydrogen bonds of length 2.92 Å; the O-H distance is 0.970 Å (corrected for thermal motion) and the H-O---O angle is 19.2°.

Communicated to Acta Crystallographica

29. Phonon Spectrum in Magnesium in the $(11\bar{2}0)$ direction - Y. Gameel*, P.R. Vijayaraghavan and P.K. Iyengar - Nuclear Physics Division - Phonon dispersion relations in magnesium in the $(11\bar{2}0)$ direction have been measured on the multi-arm spectrometer using the techniques described in the previous report. The data will be analysed using the force constants approach shortly.

*Guest Scientist from the Atomic Energy Establishment, Cairo.

30. Dynamics of Liquid CH_4 from Cold Neutron Scattering - B.A. Dasannacharya and G. Venkataraman - Nuclear Physics Division - The scattering of 4.1 Å neutrons by liquid CH_4 at 98°K has been studied at several angles using a rotating crystal spectrometer. The spectra at all angles show a broad inelastic hump associated primarily with the rotational motions and a quasi-elastic peak which is related to the translational motions. The width of the quasi-elastic peak follows the simple diffusion behaviour over almost the entire range of present experiments, and leads to a value of 2.2×10^{-5} cm^2 /sec for the diffusion coefficient. A more detailed analysis suggests that the delay time in the onset of simple diffusion behaviour is similar to that in argon. The data clearly shows that if the translations are viewed in terms of the Langevin model, then it is not necessary to consider a wavelength dependent

damping factor as has been recently proposed by Griffing. High resolution data taken at 15° scattering angle does not reveal any sharp inelastic peaks, which should be present if the rotations are free. From this it is concluded that the rotations are hindered in the liquid state in accord with earlier spectroscopic work but in disagreement with the neutron work of Hautecler and Stiller. Calculations based on a model in which the rotations are free and the translations follow the simple diffusion model show poor agreement with experiments. Consideration of a more realistic model for the translations based on the results of the computer experiments of Nijboer and Rahman for argon yields only a slight improvement. It is suggested that a proper treatment of the hindered rotations is necessary to obtain agreement with experiment.

31. Neutron Scattering from Gaseous Methane and Ammonia - G. Venkataraman, K.R. Rao, B.A. Dasannacharya and P.K. Dayanidhi - Nuclear Physics Division - The scattering of cold neutrons by gaseous methane and ammonia at room temperature have been calculated treating the rotations in a quantium mechanical fashion. Comparison with the experimental data of Webb (1) show good agreement at large scattering angles and a small discrepancy at forward angles.

(1) F.J. Webb, Inelastic Scattering of Neutrons in Solids and liquids, I.A.E.A., Vienna (1963) Vol I.

Abstract of paper to appear shortly in the Proceedings of the Physical Society (London).

32. Effect of Nuclear Spin Correlations on the Scattering of Neutrons by Molecules - S.K. Sinha* and G. Venkataraman - Nuclear Physics Division - The scattering of slow neutrons by spherical-top molecules is discussed taking into account the correlations in nuclear spin caused by the presence of identical nuclei in the molecule. Matrix elements for the scattering are evaluted between different symmetrized states using group-theoretical methods. It is shown that coherent scattering can cause only those transitions which leave the symmetry of the total molecular wave function unchanged, while incoherent scattering can cause transitions between states of different symmetry. Explicit expressions for the cross section for scattering from methane are derived. These are different from those obtained by Michael recently in a treatment of the same problem. Formulas for the cross section for symmetric-top molecules are also derived. Numerical calculations have been performed for the scattering angle by methane gas at 10° and 300°K. It is found, contrary to Michael's observations, that at 10°K nuclear-spin correlations produce considerable differences in the scattering compared with the case where their effects are ignored. At 300°K, however, their effects are negligible. These findings are in accord with the

predictions made earlier by Zemach and Glauber.

Abstract of paper to appear shortly in the Physical Review

*Now at the Department of Physics, State University of Iowa, Ames, Iowa, U.S.A.

33. A Neutron diffraction study on the crystal structure of lithium hydrazinium sulphate ($LiN_2H_5SO_4$) - R Balasubramanian and V.M. Padmanabhan - Nuclear Physics Division - A single crystal neutron diffraction investigation of lithium hydrazinium sulphate has been made in which the intensities of 215 reflections in all the three prism zones were measured. The structure was refined by Fourier and least squares techniques. The heavy-atom positions obtained agree very well with values from the x-ray determination. The hydrogen atoms of $NH_2 - NH_3^+$ ion are arranged tetrahedrally about nitrogens and the configuration was found to be staggered. The NH_2 groups of the ions are linked into infinite chains by hydrogen bonds pointing in the negative C direction. The hydrogens of the NH_3 group are static and are not rotating along the N-N axis.

Paper accepted for publication in Acta. Crystallographica

34. On the crystal structure of ammonium sulphate $(NH_4)_2SO_4$ - S. Medhi Ali and V.M. Padmanabhan - Nuclear Physics Division - Ammonium sulphate has two sets of four NH_4 ions in the crystal. N.M.R., infra-red and neutron inelastic spectra studies were not able to definitely prove whether the ions (1) are distorted and static or (2) freely rotating or (3) performing hindered rotation. Single crystal neutron intensity data for about 170 reflections were collected. Structure factor calculations based on the model with the two NH_4 ions freely rotating did not agree with observed values. Least squares analysis with the static model gave an R factor of 19%, but the bond angles and distances of NH_4 ion were found to be highly distorted and unrealistic. Structure factors are being calculated for the third model, assuming one NH_4 ion to be static and another to be performing hindered rotation, and at the present stage of refinement appears to give a best fit with the observed structure factors.

35. Crystal Structure of ammonium tartrate - Y.S. Yadav and V.M. Padmanabhan - Nuclear Physics Division - The study of the structure of ammonium tartrate is a part of a series of research undertaken with the object of finding the character of N-H .... X type of bonding in crystals. As the crystal structure has not been determined so far, three dimensional data with x-rays has been collected, It is proposed to collect the single crystal neutron diffraction data to

determine the proton positions.

36. Neutron diffraction Spectrometer at Apsara - S. Mehdi Ali and V.M. Padmanabhan - Nuclear Physics Division - A neutron diffraction spectrometer for crystal structure analysis has been set up at the Apsara Reactor. The monochramater is a lead single crystal. The incident wavelength has been chosen to be 1.013 Å. Crystal angles are to be hand set, and data can be recorded by step scannining through the peak in the θ - 2θ mode. Scan can be made in steps of $\frac{1}{10}$ of 2 θ under monitor control.

37. CDC - 3600 Programs for Neutron Diffraction - S. Srikanta and R. Chidambaram - Nuclear Physics Division - There are now at Trombay a complete set of computer programs (for the CDC - 3600 - 160A system at T.I.F.R.) for neutron diffraction calculations. Some of these have also been made available after modification to x-ray crystallographers in other laboratories. The following is a list of the programs:

1) XTALANGL computes for each reflection either all the three angles 2θ, and ∅ for a crystal mounted on the Eulerian cradle or the 2θ and ∅ angles when only zero-layer data is collected. The input information contains the unit cell dimensions, the orientation of the crystal and the space-group extinction conditions. The present version of the program incorporates modifications by S.K. Sikka.

2) DATARED processes the raw data from the neutron diffractometer and also carried out peak-versus-integral intensity correlation, the output being AF^2 or AF and its standard deviation, where A and F stand for the intensity attenuation factor due to absorption and the structure factor respectively.

3) XLFACE computes the equations of the faces of crystal (needed in calculating the absorption correction) based on some systematic measurements made on the crystal under a microscope or using the given co-ordinates of the corners.

4) ORABS - an Oak Ridge program due to Weho, Busing and Levy - has been altered slightly to take as input the outputs of programs DATARED and XLFACE to calculate the absorption correction for each reflection. These corrections are held on a magnetic tape.

5) A short program used the output of DATARED and the magnetic tape on which the absorption corrections are saved to give F^2 or F and (F^2) or (F).

6) AVERAGE now averages the values of F^2 or F for reflections recorded more than once and for equivalent reflections, if necessary.

7) A two-dimensional FOURIER program plots the Fourier or Patterson map using zero-layer data. A three-dimensional Fourier program due to Gvildys at Argonne has recently been altered by R.J. Begum to suit our computer systme.

8) GENLSFIS, a least-squares program refines two-dimensional data with isotropic or anisotropic temperature factors. A special program for the cubic space group Fd3m (used here for the study of $K_2Zn(CN)_4$) is also available. The latest version of the well-known Oak Ridge program ORFLS due to Busing, Martin and Levy has also been altered to suit our system.

9) ORFFE - an Oak Ridge program due to Busing, Martin and Levy (modified by Johnson) - has also been altered to suit our computer system. It calculates bond lengths, angles and several other functions of the positional and thermal parameters of the structure.

All the above programs have been used successfully in our structure analysis work. Some other special programs like ANOMALY for calculating structure factors when there are anomalous scatterers in the structure and LISTPLAN for calculating all crystal planes which are inclined between 85° - 95° to a given zone axis have also been written.

B. TATA INSTITUTE OF FUNDAMENTAL RESEARCH

1. The Study of the $^{51}V(p,n)^{51}Cr$ Reaction - K.V.K. Iyengar, S.K. Gupta and B. Lal - The excitation functions of the 0.75, 1.17, and 1.35 and 1.50 plus 1.56 MeV gamma rays resulting from the $^{51}V(p,n)^{51}Cr^*$ reaction have been measured from their respective thresholds upto 5.5 MeV. They all vary smoothly with proton energy and exhibit no significant structure. The ratio of the measured yields of 0.75 and 1.17 MeV gamma rays are compared with the ratio predicted by the Hauser-Feshbach theory and the spin of the levels deduced therefrom to be 3/2 and 5/2 respectively. n_1-0.75 MeV gamma and n_2-1.17 MeV gamma angular correlations have been measured at proton energies 3.1, 3.3 and 3.5 MeV in the plane of the reaction and at 3.1 and 3.3 MeV in the plane perpendicular to it. The shapes of of the measured correlations are in disagreement with the predictions of the CN statistical model.

2. Measurements of 14 MeV neutron induced reaction cross-sections on enriched isotopes of calcium - P.N. Tiwari and E. Kondaih - Some (n,t), (n,d), (n,p), (n,α) and (n,2n) reaction cross-sections have been measured by activation of $^{40,42,43,44,48}Ca$. Cross-sections for $^{45}Sc(n,2n)^{44m}Sc$ and $^{45}Sc(n,2n)^{44g}Sc$ have also been measured. A formula has been derived. This formula enables one to calculate ground state

cross-section from the ground state activity which is being fed by isomeric state also. Gamma counting using calibrated NaI(Tl) well type of crystal was employed to determine the absolute activities. The sensitivity of the counting system is such that with neutron flux of 10^7 to 10^8 neutrons/cm^2 sec, cross sections 1 micro-barn/gm of irradiated sample can be measured.

3. Decay of ^{119m}Te and the level strucutre of ^{119}Sb - R.M. Singru, S.H. Devare and H.G. Devare - The decay of ^{119m}Te has been investigated using a Ge solid state detector and a $\pi\sqrt{2}$ double focussing spectrometer for the study of the gamma and conversion electron spectra. The energies and the relative intensities of the gamma transitions have been detemmined with greater accuracy than before. The K/L conversion ratios have been determined for the 153-, 163.8- and 269. 7-KeV transitions and the K-conversion coefficients for the 153-, 269.7-, 914- and 1212-KeV gamma transitions. Gamma-gamma directional correlation measurements have been made for the 944-270 KeV, 1097-270 KeV, 2095-270 KeV and 153-1212 KeV cascades. On the basis of above studies following levels in ^{119}Sb and their corresponding spin and parity assignments are proposed: 270 KeV($7/2^+$), 1048 KeV ($7/2^+$, $9/2^+$), 1212 KeV ($7/2^+$), 1365 KeV ($9/2^-$), 2281 KeV ($9/2^-$, $11/2^-$), 2292 KeV, 2349 KeV ($9/2^-$, $11/2^-$) and 2365 KeV ($9/2^-$). The Half lives of the

270-, 1212- and 1365- KeV levels have been studied by the time to amplitude conversion technique and are shown to be ≤ 0.4 ns.

Sent for the Nuclear Physics Symposium to be held at Gattinburg, U.S.A. (1966).

4. Decay of ^{147}Nd to ^{147}Pm - K.P.Gopinathan - The decay of ^{147}Nd has been investigated by a high resolution Ge(Li) gamma ray spectrometer and scintillation and coincidence spectrometers. From gamma-gamma coincidences and delayed gating technique definite energy levels in ^{147}Pm have been established at 91, 411, 490, 531 and 686 KeV. The levels reported (1). at 260 and 886 KeV were found to be absent. Angular correlations of the following cascades have been measured and the results are :

$W(\theta_{320-91}) = 1 - (0.073 \pm 0.007) P_2(\cos\theta) - (0.007 \pm 0.011) P_4(\cos\theta)$

$W(\theta_{120-320}) = 1 - (0.010 \pm 0.010) P_2(\cos\theta) - (0.011 \pm 0.016) P_4(\cos\theta)$

$W(\theta_{400-91}) = 1 + (0.027 \pm 0.016) P_2(\cos\theta) - (0.010 \pm 0.027) P_4(\cos\theta)$

$W(\theta_{440-91}) = 1 + (0.041 \pm 0.013) P_2(\cos\theta) + (0.008 \pm 0.021) P_4(\cos\theta)$

and $W(\theta_{275-320}) = 1 + (0.020 \pm 0.010) P_2(\cos\theta) + (0.003 \pm 0.016) P_4(\cos\theta)$

The analysis of the angular correlation results combined with the results of internal conversion measurements (2) and nuclear orientati studies (3) led to the spin assignments of the levels in ^{147}Pm as follows: ground state - $7/2^+$, 91 KeV - $5/2^+$; 411 KeV - $3/2^+$; 490 KeV - $7/2^+$; 531 KeV - $5/2^+$ and 686 - $5/2^+$.

(1) Hsien Ho, Hung-Yuan Su, and Sou-Fang Wang, Acta Physica Sinica, 20 (1964) 383

(2) G.T. Ewan, R.L. Graham and J.S. Geiger, Bull. Am Phys. Soc. 6 (1961) 238

(3) G.A. Westnbarger and D.A. Shirley, Phys. Rev. 123 (1961) 1812.

5. Energy Levels of ^{149}Pm - K.P. Gopinathan and R.M. Singru - The decay of ^{149}Nd has been investigated by means of double focussing beta ray spectrometer, Ge(Li) gamma ray spectrometer and scintilation spectrometers. The following multipolarities were assigned to the gamma transitions in ^{149}Pm on the basis of international conversion measurements; 114 KeV (M1 + E2); 156 KeV (E1), 189 KeV (M1 + E2), 21. KeV (M1 + $<$ 20% E2), 240 KeV (M2), 268 KeV (M1 + $<$ 30% E2); 270 KeV(E1) and 327 KeV (E1). The gamma spectra studied in a well type 3 in x 3 in NaI(Tl) crystal as well as a Ge(Li) detector showed high energy transitions upto 1540 KeV. Gamma-gamma coincidence measurements and delayed gating technique established energy levels in ^{149}Pm at 114, 189, 211, 240, 270, 397, 538, 654, 767, and 966 KeV. Other possible high energy levels weakly populated from the decay of ^{149}Nd are discussed. A combined analysis of the earlier gamma-gamma directional correlation measurements and the present internal conversion measurements lead to the following spin and parity assignments to the low lying energy levels of ^{149}Pm :

114 KeV ($5/2^+$); 211 KeV ($5/2^+$); 240 KeV ($11/2^-$); 270 KeV ($7/2^-$); and 538 KeV ($5/2^-$).

Accepted for publication in Physical Review

6. Level Structure of ^{199}Au - K.G. Prasad, R.P. Sharma and B.V. Thosar - The energy levels of ^{199}Au are investigated from the decay of 30-min. ^{199}Pt. The high resolution gamma spectra obtaoned from a Ge(Li) detector have revealed three new gamma transitions of energy 187, 469 and 497 KeV. A new energy level at 324 KeV has been suggested from the coincidence measurements, carried out with NaI(Tl) and Ge(Li) detectors. Possibility of an $11/2^-$ isomeric state expected in this odd mass region of Au_isotopes, has been indicated at 549 KeV. A study of the internal conversion electron spectrum with a surface barrier detector has clearly shown conversion lines corresponding to 187-, 247-, 318- and 544- KeV gamma transitions and their Ke_shell conversion coefficients are obtained as 0.15 ± 0.04, 0.34 ± 0.05, 0.19 ± 0.02 and 0.047 ± 0.004 respectively. These measurements have indicated that the 187- KeV transition is almost pure E2 in character while the 247-, 318- and 544- KeV are mixtures of M1 and E2, where E2 component is very much enhanced. The gamma-gamma directional correlation of the 475-318 KeV cascade has been

found to be $W(\theta) = 1 + (0.082 \pm 0.01) P_2(\cos \theta) + (0.042 \pm 0.03) P_4(\cos \theta)$. The half life of the first excited state at 77 KeV has been determined as 1.46 ± 0.12 ns. Based on these investigations the spin and parity assignment to the 77-,318-, 324-,544-,736- and 794- KeV levels is made, and their possible nature is discussed.

Accepted for publication in the Physics Review.

C. SAHA INSTITUTE OF NUCLEAR PHYSICS, CALCUTTA 9

1. Angular Distribution Study of the $^{14}N(n,\alpha)^{11}B$ Reaction at 14 MeV - M.L. Chatterjee - The $^{14}N(n,\alpha)^{11}B$ reaction has been studied by bombarding pare nuclear emulsion plates with 14 MeV neutrons. From the experimental Q-value distribution, the states of the residual nucleus have been assigned. The angular distributions leading to the low-lying states of ^{11}B in the neighbourhood of 0.0, 2.5 and 4.0 MeV excitations show marked asymmetry about 90° c.m. with peaking in the backward hemisphere. Fits to these distributions have been calculated in terms of the heavy-particle stripping mechanism.

2. Decay of ^{76}Ga - B. Sethi and S.K. Mukherjee - ^{76}Ga is produced by (n,p) reaction with 14 MeV neutrons on ^{76}Ga GE (enriched) as well as on specpure natural germanium. The half-life of ^{76}Ga is found to be 45 sec. Its decay is investigated with standard scintillation techniques. Beta groups with end point energies at 2.2, 3.0, 4.0, 5.3 and 5.8 MeV were found to decay with a half-life of 45 sec. The gamma spectrum showed gamma rays of energies 0.560, 0.780, 1.110, 1.250, 1.80, 2.32, 2.87 and 3.43 MeV. β-γ and γ-γ coincidence experiments are performed and based on these a decay scheme of ^{76}Ga is proposed.

3. Decay of ^{98}Nb and the Energy Levels of ^{98}Mo - S.C. Gujarathi and S.K. Mukherjee - The ^{98}Nb nucleus is produced by ^{98}Mo(n,p) ^{98}Nb reaction with 14.8 MeV neutrons using enriched as well as natural isotope of Mo and is studied by standard scintillation spectroscopy techniques. A quick radiochemical separation has been employed to separate Nb from Mo and Zr. The half-life measurements give two activities as 51 ± 1 min and 1.5 ± 0.5 min, associated with ^{98}Nb. The beta and gamma measurements show four beta groups of maximum energies 3.1 ± 0.1(8%), 2.32 ± 0.1(38%), 1.94 ± 0.1(29%) and 1.42 ± 0.1(25%) MeV and twelve gamma rays of energies 0.080, 0.170, 0.330, 0.450, 0.720, 0.780, 1.16, 1.44, 1.52, 1.68, 1.88 and 1.94 MeV, decaying with a half-life of 51 ± 1 min. From the numerous beta-gamma and gamma-gamma coincidence studies the levels in ^{98}Mo at 0.780, 1.50, 1.95, 2.28, 2.66, 2.94, 3.02 and 3.19 MeV are found and a decay scheme of ^{98}Nb is proposed. The Q_{β^-} for the ^{98}Nb - ^{98}Mo transition is 4.6 ± 0.1 MeV. The (n,p) cross-sections for the ^{98}Mo has been measured as 12 ± 2 mb and 2 ± 1 mb for the 51-min and 1.5-min states respectively. The half-life of ^{100}Nb has been measured accurately as 2.8 ± 0.2 min

Accepted for publication in Nuclear Physics

4. Decay of ^{162}Tb and the Excited States of ^{162}Dy - S.C. Gujarathi, H. Bakhru and S.K. Mukherjee - Sources of 7.5 min ^{162}Tb are produced by the reactions ^{165}Ho(n,α)^{162}Tb and ^{162}Dy(n,p)^{162}Tb using 14.8 MeV neutrons and studied their decay characteristics. The beta and gamma-ray measurements show the beta groups of maximum energies 1.72 $\pm$ 0.1(13%) and 1.45 $\pm$ 0.1(87%) MeV; and the gamma-rays of energies 45 $\pm$ 5(Dy K x-ray), 80 $\pm$ 5, 130 $\pm$ 10, 195 $\pm$ 10, 265 $\pm$ 5, 390 $\pm$ 10, 630 $\pm$ 10, 690 $\pm$ 15, 810 $\pm$ 10, 880 $\pm$ 10, 890 $\pm$ 10, 1070 $\pm$ 15 and 2100 $\pm$ 15 KeV decaying with a half-life of 7.5 min. Sum and coincidence spectrum studies show that there exist the following cascades of the gamma-ray energies: 130-265-810-80; 130-265-890; 130-265-625-185-80; 130-195-880-80; 130-195-690-185-80; 130-1070-80; 395-810-80; 395-890 and 1205-80 KeV. With the 80-, 810- and 890-KeV gamma rays as gate both the beta groups appear in coincidence while with the 190- and 265 KeV gamma-ray only a single beta group of end-point energy 1.45 $\pm$ 0.1 MeV is observed. A decay scheme is proposed which involves the levels in ^{162}Dy at 80 (2^+), 265 (4^+), 890 (2^+), 960 (3^+), 1155 (2^-) and 1285 KeV. The results are discussed in the light of the unified model.

Communicated for publlcation : Physical Review

5. Decay of ^{164}Ho - B. Sethi and S.K. Mukherjee - An isomer is found in ^{164}Ho. The half-life of the metastable and the ground states are found to be 39 ± 0.5 and minutes respectively. ^{164}Ho is produced by bombarding natural holmium with 14 MeV neutrons and the cross-sections for the production of the metastable and the ground states of ^{164}Ho by (n,2n) reaction at 14 MeV neutron energy are estimated to be 1050 ± 50 and 730 ± 70 mb, respectively. Beta groups of 875 ± 20 KeV and 965 ± 20 KeV are measured using a lithium drifted silicon detector. Photons of 36, 46, 51, 72 and 90 KeV are found and the decay of each is followed with scintillation spectrometer. β-γ , γ-γ and x-ray-γ coincidence experiments are performed and on the basis of these a decay scheme of ^{m} & ^{g}Ho is proposed. The 51 and 36 KeV gamma rays are gound to arise in the decay of ^{164m}Ho. The half-life of the 36 KeV gamma ray, measured with the help of a fast-slow coincidence circuit using a time to amplitude converter, is found to be 3.5 ± 1 ns.

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6. Decay of ^{174}Tm - S.C. Gujrathi and S.K. Mukherjee - The ^{174}Tm nucleus is produced by $^{174}Yb(n,p)^{174}Tm$ reaction with 14.8 MeV neutrons on enriched (99%) Yb isotope and is studied

by means of beta-gamma scintillation counter techniques. The beta and gamma measurements show the beta groups of end energies 1200 ± 50(82%) and 700 ± 50(18%) and the gamma rays of energies 50(Yb K x-ray), 75, 175, 275, 350, 370, 500, 630, 870, 990, 1260 and 1350 KeV decaying with the half life of 5.5 ± 0.5 min of ^{174}Tm. The gamma-gamma coincidence studies confirm the previously reported gamma ray cascades 990-275-175-75; 630-350-275-175-75 KeV; 1260-175-75 KeV and 500-370 KeV and establish a new cascade of 1350-275-175-75 KeV. The gamma spectrum in coincidence with the beta rays above 300 KeV, proves the existence of previously unreported 1350-KeV gamma transition along with the cascade 500-1350-275-175-75 KeV and also gives the 870 KeV gamma transition connecting the 2380 KeV level and the 1510 KeV isomeric state in ^{174}Yb. A decay scheme of ^{174}Tm is proposed and the results are compared and discussed in the light of unified model and the pairing correlation model. The (n,p) cross-section for ^{174}Yb has been measured as 3.5 ± 1 mb.

7. <u>Decay of ^{176}Tm and Excited Levels of</u> ^{176}Yb - S.C. Gujrathi and S.K. Mukherjee - The ^{176}Tm nucleus is produced through(n,p) reaction with 14.8 MeV neutrons on enriched (97.5%)^{176}Yb. A half-life of 1.4 ± 0.2 min is assigned to ^{176}Tm. The beta and gamma measurements show three beta groups of end point energies

3050 ± 100(20%), 2000 ± 100(40%) and 1150 ± 100 (40%) KeV and eight gamma rays or energies 50 (Yb K x-ray), 91, 190, 285, 390, 870, 1050 and 1800 KeV decaying with a 1.4 min activity of ^{176}Tm. Coincidence and sum spectrum studies indicate that the 1150 KeV beta group is coincidence with a gamma ray energy cascade 870-1800-190-50 KeV; the 2000 KeV beta group is in coincidence with the 1050 KeV gamma ray and a gamma ray energy cascade 1800-190-50 KeV; and the 3050 KeV beta group is in coincidence with none. The 91, 390, 285, 190 and 50 KeV gamma rays form a cascade. A decay scheme of ^{176}Tm is proposed and the results are discussed in the light of the unified model. The Q - for the ^{176}Tm - ^{176}Yb transition is 4088 ± 100 KeV. The (n,p) cross-section for ^{176}Yb is found to be 1.5 ± 0.5 mb.

Communicated for Publication : Nuclear Physics

8. Core-Particle Model Calculations in ^{205}Tl - Ila Mukherjee and Paresh Mukherjee - The nuclei which differ from a double closed shell core by a few nucleons only are of theoretical interest since their properties can be calculated using shell model with residual interactions. ^{205}Tl nucleus is a simple nucleus with one proton hole and two neutron holes in the closed shell core of ^{208}Pb. Recent reaction works have

revealed a lot of states in this nucleus, which were not known previously. The energy levels of the proton-hole state in the region N= 50 - 82 are known from the experimentally observed energy levels of ^{207}Tl in $^{208}Pb(t,\alpha)^{207}Tl$ reaction as $(3s_{1/2})^{-1}$ g.s., $(2d_{3/2})^{-1}$ 0.35 MeV, $(1h_{11/2})^{-1}$. 1.34 MeV, $(2d_{5/2})^{-1}$ 1.67 MeV. $(1g_{7/2})^{-1}$ 3.48 MeV. Similarly the neutron hole states in N= 82-126 region are experimentally well known from the single particle spectra of ^{207}Pb nucleus. For the sake of simplicity the energy states of ^{205}Tl may be evaluated by assuming the proton-hole in N = 50-82 region lossely coupled to ^{206}Pb core, which is performing low energy quadrupole vibrations. The hamiltonian for ^{205}Tl nucleus may thus be taken as

$$H = H_{s.p.} + H_{core} + H_{int} \qquad (1)$$

where $H_{s,p}$ is the hamiltonian for the proton hole in average shell model potential, H_{core} gives the vibrational energy of the ^{206}Pb core and H_{int} representing the core-particle interaction is

$$H_{int} = \chi \hbar\omega \left(\frac{8\pi}{5}\right) \sum_{\mu} \left(b_{\mu} + (-)^{\mu} b^{*}_{-\mu}\right) Y_{2\mu}(\theta,\varphi) \qquad (2)$$

where x is the strength of coupling, $\hbar\omega$ is the energy of the phonon, b_{μ} and b^{*}_{μ} represent the usual annihilation and creation operators respectively.

For evaluation of the eigenvalues corresponding to the

hamiltonian (1) the eigenfunction for a state with spin J has been taken as:

$$\psi_J = \sum_{jNR} a_{jNR} \left| j, NR, JM \right\rangle \qquad (3)$$

where j is the angular momentum of the single hole state, R the angular-momentum of the phonon vibration of the core, N the number of phonons characterising the state of surface vibrations. The present calculation is for one phonon approximation hence N = 0 and 1, in the summation. The sum over j extends to all states lying within 2 MeV.

The matrices for H for a particular state with spin J have been formed and the eigen-values and eigenfunctions have been evaluated by diagonalisation, for different values of x and $\hbar\omega$. The best agreement with the experimentally observed level is obtained for x = 0.6 $\hbar\omega$ = 0.6 MeV. It may be observed that the agreement quite good for states below 1.5 MeV. At higher energies the approximations made here will not be valid and so the disagreement between the experimental level spectra and the calculated one is not surprising.

A comparison is made between the single particle reduced width as determined from $^{206}Pb(t,\alpha)^{205}Tl$ reactions and the theoretical predictions.

Nuclear Physics (to be published)

9. Nuclear Spectroscopic Studies on some isotopes - S. Shastry, A.K. Nigam, S. Sen and R. Bhattacharya - The spin assignment of different levels of ^{125}Sb decaying from 9.4 day ^{125}Sn was made by using directional angular correlation technique. The shape factor studies on ^{170}Tm with the help of Siggbahn-slatis beta ray spectrometer, revealed the first for bidden nature of the two transitions suggesting 1^- spin-parity for the ground state of ^{170}Tm. A thorugh spectroscopic investigation on one-day ^{187}W was performed. The results, mostly in accord with the previous results, showed some evidence in favour of high energy states expected for this nucleus.

An exact Zero - range force calculation was performed to explain the collective nature of the 2.76 MeV 3^- state of ^{88}Sr. The results show that while the EI transition rate originating from this state is in good agreement with the experimental half-life, the E3 transition falls short by a factor of ten.

Investigations on the collective properties of odd - A isotopes of Antimony were also taken up. Some theoretical calculations on level systematics of Sb - isotopes have just been undertaken using hole -particle excitations.

10. Apparatus for nuclear spectroscopic studies - R. Bhattacharya, S. Chatterjee, B.K. Sinha and A.K. Nigam - The Siegbahn Slatis beta - ray spectrometer was improved to provide facilities for beta - gamma coincidence studies. In order to

bring down the low energy cut-off for electrons to 10 KeV, collodion films deposited on fine wire mesh were developed. The arrangement for studying angular correlation in magnetic field (upto 18 K gauss) was completed. The Larmor precession frequency W which determines g - factor directly, can be extracted by using the method known as "Differential time - delay experiment", in which the angular correlation is observed in a constant magnetic field B, as a function of time delay between the radiations.

An apparatus for measuring short half-life has been constructed which includes a transitourised time to amplitude convertor, a triple coincidence unit, a delay line($\approx$ 200 ohms) of total delay of 2ns in a length of 2 ft. The resolution of the system has been found to be 2ns. This apparatus will be used in the measurement of electronic monopole transitions' half lives. The preliminary investigations on two nuclei Viz. ^{58}Fe ($2^+ \rightarrow 2^+$ transition - 0.865 MeV) and ^{169}Tm ($7/2 \rightarrow 7/2$ transition - 0.177 MeV) are being made.

An automatic angular correlation apparatus for the use with Beta - Gamma ray angular correlation measurement has just been completed.

The fabrication of electron - electron pair spectrometer to be used for measurement of short half lives and beta - gamma angular correlation has been partly completed. The magnet coils and the source chamber have been installed. The vacuum system

has been completed. The two current stabilisers required for the purpose are under construction.

B ϕ S

D. NUCLEAR PHYSICS LABORATORY, BOSE INSTITUTE, CALCUTTA 9

1. Determination of absolute (n, 2n) cross section of ^{19}F, ^{63}Cu, ^{64}Zn, ^{69}Ga, ^{107}Ag for 14.8 MeV neutrons - Arun Chatterjee, Bimalendu Mitra and Ananda M. Ghose - Absolute determination of (n, 2n) reaction cross section of the above nuclei has been performed, by employing activation analysis technique. 14.8 MeV neutrons have been obtained from Bose Institute's neutron generator, by accelerating denterons to a potential of 150 Kilovolts and using tritium absorbed targets. Absolute flux of neutrons has been measured by a method developed in our laboratory, based on the study of the characteristics of the biased plastic scintillators irradiated by 14 MeV neutrons. The absolute flux has been determined to an accuracy of the order of $\pm$ 3% of error. Absolute determination of the saturation activity of the irradiated products was performed by detection of annihilation radiations from the β^+-active end products from the above nuclei, by the method of coincidence counting.

Irradiations were performed by placing the samples in the forward geometry, at a distance from the tritium target so that the angular spread of the incident neutrons on them does not make a change of energy of neutrons more than $\pm$ 100 KeV

around 14.8 MeV. The natural samples of high purity, were irradiated for sufficiently long time to ensure generation of saturation activity. Then they were transferred to the counting system. The samples were in the shape of discs and were held between two 7.8 mm thick aluminium "converters" of positrons. The scintillation counters are 2" x 1¾" NaI(Tl) crystals coupled to 2" photomultipliers. The coincidence circuitry has been tested and counters calibrated by employing a propared ^{22}Na source of known strength. Conventional electronics viz. fast and slow coincidence circuits, amplifiers, single-channel pulse height analysers and sealers have been used. The results are given in Table I

TABLE I

Nucleus	Product	Halflife	$\sigma(n,2n)$ in mb/atom for 14.8 MeV neutrons
^{19}F	^{18}F	112 mt	49.4 ± 5.0
^{63}Cu	^{62}Cu	9.7 "	544 ± 25
^{64}Zn	^{63}Zn	38.3 "	174.4 ± 17.5
^{69}Ga	^{68}Ga	68 "	1013 ± 100
^{107}Ag	^{106}Ag	24.3 "	562.4 ± 56.3

2. Measurement of nonelastic cross sections of nuclei for fast neutrons - Arun Chatterjee and Ananda M. Ghose - The non elastic cross sections of nuclei for fast neutrons are conventionally measured by the sphere transmission technique. The extraction of the non elastic cross section from the transmission data however requires the evaluation of several correction factors which are often very large. The methods hitherto employed for the determination of these corrections are usually very complicated and require a knowledge of the total and differential elastic scattering cross section data. The latter is a particularly severe limitation especially in experiments with high energy neutrons for which these data often do not exist. We have, therefore, developed a new method which can be employed to determine non elastic cross section from transmission data alone. The method has been tested by measuring these cross sections for 14.8 MeV neutrons. Table I shows the results obtained by us.

TABLE I

Element	Non elastic cross sections for 14.8 MeV neutrons in b/atom
C	0.55 ± 0.02
O	0.85 ± 0.04
Al	0.94 ± 0.03

1	2
Cu	1.46 ± 0.03
Cd	1.85 ± 0.04
Sn	1.91 ± 0.04
Ce	2.03 ± 0.08
W	2.44 ± 0.06
Pb	2.50 ± 0.05

3. Reaction cross section of 14 MeV neutrons - Bimalendu Mitra and Ananda M. Ghose - The (n,p) and (n,α) reaction cross sections of 14 MeV neutrons have been determined, for low atomic number nuclei. Measurements have been done relative to (n,2n) cross section of ^{63}Cu, this standard estimated from Glooer and Weigold's (1962) value at 14.8 ± 0.1 MeV which is 530 ± 25 mb. Total (n,p) of ^{16}O, ^{19}F, ^{23}Na, ^{27}Al, ^{28}Si, ^{37}Cl, ^{51}V, ^{52}Cr and ^{55}Mn have been determined. Various systematic errors associated with such measurements have been throughly studied and experimentally minimized or eliminated. As comparatively thick samples $\approx$ 20 mg/cm^2 thickness were used, a method was developed for determining accurately the self absorption and self scattering factors in the β-counting by end window counters. Efficiency of the counter was estimated

from an empirical relation developed in the form: $\epsilon = 1 - e^{-b\bar{E}_\beta}$ where ϵ = maximum efficiency of the counting system; $\bar{E}_\beta$ = average β-energy, and 'b' is a constant. The value of the constant was estimated by measuring the activity induced by 14 MeV neutrons in copper and almunium foils of different thicknesses. The effects of self scattering and self absorption have been determined upto an error limit ± 3%. Special sample transfer system has been devised and error in timing has been minimized to ± 1/50th of a second. Activity has been recorded for small half life products by a two scaler method where one scaler operating as timer was photographed with the scaler (recording counts) with the G.M. tube, and they were photographed simultaneously on the same frame, each frame automatically exposed one after another, at an interval of 2 secs. The values of the $\sigma_{n,p}$ obtained for low Z elements, are given in Table I.

TABLE I

Nucleus	σ(n,p) in mb/nucleus
^{16}O	40.1 ± 2.7
^{19}F	23.3 ± 2.8
^{23}Na	41.8 ± 2.8
^{27}Al	97.0 ±10.0
^{28}Si	222.0 ±12.0
^{37}Cl	21.3 ± 2.1
^{51}V	24.7 ± 2.2
^{52}Cr	82.8 ± 5.8
^{55}Mn	59.5 ± 5.9

E. LABORATORIES FOR NUCLEAR RESEARCH ANDHRA UNIVERSITY, WALTAIR

1. Polarisation Effects in Compton Scattering - A.S. Raju, J. Rama Rao and V. Lakshminarayana - An experimental investigation was made on the polarisation of effects in inelastic scattering of 662 Ke V photons from a 10-curie ^{137}Cs source. The polarisation Analyzer consisted of 3 scintillation detectors connected in 2 sum-coincidence arrangements using which the data in two different planes were collected simultaneously for statistical superiority. The experiments were conducted at 4 scattering angles (45°, 60°, 75° and 90°) and 3 azimuthal angles (30°, 60° and 90°). The results are in satisfactory agreement with the predictions of the Klein-Nishina theory after allowing for about 3% discrepancy between the geometric and experimental solid angles.

2. Rayleigh Scattering of Polarised Photons - D.R.S. Somayajulu, J. Rama Rao and V. Lakshminarayana - A partially polarised beam of photons was produced by compton scattering of 662 KeV gamma-rays from a 10 curie ^{137}Cs source and employed to study the asymmetry ratio in Rayleigh scattering by lead. The variation of the asymmetry ratio with Rayleigh scattering angle was investigated at angles 45°, 60°, 75° and 90°. The results are found to be in good agreement with the values

estimated from the theory of Brown et al.

The polarisation effects in Rayleigh scattering were investigated at scattering angles 45°, 60°, 75° and 90°. The polarisation analyser consisted of 3 scintillation detectors connected in 2 sum-coincidence arrangements. The results are in fair agreement with the predictions of the exact theory of Brown et al.

3. Beta Decay Matrix Elements of the 700 KeV transition in ^{111}Ag - V. Seshagiri Rao and V. Lakshminarayana - The Beta-Gamma directional correlations for the $\frac{1}{2}^{-}$ (700 KeV β) $\frac{3}{2}^{+}$ (340 KeV γ) $\frac{1}{2}^{+}$ cascade were investigated in the energe range between 240 and 630 KeV, the values of the corrected correlation coefficients at these energies being - 0.016 $\pm$ 0.006 and 0.029 $\pm$ 0.006 respectively. The log ft. value of the transition is normal (7.3). But the Fermi plot was found to be non-allowed and showed a deviation of 17%. It is therefore possible that the normal matrix elements are reduced and an unusual combination of matrix elements contributes to the transition. A computer programme was worked out using Buhring's notation with the present values of the correlation coefficients and the previous experimental results on the beta spectrum shape factor. Preliminary results indicate reduction in size of the matrix element.

4. Beta-Gamma Directional Correlation Stxudies in the Decay of ^{160}Tb - V. Seshagiri Rao and V. Lakshminarayana - The ground state spin of the radioactive nucleus ^{160}Tb has been recently revised as 3^- (instead of the hitherto adopted value of 4^-.). Thus the 860 KeV Beta transition, feeding the 2^+ state at 967 KeV in ^{160}Dy, now becomes first-forbidden non-unique. However, a log ft value of (8.8) being unusual for such a transition, it is interesting to examine the matrix elements involved. A beta gamma directional correlation experiment is therefore conducted with beta energies in the range 450 to 750 KeV and gamma energies 880 and 967 accepted in the gamma channel. The corrected correlation coefficients varied from - 0.028 $\pm$ 0.003 to - 0.037 $\pm$ 0.004 for beta energies 450 and 750 KeV respectively. Although small anisotropy and little energy variation of the modified correlation coefficient are suggestive of the applicability of ξ-approximation, an unusual value for the log ft is indicative of the "selection rule" or "cancellation" effects on the matrix elements. Experimental studies on the beta spectrum shape factor will be helpful to provide additional information for a computer programme.

5. Internal Bremsstrahlung from ^{32}P and ^{210}Bi - K. Narasimha Murty and Swami Jnanananda - The continuous spectra of

internal bremstrahlung from the beta-decays of ^{32}P and ^{210}Bi are measured by using a single-channel NaI(Tl) scintillation spectrometer along with a standard geometrical arrangement. Sufficient care is taken to avoid spurious effects and corrections are made for several factors, such as background, energy resolution, backscattering, Compton and escape electrons, geometrical and gamma-detection efficiency of the crystal and absorption of the radiation between source and detector. Also the total yields of intensity and of energy of internal bremstrahlung from each of the isotopes ^{32}P and ^{210}Bi in the investigated energy regions are determined and compared with the corresponding theoretical values. The experimental results in the case of ^{32}P are compared in the energy region of 100 to 1200 KeV with the allowed theory of Knipp and Uhlenbeck and of Bloch (KUB Theory) and also with the coulomb corrected theory due to Lewis and Ford and the agreement is fairly good throughout. In the case of ^{210}Bi the experimental results are compared in the energy range from 90 KeV to 550 KeV with the KUB theory and also with the coulomb corrected theories of Lewis and Ford and of Nilsson. A fiarly good agreement is obtained between the experimental distribution and the Nilsson theoretical distribution throughout the investigated energy region. This paper will appear in NuovoCimento.

6. Internal Bremsstrahlung from ^{204}Tl and ^{91}Y - K. Narasimha

Murty and Swami Jnanananda - The continuous spectra of internal bremsstrahlung from the beta-decays of ^{204}Tl and ^{91}Y are measured by using a single channel NaL(Tl) scintillation arrangement. Also the total yields of intensity and of energy of internal bremsstrahlung from each of the isotopes ^{204}Tl and ^{91}Y in the investigated energy regions are determined. In the investigated energy region from 90 KeV to 550 KeV for ^{204}Tl there is reasonable agreement between experiment and coulomb corrected theory of Nilsson above 300 KeV, while below 300 KeV considerable experimental excess is definitely present. For ^{91}Y there is no harmony at all between experiment and theory throughout the investigated energy from 100 to 1000 KeV, the experimental results being in large excess over theory. Moreover, the divergence between experiment and theory is found to icrease with increasing energy.

7. Internal Bremsstrahlung from ^{51}Cr - K. Narasimhamurty and Swami Jnanananda - The high energy part of the continuous spectrum of internal bremsstrahlung associated with the ground to ground transition and appearing as a low intensity tail on the high energy side of the 325 KeV discrete gamma-ray line of ^{51}Cr is studied in the energy region of 400 KeV to 700 KeV with a single-channel NaI(Tl) scintillation spectrometer along with a standard geometrical arrangement. Sufficient care is taken to avoid spurious effects and corrections are made for several

factors. Suitable precautions are taken to minimise the random superposition of pulses resulting from the relatively more intense 325 KeV discrete gamma-rays. A value of 778 ± 40 KeV is obtained for the energy of disintegration. By using the theoretical expression of Morrison and Schiff for the intensity of the internal bremsstrahlung spectrum, a value of 8.3% is obtained for the percentage of disintegrations decaying to the 325 KeV level of ^{51}V. These results are found to be in good agreement with measurements made by independent methods.

8. Decay Schemes of ^{97}Zr and ^{99}Mo - P. Jagam and V. Lakshminarayana - The decay schemes of ^{97}Zr and ^{99}Mo are re-investigated to settle some disputed points, using the sum and sum-peak coincidence techniques and a 100-channel analyser. In the case of the decay ^{97}Zr to ^{97}Nb, preliminary studies indicate the need for a doublet at 750 KeV (750 and 770 KeV) and a level at 2580 KeV. In the case of ^{99}Mo the results on the sum-coincidence and sum-peak spectra could only be explained by including additional levels at 370 and 1290 KeV.