International Atomic Energy Agency

INDC(SEC)-35/L

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

CONSOLIDATED PROGRESS REPORT FOR 1973 ON NUCLEAR DATA ACTIVITIES IN THE NDS SERVICE AREA

Australia

Bangladesh

Brazil

India

Korea

Romania

South Africa

Yugoslavia

August 1973

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

FOREWORD

This consolidated progress report for 1973 has been prepared for the countries in the NDS service area. It is intended to encourage a closer relationship between Member States and provide for a wider circulation of unpublished progress reports from countries within the Nuclear Data Section service area. A second report INDC(SEC)-36/L covers countries outside the NDS service area.

The report is arranged alphabetically by country, and reproduces the content of each individual report as it was received by the INDC Secretariat. Also included in the Table of Contents is a list of each laboratory, institute and university referred to in the report, preceded by its internationally used EXFOR code.

As in all progress reports the information included here is partly preliminary and is to be considered as private communication. Consequently, the individual reports are not to be quoted without the permission of the authors.

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(3INDTRM)	Bhabha Atomic Research Centre, Bombay	
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pages

(3INDMUA) Aligarh Muslim University, Aligarh

(3INDAUW) Andhra University, Visakhapatnam

(3INDBHU) Banaras Hindu University, Varanasi

(3INDBIT) Birla Institute of Technology, Pilani

(3INDBOS) Bose Institute, Calcutta

(3INDDAE) Department of Atomic Energy, New Delhi

(3INDITB) Indian Institute of Science, Bangalore

(3INDIIB) Indian Institute of Technology, Bombay

(3INDITK) Indian Institute of Technology, Kanpur

(3INDIIK) Indian Institute of Technology, Kharagpur

(3INDKUK) Kurukshetra University, Kurukshetra

(3INDMSB) M.S. University, Baroda

(3INDPRA) Physical Research Laboratory, Ahmedabad

(3INDPUC) Panjab University, Chandigarh

(3INDPAT) Panjabi University, Patiala

(3INDDLH) University of Delhi, Delhi

(3INDPOO) University of Poona, Poona

(3INDURR) University of Roorkee, Roorkee

(3INDVUU) Vikram University, Ujjain

(3INDUBU) Viswa-Bharati University, Santiniketan

(3INDECB) Government Engineering College, Bilaspur

(3INDPCP) Government Post-graduate College, Panna

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(3KORSEO) Korea Atomic Energy Research Institute, Seoul

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(3RUMBUC) Institute for Atomic Physics, Bucharest

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(3SAFSUN) Southern Universities Nuclear Institute, Faure

(3SAFPEL) Physics Division, Atomic Energy Board, Pelindaba

(3SAFUPR) University of Pretoria, Pretoria

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(3YUGRBZ) Institute Rudjer Boskovic, Zagreb

(3YUGBKB) Institute Boris Kidric, Vinca

(3YUGNJS) Institute Jozef Stefan, Ljubljana

Progress Report on Nuclear Data Activities in Australia

Compiled by

W. Gemmell

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A. AUSTRALIAN ATOMIC ENERGY COMMISSION RESEARCH ESTABLISHMENT LUCAS HEIGHTS

1. NUBAR DATA

1.1 Absolute Measurement

The value for the spontaneous fission from ^{252}Cf remains

$$\bar{\nu}_p = 3.735 \pm 0.014$$

Two further sources of error have been considered since the Vienna meeting.

(i) Variation in the efficiency of the scintillator for neutron capture detection as a function of capture position in the scintillator. The effect of the axial hole has also been considered. The effect has been shown to be very small ($\sim$0.1 per cent).

(ii) Errors in the estimation of the dead time correction caused by variation in the scintillator dead time produced by the effect of different background spectrum on the scintillator triple coincidence. For the experimental condition of the absolute $\bar{\nu}$ measurement this effect is completely insignificant ($\sim$0.01 per cent).

An absolute value has been estimated for $\bar{\nu}_p$ for the thermal neutron fission of ^{235}U based on recent experimental data for the ^{235}U fission neutron spectrum from Holmquist, Knitter and Ferguson. The absolute value is 2.385 ± 0.0095.

1.2 Relative $\bar{\nu}_p$ Measurements

A measurement has been made of $\bar{\nu}_p$ for the spontaneous fission of ^{248}Cm and earlier measurements for ^{240}Pu and ^{242}Pu have been revised. The data are listed in the enclosed papers.

1.3 Energy Dependence of $\bar{\nu}$ and the Average Total Fragment Kinetic Energy

The variation of the average total fragment kinetic energy for

^{233}U with neutron energy has been measured to 1 MeV neutron energy. The values (see Kiev paper) confirm the earlier $\bar{\nu}_p(E_n)$ measurements for ^{233}U. They also suggest a minimum in $\bar{\nu}_p$ for ^{233}U at 120 keV. This is to be checked in a future experiment.

1.4 Neutron Emission from Specific Fission Fragments of ^{252}Cf

The neutron emission from fission fragments, as determined by a 90 KΩ-cm silicon K-X-ray detector (resolution 440 eV FWHM at 26 keV), were detected in a 40 cm diameter liquid scintillator tank.

The relative $\nu(Z)$ data for the light and heavy fragment groups, as well as the total neutron emission $\nu_{total}(Z)$ are shown in Figure 1. Normalisation to the tank efficiency has yet to be done. The shape of the light fragment data is in good agreement with Nifenecker et al. (1969)[1] (resolution 1000 eV at 30 keV), as given in Figure 2 with an approximate normalisation of the average total neutron emission of the present work to that in (1). However, the heavy group data exhibits much less Z dependence than the heavy group data of (1). The effect of this flatter Z dependence for the heavy group is to produce a substantially greater shape in the $\nu_{total}(Z)$ curve than that reported in (1). The present data imply $d\nu_{total}/dZ$ $(Z = 40 - 45) \sim 0.12$ n/Z, differing markedly from the value ~ 0.035 n/Z[1], but agreeing well with the data obtained in a recent very accurate study in total neutron emission alone[2]. This value was $d\nu_{total}/dZ$ $(Z = 40 - 45) = 0.10$ n/Z. The present data for $\nu_{total}(Z)$ are compared with that of (2) in Figure 3.

The lower $\nu(Z)$ slope for the heavy group is to be expected, of course, from the well known shape of the $\nu(A)$ data and because of the correspondence between A and Z. $d\nu(A)/dA$ (heavy group) is about one half $d\nu(A)/dA$ (light group) in the mass range A = 100-115, corresponding to the range Z = 40-45.

From the present data

$$\nu_{total}\ (\text{weighted over } Z_H = 40,\ 42,\ 44) = 3.61 \pm 0.19$$

$$\nu_{total}\ (\text{weighted over } Z_H = 41,\ 43,\ 45) = 3.52 \pm 0.15$$

Thus the forecast 0.2-0.3 neutrons excess emission for even Z fragment pairs over odd Z pairs has not been found, in agreement with the findings of (1) and (2).

Nifenecker et al.[1] reported two plateaux in the heavy fragment $\nu(Z)$ curve at Z = 52-53-54 and Z = 55-56-57 and suggested a correlation between this $\nu(Z)$ 'fine structure' and the fine structure in the ^{252}Cf mass yield curve in the same region. The present higher resolution data contain no evidence of any such plateaux.

Because of the low count rates, the statistical errors associated with this work are relatively large. It is intended to increase the count rate by increasing the fission fragment surface barrier detector size. The high value for $\nu(Z = 54)$ is very probably not genuine.

2. ANALYSIS OF ORNL NEUTRON CAPTURE CROSS SECTION DATA

2.1 The experimental raw data from experiments performed on ORELA at Oak Ridge have been analysed to provide capture cross sections and relevant parameters. The data are corrected for dead time and time independent background. A peak search and background fitting routine is then utilised to obtain first estimates for peak channel numbers, peak area (minus background) and peak widths. Also the error in the peak area is calculated at this stage.

The trial estimates are then iterated in a non-linear least squares fitting program developed at Lucas Heights. The program fits parameters to up to 10 levels within 2000 energy channels. The majority of levels detected are unresolved (i.e. have widths much less than the resolution width) and are therefore well fitted by a Gaussian line shape of width equal to the resolution width. Occasionally a broad resonance is resolved however, and in this case an option to perform a Breit-Wigner fit to such a broad resonance is provided.

In the next stage of analysis the resonance areas obtained above are normalised using the ^{6}Li cross section and the quantity $g\Gamma_n\Gamma_\gamma/\Gamma$ obtained for each resonance. A correction is also applied at this stage for self shielding effects and for all resolved resonances a further Monte Carlo calculation is made to correct for multiple scattering and give an improved self shielding correction. The Monte Carlo routine is a modified version of a code originating at RPI and iterates to obtain the best estimates for the resonance parameters.

Because of the high resolution of the ORELA data an unprecedented number of weak (presumably p-wave) levels are detected. In the final stage of analysis it is our aim to attempt a separation of s- and p-wave levels with only values of $g\Gamma_n\Gamma_\gamma/\Gamma$ to rely upon.

We use Porter-Thomas statistics to decide how many s-wave levels are present in the final population and for each level a calculation is made giving the relative probability that it belongs to either s- or p-wave population. Further, the statistics of the level spacings of the final s-wave population are compared with the Wigner distribution. Too many small spacings show immediately the present of p-wave levels included among the s-wave population. A final calculation of the cross section is made with the averaged parameters derived from the above analysis, for comparison with the experimental capture cross section. This is a further check on the derived p-wave strength function in particular. An example of this calculation for ^{134}Ba is shown in figure 4.

2.2

The analysis of the data for calcium isotopes 40-44 highlighted an interesting feature of the radiation widths. The width of the s-wave resonances were found to be at least a factor of two greater than p-wave resonances.

TABLE 1

ANALYSIS OF DATA FOR CALCIUM ISOTOPES 40-44

	^{40}Ca	^{42}Ca	^{43}Ca	^{44}Ca
$\Gamma_\gamma(s)$ eV	3.4	1.6	0.8	1.0
$\Gamma_\gamma(p)$ eV	1.0	0.4	0.4	0.4

This result is evident in Figure 5 where the distribution of $[g\Gamma_\gamma\Gamma_n/\Gamma]/\bar{\Gamma}_\gamma(s)$ is shown for ^{40}Ca. A strong peak is observed well below the s-wave mean and because of the high sensitivity of the measurement to small resonances, the peak is believed to be real. Very small values correspond to p-wave resonances with $\Gamma_n << \Gamma_\gamma$ and from these a lower limit of the p-wave strength function can be obtained using Porter-Thomas statistics. It is found then that in most cases $\Gamma_n > \Gamma_\gamma$ for those resonances in the peak and consequently $\bar{\Gamma}_\gamma(p)$ can be derived.

The statistical model is used to calculate the average capture cross section with average parameters derived from the resonance analysis. Different radiative widths are used to calculate the s- and p-wave components and the results are compared with the averaged data for ^{44}Ca in Figure 6.

2.3

A review of keV capture γ-rays has been published in Nuclear Data by Bird, Allen, Bergqvist and Biggerstaff[3].

3. INTEGRAL EXPERIMENTS ON THORIUM METAL ASSEMBLY

Pulsed experiments in thorium have been mounted at this laboratory as an integral check on the ^{232}Th nuclear data. The fission rates of ^{237}Np, ^{235}U and ^{239}Pu have been measured as a function of time and space following a burst (~10 ns long) of energetic neutrons from the Be(d,n) (E_d = 2.8 MeV) reaction. Analysis has been completed on experiments which cover the time range 0 to 200 ns after the pulse where the average

neutron energy sweeps through the range ~4 MeV to ~45 keV.

Time dependent diffusion calculations indicate that the precision with which these experiments have been done is sufficient to allow detection of sytematic changes of about 5 to 10 per cent in the elastic cross section. The sensitivity studies were done assuming that σ_{total} was well defined and any change in σ_{el} produces a corresponding change in σ_{inel}.

The data used in the analysis was ENDF B (1969), much of which comes from BNL 325 (2nd Edition).

The agreement between theory and experiment is poor in the early ~0 to 100 ns time range, but good from 100 to 200 ns. Further experiments have been done using longer pulse lengths which should produce information at longer times and lower energies and also with different source spectra. The results of these experiments have yet to be analysed.

4. FISSION CROSS SECTION CALCULATIONS

Calculations of the fission, capture and inelastic scattering cross sections of the fissile nuclei were performed for neutrons in the energy range of 10 to 500 keV.

The theory used was the Hauser-Feshbach theory with fluctuation corrections. The transmission coefficients for fission were obtained from the penetration of double humped fission barriers.

Unexpected difficulties were encountered in that the calculated fission cross sections turned out too small, a situation which could only be remedied by postulating an inordinately large number of fission channels. The source of the difficulty appeared to be the fact that the Hauser-Feshbach theory holds only when the ratio $\bar{\Gamma}/\bar{D}$ is small where $\bar{\Gamma}$ is the average total width of the resonances and $\bar{D}$ the average level spacing. For the fissile nuclei this condition is not satisfied. It was therefore decided to use Moldauer's statistical theory which is based on a multilevel R-matrix formalism. However, upon closer examination, this theory was found to contain a serious error. In the evaluation

of certain averages the unitarity of the collision matrix was ignored. The unitarity condition introduces correlations between the complex partial widths and the level spacings and thus renders Moldauer's method of averaging invalid.

Attempts at rectifying the error have so far been unsuccessful. Investigations into this problem are continuing.

Multilevel resonance parameters have been evaluated within the context of the Adler-Adler resonance theory and a statistical analysis carried out of the parameters for ^{233}U and ^{235}U.

5. COMPILATION ACTIVITIES

A compilation of nuclear level schemes and gamma decay data for the activation analysis of stable nuclides is in progress. A similar compilation of fission product gamma decay data has been suspended pending consultation with overseas groups engaged in similar work.

In connection with the proposed nuclear parameter data file, some information within the scope of CINDA has been compiled and evaluated. Musgrove (1973)[5] has completed a compilation and evaluation of s- and p-wave strength functions and proposes similar work on neutron radiation widths.

6. REFERENCES

1. Nifenecker, H., Frehaut, J. and Soleilhac, M. (1969) - 2nd IAEA Symp. on Phy. and Chem of Fission, Vienna, p. 491.
Nifenecker, H. et. al. (1969) - Nucl. Phys. A131, 261, p. 491.

2. Nifenecker, H., Poitou, J., Babinet, R., Girard, J., Matuazek, J. and Ribrag, M. (1972) - private communication to R. Walsh. Paper entitled 'Gamma and neutron emission by fragments of known charges in the binary and long range particle accompanied fission of ^{252}Cf'.

3. Bird, J. R., Allen, B. J., Bergqvist, I. and Biggerstaff, J. (1973) - Nuclear Data 11, 6, 433.

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4. BNL325 (2nd Edition).

5. Musgrove, A. R. (1973) - A compilation of s- and p-wave neutron strength function data. AAEC/E277.

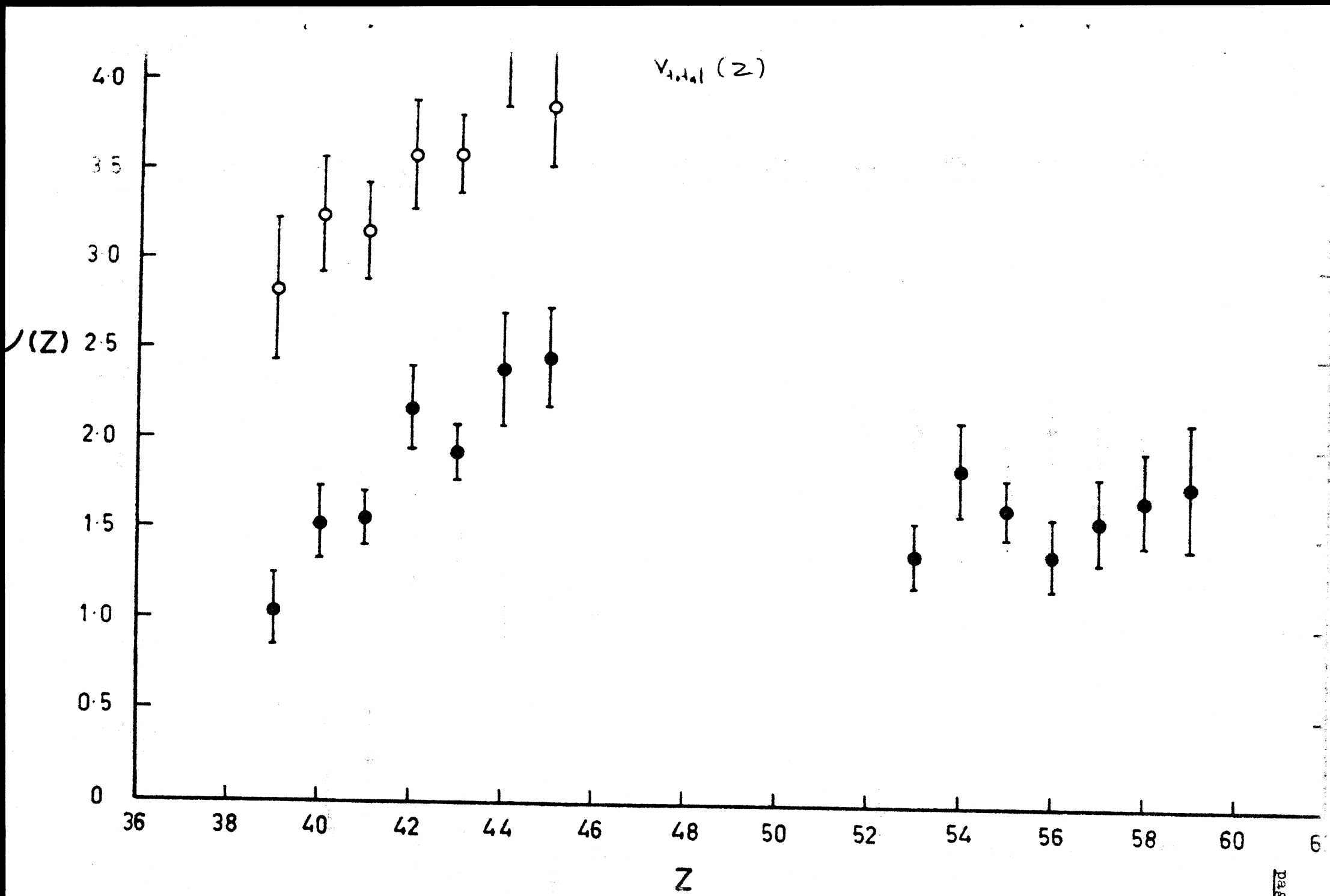
V_{total} (Z)
4·0
3·5
3·0
V(Z) 2·5
2·0
1·5
1·0
0·5
0
36
38
40
42
44
46
48
50
52
54
56
58
60
Z

FIGURE 1

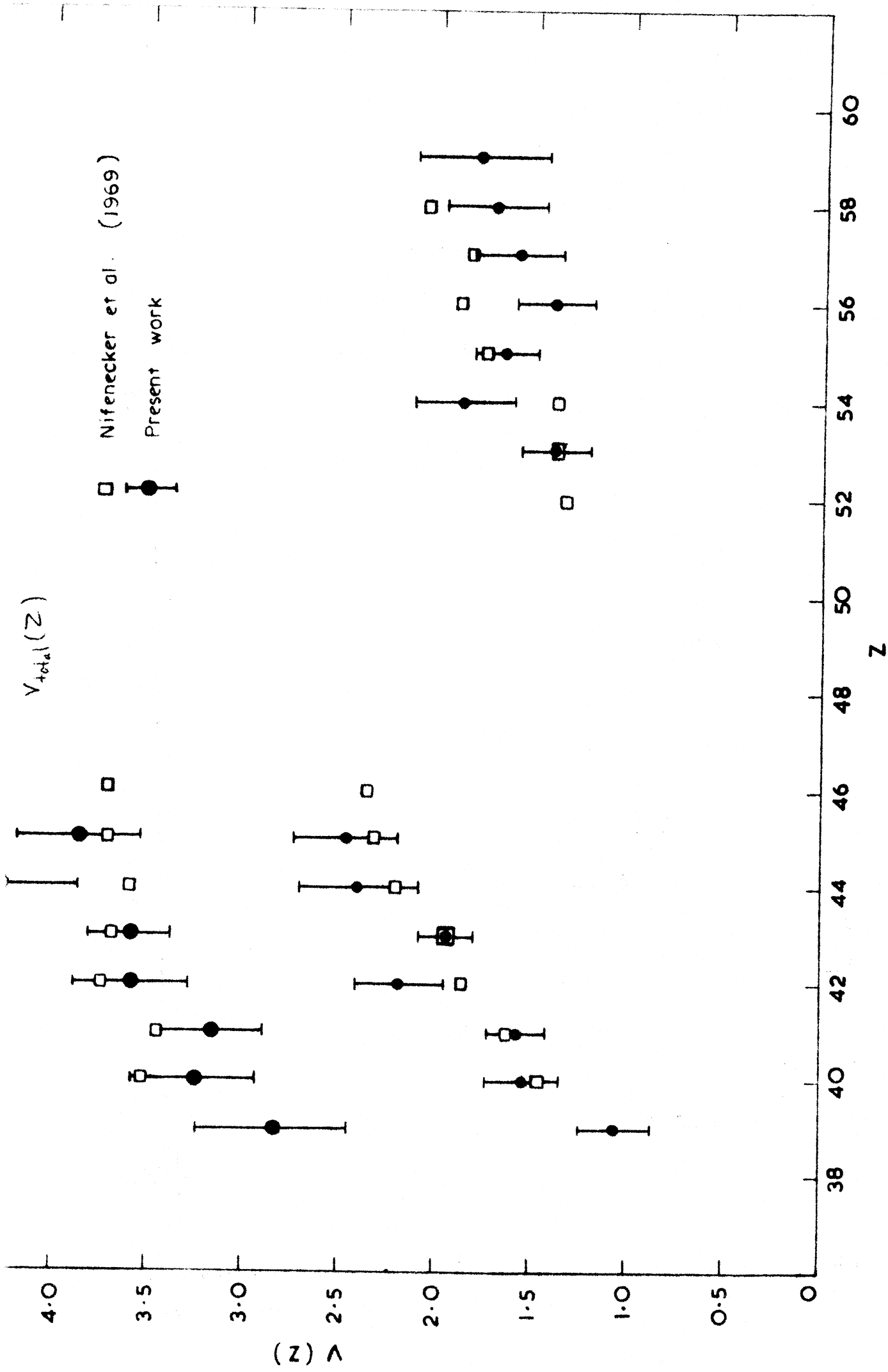
Nifenecker et al. (1969)
Present work
$Y_{total}(Z)$
Z
$\nu(Z)$
38
40
42
44
46
48
50
52
54
56
58
60
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
4·0

FIGURE 2

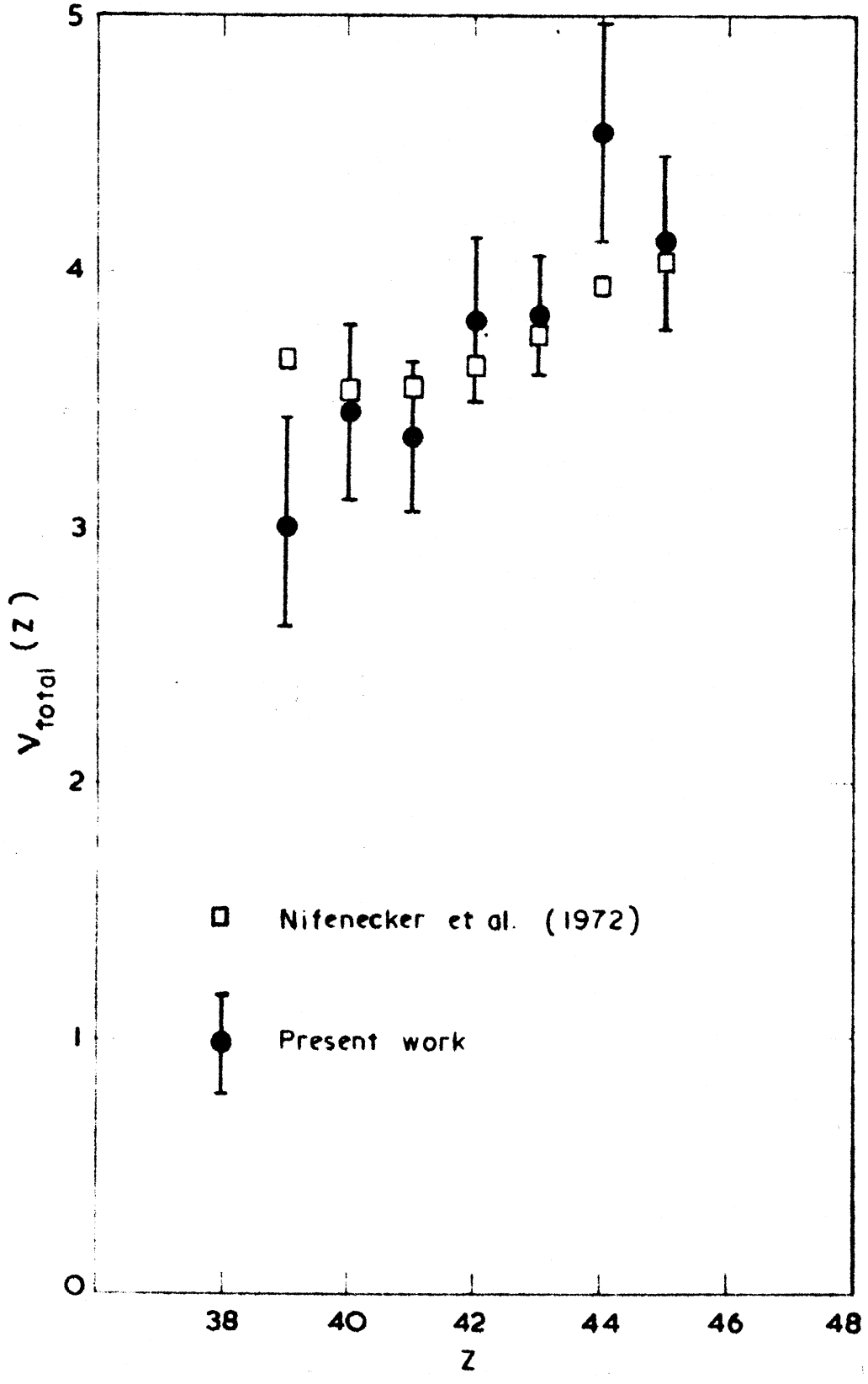
5
4
3
2
1
0
ν_{total} (Z)
38
40
42
44
46
48
Z
Nifenecker et al. (1972)
Present work

FIGURE 3

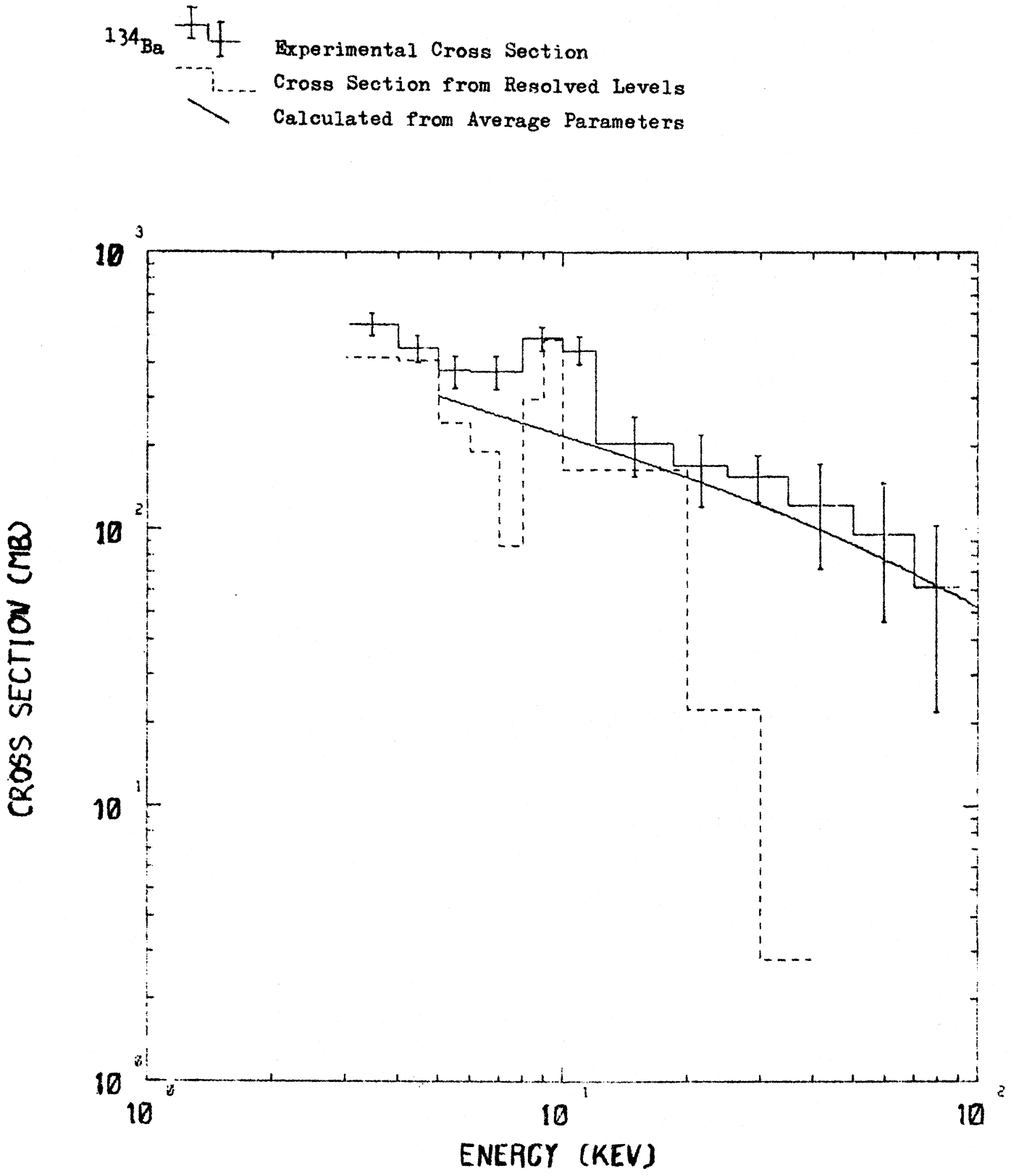
134Ba
Experimental Cross Section
Cross Section from Resolved Levels
Calculated from Average Parameters
CROSS SECTION (MB)
10 3
10 2
10 1
10 0
10 0
10 1
10 2
ENERGY (KEV)

FIGURE 4

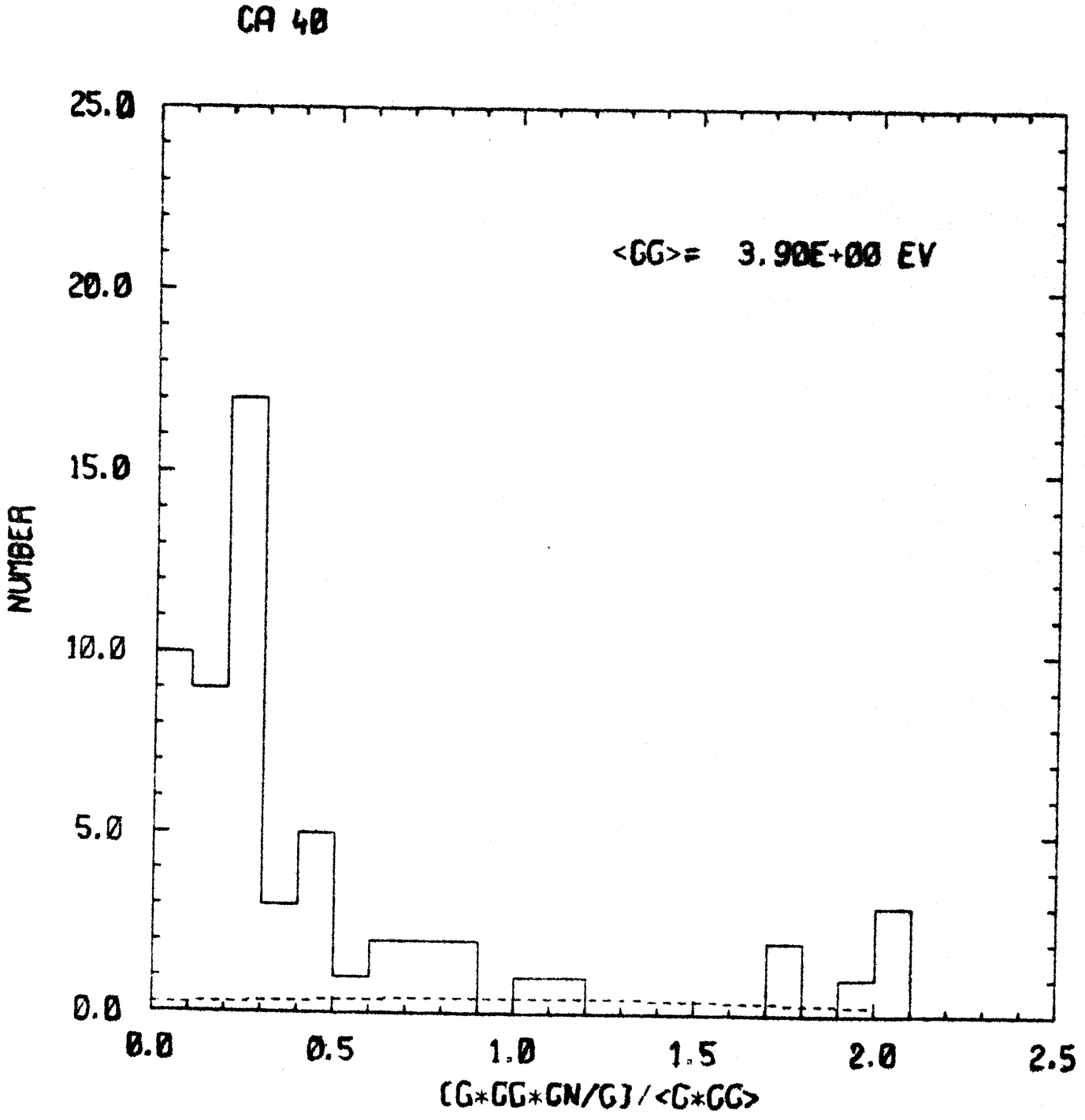
CA 40
<GG>= 3.90E+00 EV
NUMBER
25.0
20.0
15.0
10.0
5.0
0.0
0.0
0.5
1.0
1.5
2.0
2.5
[G*GG*GN/G]/<G*GG>

FIGURE 5

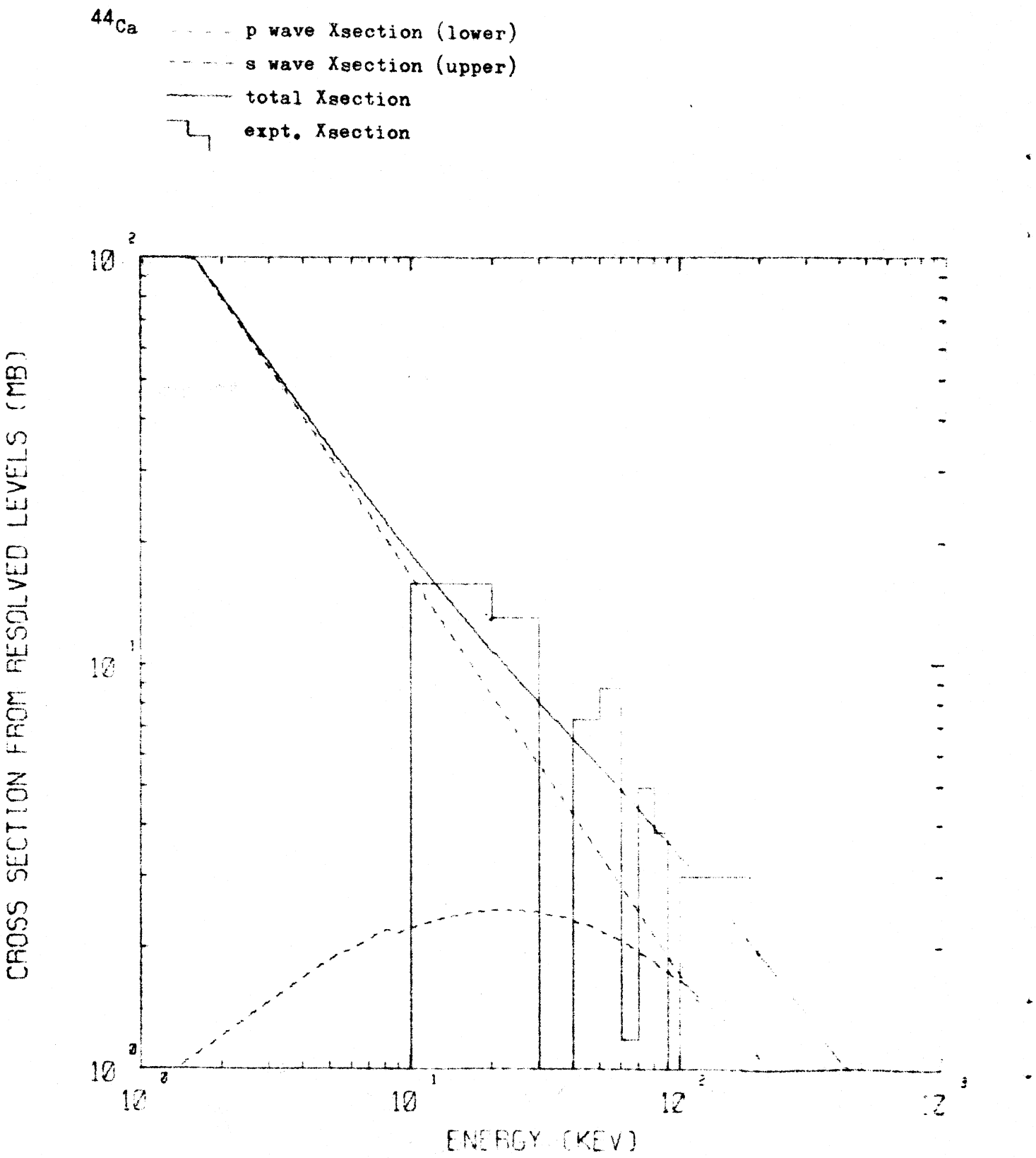
^{44}Ca
p wave Xsection (lower)
s wave Xsection (upper)
total Xsection
expt. Xsection
CROSS SECTION FROM RESOLVED LEVELS (MB)
ENERGY (KEV)

FIGURE 6

B. AUSTRALIAN UNIVERSITIES

B.1 UNIVERSITY OF MELBOURNE

School of Physics
Physics Theory Group

ANALYSES OF SPIN DEPENDENT DATA FROM INELASTIC NUCLEON SCATTERING

R. Smith, F. Ruzzene and K. Amos

An antisymmetrized distorted wave approximation has been used to evaluate the differential cross sections, polarization, spin flip probability amplitudes and asymmetries associated with inelastic nucleon scattering from nuclei. Data is available for many of these quantities, but is predominantly associated with the excitation of the so-called collective states. Miscroscopic distorted wave analyses of such data is dominated by contributions from the core polarization reaction mechanism. The direct core polarization amplitudes, which correspond to the standard generalized optical model calculations, are normalized by an analysis of the γ-ray transition rates for the decay of the residual nuclear state in inelastic scattering. The core polarization exchange amplitudes are normalized by the properties of giant multipole resonances of the target. Such amplitudes have been shown to be important and are essential to understand structure in the spin dependent measurables associated with inelastic nucleon scattering. Asymmetries are difficult to predict since they involve differences between scattering probabilities and thus provide a most sensitive test of details of the reaction mechanism.

OPTICAL MODEL CALCULATIONS OF NEUTRON STRENGTH FUNCTIONS

R. F. Barrett

Calculations of the s, p and d wave neutron strength functions based on the spherical optical model have been performed for the mass region A = 40-70. The aim was to investigate the radiative neutron capture observed in this region leading to final states with spin and parity $J^{\pi} = 5/2^{-}$ and $J^{\pi} = 7/2^{-}$. Results of the calculations indicate that d-wave neutron capture followed by E1 radiative decay is the most likely explanation of the process.

CONTINUUM SHELL MODEL CALCULATIONS OF PHOTONUCLEAR CROSS SECTIONS

R. F. Barrett

The bound-state shell model with residual interactions has been used successfully to describe the giant dipole resonance in many nuclei. Calculations based on such a model do not treat the continuum nature of the particle wave functions correctly and thus do not obtain the widths associated with resonances. The eigenchannel theory of nuclear reactions was developed to remedy this defect, and many calculations using the eigenchannel method have been performed for magic nuclei where the simple one-particle one-hole model has been used as a basis for the continuum shell model calculations. The eigenchannel method, however, lends itself readily to the treatment of a more sophisticated nuclear model. Calculations have now been performed for the nuclei ^{12}C and ^{28}Si based on an extension of the collective correlation model of Drechsel, Seaborn and Greiner to include the particle continuum. These calculations yield substantially improved agreement with experiment compared with the one-particle one-hole model.

UNIVERSITY OF MELBOURNE (cont'd)

Continuum calculations for the nuclei ^{15}O and ^{15}N have been performed based on a two-hole one-particle model, and also yield reasonable agreement with experiment. The nucleus ^{13}C is being investigated in a two-particle one-hole model.

Nuclear Structure Studies - Experimental

New Facilities

Funding has been obtained, and contract entered into, for the purchase of a 5 UD Pelletron Accelerator (5 MeV protons). This is a single-stage electrostatic accelerator scheduled for delivery in mid-1974, to be housed in the new Nuclear Physics Research building at the University. It will replace the present low-energy Statitron and will complement the energy range of the Melbourne University Variable Energy Cyclotron. These accelerators, operated separately, will provide variable and continuous energy selection up to ~11 MeV protons, ~13 MeV alphas and ^{3}He.

B.2 THE FLINDERS UNIVERSITY OF SOUTH AUSTRALIA
School of Physical Sciences,
Nuclear Theory Group

NUCLEAR STRUCTURE

NAMES: I. R. Afnan, D. R. Cameron, P. Cooke, J. Janiszewski, I. E. McCarthy, K. F. Tan

DETAILS: Ground state properties of finite nuclei are being investigated by variational methods using different types of NN interaction. Methods include Hartree-Fock, and the use of the eigenstates of a non-local potential in forming the determinant trial function.

PUBLICATIONS: J. Janiszewski, 'A non-local single-particle potential for nuclei', M.Sc. Thesis.

BOUND STATES AND STRENGTH FUNCTIONS IN SINGLE-PARTICLE POTENTIALS
W. Clerke, P. Cooke and I. E. McCarthy

The description of single particle bound states and strength functions using complex potentials is being investigated with a view to correlating data from AAECRE and elsewhere.

B.3 UNIVERSITY OF WESTERN AUSTRALIA
Physics Department
Electron Synchrotron Group

PHOTONEUTRON PRODUCTION CROSS SECTION OF URANIUM IN THE RANGE 5-8.5 MeV
P. Holland, R. Koch, R. Kirkman, and H. H. Thies

An experiment is underway to measure with brehmstrahlung from the Perth 30 MeV electron synchrotron the photonuclear production cross section in a depleted and in a natural uranium target. Neutrons are detected

UNIVERSITY OF WESTERN AUSTRALIA (cont'd)

in a multi-BF_3-counter detection system which has a verified flat response[1] (variation of neutron detection efficiency from its average value less than 5% from 30 keV to 0.75 MeV and less than 1% from 0.75 MeV to 4.5 MeV). The accelerator is operated using energy sweeping[2]. This means that the peak brehmstrahlung energy therefore varies with each machine pulse according to a repetitive program and guarantees that systematic yield errors do not affect the cross section ordinates calculated by photon-difference methods. Calculated cross section ordinates are decorrelated[3] to avoid the appearance of any spurious structure. The aim of this experiment is to investigate with greatly increased precision and resolution predicted structure in the region of 5 to 8.5 MeV gamma excitation.

REFERENCES:

1. D. M. Crawford, B. W. Thomas, K. Bottcher, R. Koch and H. H. Thies - Nucl. Inst. and Meth. 106, 1973, 311.

2. H. H. Thies, D. M. Crawford, P. Koch and B. W. Thomas - Nucl. Inst. and Meth. 100, 1972, 45.

3. D. M. Crawford, R. Koch, K. Bottcher and H. H. Thies - 'Effective decorrelation of errors of photon difference data' - submitted to Nucl. Inst. and Meth.

B.4 AUSTRALIAN NATIONAL UNIVERSITY
Department of Nuclear Physics

The Stack of the 14UD tanden accelerator at ANU was recently completed and voltage tests were made on it at the end of February. At least 18 MV was obtained at a pressure of 100 psi of SF_6. This is entirely satisfactory. The complex system for handling the 30 tons of SF_6 gas worked very well. The tube and vacuum system are now being installed.

AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF PHYSICAL SCIENCES

DEPARTMENT OF NUCLEAR PHYSICS PROJECTS - 1972

Facilities: Tandem Accelerator, Cyclotron Injector, 2 MeV Accelerator

1. REACTION MECHANISM STUDIES

   1.1 Two-step direct reactions in light nuclei
   (Maclean, Nurzynski, Treacy)

   1.2 The reaction $^{50}Cr(p,d)$
   (Barbopoulos, Borsaru, Gebbie, Hollas, Nurzynski, Quinton)

   1.3 The $^{54}Cr(d,t)^{53}Cr$ and $^{68}Zr(d,t)^{67}Zn$ reactions
   (Borsaru, Hollas, Merrill, Nurzynski, Whineray)

   1.4 The $(^{3}He,n)$ reaction in the 2s-1d shell
   (Davis, Nurzynski)

   1.5 The optical model for tritons
   (Nurzynski)

   1.6 Studies of (d,p) - induced fission
   (Maclean, Treacy)

   1.7 Direct reactions to particle unstable final states
   (Treacy)

2. ISOBARIC ANALOGUE STATES

   2.1 A search for the lowest T = 2 state of ^{12}C via isospin - forbidden reactions
   (Ahmad, Gardner, Moss, Spear)

   2.2 Isobaric Analogue resonances in ^{90}Zr
   (Borsaru, Gebbie, Hollas)

   2.3 Isobaric analogue resonance studies in some rare-earth nuclei
   (Borsaru, Hollas, Merrill, Weisser, Whineray, Zuk)

3. HEAVY-ION INDUCED REACTIONS

   3.1 Excitation functions for the $^{12}C(^{16}O,\alpha)^{24}Mg$, $^{12}C(^{16}O,p)^{27}Al$ and $^{12}C(^{16}O,d)^{26}Al$ reactions
   (Branford, Nagorka, Newton, Robinson)

   3.2 Inelastic scattering of ^{16}O on ^{12}C nuclei leading to the 3^- state in ^{16}O at 6.13 MeV
   (Branford, Nagorka, Newton, Robinson)

   3.3 Heavy-ion particle transfer reactions
   (Branford, Leigh, Parkinson, Weisser)

   3.4 Hyperfine interactions of excited ^{16}O and ^{20}Ne excited states in hydrogen-like ions
   (Branford, Ferguson, Foote, Leigh, Newton, Parkinson, Weisser)

4. RADIATIVE PROTON-CAPTURE STUDIES WITH Ge(Li) DETECTORS

   4.1 Studies using the $^{23}Na(p,\gamma)^{24}Mg$ reaction
   (Branford, Carlson, Huang, Ophel)

   4.2 The 1522 keV transition in ^{28}Si
   (Branford, Carlson, Huang, Ophel)

RADIATIVE CAPTURE OF COMPLEX PARTICLES USING THE 10 in NaI(Tl) DETECTOR

5.1 Alpha capture by Ar nuclei in the region of the giant dipole resonance
(Bell, Branford, Foote, Huang, Weisser)

5.2 Investigation of the $^{56}Fe(\alpha,\gamma)^{60}Ni$ reaction in the region of the giant dipole resonance
(Bell, Branford, Foote, Watson)

GENERAL NUCLEAR SPECTROSCOPY

6.1 Excited states of ^{16}O between 13.5 and 15.0 MeV
(Martin, Ophel)

6.2 Energy levels of ^{30}Si
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6.3 The 5.80 MeV state of ^{32}S
(Carlson, Gardner, Moss, Spear)

6.4 Gamma-ray decay schemes of levels at intermediate energies in ^{32}S
(Ahmad, Baxter, Carlson, Gardner, Moss, Spear)

6.5 Gamma transitions in ^{34}Ar
(Bell, Thompson)

6.6 Spins and lifetimes of levels in ^{47}V and ^{49}V
(Bell, Carlson, Najam, Thompson)

6.7 Lifetimes of states in $^{62,64}Cu$ and $^{67,70}Ga$
(Bell, Carlson, Davidson, Najam, Thompson, Zuk)

6.8 The placement of the 188 keV transition in ^{70}Ga
(Biggerstaff, Carlson, Davidson, Martin, Najam)

6.9 Gamma-ray decay schemes and angular distribution measurements for low-lying levels in ^{70}Ga
(Carlson, Davidson, Najam, Zuk)

6.10 Neutron transfer reactions among the selenium isotopes
(Gebbie, Nurzinsky, Quinton)

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Progress Report on Nuclear Data Activities in Bangladesh

Compiled by

N. Ahmed

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ATOMIC ENERGY CENTRE
DACCA, BANGLADESH

Neutron Total Cross-section

(M. Husain, Enayetullah, M. Farooque, N.I. Molla, M. Hussain and M. Hossain*)

Experimental procedure

Neutron total cross section was measured using the transmission method with "good geometry". D-C beam from the 3 MV Van de Graaff accelerator of the Atomic Energy Centre, Dacca was used for the production of neutrons using deuterium and tritium solid targets on gold and silver backings. Neutrons were detected by a ZnS detector with neutron-gamma pulse shape discrimination. Background neutrons were measured by placing a shadow-bar in the neutron beam path. Beam-charge intergration was used for monitoring purpose.

Results.

Neutron total cross section has been measured for Dysprosium and Mercury in the following energy ranges in steps of 100 keV. The beam energy spread was of the order of 10 keV.

(a)	Mercury	4	to	6	MeV
		16	to	19	MeV
(b)	Dysprosium	1	to	2	MeV
		4	to	6	MeV
		16	to	19	MeV

Preliminary analysis of the data have been made. Detailed calculations are under progress.

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* Department of Physics, Dacca University.

Future programme

Measurements for other elements in different energy regions with different energy resolutions will be taken up.

Fast neutron Scattering.

(M.M. Islam, M. Hussain*, M. Husain and M. Ahmed)

With the installation of a HVEC 4 nanosecond pulsing system with 5 MH_z repetition rate in our 3 MV Van de Graaff accelerator, we are now ready for the measurement of fast neutron scattering. The neutron pit area of the target room is now being covered with metallic sheets to facilitate the movement of detectors for angular distribution measurements. Neutrons will be produced by $T(p,n)^3He$, $D(d,n)^3He$ and $T(d,n)^4He$ reactions using solid and gas targets.

The neutron detectors consist of a NE213 liquid scintillator 2" in diameter and 2" in length, viewed directly by a RCA 8575 photomultiplier mounted on a constant fraction timing base, model ORTEC 270. Large detector shieldings are also being fabricated.

Measurements on the angular distribution of elastically scattered neutrons on Carbon in the neutron energy range of 200 keV to 2 MeV will be started soon.

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* Department of physics, Dacca University

Measurements will then be continued on heavy elements and reactor structural materials depending on the availability of the samples.

Fission neutron energy distributions from heavy elements will also be studied using fast neutrons to induce fission.

Fast Neutron Induced Fission

(M.M. Islam, A.H. Khan, M. Husain and M. Ahmed)

A project for the study of fast neutron fission cross-sections of heavy elements and the fission fragment mass-energy correlations has been taken up. Neutrons will be produced by $T(p,n)^3He$ $D(d,n)^3He$ and $T(d,n)^4He$ reactions using the 3 MV pulsed Van de Graaff accelerator of the AEC, Dacca. A 18" scattering chamber is already available and heavy ion detectors of the surface barrier type and other equipment are being procured for this purpose.

Fast particle activation

(A.H. Khan, D. Hossain and M.A. Awal)

Recently it has been observed that low energy particle accelerators are being put to use for solving problems of practical importance in industries, agriculture, medicine and environmental studies. Keeping in view the limitations of our accelerator which can accelerate positive ions only upto 3 MeV,

we have chalked out the following plan of work accordingly:

(1) Proton-induced X-ray fluorescence spectroscopy for elemental trace analysis,

(2) Measurement of activation cross sections by detecting prompt gamma radiations,

(3) 14-MeV neutron activation cross section measurements.

At present work is going on X-ray fluorescence spectroscopy. Experiments are being performed to indentify the characteristic X-rays of Cu, Zn, Pb and natural uranium. After completion of this qualitative work, attempts would be made to measure the fluorescent yields of these target elements as a function of proton energy. Experimental procedures for these measurements are as follows:

Targets are prepared either in the metallic or oxide form by vacuum evaporation on to spectroscopically pure carbon backing of thickness, 50-100 $\mu g/cm^2$, also prepared by the same evaporation technique. These targets are collected on square brass frames having a 1 cm diameter hole. Three such frames can be placed on a brass ladder which is inserted into a 18" diameter irradiation chamber through a vacuum lock. A cold trap is used before the chamber to absorb impurities from the pumping system. The proton beam is collimated to 2 mm and it strikes the target placed at 45° to the beam direction. Protons are stopped in a Faraday Cup which is insulated from the

chamber; the total current is measured by a digital current integrator. Secondary electrons from the target are deflected from the cup by an electron suppressor kept at - 250V.

A Si(Li) detector at room temperature, placed at 90° to the proton beam and connected to a FET preamplifier is used for the measurements. Pulses are amplified by a research amplifier and analyzed by a ND 4096 channel Pulse Height analyzer. A magnet is used infront of the detector to suppress electrons from the target while an aluminium absorber stops all scattered protons from reaching the detector. In course of time, we hope to improve the detection system by using a cryostat.

Study of Isobaric Analogue Resonances

(M.A. Rahman, S.Khatun, M.A. Awal, M. Rahman and H.M. Sen Gupta*)

Isobaric analogue states have been identified by (p,γ) (p,n) and (p,p) reactions on ^{27}Al, ^{51}V, ^{54}Fe, ^{55}Mn, ^{57}Fe and ^{59}Co target nuclei.

The experiments were performed with proton beam from the 3 MV Van de Graaff accelerator of the Atomic Energy Centre, Dacca. A 25° beam deflection was achieved with an analysing magnet the field of which was measured by a proton - spin resonance device. An electronic stabilizing system kept the

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* Department of physics, Dacca University

proton energy spread below 1 keV. The experimental arrangements for different reactions studied are as follows:-

(p,γ) experimental set up

The Scintillation spectrometer consists of a 5" x 6" NaI (Tl) crystal mounted on an EMI photomultiplier tube 9578. The detector was shielded by a cylindrical lead shielding of 10 cm thickness around the crystal and it was kept at a distance of 9 cm from the target, making an angle of 55° with the direction of the bombarding proton beam to ensure that the measured intensities are averaged for all possible angular distributions. The γ- ray excitation function were measured with two differential discriminators and scalers. Two channels were set to accept pulses $\geq$1.5 and 3.0 MeV arbitrarily corresponding to γ-rays deexciting the product nuclei resonance levels. Each point of measurement on the excitation curve corresponds to 100 μc of charge deposited on the target as measured by a current integrator. Signals from the preamplifier output could also be fed to the multichannel analyzer for the measurement of detector resolution as well as for the study of decay schemes.

(p,n) experimental set up.

The neutron yields were measured with a 1½ x 1" Stilbene scintillation detector incorporated with ORTEC

n-γ discrimination system. The current signal derived from the 9th dynode of PM tube and shaped in a fast preamplifier model ORTEC 264 is fed to the input of a linear amplifier (ORTEC 410). The bipolar pulses obtained from the linear amplifier are fed into a timing single channel analyzer (ORTEC 420) that provides an output at the time the input pulse goes through zero. The negative fast spike appearing at the output of the single channel analyzer constitutes what is called the 'stop' signal of a time-to-pulse-height converter (ORTEC 437). The 'Start' signal of the TPHC is obtained from the anode of the P.M. tube through a walkfree time derivation unit. This is a fast negative timing signal. The time derivation unit is controlled by an ORTEC 403 time pick off control unit and the output passing through a gate and delay generator (ORTEC 416) actuates the 'start'input of the TPHC. The anode pulses are arranged to arrive in time coincidence or to be slightly delayed with respect to the bipolar dynode pulses, which have components of different zero crossover times, so that a STOP pulse occurs with every START pulse. The TPHC on receiving the 'Start' and 'Stop' signals converts the time difference between the two into a voltage signal which appears at its output. Thus the spectra of the output pulses from the TPHC shows two peaks corresponding to the neutron and gamma rays when analyzed in a multichannel analyzer.

The discriminator level of the single channel analyzer (ORTEC 420) is then adjusted so that the gamma pulses are rejected and the neutron output pulses are recorded in a scaler.

(p,p) experimental set up

Elastically scattered protons were detected by two ORTEC surface barrier detectors of 100 mm^2 sensitive area and depletion depths of 500μ and 1000μ respectively. The energy resolutions of the detectors for 5.477 MeV α-particles from ^{241}Am were 60 keV and 67 keV respectively. The target was kept at an angle of 45° with respect to the proton beam and the detectors were placed at distances of 10 cm inside a 18" scattering chamber. The target holder can contain 3 targets at a time and can be changed from outside. Both the target angle and the detector angle can be adjusted from outside without breaking the chamber vacuum.

The proton beam enters the scattering chamber through a tantalum callimator 2 mm in diameter. The elastically scattered protons fall on the sensitive area of the detector through a button magnet and two tantalum collimators of 2 & 3 mm in diameter placed just in front of the detector. The magnet was used as a suppressor of electrons. The protons after passing through the target are collected in a Faraday cup which is insulated from the chamber. Each point on the measurements corresponds to 100 μc of charge collected by the Faraday cup.

The detector pulses were fed to a set of scalers via a charge sensitive preamplifier, a linear amplifier and a single channel analyser. The desired peak area of elastically scattered protons from the target is gated by the discriminater levels of the single channel analyser ORTEC 420 which was previously calibrated. The discriminator levels are adjusted accordingly for each increase in the proton beam energy so that only the counts in the desired peak are registered in the scalers.

Results

The results of the measurements are summarized in table I. In addition to identifying the analogue resonances, they have been assigned to the corresponding levels in the isobaric nuclei. The coulomb displacement energy ΔEc between the isobaric pairs has also been calculated.

Some of the analogue resonances in the compound nuclei ^{52}Cr, ^{56}Fe and ^{60}Ni display fine structures enveloping gross structures and show assymmetry on both sides of the resonance energies.

Excitation function for elastic scattering of protons on ^{54}Fe and ^{27}Al have been measured at the laboratory angles of 160°, 154°, 149.5°, 140.8°, 125.3° and 90°, and 140.8° 125.3° and 90° respectively. The proton energy range was 2.2 MeV to 3.0 MeV for the former and 0.85 MeV to 3.0 MeV for the later. The analysis of the data is in progress.

Table I : Summary of the results.

Targets	Proton Energy Range (MeV)		No of analogue Resonances observed			Isobaric pair	ΔE_c (MeV)	Published in
	(p,γ)	(p,n)	(p,γ)	(p,n)	Total			
^{27}Al	0.85to3.00	-	26	-	26	^{28}Al-^{28}Si	5.439±0.051	Z.physics, 257 (1972)380.
^{51}V	0.70to2.98	2.0to3.12	14	9	15	^{52}V -^{52}Cr	8.073±0.03	Il Nuovo Cimento 11A (1972)476. Lettere al Nuovo Cimento 1(1971) 327
^{54}Fe	0.80to2.992	-	11	-	11	^{55}Fe-^{55}Co	9.079±0.054	Lettere al Nuovo Cimento 3(1972) 299
^{55}Mn	1.28to3.05	1.7to3.11	24	21	24	^{56}Mn-^{56}Fe	8.641±0.047	J.Phys.Soc.Japan, No.2, 35(1973).
^{57}Fe	0.85to3.05	2.5to3.05	20	10	20	^{58}Fe-^{58}Co	8.823±0.047	
^{59}Co	1.5 to3.05	2.6to3.05	17	5	17	^{60}Co-^{60}Ni	9.050±0.043	

Reaction Mechanisum and life time measurements

(Khaliquzzaman and D. Hossain)

The programme includes the study of the mechanism of charged particle capture reactions: direct capture processes and correlation effects; statistical analysis of resonances (namely Porter Thomas distribution) and the Life time measurements of Nuclear levels by Doppler shift attenuation method.

No progress has, so far been made in data taking due to the non-availability of Ge(Li) detector, although couple of isotopic targets has been procured from the U.K. A.E.R.E., Harwell. However, some progress has been made in data handling process e.g. two computer programmes, one for the location of new levels and fitting of observed gamma rays to known level scheme, and the other for automatic location of peaks in the spectrum, have been developed. Besides, a target holder for 1" dia. target has been fabricated and vacuum tested. The thinning of the thick evaporated target has been investigated as well.

Study of low energy (d,p) reaction

(M. Ahmed and A.K.M. Siddiq*)

A programe of studying (d,p) reaction in light nuclei has been taken up around the 3 MeV Van-de-Graaff accelerator of the Atomic Energy Centre, Dacca. An 18" scattering chamber and silicon surface barrier detectors of 1 mm thickness and 25 mm^2 sensitive area are being employed for the above experiment. Energy calibration of the pulse height spectrum is done with a calibrated pulser.

A test run with ^{27}Al target has produced encouraging results from the experimental point of view. Data for ^{6}Li will be taken as soon as the target is available.

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* Physics Department, Dacca University

UNIVERSIDADE DE SÃO PAULO
Instituto de Física

PROGRESS REPORT ON NUCLEAR DATA IN BRAZIL

(June 1972 - May 1973)

compiled by

S.B. Herdade
Liaison Officer for Brazil
International Nuclear Data Committee

Work supported by COMISSÃO NACIONAL DE ENERGIA NUCLEAR,
Project TC-DPCT Nº08/73

PROGRESS REPORT ON NUCLEAR DATA IN BRAZIL[+]

(June 1972 - May 1973)

Introduction

This Progress Report covers the period: June 1972 - May 1973. It is a collection of abstracts which have been submitted to the INDC Liaison Officer upon request. The request was addressed to individuals who might represent groups doing research in nuclear physics, reactor physics, nuclear chemistry and nuclear engineering, whose results could be of interest to nuclear data compilers and evaluators. Although it was tried not to miss any appropriate institution or individual, there might have been some oversight.

Some of the abstracts here presented have been prepared to be presented at the Annual Meeting of the Brazilian Society for the Advancement of Science - Rio de Janeiro,GB - July 1973.

The information herein contained must be considered as private communications, and should not be quoted without author's permission.

S. B. Herdade

+ Work supported by COMISSÃO NACIONAL DE ENERGIA NUCLEAR, Project TC-DPCT Nº 08/73

1. Main Experimental Facilities for Nuclear Physics Research

1.1 22 MeV Herb Pelletron Accelerator (Instituto de Física - Universidade de São Paulo)

The Pelletron system consists on a 4-MV injector and a tandem- type accelerator. It is capable of furnishing beams of 22 MeV protons, 27 MeV alphas and heavy ions of energy 50 MeV for Oxygen to 80 MeV for sulphur.

The main accelerator and the injector have been installed and aligned together with the auxiliary beam handling equipment. Experimental arrangements are in various stages of development and some groups have practically completed the mounting of their chambers and detectors. Beam has been obtained in the target area.

1.2 University of São Paulo Electrostatic (Van de Graaff) Accelerator (Instituto de Física - Universidade de São Paulo)

This accelerator is capable of producing 3.5 MeV protons and deuterons and 7 MeV alphas. Beam currents obtained are 10 μamp for protons and deuterons, and alphas up to 3.5 MeV. Above 3.5 MeV the alpha current is approximately 0.1 μamp. The beam may be either continuous or pulsed at 5 MHz with about 5 manosecond pulse widths for neutron time-of-flight experiments.

1.3 PUC-RJ Van de Graaff Accelerator (Pontificia Universidade Católica - Rio de Janeiro)

High Voltage Eng. Model KN-4000 machine, with the following characteristics:

protons or deuterons: 0.5 to 4.0 MeV, 3 keV resolution, 200 μA intensity;

electrons: 1.5 to 3.0 MeV, 20 keV resolution,

900 μA itensity.

The accelerator is in operation, being utilized for atomic and nuclear physics research.

1.4 75 MeV Electron Linear Accelerator (Insituto de Física - Universidade de São Paulo)

The University of São Paulo linear accelerator is composed by two SLAC type section three meter long each. Electron beam is supplied by a 100 KV pulsed electron gun at a repetition rate of 60, 120, 180, 240, 300 and 360 cycles per second. After prebunching and focussing the beam is accelerated up to 60 MeV by the two sections. An analysing magnet allows a beam with a resolution of 0.5% in energy and an analysed current of 0.2 μA at 60 cps.

Research programs include electrodisintegration studies, electron and bremsstrahlung induced fission, and nuclear spectroscopy.

1.5 Variable Energy Cyclotron (Instituto de Engenharia Nuclear - Rio de Janeiro)

A CV-28 machine from the Cyclotron Corporation, will deliver over 50 μA of external beams of 2 to 24 MeV protons, 3 to 14 MeV deuterons, 5 to 38 MeV $^{3}He^{++}$, and 6 to 28 MeV $^{4}He^{++}$. Heavier ions can also be accelerated. Production of neutron deficient radionuclides for medical uses will be a practical application of the cyclotron. Research on nuclear spectroscopy, neutron physics, activation analysis, radiation damage, and nuclear reactions will be stimulated. The housing for the accelerator is already under construction, and will be a 1500 m^2 building with Physics and Chemistry laboratories, with a 400 m^2 experimental area.

1.6 IEA-R1 5 Mw Swimming Pool Research Reactor (Instituto de Energia Atômica - São Paulo)

Built by Babcock and Wilcox Co., became critical for the first time in September 1957. It is operated normally at 2 Mw, 8 hours a day, 5 days a week. Low-power operation and maintenance is carried out one day each fortnight. The facilities for experiments and irradiation include: 8 radial beam-holes, 2 tangential beam-holes, 2 pneumatic "rabit" stations, and 22 irradiation rigs in the core.

The reactor is utilized mainly for nuclear, neutron and solid state physics experiments, radioisotope production, and activation analysis.

Reactor power is being upgraded to 10 Mw.

1.7 IPR Triga Reactor (Instituto de Pesquisas Radioativas - Belo Horizonte)

Reactor type: Solid homogeneous, highly enriched (20%) uranium, zirconium hydride and light water moderated, light water cooled, graphite reflected.

Nominal reactor power: 30 Kw (Power is being upgraded to 250 Kw).

Purpose: Neutron physics, solid state physics, engineering tests, medicine, chemistry, isotope production, educational purposes.

Location: Belo Horizonte, MG, Brazil.

Designer and builder: General Atomic, Division of General Dynamics Corporation.

Present status: in operation.

1.8 Brazilian Argonauta Research Reactor (Instituto de Engenharia Nuclear - Rio de Janeiro)

Designed in Argonne National Laboratory, USA, and built by Mecânica CBV Ltda., Rio de Janeiro, Brazil.

Type: Argonauta (H_2O-graphite; enriched uranium 20% in ^{235}U).

Power: 10 Kw (maximum)

Fuel: UO_2-Al pressed powder mixture with cladding.

Critical mass: 2.088 Kg ^{235}U (one slab loading)

Neutron flux: average thermal: 0.57×10^{11} $n/cm^2.s$
peak thermal : 1.20×10^{11} $n/cm^2.s$
peak fast : 0.65×10^{11} $n/cm^2.s$

Experimental facilities: neutron beams (horizontal-vertical); isotope production (holes, cavities, channels); short time irradiation (rabbit pneumatic system); thermal column (internal and external); shield test removable.

Utilization: neutron and reactor physics, solid state physics, engineering test, radiochemistry, isotope production, graduate education.

1.9 Electron Linear Accelerator (Centro Brasileiro Pesquisas Físicas- Rio de Janeiro)

Energy: 28 MeV; 60 μA mean current; pulsed beam with pulses from 500 n sec to 3 μsec. This accelerator was designed and built by the Centro Brasileiro de Pesquisas Físicas Accelerator Development Group. It is in operation since 1968 and has been utilized for radio-nuclide production in nuclear spectroscopy studies. An uranium target is used for the production of pulsed neutron beams. Flight paths of 5, 10, 15, 20 and 25 meters are available for neutron time-of-flight experiments.

A high flux ^{235}U neutron source is being developed.

2. Neutron Nuclear Data

2.1 Neutron Cross-section Measurements in the keV and MeV Energy Regions

Pelletron and Van de Graaff Laboratories (Instituto de Física - Universidade de São Paulo)

A program for neutron cross-section measurements in the keV and MeV energy regions is being elaborated with the colaboration of the INDC liaison officer for Brazil.

This program will be partially based on the 1973 edition of WRENDA, and it is expected that the first experiments will start in September 1973, at the Herb Pelletron Accelerator (see §1.1 of this report), using the reaction T(p,n) as a neutron source.

Both time-of-flight and associate particle techniques are going to be used for neutron spectrometry measurements.

2.2 Spin Assignment to Neutron Resonances in Silver odd-odd Compound Nuclei

A. Gonçalves, N. Lisbona and S. de Barros (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro; and Instituto de Física - Universidade de São Paulo)

The gamma-rays emitted after the capture reaction $^{107,109}Ag(n,\gamma)^{108,110}$ have been studied with a neutron time-of-flight spectrometer in the energy range 7 to 440 eV.

The method of spin assignment to neutron resonances, based on the multiplicity of the gamma-gamma cascade, previously applied to odd-odd target nuclei with relatively high spin, has been employed with success for the case of the odd-odd Ag isotopes with spin 1/2.

Spin 0 has been assigned to the level 139,7 eV of the ^{110}Ag compound nucleus. (See also item 2.7)

2.3 Slow-neutron Scattering Cross-section for Methanol, Ethanol, Propanol, Iso-propanol, Butanol, Ethanediol, and Propanetriol

C. Rodriguez, L.A. Vinhas, S.B. Herdade+ and L.Q. Amaral (Instituto de Energia Atômica - São Paulo)

J.Nucl.Energy 26, 379(1972)-EXFOR 30230

Slow neutron scattering cross-sections per proton σ_s/H for methanol, ethanol, n-propanol, isopropanol, n-butanol, ethanediol and propanetriol have been measured in the liquid phase, in order to study the freedom of rotational motion of hydrogenous groups. The measurements, at room temperature, were carried out using a curved slit slow-neutron chopper and time-of-flight spectrometer. The slopes of the cross-section curves as a function of neutron wave-lenght in the range 4.8 Å to 10.0Å have been derived. The results show the importance of methyl group rotational motion and give evidence of the contribution of methylene groups in the inelastic scattering of slow neutrons. The curve σ_s/H for methanol is compared with the already calculated curve on basis of the Krieger-Nelkin model.

2.4 Study of the Atomic Motions of tert-butanol by Slow-neutron Scattering

L.Q. Amaral - PhD Thesis (November 1972) Instituto de Física - Universidade de São Paulo (187 pages, in portuguese)

The atomic motions of tert-butanol $(CH_3)_3COH$, classified as a globular compound, with a melting

+ Presently at the Instituto de Física - Universidade de São Paulo

point at $\sim 25^{o}C$ and a first order phase transition at $\sim 13^{o}C$, are studied in the temperature interval $0^{o}C$ to $40^{o}C$ by neutron transmission and neutron inelastic scattering measurements, performed with a single crystal spectrometer and a Be filter/chopper/time-of-flight spectrometer at the IEA-R1 swimming-poool research reactor.

A survey about neutron scattering as a spectrometric technique and a review of the theory, with emphasis in the incoherent scattering by molecular solids and liquids, are also presented.

In the data analysis the complementary character of the information obtained from transmission, inelastic and quasi-elastic scattering is stressed. Transmission data, as a function of temperature and neutron wavelenght, shows that the dynamical changes are more important at the state transition and give an estimative of (3.8 ± 0.5) kcal/mol for the barrier hindering the CH_3 internal rotation. The generalized frequency spectrum up to 80 MeV is obtained from the inelastic distribution and expressed as a sum of seven gaussians, after correction for the width of the incident line, with peaks at 4.5, 7.4, 12, 19, 31 and 58 MeV. The assignment of the 31 MeV peak as the $1 \rightarrow 0$ transition of methyl torsion gives a value of (4.0 ± 0.2) kcal/mol for the three-fold barrier hindering internal rotation, which is practically independent of intermolecular forces. The quasi-elastic line broadening is analysed in terms of models for diffusion and relaxation processes.

The results evidentiate the solid-like behavior of liquid tert-butanol, suggesting that the low entropy of melting is due to ordering in the liquid and not to almost free rotation in crystal I. However, rotational diffusion does occur in the solid state, but must involve aggregates of bound molecules.

2.5 Slow Neutron Scattering in Hydrogenous Molecules

L.Q. Amaral, R. Fulfaro and L.A. Vinhas (Instituto de Energia Atômica - São Paulo)

Integral and differential measurements of the slow-neutron scattering in some Hydrogenous molecules are being carried out in parallel, with the objective of obtaining complementary information. Being sensitive to all kinds of hydrogen motions, the slow-neutron scattering provides information on the internal dynamics of the molecula as well as on the overall molecular rotations, and lattice vibrations.

Transmission measurements are carried out using a crystal spectrometer that, by utilization of convenient monochromators and filters, can be operated in the energy range from 1 meV to 1 eV. Differential measurements are being performed with a Be filter/chopper/time-of-flight spectrometer. The quasi-elastic line broadening is analysed in terms of models for the diffusion and relaxation processes; from the inelastic distribution the effective frequency spectrum of hydrogen in the molecule is obtained up to 80 MeV.

Compounds that present phase transitions in the solid state are under study. A cryostat allows measurements until liquid nitrogen temperature-Globular compounds (tert-butanol, cyclohexane and cyclohexanol) and biological molecules (DNA) are being investigated.

2.6 Three-axis-Crystal Spectrometer

R. Fulfaro, L.A. Vinhas and L.Q.Amaral (Instituto de Energia Atômica - São Paulo)

A three-axis crystal spectrometer is being built

at one of the experimental channels of the IEA-R1 research reactor. It is intended to be utilized for neutron inelastic scattering measurements and lattice dynamics studies.

The heavy structural and shield parts, built by a local company, have been installed and aligned with a laser. The colimation system has been projected and is being built. The goniometric tables for the monochromator, sample and analyser have been imported from Poland. The system for energy analysis has been ordered from Picker Company, pyrolitic graphite single crystals are also being imported. The monochromator controlling system has been built by a local industry.

This spectrometer is expected to be operational by the end of 1973.

2.7 Radioactive Neutron Capture in odd-even Nuclei $^{107,109}Ag$ and ^{133}Cs

S. de Barros, A. Gonçalves and N. Lisbona(Instituto de Física - Universidade de São Paulo)

The neutron energy range previously covered for silver (see §2.2) has been extended up to 900 eV. In the case of cesium, resonances have been analysed in the energy range from a few eV up to 900 eV. Both experiments, on silver and cesium, are in a phase of data analysis. Spins are being assigned to several s-wave resonances of the odd-odd nuclei $^{108,110}Ag$ and ^{134}Cs.

2.8 Spin Assignments to the odd Nucleus $^{75}As+n$

N. Lisbona, S. de Barros, and A. Gonçalves (Instituto de Física - Universidade de São Paulo and Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro)

Spins 2, 1, 2, 1 and 1 have been assigned to the resonances 47.0 ± 0.2, 92.4 ± 0.3, 252.7 ± 0.5, 455.5 ± 0.6 and 476.9 ± 0.6 eV, respectively. A disagreement has been observed for the spin 1, assigned in this work to the resonance 326.7 ± 0.5 eV, as compared with previous assignments (spin 2). Three new resonance levels have been evidenced, 308 ± 5, 516 ± 10, and 713 ± 13 eV, and are probably related to p-waves in ^{76}As. Two other levels, 493.3 ± 0.3, and 874.6 ± 0.6 eV, previously evidenced by other authors, have been confirmed in the present work.

3. Fission Data

3.1 Number of Neutrons ν Emitted in the Photofission of ^{238}U

O.Y. Mafra, M.F. Cesar, A.M.P. Kuniyoshi (Instituto de Energia Atômica), and J. Goldemberg (Instituto de Física - Universidade de São Paulo)

Measurements of the average number of neutrons ν emitted in the photofission of ^{238}U as a function of energy in the range 5 to 11 MeV are being carried out.

Neutron-capture gamma rays produced in the IEA-R1 research reactor are utilized. A fission chamber is placed in the gamma-ray beam and the neutrons produced in each fission event are detected by a "long-counter" formed by 6 BF_3 detectors surrounding the chamber. A coincidence system with a variable delay time is utilized. This system is being initially tested with a ^{252}Cf source in which the number of neutrons per fission ν is well known.

3.2 Angular Distribution of the Fragments from the Photofission of ^{238}U

S. Kuniyoshi, C. Renner, O.Y. Mafra (Instituto de Energia Atômica) and J. Goldember (Instituto de Física - Universidade de São Paulo)

The angular distribution of the fragments from the photofission of ^{238}U induced by monochromatic photons of 5.43 MeV has been measured using glass detectors. The gamma-rays have been produced by thermal neutron capture in sulfur, at the IEA-R1 research reactor. In the analysis of the results only the contributions of the terms (J^{π},K), $(1^-,0)$, $(1^-,1)$ and $(2^+,0)$ (Dipole and quadrupole) have been considered, so that the angular distribution of the fragments may be given by:

$$W(\theta) = a + b\sin^2\theta + c\sin^2 2\theta$$

The following values have been obtained for the coefficients of the above distribution, already corrected for the contributions of secondary gamma-ray lines from the source:

$a = 0.03 \pm 0.59$

$b = 1.2 \pm 0.7$

$c = 0.6 \pm 0.3$

Therefore, the existence of a strong quadrupole component has been observed at this energy.

3.3 Electron Induced Fission of ^{238}U

J.D.T. Arruda Neto, S.B. Herdade and I.C. Nascimento
(Instituto de Física - Universidade de São Paulo)

The electron induced fission cross-section of ^{238}U has been measured in the energy range 8 to 52 MeV, using the electron beam of the Linear Accelerator of the University of São Paulo. Mica foils have been used as fission fragment detectors.

The experimental results have been compared with calculated curves for E1, M1 and E2 transitions, and also with the curve obtained by Onley and Ressler (Phys. Rev. Letters 22,236-1969) corresponding to the contribution of the giant resonance for the cross-section.

For energies above 20 MeV the experimental points are consistent with the calculations corresponding to E1 or M1 transitions, excluding the possibility of significant contributions of E2 transitions. The comparison with the calculations by Onley and Ressler shows a pronounced discrepancy that cannot be explained even taking into account corrections for Coulomb distortions of the electron waves and the experimental uncertainties.

3.4 High-energy-proton fission Cross-Sections of U, Th and Bi

H.G. de Carvalho, R.A.M.S. Nazareth and A.F. Stehney (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro)

Notas de Física, XIX, No.2 (1972)

Proton fission cross-sections of uranium, thorium and bismuth at 12.3 GeV were measured using nuclear emulsion techniques. The results ($\sigma_f(U)=794\pm80$ mb; $\sigma_f(Th)=597\pm60$ mb; $\sigma_f(Bi)=114\pm12$ mb) show that for these heavy nuclei, the fission cross-sections all decrease by a factor of about 2, when compared with their maximum value in the plateau region of 100 MeV up to 1000 MeV. A semi-empirical interpretation, about the mechanism responsible for such a fission cross-section decrease, was made.

3.5 On the Ternary Fission Induced by High Energy Protons

H.G. de Carvalho and H. Schechter (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro)

(To be published in "Il Nuovo Cimento", 1973)

Uranium was irradiated with high-energy protons: 600 MeV, 2.9 GeV, 12.3 GeV and 21.8 GeV. Using nuclear emulsions as detectors, three-prong events with cross-sections 1.2 ± 0.1 mb, 2.2 ± 0.1 mb, 4.8 ± 0.8 mb and 6.5 ± 1.2 mb, respectively, were found, along with the usual fission tracks. Our results show that as well as a true ternary fission process, a variety of other phenomena exist which can produce three-prong events and must be taken carefully into account.

3.6 Comparison of Prompt and Isomer Fission Modes

C.A. Fontenla and D.P. Fontenla (Instituto de Física Universidade de São Paulo)

Similar but not identical values within errors,

were obtained after a detailed analysis of the prompt and isomer fission modes of ^{242}Am from a previous experiment. In this regard all experimental errors, systematic, accidental and from counting statistics were propagated step by step through all the algebra up to the final formulae. We found that the fact of having twin experiments allows a partial cancelation in some systematic errors. In our results, the known prompt fission trend expected for fission of a nucleus with increasing excitation energy is not followed. If this were the case a more symmetrical mass yield distribution with a Peak/Valley value several times greater should be obtained for isomer fission with $E^* \simeq 2.9$ MeV, in comparison with the prompt fission with $E^* \simeq 5.7$ MeV. In the double potential barrier model, the two barriers can have different width and height, with experimental evidence for the second one being lower for the ^{242}Am (Gangrskii et al. Sov. J. Nucl. Phys. 10 (1970)38). Both saddle points may differ in symmetry of shape (Bolsterli et al., Phys.Rev. C5 (1972 1050). In this case and if the properties of fission are defined more by the properties of the first barrier, and isomer fission only by the second, when tunneling with 14 msec half-life. Nix et al. (Nucl.Phys. A132 (1969) 60) discussed an inconsistency for ^{242}Am when relating parameters of the spontaneous fission of the ground state and isomer fission. To remove the inconsistency they propose a two dimensional potential energy surface with two different fission paths. If we assume that a small percent of the sub-barrier ^{242}Am induced fission follows the one saddle-point path, then there will be small differences between n-induced and isomer fission. There is no way of concluding from our experiment that this could be or not the case. All suggests the necessity of a systematic study of isomer fission modes as a contribution to the mass yield distribution theory.

3.7 Determination of the yield of ^{115}Ag in the Fission of ^{232}Th induced by 14.7 ± 0.2 MeV Neutrons

A.M. dos Santos and Bartyra Arezzo (Instituto de Engenharia Nuclear - Rio de Janeiro)

A comparison of the mass-distribution curve for the fission of ^{232}Th with 14.7 ± 0.2 MeV neutrons with those of ^{235}U and ^{238}U for neutrons of the same energy shows some evidence of a small peak in the region of symmetric fission.

Few experimental data have been reported for the system ^{232}Th (14.7 ± 0.2 Mev n,f) in the mass region A=105-127, where the symmetric peak would be expected.

The present work was undertaken to measure the fission yield of ^{115}Ag to help to establish the existence of the symmetric peak. A fast radiochemical method was used to separate silver, and the ^{115}Ag was identified by its half-life and gamma-rays measured in a large active volume Ge(Li) detector.

The result obtained for the fission yield of ^{115}Ag, 0.94%, and the calculated value for the total cumulative yield of the 115 chain, 1.11-1.5%, seem to confirm the observations of several authors.

4. Photonuclear Reaction Data

4.1 Nuclear Resonance Scattering of Gamma-rays in Sb

A.A. Suarez, N. Bloise, M.L.B.C. Freitas and V.S. A. Segreto (Instituto de Energia Atômica - São Paulo)

Elastic and inelastic scattering of monochromatic photons were used for studying the nuclear energy levels of a Sb target; the photons were produced by thermal neutron capture in titanium. Two independent resonance levels were found at 6413 and 6753 keV. Angular distributions of the observed elastic and inelastic lines were measured giving the spins of some of the feeding levels. The total and partial radioactive widths of the 6413 keV and 6753 keV levels were also measured.

4.2 Re-investigation of Resonant Scattering of Gamma-rays in Cu Targets

A.A. Suarez, N. Bloise, M.L.B.C. Freitas and V.S. A. Segreto (Instituto de Energia Atômica - São Paulo)

Elastic and inelastic resonance scattering of monochromatic photons from Cu has been studied using a 40 cc Ge(Li) detector. The gamma source was obtained from thermal neutron capture in titanium. According to Giannini et al. (Nucl. Phys. A101 (1967) 145) the resonance energy was 6.07 MeV instead of 6.55 MeV as determined by us. This discrepancy was probably due to the use of NaI(Tl) detectors and a high level background. By measuring the angular distribution and realizing temperature and self-absorption experiments it was possible to establish the spin, the Γ_o/Γ ratio and the total radioactive width Γ of this resonance level.

4.3 Nuclear Elastic and Inelastic Scattering of Iron Capture Gamma-rays from Lead and Nickel

F.G. Bianchini (Instituto de Energia Atômica - São Paulo)

Revista Brasileira de Física, Vol.2, No.3 (1972),pg.191

An experimental study of some highly excited individual nuclear levels near the threshold for particle emission was carried out employing capture gamma-rays from iron, through nuclear resonant scattering measurements. The experiments were performed at a direct-beam tube facility of the IEA-R1 reactor. A large volume Ge(Li) detector installed on a rotating table was used to perform the measurements. The energies of the elastically and inelastically scattered gamma-rays, as well as the angular distribution of the elastically scattered gamma-rays from lead and nickel are presented. The spins of the resonant levels were determined and found to be in agreement with previous determinations.

4.4 Photonuclear Reactions in ^{55}Mn between 300 MeV and 1000 MeV

H.G. de Carvalho, J.B. Martins, O.A.P. Tavares (Centro Brasileiro de Pesquisas Físicas- Rio de Janeiro) and V. di Napoli, F. Salvetti (Instituto di Chimica Generale ed Inorganica dell'Universitá - Roma)

Presented at the International Conference on Photonuclear Reactions and Applications - Asilomar - Pacific Grove - California

The present work reports measurements of the cross-sections per equivalent quantum for $^{55}Mn(\gamma,n)^{54}Mn$, $^{55}Mn(\gamma,3n)^{52m}Mn$, $^{55}Mn(\gamma,3n)^{52}Mn$ and $^{55}Mn(\gamma,4n)^{51}Mn$ reactions by the activation

method, using the irradiations facilities of the Frascati 1 GeV Electron-Synchrotron at several maximum energies of the bremsstrahlung beams ranging from 300 MeV up to 1000 MeV. The ^{52}Mn isomeric yield ratio, as well as the absolute cross-section, are also presented.

4.5 The (γ,n) Reaction in ^{19}F and ^{23}Na at Energies between 0.3 GeV and 1 GeV

F. Salvetti, C. Aurisicchio, V. di Napoli (Instituto di Chimica Generale ed Inorganica dell' Universitā - Roma) and H.G. de Carvalho, J.B. Martins (Centro Brasileiro de Pesquisas Fīsicas- Rio de Janeiro)

Measurements of the cross-section per equivalent quantum of the $^{19}F(\gamma,n)^{18}F$ and $^{23}Na(\gamma,n)^{22}Na$ reactions in the energy range 0.3-1.0 GeV have been carried out. Average absolute cross-sections have been calculated of (1.30 ± 0.10) mb and (1.60 ± 0.20) mb for the two reactions, respectively, over the whole energy range considered, by means of the photon difference method.

4.6 Photoproduction of ^{18}F from ^{27}Al at energies between 0.3 and 1 GeV

V. di Napoli, A.M. Lacerenza, F. Salvetti and S.M. Terenzi (Instituto di Chimica Generale ed Inorganica dell'Universitā - Roma) and H.G. de Carvalho and J.B. Martins (Centro Brasileiro de Pesquisas Fīsicas - Rio de Janeiro)

J.inorg.nucl.Chem. 35(1973)1419-1427

Aluminium targets have been irradiated with bremsstrahlung beams at energies between 0.3 GeV and 1 GeV and the cross-sections of ^{18}F have been measured by activation analysis.

4.7 Photon-Induced Fragmentation in ^{27}Al and ^{32}S by 1-GeV Bremsstrahlung

V. di Napoli, F. Salvetti, M.L. Terranova (Instituto di Chimica Generale e Inorganica dell'Università - Roma) and H.G. de Carvalho and J.B. Martins (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro)

To be published in Physical Review 1973

Polyethylene, water, lithium fluoride, aluminium, and sulphur targets have been irradiated with 1-GeV bremsstrahlung beams at the Frascati electron synchroton and the yields of some spallation products from ^{27}Al and ^{32}S and of ^{11}C and ^{7}Be from ^{12}C, ^{16}O, ^{19}F, ^{27}Al, and ^{32}S have been measured by the induced activity and radiochemical methods. Evidence has been deduced for fragmentation from the mass-yield distribution of the photo-produced nuclides in ^{27}Al and ^{32}S.

4.8 Formation of ^{110}In isomeric States by $(\gamma,3n)$ Reaction as a Function of Energy

S.A.S. Vitiello, O.A.M. Helene and I.D. Goldman (Instituto de Física - Universidade de S. Paulo)

Indium foils (200 mg) have been irradiated at the USP Linac, with bremsstrahlung in the energy range 33 to 46 MeV (reaction threshold = 27.1 ± 0.2 MeV).

The induced activity has been measured using a Ge(Li) detector, with 3 keV resolution (for the line 1.33 MeV of Co-60), and the transitions 657.8 keV and 884.7 keV corresponding to the isomeric states 2^+(67 min) and 7^+(4.9 h), respectively, have been studied.

Significant results have been obtained for energies above 36 MeV, indicating a marked variation of the ratio $R = \Sigma 2^+ / \Sigma 7^+$, from 0.7 to 3.7.

4.9 Measurements of the Reaction $^{121}Sb(\gamma,\alpha)^{117}In$ by Residual Activity

E.A. Finotti, V.R. Vanin and I.D. Goldman (Instituto de Física - Universidade de São Paulo)

Emission of charged particles by excited nuclei with intermediate mass is strongly inhibited by the Coulomb barrier. Previous experimental results indicate that this emission is carried out through a compound nucleus mechanism (Dyal and Hummel, Phys.Rev. 115(1959)1264).

In order to complement these data, preliminary measurements of the simultaneous reactions (γ,n) and (γ,α) in Sb isotopes have been carried out at 42 MeV using bremsstrahlung from the USP Linac.

The value obtained for the ratio of the yields of the reactions $^{121}Sb(\gamma,\alpha)^{117}In$ and $^{123}Sb(\gamma,n)^{122}Sb$ was 5×10^{-4}.

4.10 Formation Ratio of Isomeric States of ^{120}Sb by (γ,n) Reactions as a Function of Energy

V.R. Vanin, J.S. de Goes and I.D. Goldman (Instituto de Física - Universidade de S.Paulo)

The antimony isotopes (Z=51) behave like spherical nuclei due to the proton stabilizing shell. The moment of inertia is reduced, this characteristics being reflected in the value less than 3, obtained for the spin cut-off parameter σ in previous results. The variation of the excitation energy may lead to alterations in σ.

Antimony foils have been irradiated with bremsstrahlung at the USP Linac, in the energy range 20 to 38 MeV. The residual activity was measured by following the decay of the transition 1171 keV, common to the states 1^+ (15.9 m) and 8^- (5.8 d). The experimental results indicate an

increase in the formation ratio $R = \Sigma 8^- / \Sigma 1^+$, with the irradiation energy. Adjusted values of R for the energies 20 MeV and 38 MeV gave the values 0.085 and 0.125, respectively. These results are consistent with the increase of σ with the energy.

4.11 Spin Distribution and Transmissibility in the Statistical Model - Isomeric State Formation

S.A.S. Vitiello and I.D. Goldman (Instituto de Física - Universidade de São Paulo)

The effect of different spin distributions, including a sharp and a smooth cutoff at a maximum spin, and the use of a parabolic potential for transmissibility calculations, was investigated following Huizenga and Vandenbosch formalism. The results have been applied to the $^{113}In(\gamma,3n)^{110}In$ and ^{110m}In reaction.

4.12 Quadrupole Transition Absorption and the Variation of Isomeric Rate Formation in the Reaction $^{121}Sb(\gamma,n)^{120}Sb$

O.A.M. Helene, J.S. Goes and I.D. Goldman (Instituto de Física - Universidade de São Paulo)

Calculations with the model proposed by Huizenga and Vandenbosch give significative variation at the isomeric rate formation with different absorption of dipole + quadrupole composition. In the calculations of the rate $\Sigma 8^- / \Sigma 1^+$ for ^{120}Sb, we have obtained differences of up to 8.5% for 80%D + 20%Q composition. From the measurement of isomeric state formation by photo- and electrodisintegration, the quadrupole composition can be deduced.

4.13 Electron - and Photodisintegration reactions in ^{12}C, ^{19}F, ^{35}Cl, ^{63}Cu and ^{65}Cu

E. Wolynec, M.N. Martins, O.D. Gonçalves, J.R. Moreira and G. Moscati (Instituto de Física - Universidade de São Paulo)

Measurements of the ratio of the electron to the photodisintegration reaction cross-section (σ_e/σ_γ) carried out for some nuclides by Barber (P.R. 111(1958) 1642) and others, have shown that the results may be explained assuming a convenient admixture of El and Ml transitions. High Z nuclides present some difficulties due to approximations that are used in the theoretical calculations.

In the present work these measurements are extended to other elements, covering low, medium and high Z. Cross-section measurements for electro- and photodisintegration of ^{12}C, ^{19}F, ^{35}Cl, ^{63}Cu and ^{65}Cu, have been carried out by irradiating, in each case, 2 thin targets ($\sim 3\times10^{-3}$RL) separated by an aluminum radiator ($\sim 2\times10^{-2}$RL), in the energy range 18 to 40 MeV, with 1 MeV energy intervals. Analysis of the data for ^{12}C has shown an agreement with previous data in the literature. Results for ^{19}F can be explained if it is assumed an almost 100% El transition. Data for the other nuclides are being processed.

5. Charged Particle Reactions

5.1 Energy Levels of ^{111}Sn, ^{113}Sn and ^{123}Sn

T. Borello, E. Frota-Pessoa, C.Q. Orsini, O. Dietzsch and E.W. Hamburger (Instituto de Física - Universidade de São Paulo)

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The reactions $^{112}Sn(d,t)^{111}Sn$, $^{112}Sn(d,p)^{113}Sn$, $^{122}Sn(d,p)^{123}Sn$ and $^{124}Sn(d,t)^{123}Sn$ were studied at incident energies of 12 or 17 MeV. The scattered particles were analysed by a high resolution magnetic spectrograph and detected in nuclear emulsions; energy resolution was ~9keV. A large number of energy levels were identified in the final nuclei: 6 levels of ^{111}Sn up to 1 MeV excitation energy, 67 levels of ^{113}Sn and 73 levels of ^{123}Sn, up to 5 MeV excitation. Angular distributions were fitted with the distorted-wave Born approximation (DWBA), yielding transfer angular momenta and spectroscopic factors for 55 states of ^{113}Sn and 39 of ^{123}Sn. The results obtained are compared with pairing theory and the weak coupling theory.

5.2 Some $^{14}N(d,p)^{15}N$ Reactions in the Deuteron Energy Range from 1 to 3 MeV

V. Porto (Instituto de Física - Universidade de São Paulo)

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In general, the (d,p) and (d,n) reactions in the energy range from 1 to 3 MeV in light nuclei show a large contribution from the stripping mechanism and also pronounced structures in the excitation curves. The structures observed seem

to be associated with the excitation of only a few particues in the compound nucleus. The purpose of this paper is to discuss some ideas concerning the $^{14}N(d,p_4)^{15}N$ (ex = 7.16 MeV), $^{14}N(d,p_5)^{15}N$ (Ex = 7.31 MeV) and $^{14}N(d,p_6)^{15}N$ (Ex = 7.57 MeV) reaction mechanism and a model is proposed to explain the broad structure ($\Gamma \sim 650$ keV) observed in the p_5 excitation curves.

5.3 Mass Excess for Tin Isotopes

M.J. Bechara and O. Dietzsch (Instituto de Física - Universidade de São Paulo)

The Q values for the reactions (d,p) and (d,t) induced in all even isotopes of Sn (A = 112, 114, 116, 118, 120, 122, 124) have been determined by the simultaneous observation of the proton and triton groups corresponding to transitions to the ground states. A target containing all even Sn isotopes in equal percentage has been utilized. The protons and tritons from the reactions have been detected by nuclear emulsions located in the focal plane of the magnetic spectrograph of the University of Pittsburgh. The values of Q(d,p) and Q(d,t) are in good accordance with the ones obtained from the table of Wapstra and Gove (Nuclear Data Tables A9 (1971) 303) for most of the reactions. Nevertheless, our results indicate values 10 keV and 18 keV higher for ^{120}Sn and ^{114}Sn respectively, than the ones presented in the table of Wapstra and Gove.

5.4 Inelastic Scattering of Protons by ^{122}Sn through Isobaric Resonances

M.S. de Assumpção, O. Dietzsch and E.W. Hamburger (Instituto de Física - Universidade de São Paulo)

The level structure of ^{122}Sn has been investigated by observing the states that are populated in the

decay by protons of isobaric analog resonances formed in the reaction $^{122}Sn + p$. Special attention has been given to states with excitation energies greater than the colective states 2^+ and 3^-, previously investigated (Dietzsch, Hamburger and Schechet, Bull. Am. Phys. Soc. 12 (67) 19). A total of 72 levels have been observed in the decay of the resonances that occur at proton energies 8.95 MeV (d 5/2), 9.25 (d 5/2) and 10.47 MeV (f 7/2). The experimental resolution for the four detectors simultaneously utilized in four different angles in less than 20 keV. The distribution of the partial widths among the several populated states is discussed.

5.5 Study of the Reaction $^{91}Zr(d,d')^{91}Zr$

T. Borello-Lewin, O. Dietzsch, E.W. Hamburger and L.B. Horodynski Matsushigue (Instituto de Física - Universidade de São Paulo)

Detailed experimental information on nuclei with proton or neutron numbers near closed shells present a great interest since, in this case, the approximations used in the theoretical calculations of nuclear structure are less drastic. We know that ^{90}Zr (N=50) presents states of strong colective characteristics; that result from the coupling of an independent particle with the excited states of ^{90}Zr, could be evidenced. Targets of ^{91}Zr have been bombarded by deuterons of 17 MeV in the University of Pittsburgh Tandem. The scattered deuterons, analysed by a magnetic spectrograph type split-pole, have been detected in nuclear emulsions with a resolution of 18 keV. The analysis of the nuclear emulsions has been carried out in São Paulo, and a preliminary study

of the data lead to the identification of 27 energy levels up to 3.3 MeV excitation, with good agreement with the proton scattering data (Phys. Rev. 182 (1969) 1320). The analysis of the angular distributions using DWBA is underway.

6. Nuclear Level Scheme and Radioactive Decay Data

6.1 Nuclear Spectroscopic Studies of Low-Lying States in ^{77}As

J.M. Gualda and R.N. Saxena (Instituto de Energia Atômica) and F.C. Zawislak (Instituto de Física - Universidade Federal do Rio Grande do Sul)

The technique of directional gamma-gamma angular correlation has been used to investigate the decay of ^{77}Ge to levels in ^{77}As. The coincidence measurements were performed using a 35 cm^2 Ge(Li) detector and a 7.6x7.6 cm Na(Tl) detector. The results of nine measured correlations served to verify the spin assignments of the low energy levels and in addition yielded values for the multipole mixing ratios of the involved gamma transitions. We also make a comparative analysis of ^{77}As and 75 As nuclei; both isotopes have a very similar low energy level structure.

6.2 Conversion Electron-Gamma and Gamma-Gamma Directional Angular Correlations in ^{160}Dy

F.C. Zawislak, J.D. Rogers and E.A. Menêses (Instituto de Física - Universidade Federal do Rio Grande do Sul)

Gamma-gamma and conversion electron-gamma angular correlations in ^{160}Dy have been measured for the 298-966 keV and 298-879 keV cascades. Particle parameters of the 966 keV E2 transition

were determined to be $b_2(E2; e_k) = +1.23 \pm 0.08$ and $b_2(E2; e_{\Sigma L+\Sigma M}) = +1.27 \pm 0.23$. The multipole mixing ratio for the 298 keV radiation was determined to be $\delta(M2/E1) = +0.04 \pm 0.01$ and we have confirmed the value $\delta(E2/M1) = -13 \pm 2$ for the 879 keV. The E0-E2 mixture parameter for the 879 keV transition was determined as $q_k = -0.03 \pm .09$ assuming penetration effects to be negligible.

6.3 Levels in the N=82 Nucleus ^{142}Nd

F.M. Smolka and A.G. Pinho (Departamento de Física, Pontificia Universidade Católica - Rio de Janeiro)

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Decays of both ^{142}Pr and ^{142}Pm to levels in the 82 - neutron isotone ^{142}Nd were investigated with Ge(Li) detectors. The ^{142}Pm was not separated from the ^{142}Sm source and some ambiguity is present in the assignment of gamma-rays with energies up to 2.05 MeV. Spin and parity assignments were made for all levels. The resulting level scheme is compared with predictions of theoretical calculations.

6.4 The decay of ^{58}Cu

H.W. Jongsma, J. Bron, H. Verheul (Natuurkundig Laboratorium der Vrije Universiteit, Amsterdam, The Netherlands), and A.G. da Silva (Instituto de Engenharia Nuclear - Rio de Janeiro)

Nucl.Phys.A179 (1972) 554-560

The energies and relative intensities of the gamma-rays and the relative intensity of the annihilation radiation from the decay of ^{58}Cu have been measured. Levels at 4449.9 keV and 4538.3 keV in ^{58}Ni were found to be populated in this decay. The intensity of the β^+ feeding of the 3594.9 keV level was found to be <0.1%.

6.5 Decay Scheme of ^{228}Ac

H.M. Vasconcellos (COPE, Universidade Federal do Rio de Janeiro), A.G. da Silva, L.T. Auler (Instituto de Engenharia Nuclear - Rio de Janeiro), and T.A.E.C. Pratt (Instituto de Física - Universidade Federal do Rio de Janeiro)

Studies of the disintegration of ^{228}Ac have been started. Preliminary results indicate new transition. A computer code has been utilized to obtain the positions and areas of the peaks appearing in the gamma-ray spectra.

6.6 Excited Levels in ^{208}Tl

A.G. da Silva, L.T. Auler, G.L. de Almeida, R.H. Topke (Instituto de Engenharia Nuclear - Rio de Janeiro)

The energies and relative intensities of gamma-rays from excited levels of ^{208}Tl populated in the alpha-decay of ^{212}Bi have been measured using coincidence techniques. These values are consistent with those obtained from alpha-particle spectroscopy data. Low intensity gamma-ray transitions of 493 and 620 keV have been found which had not been detected before. An upper limit of .004% has been set for the intensities of possible transitions of 124, 145, 165 and 295 keV report earlier. K-shell internal conversion coefficients were obtained.

6.7 Half-lives of some Excited States of ^{208}Tl

A.G. da Silva, L.T. Auler, G.L. de Almeida, R.H. Topke (Instituto de Engenharia Nuclear - Rio de Janeiro)

The Doppler shift attenuation method is being utilized to try to measure half-lives ($\sim 10^{-12}$ sec)

of excited states of ^{208}Tl, populated by the α-decay of ^{212}Bi. This Method is frequently utilized when the states are reached through nuclear reactions in light nuclei, since in this case the Doppler shift is enhanced due to the high speed of the recoil nucleus. This is not the case for the recoil nucleus ^{208}Tl, the maximum shift being of one part in 1000, approximately, corresponding to ~300 eV for the 288 keV gamma radiation of this nuclide. Nevertheless, this effect has been detected by α-γ coincidence measurements using Ge(Li) detector, the ^{208}Tl recoiling in vacuum. The choice of a convenient material is under study to be used as a moderator for the recoil nucleus so that the half-lives could be evaluated.

6.8 Weak Transitions in ^{44}Ca

L. Tauhata and A. Marques (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro)

Notas de Física, XVIII, No.21 (1972)

An analysis has been made of the excited states of ^{44}Ca using the gamma transitions from the β^+ and EC decay of $^{44m,44}Sc$. Besides the already known transitions, two other have been detected, 728 keV and 564 keV, of low intensity.

The transition of 728 keV between the states 0^+ at 1885 keV and 2^+ ($\nu=2$) at 1157 keV, suggests the possibility of the state 0^+ to be formed by the decay of $^{44m,44}Sc$ (log ft=8.6), being characterized as a state of core excitation with configuration described by $(f\ 7/6)^6.(d\ 3/2)^{-2}$ or $(f\ 7/2 - p\ 3/2)^6.(s\ 1/2 - d\ 3/2)^{-2}$.

The asign of $(5^+,-)$ has been given to the 2850 keV state.

6.9 IEA-R1 Conversion Electron Magnetic Spectrometer

Brigitte R.S. Pecequilo and A.A. Suarez (Instituto de Energia Atômica - São Paulo)

The spectrometer has been optimized as far as the target and detector positions are concerned.

The K 411 conversion line of Hg-198 has been measured in order to verify intensity effects observed in the spectrometer.

6.10 X_L-rays from Heavy Elements: Fluorescence and Coster-Kroning Yields

M. Weksler and A.G. de Pinho (Departamento de Física - Pontificia Universidade Católica - Rio de Janeiro)

The X_L-ray spectra resulting from the internal conversion of nuclear electromagnetic transitions have been analysed for four heavy elements: Bismuth (Z=83), Radon (Z=86), Radium (Z=88), and Neptunium (Z=93). Informations on the fluorescence yield as well as on the probabilities of relative transitions by the non-radiactive processes (Auger and Coster-Kroning) are obtained. The results are compared with the (few) experimental data already known and with the available theoretical calculations.

6.11 Decay of 2.1-hour ^{178}Ta

O.A.M. Helene and I.D. Goldman (Instituto de Física Universidade de São Paulo)

A recent measurement (Helner and Reich, NPA 114 (1968) 649) of the ^{178}Hf levels, has demonstrated the existence of a rotational band with K=8, based on the 1147.44 keV level. A lower limit for the existence of the transitions $(8^-) \rightarrow (9^-)$, 116 keV and $(9^-) \rightarrow (8^-)$, 216.67 keV, was determined preliminarily with intensities $< 0.1\%$.

6.12 Study of the Levels of ^{53}Mn through the decay of ^{53}Fe

L.F. Ulhoa Canto and S. de Barros (Instituto de Física - Universidade de São Paulo)

Excited states of ^{53}Mn resulting from the decay of ^{53}Fe have been studied with high resolution γ-ray spectrometry and good statistics. Two new lines have been observed, 1177 keV and 2306 keV, attributed to transitions from the level 2686 keV (already known) to the level 380 keV, and from the level 1177 keV to the ground state, respectively. For the β groups that feed the levels 1177 keV and 2686 keV, values of log ft equal to 5.8 and 5.5 have been determined, respectively.

From the results of the present work, a new decay scheme for ^{53}Mn is proposed.

6.13 Study of the Levels of ^{38}Ar through the β-decay of ^{38}K

S. de Barros, A. Miranda and C. Pascholati (Instituto de Física - Universidade de São Paulo)

The nuclide ^{38}K ($T_{1/2}$=7.7 min) has been obtained by irradiation of samples of KI with a bremsstrahlung beam at the USP Electron Linac. The gamma spectrum of the activated samples has been analysed with high resolution and good statistics. A new decay scheme for ^{38}K is proposed.

Addresses of Institutions mentioned in this Progress Report

Instituto de Física - Universidade de São Paulo
Caixa Postal 20516 - São Paulo-SP, Brazil

Instituto de Energia Atômica
Caixa Postal 11049 - Pinheiros
São Paulo-SP, Brazil

Centro Brasileiro de Pesquisas Físicas
Av. Wenceslau Braz, 71
Rio de Janeiro-GB, Brazil

Instituto de Física
Pontificia Universidade Católica
Rua Marquês de São Vicente, 209/263
Rio de Janeiro-GB, Brazil ZC-20

Instituto de Engenharia Nuclear
Caixa Postal 2186 - ZC-00
20000 Rio de Janeiro-GB, Brazil

Instituto de Pesquisas Radioativas
Caixa Postal 1941 - Belo Horizonte-MG, Brazil

Instituto de Física
Universidade Federal do Rio Grande do Sul
Av. Luiz Englert s/n
90000 Pôrto Alegre-RS, Brazil

S.B. Herdade
Liaison Officer for Brazil - INDC
Instituto de Física - USP
Caixa Postal 20516
São Paulo-SP, Brazil

GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN INDIA - IX

Compiled by

M. Balakrishnan and A.S. Divatia
Indian Nuclear Data
Nuclear Physics Division

BHABHA ATOMIC RESEARCH CENTRE
BOMBAY, INDIA

1973

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INDIAN NUCLEAR DATA GROUP

MEMBERS

1.	M. Balakrishnan (Secretary)	: Nuclear Physics Division * BARC
2.	V.C. Deniz	: Reactor Engineering Division BARC
3.	A.S. Divatia (Convener)	: Nuclear Physics Division BARC
4.	S.S. Kapoor	: Nuclear Physics Division BARC
5.	D.N. Kundu	: Saha Institute of Nuclear Physics, 92 Acharya Prafulla Chandra Road, Calcutta-9.
6.	B.P. Rastogi	: Reactor Engineering Dmision BARC
7.	N.S. Satya Murthy	: Nuclear Physics Division BARC
8.	N.C. Bhattacharya (Co-opted)	: Variable Energy Cyclotron Project, BARC
9.	S.B. Garg "	: Reactor Engineering Division BARC
10.	M.C. Joshi "	: Dept., of Physics University of Bombay, C.S.T. Road, Kalina, Bombay 400029
11.	S.K. Mitra "	: Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400005
12.	M.P. Navalkar "	: Nuclear Physics Division, BARC
13.	P.K. Patwardhan "	: Electronics Division, BARC

* Bhabha Atomic Research Centre, Trombay, BOMBAY 400085

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I N T R O D U C T I O N

The ninth progress report on Nuclear Data Activities in India covers the work done during the year 1972. A part of the work given in this report has been presented at the Nuclear Physics and Solid State Physics Symposium held at Chandigarh during December 1972.

The total number of CINDA entries sent to the Nuclear Data Section of the International Atomic Energy Agency during the period of the report is 75. The liaison activity with computer programme library (CPL) of the OECD Nuclear Energy Agency was continued.

Progress report on new facilities for research is as follows:

1. Pulsed Fast Reactor

Further design work on the Kalpakkam Pulsed Fast Reactor continued during the year. Since the criticality of the PURNIMA critical facility at Trombay, in May 1972, several measurements have been carried out in connection with the optimization of the physics parameters of the Pulsed Fast Reactor. The mean prompt neutron life time of the PuO_2 fuelled reference core has been measured as 50 nano seconds. Reactivity measurements are being carried out with sliding blocks of Beryllium, Aluminium, Titanium etc. which are being considered for the pulsing mechanism.

2. 224 cm Variable Energy Cyclotron

The construction work on the 224 cm Variable Energy Cyclotron at Calcutta has made further progress during the year. The fabrication of the magnet at the Heavy Engineering Corporation, Ranchi is nearing completion, and the delivery is expected around October, 1973. Half of the magnet coils are ready at the Heavy Electricals (India) Limited, Bhopal. The R.F. System fabrication is well under way. The Power supplies have been built and tested. The vacuum system is being assembled at site, and work on the deflector, ion source and other components is also progressing. The tender for the analysing magnet castings has been issued. The VEC Laboratory building is ready and it has been occupied. Detailed preparations for the utilization of the cyclotron have started. The cyclotron is expected to go into operation in 1974.

(A.S. Divatia)
Convener
Indian Nuclear Data Group

A. BHABHA ATOMIC RESEARCH CENTRE, BOMBAY 400 085

1. (p,n) Reaction Cross-Section Measurements on ^{50}Ti, ^{54}Cr, and ^{59}Co - S.N. Chintalapudi , S. Kailas, N.K. Ganguly, S. K. Gupta, L.J. Kanetkar, S. S. Kerekatte and M.K. Mehta - Measurements of total cross-sections for the reactions $^{50}Ti(p,n)^{50}V$, $^{54}Cr(p,n)^{54}Mn$ and $^{59}Co(p,n)^{59}Ni$ have been done for the ranges of proton energy E_p from 3.4 to 4.9 MeV, 2.2 to 5.2 MeV and 2 to 5.1 MeV respectively employing a 4π- geometry neutron counter. The thicknesses of the targets were of the order of 4 keV in all cases for $E_p \sim 4$ MeV. The excitation functions measured with keV steps exhibit structures of about 15 keV widths. On averaging the excitation functions over about 100 keV intervals, they show intermediate width structures. The optical model has been used to calculate theoretical reaction cross-sections to fit the measured data after performing averages over suitable intervals.

2. The Reaction $^{40}Ca(\alpha,\gamma)^{44}Ti$ in the Region of Excitation Above 8 MeV in ^{44}Ti - M. Ismail, M. A. Eswaran and N.L. Ragoowansi - With a view to study the isobaric analogue states in the region of excitation function for the reaction $^{40}Ca(\alpha,\gamma)^{44}Ti$ has been obtained in the range of bombarding energies E=3.240 to 3.410 MeV and 4.390 to 4.750 MeV. A weak

resonance was located at E_α = 3.346 ± 0.015 MeV (Γ < 5 keV) corresponding to the compound nucleus excitation of 8.162±0.015 MeV in ^{44}Ti. This is in agreement with the level located at an excitation of 8.17 ± 0.20 MeV in ^{44}Ti by Cerny et al[1] in their study of β - delayed α particles from the decay of the neutron - deficient isotope ^{44}V (T = -1). The upper limit of the strength of this resonance has been determined to be $(2J+1)\Gamma_\alpha\Gamma_\gamma/\Gamma$ < 3.5 eV. In the higher range of bombarding energies studied in the present work, two resonances at E = 4.470 and 4.520 MeV have been located with widths Γ < 20 keV and Γ < 30 keV respectively.

(1) J. Cerny, D.R. Goosman and D.E. Alburger, Phys. Lett. 37 B (1971) 380.

3. Properties of States in ^{33}S - M. Balakrishnan, M. K. Mehta, S. Kailas, L.J. Kanetkar and A.S. Divatia - Levels in the compound nucleus ^{33}S have been investigated by measuring the total yield of neutrons from the reaction ^{29}Si(α,n)^{32}S for alpha energies E_α = 2.3 MeV to 4.7 MeV in steps of 2.5 keV using a 4π neutron counter. The target thickness was estimated to be 7.7 keV for 1.6 MeV alphas from a separate alpha scattering measurement. The yields were converted to absolute total cross sections. 103 resonances were identified and total level widths determined for 75 stronger and resolved widths γ_α^2 and γ_n^2 have been determined for 19 resonances.

4. Resonances Below The Analogue Threshold in ^{73}As

- M.G. Betigeri, N.S. Thampi, L.P. Varma* and M.Y. Vaze - The elastic scattering of protons on ^{72}Ge in the energy range 2.6 - 3.4 MeV in steps of 1.5 KeV was studied. A number of resonances of approximately 20 KeV width are observed. The results are compared with $^{72}Ge(p,p'e)$ studies in the same energy range. It is known that the isobaric analogue threshold occurs at E_p =3.374 MeV. It is interesting to know what these resonances are.

5. Statistical Properties of Excited Nuclei And the Determination of the Ground-State Shell Correction Energies

- V.S. Ramamurthy and S.S. Kapoor - A new method is proposed to calculate the ground-state shell correction energies of nuclei without recouree to Strutinsky's smearing procedure. We have shown earlier that a plot of the square of the calculated thermodynamic entropy of a nucleus versus its excitation energy exhibits in the asymptotic high energy region, a smooth behaviour and the energy intercept of the smooth part of the plot is numerically equal to the ground state shell correction energy of the nucleus. In the present work, we have examined in detail the temperature dependence of the thermodynamic quantities, namely the chemical potential, entropy and the total energy of a nucleus, and show that their asymptotic high energy behaviour leads to a unique definition and determination of the ground state shell correction energies. Results of calculations are presented for a number of nuclei starting from a modified harmonic oscillator

* Banaras Hindu University, Varanasi

single particle energy level scheme. The calculated shell corrections are in close agreement with the values obtained by the Strutinsky prescription and, as a function of deformation, give rise to the familiar double humped fission barriers for actinide nuclei.

6. Hauser-Feshbasch Calculations on U^{235} - U.Satyanarayana,* S.Rama Murty* and S.B. Garg - Hauser-Feshbasch calculations have been performed for $U^{235}(n,n)$, E_n = 1 MeV, taking into account the five known rotational bands of U^{235}, based on 0, 0.0008, 0.12927, 0.33282, 0.39319 MeV levels and a 6-parameter Saxon - Woods form optical potential in an ABACUS programme in order to see the role played by the different rotational bands, as also the spin-parities of 0.01303, 0.04622, 0.05169, and 0.1303 MeV levels. The parity of a level has a pronounced effect on the cross section changing even the order of magnitude, whereas the spin of a level does not have such an effect. The effect of the presence of several rotational bands appears clearly and invariably, to be a reduction in the cross section.

7. Su(4) Symmetry Exhibited By Odd-Odd Nuclei in 1 f 7/2 Shell - S.K. Gupta.- The experimental separations $\Delta E(T_z+1, T_z)$ between the lowest $T = T_z + 1$ and $T = |T_z|$ states for odd-odd nuclei in the 1 f 7/2 shell show that $\Delta E(2,1) - \Delta E(1,0) \approx 2[\Delta E(3,2) - \Delta E(2,1)] \approx 2[\Delta E(4,3) - \Delta E(3,2)]$ This feature is very

* Laboratories for Nuclear Research, Andhra University, Waltair.

well predicted by the supermultiplet scheme emplying the SU(4) group. It has been found that the Wigner plus Majorna interaction dominates the Bartlett plus Heisenberg interaction by analyzing the experimental data.

8. On the Ground State Spins of the Spherical Odd-Odd Nuclei - S. Saini and S.K. Gupta - An up to date analysis of the ground state spins of the odd-odd nuclei has been done. The spherical nuclei with the configuration $(n_p\ l_p\ j_p)^{k_p}$, $(n_n\ l_n\ j_n)^{k_n}$ can be classified in to three classes, according to whether 1) $n_p = n_n, l_p = l_n$, $j_p = j_n$; 2) $l_p \neq l_n$, $j_p \neq j_n$ or $l_p = l_n$, $j_p = j_n$, 3) $l_p \neq l_n$, $j_p = j_n$. In the case of (1), rules given by Gupta are applicable. Defining $\lambda = \frac{(2j_p + 1 - 2k_p)}{2j_p - 1} \frac{(2j_n + 1 - 2k_n)}{2j_n - 1}$ and $N = j_p + l_p + j_n + l_n$, the nuclei falling in the case (2) are classified according to whether 2a) $\lambda \geq 0$ (j_p or $j_n \neq \frac{1}{2}$) and N even or odd 2b) $\lambda = 0$, j_p or $j_n = \frac{1}{2}$ and 2c) $\lambda < 0$. In case (2a-c), the Nordheim's rules, the De-Shalit and Walecka rule and the Brennan and Brenstein rule are applicable respectively. In case (3): a new empirical rule is proposed. Assuming a zero range interaction rules (2a-c) have been analysed.

9. Neutron Time-Of-Flight Spectra in the Reaction $^{26}Mg(\alpha, n\gamma)^{29}Si$ - N.L. Ragoowansi, M.A. Eswaran, H.H. Oza and M. Ismail - With a beam of 4.5 MeV particles from the Van de

Graaff accelerator, the time-of-flight spectra of several outgoing neutron groups have been obtained simultaneously in the reaction $^{26}Mg(\alpha,n\gamma)^{29}Si$. The time range possible in the system is 150 nano-seconds. With a flight path of 1.5 meters and using the γ-ray pulse for the start signal the time-of-flight spectra were obtained by recording data in a two-parameter mode in a 64 X 64 channel analyser, with neutron time of flight as one parameter and γ-ray pulse-height as the second parameter. By this arrangement time-of-flight spectra for the four neutron groups feeding the excited states at 1.275, 2.032, 2.427 and 3.069 MeV in ^{29}Si have been obtained simultaneously in a single accelerator run in coincidence with the corresponding rays deexciting these four excited states.

10. Evidence for the Simultaneous Emission of Two Light Charged Particles in Thermal Neutron Fission of U^{235} - S. S. Kapoor, R.K. Choudhury, S.K Kataria, S.R.S. Murthy and V. S. Ramamurthy - The present investigations in the thermal neutron fission of U^{235} have shown the occurance of some rare events which involce a simultaneous emission of two main fragments. The probability of such events is found to be about one in 10^6 binary fission events, if the data are analysed on the assumption that the directions of emission of the two LCP are uncorrelated. The energy spectrum of the LCP emitted in such events appears to have a two-peaked shape with the most probable energies in the neighbourhood of 8 MeV and 15 MeV. Different possible mechanisms leading to a simultaneous emission of two

light charged particles in fisson are examined.

11. The (n,2n) Reaction Cross-Section of K^{39} and N^{14} at 14 MeV - S.C. Misra, U.C. Gupta and U.S. Rao - The $K^{39}(n,2n)K^{38}$ and $N^{14}(n,2n)N^{13}$ cross sections have been measured relative to the (n,2n) cross section of Cu^{63} at 14.6 ± 0.2 MeV. The activity of the irradiated samples was measured by counting the 0.51 MeV annihilation photons in a well type NaI(Tl) crystal. The measurements were taken for three different volumes of the sample. Effect of short term variation of flux was studied by monitoring the neutron output during irradiation and was found to be negligible. The values obtained are 2.12 ± 0.15 mb and 5.37 ± 0.43 mb for K^{39} and N^{14} respectively. The (n,2n) cross section of Cu^{63} used for these measurements was 532 mb.

12. Energy Variation of Real Optical Potential for Protons - D.K. Srivastava, B.C. Sinha* and N.K. Ganguly - The direct and exchange contributions to the real part of the reformulated optical potential are calculated for Ca-40 and Pb-208 in the energy range of 20-100 MeV, using the strong density dependent nucleon-nucleon potential of Green. The direct part and the total real optical potential are found to decrease linearly with energy with the gradients of 0.05 and

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* Visiting Member from King's College, London.

0.20 respectively. The volume integral of the real potential is also found to decrease with energy.

13. Analysis of the ^{28}Si Elastic Scattering From ^{28}Si - S. Saini and M.K. Mehta - An optical model, with a ℓ- dependence in the imaginary part of the potential; is used to fit the Chalk River data on ^{28}Si + ^{28}Si elastic scattering. We have done the fitting with and without the ℓ -dependent imaginary part. We find that at lower energies (20,25,30 MeV), a shallow potential fits the angular distributions quite well. The introduction of ℓ - dependent imaginary potential does not change the character of fits at these energies. But at higher energies (33.5, 38.5, 42 MeV), an ℓ -dependence improves the quality of the fits. The optical model parameters used are; V=7.0+0.25 E cm. W=(0.2+0.15 E cm.), R_c=5.000F, R_o=1.35F and a=0.49F. The fit to the excitation functions are also satisfactory.

14. Studies on an N=8, E=½ mc^2 Spiral Sectored Cyclotron - A. Jain and A.S. Divatia - Expressions for the orbit properties τ , ν_z and ν_γ convenient for sector design and optimization in azimuthally varying field cyclotrons have been derived and verified by constructing the sectors for an N=3, ½ mc^2 electron analogue cyclotron magnet[1]. These equations are now investigated for the case of N=8 sectors. Spiral sectors for an N=8,

$\frac{1}{2}$ mc^2 electron cyclotron magnet have been constructed and the magnetic field mapped. Difficulties observed in the numerical integration of the orbits arising from the presence of high field gradients in this case are analysed. In an attempt to overcome these difficulties, application of an analytical representation of the magnetic field in a curved co-ordinate system has been investigated. Orbit properties expected using the design equations[1] are compared with those obtained by numerical integration of the orbits.

1) 'Orbit Dynamics and Design Theory for Optimization of Sector Shapes in Isochronous Cyclotrons'. A. Jain and A.S. Divatia, to be published.

15. He^3 Neutron Spectrometer - B.K. Godwal and M.P. Navalkar - The difficulties encountered in using He^3 nuclear detector as neutron spectrometer are mainly two-fold: (a) Wall Effect and (b) Recoil Effect. In the present work it is shown how the above limitations in the use of a He^3 detector can be eliminated and the raw spectrum is made free of wall and recoil effect events. The resultant spectrum can then be used directly to obtain the neutron spectrum of any neutron source. A computer program in Fortran-IV for CDC 3600 has been written in this connection. Preliminary experimental results have also been obtained.

16. Recoil Implantation of Ga in Si by Ar^+ and Kr^+ Ions - A.G. Wagh, N. Sarma, D.K. Sood and N.S. Thampi - The technique of recoil implantation could be an economic means of producing n-type or p-type layers of submicron thickness on semiconductors by using gas ion beams. To investigate the usefulness of this technique, we have studied recoil implantation of Ga in Si by using Ar^+ and Kr^+ ions. Single crystals of n-type Si with high and medium resistivity are chosen. Ga is vacuum evaporated as a thin layer on Si, with predetermined thickness monitored by a quartz crystal oscillator unit. Such prepared layers are then bombarded with Ar^+ and Kr^+ ions in the energy range of 100 to 300 keV and several samples are prepared with fluences varying from 6.24 X 10^{16} ions/cm^2. The unimplanted Ga is disolved on prolonged treatment with concentrated HNO_3.

The number N, of recoil implanted Ga atoms per incident gas ion is measured by back scattering of 2 MeV alpha particle beam. Variation of N with the incident ion dose, energy and mass is discussed. On annealing at 700°C for 45 minutes in Argon atmosphere, the implanted atoms show electrical activity. Measurements on the resistivity of the implanted layers and on the junction characteristics of the p-n junctions thus formed are in progress.

17. A Δ E Gas Ionization Chamber For Fission Fragments - N.N. Ajitanand, S.K. Kataria, S.S. Kapoor and P.N. Rama Rao - In certain fission experiments, which do not require a measurement of kinetic energies of fragments, but only the separation

of the light and heavy groups of fragments and their collimation, a simple Δ E device described here can be used with advantage. This device makes use of the fact that in a selected small central portion of the fragment-tracks the ratio of the differential energy losses for the light and heavy groups is even greater than the ratio of their kinetic energies. Consequently this device gives a better separation of the light and heavy groups than one which measures kinetic energy E, especially for cases of thick and non uniform sources and also for fission of nuclei like Cf^{252} where the intrinsic peak to valley ratio of the kinetic energy distribution is not very large. Results obtained with a Cf^{252} fission source are analysed.

18. **Cross-Section Work For Reactors** - S.B. Garg - Reactor Engineering Division - Energy point and multigroup cross-sections were generated in the unresolved resonance region for Pu-239 and U-238 by taking averages over the Porter-Thomas distribution of neutron and fission widths and Wigner distribution of level spacings, Multigroup cross-sections were also generated for the fuel, coolant and moderator elements in the resolved resonance region, using single level Breit-Wigner theory and resonance parameters from ENDF / B and UKNDF libraries. These cross-sections would be used in the neutronic analysis of thermal and fast systems.

A few interpolation schemes were programmed to obtain the self-shielding factors given in the 26 group ABBN set, for various reactor compositions at various temperatures.

Based on optical and statistical models inelastic scattering cross-sections were calculated for U-235 at 1.0 MeV neutron incident energy with five rotational bands. The role of spins and parities in the cross-section evaluation was also examined. It was concluded that the parity of a level had a pronounced effect whereas the spin of the level did not have such an effect.

Efforts were also made to commission the ENDF/B data library and the associated computer codes.

A critical review was made of the various theoretical models and techniques used to generate energy-point or multigroup cross-sections from the point of view of reactor applications.

B. TATA INSTITUTE OF FUNDAMENTAL RESEARCH, BOMBAY-400 005

1. Multiple Scattering Effects in Charged Particle Channeling and Blocking Experiments - K.B. Prasad, J.K. Srivastava and R.P. Sharma - The 2 MeV α-particles are channelled in a $\langle 111 \rangle$ single crystal of Ge. The effect of multiple scattering on minimum yield as a function of depth has been investigated. Similarly in the reverse process the blocking of 3 MeV α-particles emitted in a resonance reaction $^{31}P(p, \alpha)^{32}S$ at 1.51 MeV incident proton energy has been used to study multiple scattering effects in phosphorous. In the blocking measurement the incident proton energy has been adjusted to get the α-particle yield from different depths. The importance of multiple scattering in short nuclear lifetime measurements along with other effects such as radiation damage and surface disorder has been explained.

2. Magnetic Moments of The A = 21 Mirror Nuclei - M.R. Gunye - The magnetic moments of the $J = 3/2^+$ ground states of ^{21}Ne, ^{21}Na are correctly predicted by a multishell Hartree-Fock projection calculation. The energy spectrum of ^{21}Ne is also explained.

3. Half Life of 77 KeV Level in ^{197}Au - R.C. Chopra, P.N. Tandon, S.H. Devare and H.G. Devare - Recent measurements by Potzel et al[1] on the width of the Mossbauer line in ^{197}Au

indicate that the accepted value of life time of the 77 KeV level in ^{197}Au could be in error. We have therefore remeasured the half life of this level employing the $\beta - \gamma$ and $\beta - e^-$ delayed coincidence techniques. The value obtained from these is $T_{1/2} = 1.87 \pm 0.05$ nsec. The half life of 268 KeV level is estimated using the same techniques and is compared with the Coulomb excitation data.

4. Electromagnetic Properties of Low Lying Levels in ^{75}As - R.C. Chopra and P.N. Tandon - The half-life of the 280 keV level has been measured to be $T_{1/2} = 0.31 \pm 0.03$ ns using $\gamma - \gamma$ delayed coincidences. In addition, the g-factors of the 265 and 280 keV levels have been measured to be 0.61 ± 016 and 0.295 ± 0.049 respectively. The PAC technique was used for the measurements. Electromagnetic properties of the various levels have also been calculated on the core-particle coupling model. A good agreement with the experimental results is obtained. The results are compared with other existing theoretical calculations.

5. Electromagnetic Transition Probabilities in ^{165}Ho - S.B. Patil and K.P. Gopinathan - The half-life of the 715.5 keV level in ^{165}Ho populated in the decay of the 2.3 h ^{165}Dy has been measured by $\gamma - \gamma$ and $\beta - \gamma$ delayed coincidence method to be $t_{1/2} = 33 \pm 3$ ps. The upper limit of the half-life of the 995.3 keV level is determined to be < 30 ps. Angular

correlation measurements using Ge(Li) and NaI (Tl) detectors gave the following results: $A_2 = -0.021 \pm 0.010$, $A_4=0$ for the 279.8 - 715.5 keV cascade, $A_2 = 0.018 \pm 0.016$, $A_4=0.017\pm0.026$ for the 479.7 - 515.4 keV cascade. The K and L subshell conversion ratios of the 94.7, 279.8 and 361.7 keV transitions have been measured by a double focusing electron spectrometer. The results are: $L_1/L_{11}/L_{111}$ = 100/17.5/10.5 for the 94.7 keV transition; $K/L_1+L_{11}/L_{111}$ = 100/18.3/3.7 for the 279.8 keV transition and $K/L_1/L_{11}/L_{111}$ = 100/16.0/4.1/2.4 for the 361.7 KeV transition. From the analysis of these results the mixing ratios of the transitions are determined to be: 94.7 keV - M1 +(3.9 ± 0.3)% E2; 279.8 keV - M1+(2.0 ± 0.4)% E2; 361.7 keV-M2. +(25±3)%E3; 715.5 keV-E1; 479.7 keV-E1 and 515.4 keV-E2. The transition probabilities of transitions from the 94.7, 361.7 and 715.5 keV levels have been calculated and compared with Nilsson model predictions.

6. Half Lives of the 635.4 and 912.8 keV Levels in ^{171}Tm - S.B. Patel, A.P. Agnihotry and K.P. Gopinathan - The limit of the half-life of the 635.4 keV level in ^{171}Tm has been measured by delayed coincidence methdd using fast plastic scintillators. From the 277.4 - 210.4 keV $\gamma-\gamma$, and the 580 keV β - (277.4 + 210.4) keV γ delayed coincidences the limit of the half-life of the 635.4 keV level has been determined to be $t_{1/2}$ (635.4) $\leqslant$ 40 ps, and that of the 912.8 keV level as $t_{1/2}$ (912.8) $\leqslant$ 40 ps. The angular correlation of

277.4 - 210 keV $\gamma - \gamma$ cascade has been measured to be $W(\theta) = 1 + (0.11 \pm 0.02) P_2(\cos \theta)$. Analysis of the results of the angular correlation measurement combined with the recent internal conversion measurements uniquely establishes the spin of the 635.4 keV level to be 7/2 and the mixing ratio of the 277.4 keV transition to be M1 + (9 ± 2)% E2. The Nilsson assignment of the 635.4 keV level, consistent with the observed β and γ transition probabilities is suggested to be $7/2^+ [633]$.

7. Electromagnetic Properties of the 285.5 keV Level in ^{239}Pu - S. B. Patel, A.P. Agnihotry, K.P. Gopinathan and P.N. Tandon - The g-factor of the 285.5 keV $5/2^+$ level in ^{239}Pu has been measured using perturbed angular correlation of the 106.1 - 228.2 keV gamma-gamma cascade in an external field of 20 kG. The rotation of the angular correlation was $\omega\tau$ = (0.135 ± 0.035) rad. Using the value of the mean life τ = 1.58 ± 0.08 ns from our earlier measurement we obtain $g\beta$ = -0.39 ± 0.23 where β is the paramagnetic enhancement factor.

8. Evidence for Core-Excitation in ^{79}Br And ^{81}Br - R.C. Chopra - The M1 and E2 reduced transition probabilities between the low lying levels, in the case of ^{79}Br and ^{81}Br, have been calculated on the De-Shalit core-excitation model. To account for the observed M1 transition probabilities a few percent admixture among the like spin states is taken. In addition, the

ground state magnetic moment and quadrupole moment have been computed. A good agreement with the experimental results is obtained. The results are compared with other theoretical calculations.

9. Conversion Electron Studies of the Excited States in ^{74}As From the ^{74}Ge(p,n e)^{74}As Reaction - Y.K. Agarwal, S.M. Bharathi, S.K. Bhattacherjee, B, Lal and Baldev Sahai - The internal conversion coefficients of some of the low energy transitions in ^{74}As following the ^{74}Ge(p,n)^{74}As reaction have been measured with a six-gap beta-ray spectrometer. From the known decay scheme[1] and the multipolarities obtained in the present study, probable spins and parities are assigned to levels in ^{74}As upto 477 keV excitation energy. Using an $e^- - \gamma$ coincidence set-up, the life-time of the 274 keV level has been measured to be 27.0 $\pm$ 0.2 ns which agrees well with the value reported in reference 1). The upper limits to the half-lives of the 198, 207 and 421 keV levels are found to be 1 ns, 0.9 ns and 0.7 respectively.

10. Conversion Electron Studies in the 208 keV (E1+M2) And 113 keV (M1+E2) Transitions in ^{177}Hf - A.P. Agnihotry, K.P. Gopinathan and H.C. Jain - The electron-gamma and gamma-gamma

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1. T. Christiansen, H.E. Mahnke, E. Recknagel, D. Riegel and W. Whitthuhn, Nucl. Phys. A164 (1971) 367.

angular correlations of the 208-113 keV cascade in ^{177}Hf have been studied using a single gap electron spectrometer, and scintillation and solid state gamma ray spectrometers. The particle parameters for K-conversion electrons of the 208 and 113 keV transitions have been measured to be $b_2^K(208) = 1.54 \pm 0.14$ and $b_2^K(113) = -0.20 \pm 0.02$. The K and L subshell conversion coefficients of the 208 keV transition are measured using a double focussing electron spectrometer and the values are : $\alpha_K = 0.046 \pm 0.010$, $\alpha_{L1} = 0.0075 \pm 0.0010$, $\alpha_{L11} = 0.0015 \pm 0.0004$ and $\alpha_{L11} = 0.0016 \pm 0.0004$. A least square fit of the measured values gave the M2 admixture = $(0.45 \pm 0.30)\%$ and the penetration parameter $\lambda_1 = -2.9 \pm 2.4$ for the 208 keV transition. The mixing ratio of the 113 keV transition is obtained to be $\delta(113) = -3.75 \pm 0.25$ from the measured gamma - gamma angular correlation. The analysis of the particle parameter and L subshell ratios gives the range of the penetration parameter, $-15 < \lambda < -1$ for the 113 keV transition. The values of the mixing ratios and the penetration matrix elements are discussed in terms of the existing nuclear models.

11. Capture and Elastic Scattering of Protons by ^{51}V

- K.V.K. Iyengar, A. Roy, M.L. Jhingan, S.K. Bhattacherjee and U.T. Raheja - Gamma-ray yield from $^{51}V(p,\gamma)^{52}Cr$ reaction was measured in the proton energy range 720-935 keV with an overall energy resolution of 2.5 keV. Peaks at E_p(lab)= 755, 766, 775

784, 800 and 912 keV were the most prominent. Those at E_p = 766, 784 and 912 keV (E_x = 11.252, 11.269 and 11.395 MeV in ^{52}Cr) were identified as the analogs of ground, second and third excited states of ^{52}V. The level width, the strength function and the cross section for excitation of the 11.395 MeV state by proton capture were determined to be (1.2±0.2)keV, (0.58±0.10)eV and (90±30)μb respectively. Elastic scattering studies show anomaly at E_p = 912 keV. Angular distribution of the primary γ-rays from the decay of the 11.395 MeV state was measured and the resonance parameters were obtained from analysis of elastic scattering data.

C. SAHA INSTITUTE OF NUCLEAR PHYSICS, CALCUTTA-9.

1. Isobaric Analogue Resonances in $V^{51}(p,n)Cr^{51}$ Reaction - Kewal Krishan and D. Pal - Application of the shell model in the continuum theory of Mahaux and Weidenmullar has been made to study the reaction $V^{51}(p,n)Cr^{51}$ with particular emphasis on 4^+ level in Cr^{52} at 12.8 MeV excitation identified as the analogue of the 4^+ level at 1.55 MeV in V^{52}.

2. Decays of 3.75 min ^{68}Cu And 30 sec ^{68g}Cu -.V.K. Tikku, H. Singh and B. Sethi - The decays of 3.75 min ^{68m}Cu and 30 sec ^{68g}Cu have been studied utilizing NaI(Tl) and 32.2 cc high resolution Ge(Li) spectrometers. The radioactive sources were produced by irradiating enriched (99.3%) ^{68}Zn targets with 14.7 MeV neutrons. In the present investigation we observe thirty γ-rays in the decay of the ^{68}Cu isomers, of these the following energies 151.6, 499.2, 610.5, 671.2, 736.9, 983.4, 1184.4, 1194.2, 1227.3, 1289.4, 1335.8 1428.5, 1529.7. 1541.7, 1675.9, 1795.2 and 2110.1 keV were not reported by us previously.[1] Fourteen γ-rays were assigned to ^{68m}Cu decay on the basis of detailed studies of the half lives of the γ-transitions. The isomeric level at 721.7 keV is seen to decay approximately 93% through the 110.7 keV transition which we deduce to be M3. The 84.6 KeV transition in ^{68}Cu has been inferred to be mixed M1E2. The results have been utilized to discuss the probable spin - parity assignments to the excited levels in ^{68}Cu. Based on

the present measurements, modified decay schemes of ^{68m}Cu and ^{68g}Cu are proposed. The activation cross sections for the production of the two activities ha. been estimated.

1. Nuclear Phys. A 174(1971) 426

3. Energy Levels in ^{94}Zr From The Decay of ^{94}Y - H.Singh, V.K. Tikku and B. Sethi - The decay of ^{94}Y excited levels in ^{94}Zr has been studied by means of Ge(Li) and scintillation spectrometers. The ^{94}Y sources were produced by the irradiation of enriched ^{94}Zr (92.8%) as well as spectroscopically pure Zr targets with 14.7 MeV neutrons. The ^{94}Y electron decay curves gave an average $T_{\frac{1}{2}}$ = 19.7±0.5 min. Six β-groups with end-point energies of 4.90±0.10, 3.84±0.20, 3.24±0.2, 2.84±0.15, 2.08±0.30 and 1.14±0.30 MeV are being reported for the first time. The γ-rays found to decay with the above half-life are 387.7±0.8, 551.5±3.0, 588.3±1.5, 753.1±1.0, 920.4±0.4, 1139.2±0.7, 1447.8±1.6, 1672.3±0.8, 1847.0±1.0, 1897.8±1.0, 2147.0±1.0, 2224.1±1.0, 2518.3±1.6 and 2839.2 ± 1.6 keV. A decay scheme of ^{94}Y consistent with the results of the singles, $\beta-\gamma$ and $\gamma-\gamma$ coincidence experiments is proposed. The g.s. of ^{94}Y is assigned a spin - parity of 2^-. The cross section for the reaction $^{94}Zr(n,p)^{94}Y$ at 14.7 MeV neutron energy has been measured as 3.9 ± 1.9mb.

4. Disintegration of ^{109g}Pd - M.B. Chatterjee and B. B. Baliga - The decay of 13.5h ^{109g}Pd to ^{109}Ag has been studied by observing the gamma rays with a high resolution Ge(Li) detector.

Enriched isotope of ^{108}Pd, irradiated with thermal neutrons, produced ^{109}Pd through thermal neutron capture. The gamma rays belonging to ^{109}Ag have been assigned on the basis of lifetime measurements. Measured the energies and intensities of the gamma rays in ^{109}Ag. Assignments of 286keV, 396keV, 497keV and 1011keV lines to ^{109}Ag has been confirmed. A new gamma line of energy 328keV has been observed from the decay of ^{109g}Pd.

5. <u>(d,P) Reaction Theory Including Deuteron Break-up Channel</u> - S. Ray, S.K. Samaddar and Suprokash Mukherjee - The transition amplitude for (d,p) or (p,d) reaction has been considered with the inclusion of the break-up channel of the deuteron. In normal DWBA calculation, a part of the break-up channel is considered indirectly through the deuteron-target optical potential but here the whole break-up contribution has been considered in a direct fashion by using Feshbach's Projection Operator Technique. We have also estimated the effect of the target excitation through proton-target interaction and this is found to be about 20% of the total cross section.

6. <u>Neutron Activation Cross Sections, Isomeric Ratios And Systematics of (n,p) Reaction at 14.7 MeV</u> - V.K. Tikku, H. Singh and B. Sethi - Activation cross sections for thirteen

(n,p) reactions at 14.7 ± 0.3 MeV were determined for the isotopes of following naturally occurring elements: Ti, V, Zn, Mo, Sr and Te. Both the mixed powder and the internal calibration techniques with high resolution large volume Ge(Li) spectrometer were used. Isomeric (n,p) and (n,2n) cross ratios were determined for the production of $^{63m\&g}Cu$ and $^{91m\&g}Mo$, respectively. On the basis of the present precision data, a systematics for the (n,p) reaction cross section is obtained. The experimental values of the cross sections have been compared with the predictions of the statistical theory.

7. Core-Polarization : An Approximate Method - M.K. Pal and J.N. De - Core-polarization effects are generally taken into account either through a renormalisation programme in shell-model calculation, or in a multi shell Hartree-Fock projection approach. An alternate method for treating co re-polarisation phenomenon in two-valence nucleon systems has been done and a formal derivation has been given to separate out the polarization correction in the energy spectrum. The theory has been put to test in the case of ^{18}O nucleus and it is found that polarization corrections are J-independent. An excellent spectrum fit is obtained after an effective parameterization of the T = 1 matrix elements.

8. Band-Mixing in ^{18}O Nucleus - J.N. De and M.K. Pal - The intrinsic excited bands of ^{18}O nucleus are generated in the Tamm-Dancoff approximation and good angular momentum states are projected out. The bands crowd together in a narrow energy interval, so also the projected levels. It is seen that band mixing is sizably important and plays a crucial role in producing a qualitative spectral agreement.

D. ALIGARH MUSLIM UNIVERSITY, ALIGARH

1. The Decay of ^{187}W and Magnetic Moment of 206-KeV State in ^{187}Re - D.K. Gupta; A.K. Singhvi and G. N. Rao, (Indian Institute of Technology, Kanpur)- The decay of ^{187}W has been examined with use of semiconductor detector spectrometer. A series of timed gamma spectra is recorded. The gamma rays which follow the decay of ^{187}W are recognised and their energy and relative intensity are determined. The half-life of the 206-KeV state in ^{187}Re is measured using delayed coincidence technique. The value obtained for the half-life ($T_{1/2}$) is = 555.3 $\pm$ 1.7 nsec. Using time differential perturbed angular correlation (TDPAC) technique the magnetic moment of 206-KeV state is also measured in an external magnetic field of 7 KOe. The value obtained for the magnetic moment (μ) is = + 5.04 $\pm$ 0.14 nm.

2. Study of (n,α) Reactions at Thermal Energies - J. Alam and M.L. Sehgal - (n,α) cross-sections for Hf^{180}, Tl^{203}, Pb^{208} and Bi have been measured by activation technique making irradiations in the thermal column of Apsara Reactor, Bombay (India). These measured values have been compared with the calculated values obtained from statistical theory.

E. ANDHRA UNIVERSITY, WALTAIR, VISAKHAPATNAM-3(AP)

1. Extended Core Excitation Model For Z = 29 and N=29 Nuclei - M.N. Seetharamanath and V. Lakshminarayana - The energy levels and electromagnetic properties of the different levels are estimated in Z=29 nuclei Cu-59, Cu-61, Cu-63 and Cu-65 using extended core excitation model assuming dipole - dipole, quadrupole - quadrupole and octupole-octupole terms in the interaction Hamiltonian. Similar calculations are also made for N=29 nuclei Ti-51, Cr-53 and Fe-55. In each case the energy levels, B(E2) and B(M1) values, electromagnetic moments and spectroscopic factors are estimated and compared with the experimental values and the theoretical values estimated from the intermediate coupling model calculations as well as core-excitation model calculation of Tankappan and True-type. For the nuclei considered the core excitation models are found to be more suitable than the intermediate - coupling model in many respects.

2. Odd Parity States in Au-195 - P. Ila and V. Lakshminarayana - Recent experimental studies on the decay of Hg-195m indicated several negative parity states in Au-195 and were accounted qualitatively by the core excitation model. Detailed calculations are made using the intermediate coupling model of the intermediate type. The energy levels at 318(11/2-), 525 (7/2-), 706(15/2-) and 894(9/2-), the ratios of the B(E2) of

the $15/2 \rightarrow 11/2$ and $7/2 \rightarrow 11/2$ and the ratios B(M1) of the $9/2 \rightarrow 7/2$ and $9/2 \rightarrow 11/2$ are accounted with a phonon energy of 0.18 MeV and a coupling strength of $\xi = 1.5$. The phonon energy, however, is smaller than that of the core(0.3285). An alternative approach is being made by the inclusion of the anharmonicities and dipole-diple interaction term in addition to the quadrupole-quadrupole term in the interaction Hamiltonian.

3. Shapes of Unique First-Forbidden Beta Ray Spectra in K-42 and Pr-142.- C. Narasimha Rao, B. Mallikarjuna Rao and K. Venkata Reddy - The shapes of the first-forbidden unique beta transitions in K-42 and Pr-142 have been carefully measured with an intermediate-image spectrometer and compared with the theoretical predictions in terms of a linear shape factor of the form (1+aW). The measured form factors are $a = (-0.011 \pm 0.005)/mc^2$ for the K-42 ground state transition and $a = (-0.029 \pm 0.0022)/m_o c^2$ for the Pr-142 transition.

4. Alpha Particle Stopping Cross-Sections - T.V.S. Sastry, V. Seshagiri Rao and D.L. Sastry - Alpha particle stopping cross sections are determined in a large number of elements using Americium-241 (predominantly 5.48 MeV) and Plutonium-239 (predominantly 5.15 MeV) using a Si(Li) detector. Theoretical stopping cross-sections are being calculated at the above energies. The theoretical stopping cross-sections computed at $E_\alpha = 2$ MeV as a function of Z in the range 1 to 48 taking into account the

non-participation of K and L-shell electrons in the stopping process are found to be quite in accordance with the experimental values reported by Chu and Powers, including a zig-zag pattern in the intermediate range of the present study.

5. Vibration - Rotation Interaction Model For U-235 and Pu-239 - S. Ramamurty and U. Satyanarayana - The parameters a, b in vibration-rotation interaction model for U^{235} and Pu^{239} are given below.

The formula used is

$$E = a\left(-1 + \sqrt{1+b\ J\ (J+1)}\right)$$

Isotope	Band	I	II	III	IV	V
U^{239}	a	2.230	1.799	1.636	1.352	2.250
	b	0.005	0.007	0.008	0.008	0.006
Pu^{239}	a	3.048	2.67	2.042	2.239	5.02
	b	0.004	0.005	0.005	0.005	0.004

6. Double Focussing Beta Ray Spectrometer - P. Jagam, U.V. Chalapathi Rao, S. Bhuloka Reddy, B.V. Tirumala Rao and V. Lakshminarayana - A double focussing beta ray spectrometer is set-up for high resolution conversion electron measurements. The magnet with a $1/\rho$ field shaping around ρ = 40 cm was obtained from Manchester, England. The magnet provides field

values up to 1000 gauss with an excitation current upto 100 amperes. The magnet is being powered currently with a heavy duty battery system, the fine variation of current being made through the variation of base current of a series power transistor included in the magnet circuit. The annular vacuum chamber between the pole pieces is evcuated with a high vacuum system capable of producing 10^{-6}mm. The diffusion pump cooling is effected by water circulation incorporating automatic shut-off facility. Source mounting arrangement with an air lock is made with non-magnetic brass. A G.M. tube is used as a detector and is situated at $\theta = \sqrt{2}\,\pi$ with respect to the source. Necessary baffles are introduced between the source and the detectors. The resolution and transmission characteristics of the unit are under study. Preliminary data indicated a resolution of 0.34% at 624 keV K-line of Ba-137.

7. <u>The Parameters in Variable Moment of Inertia Model for Light Nuclei</u> - U.Satyanarayana and S. Ramamurty - The parameters I_o, C_o in variable moment of inertia model for light nuclei are given below

The formula used for the calculation is

$$E_j = \frac{\hbar^2}{2\mathcal{I}_J} J(J+1) + \frac{C_o}{2}\left(\mathcal{I}_J - \mathcal{I}_o\right)^2$$

Isotope	Parameters	
	I_o	C_o
Ne^{20}	1.228	0.5832
Ne^{22}	1.629	0.2977
Mg^{24}	2.053	2.19
Si^{28}	1.112	0.7345
Ti^{48}	0.8549	0.04826

F. BANARAS HINDU UNIVERSITY, VARANASI-5.

1. Negative Isomer Shifts and Models of Rotational Spectra - A.N. Mantri and P.C. Sood - Some recent Mossbauer studies and muonic X-ray experiments designed to measure the changes (isomer shifts) in nuclear charge radii $\delta \langle r_p^2 \rangle$ for the $2^+ - 0^+$ transition in even-even nuclei have resulted in the puzzling conclusion that in the case of several hard rotors this isomer shift is negative. Such a characteristic cannot be explained on the basis of any of the otherwise successful phenomenological models of rotational spectra. These models, explicitly or implicitly, make the usual assumption that rotation causes the charge to spread out (centrifugal stretching). A model is formulated based on the idea of generalized (effective) stretching which, after incorporating an appropriate dependence of the nuclear moment of inertia $\mathcal{I}$ on spin I and generalised stretching parameter, reduces to a simple cubic polynomial (CP) expression. This CP model is found to give shrinkage from the 0^+ to the 2^+ state, i.e., $\mathcal{I}_2$ is found to be smaller than $\mathcal{I}_0$, in line with the negative isomer shift. Conditions for 'shrinkage' to occur are derived in terms of model parameters and specific cases are pointed out where it may be looked for.

2. Coriolis Coupling Effects on Energy Levels of $3/2^-$ [521] - Based Rotational Bands - P.C. Joshi and P.C. Sood - Coriolis coupling term in the Hamiltonian brings about $K = \pm 1$

admixture in the levels of any particular K band. In particular it introduces a series of terms with the coefficient $(-1)^{I+K}$ in the expression for the rotational energy $E_K(I)$. We have studied the contribution of such a term, theoretically as well as from experimental spectra, in the rotational bands based on the neutron state $3/2^-[521]$ in odd-mass rare-earth nuclei in the region $150 < A < 170$. Effects arising from the coupling with all the six possible 1/2 states in N = 5 shell are calculated and compared with the available experimental information.

3. Limiting Spontaneous Fission Half-Lives For Heavy Nuclei - P.C. Sood and A.K. Jain - Based on the experimentally observed spontaneous fission half-lives τ^{SF} of transuranic nuclides, a linear relationship is deduced between log τ^{SF} and the fissility parameter x (proportional to Z^2/A) which sets an upper limit of experimental τ^{SF} for each set of isotopes in the interval $92 \leqslant Z \leqslant 104$. A comparison of the extrapolated results with the theoretically predicted values of τ^{SF} for superheavy nuclei reveals significant discrepancies some of which cannot fit in with the variations expected from shell corrections:

4. Sum Coincidence Studies in the Decay of Fe^{59} - L. Chaturvedi, S.P. Ram, Rajendra Prasad, S.N. Chaturvedi and A.K. Nigam - Recently few controversies have arisen in the level structure of Co^{59} obtained from the decay of 45 day Fe^{59},

regarding the presence of 190 keV gamma transition between 1482 keV and 1291 keV states, and few others which are submerged in the large compton contribution. This has been solved by the fast-slow coincidence and sum-coincidence spectrum studies at 1480 and 1292 keV sum-gates.

5. Level Structure of ^{125}Te,- S.N. Chaturvedi, Rajendra Prasad, S.P. Ram, L. Chaturvedi and A.K. Nigam - Level scheme of ^{125}Te has been studied following the beta decay of ^{125}Sb. The use is made of the high resolution Ge(Li) detector for singles gamma ray studies. The genetic relationship between the observed gamma rays has been critically studied employing gamma-gamma sum-coincidence and slow-fast coincidence studies using scintillation detectors. In all, twentysix gamma rays have been observed, out of which two weak gamma rays with energies 366 and 401 keV have been reported by us for the first time. These gamma rays have been fitted by assigning a new level of 401 keV energy. The positions of 122 keV and 80 keV gamma rays have been changed on the basis of our sum-coincidence measurements. The new level scheme of ^{125}Te consistent with present measurements has been reported.

6. Sum-Coincidence Studies in the Decay of Ir^{192} - S.P. Ram, Rajendra Prasad, L. Chaturvedi, S.N. Chaturvedi and A.K. Nigam - The level structure of Pt^{192} and Os^{192} obtained from the decay of Ir^{192} has been investigated using a Ge(Li)

detector and fast-slow coincidence and sum coincidence spectrum measurements. On Os^{192} side, two new levels at 903 and 1118 keV energies have been proposed which are confirmed with sum coincidence spectra at 1118 keV and 697 keV gates giving new gamma transitions of 912.1 and 628.5 keV arising between the 1118-206, 1118-439 keV states and 212 keV between the 903-691 keV states. In Pt^{192} level structure, two new direct transitions of 921 and 734.5 keV have been observed which are clearly established by the sum coincidence spectrum studies. The modified decay scheme of Ir^{192} has been proposed.

7. Decay of ^{207}Bi - Rajendra Prasad, L. Chaturvedi, S.P. Ram, S.N. Chaturvedi and A.K. Nigam - The radioactive decay of ^{207}Bi has been studied using Ge(Li) gamma-ray spectrometer, NaI(Tl)-NaI(Tl) sum coincidence and fast-slow coincidence techniques. Gamma rays with 375, 570, 890, 1063, 1085, 1255, 1430, 1770 and 1965 keV energies are observed. Of these, the 375, 1085, 1255 and 1965 keV weak gamma rays are reported by us for the first time and have been fitted in the existing decay scheme by assigning new levels at 1255 and 1965 KeV in ^{207}Pb. A new decay scheme of ^{207}Bi has been proposed.

8. Spontaneous Fission Half-Lives For Even Nuclei Around Z = 100 - P.C. Sood and C.M. Burman - A plot of experimentally observed spontaneous fission half-lives τ^{SF} versus

$(x - x_0)$, where x and x_0 are the fissility parameters for a particular isotope and the longest-lived (against SF) isotope respectively of an element, shows very similar behaviour for nuclei with Z = 98, 100 and 102. The quantitative results for each element are satisfactorily described by a two-parameter equation corresponding to a hyperbola.

9 Magnetic Moment of Deuteron and Nucleon-Nucleon Spin-Orbit Potentials - Radhey Shyam and Shankar Mukherjee - Contribution to the deuteron magnetic moment due to the presence of spin-orbit term in the nucleon-nucleon interaction has been estimated for Reid, Hamada-Johnston and Yale potentials. Present estimates are more close to experimental value than those obtained previously by Feshbach. Importance of these estimates in clarifying the role of spin-orbit term in nucleon-nucleon interaction has been pointed out.

10. Triton Binding Energy and n-d Scattering Lengths in UPA, Using Spin-Dependent Hard-Core Potentials - C. Maheshwari and V.S. Mathur - A calculation for the triton binding energy is made with local potentials with spin-dependence and hard-core. A'unitary pole approximation (UPA)' for the input t-matrix is used in the three-body equations. It is found that the hard-core does decrease the binding energy but not to the extent it does in a variational calculation. Calculations for the doublet and quartet n-d scattering lengths in UPA are also

done using the same two-body potentials.

11. Volume Integrals of the Optical Potentials - D.C. Agrawal and P.C. Sood - The ambiguities arising out of different geometry assumed in different optical model analysis of nucleon-nucleus elastic scattering data have been sought to be removed by considering volume integral per particle J/A of the optical potential rather than the depth parameter V for a given geometry. These volume integrals have been found to be fairly well defined quantities in analysis at any particular energy; however the energy variation of these quantities has not been generally discussed. The available proton and neutron data at various energies, to study this feature, have been examined.

12. Occurence of Gallacher-Moszkowski Pairs in Odd-Odd Rare-Earth Nuclei - D.K. Gupta and P.C. Sood - Following our investigation of the applicability of Gallagher-Moszkowski coupling rules to the ground state spin-parities of odd-odd rare earth nuclei (Proc. Nucl. Phys. Symposium (1971) p.255) we have extended the study to examine the excited states in these nuclei. While only a few examples were available where the anti-parallel spin-spin coupled state (corresponding to the parallel coupling in the ground state) had been observed, we have found a large number of such cases in excited states of

the same nuclei wherein both members of the G-M pairs have been experimentally identified. Nilsson configurations for the odd neutron and proton giving rise to such pairs is listed and separation energy between the two members of each G-N pair is analysed.

G. BIRLA INSTITUTE OF TECHNOLOGY, PILANI, RAJASTHAN

1. Mixed-Configuration Shell-Model Wave Functions And Energies of ^{51}V - G. Ramachandra Rao and K.S. Subudhi - The mixed configuration shell-model wave functions and energies have been calculated for ^{51}V using the recent values of effective interaction two-particle matrix elements determined by Lips and McEllistrem and those determined by Kuo and Brown. A comparison of the present work with the earlier work has been made. The second $5/2^-$ excited level can be better described with the mixture of $1f_{7/2}$ and $2P_{3/2}$ configuration only without considering the mixture of $1f_{5/2}$.

2. Realistic Nuclear Charge Distributions and Proton Optical Potential - P.R. Marwadi and C.S. Shastry - Electrostatic potentials due to the realistic charge distributions are calculated for O^{16}, Ca^{40}, and Au^{197} and are compared with the corresponding potentials due to uniform charge distribution. The effect of the realistic charge distribution on the proton-nucleus optical potential is analysed.

H. BOSE INSTITUTE, CALCUTTA-9.

1. A New Electrospraying Apparatus For The Preparation of Thin Targets and its Application in the Absolute Beta - Counting in Context of Fast Neutron Cross Section Measurement By Activation - S. Sen, M. Majumdar and B. Mitra - An electrospraying apparatus has been developed. Very thin ($\mu gm/cm^2$) uniform samples could be deposited from solution of different salts in ethanol, doped with pure β -emitters of different energies. Using these thin radioactive samples, self-scattering and self-absorption factors in β -ray intensity measurements were determined in an unconventional way by constructing plots of counts efficiency vs 'Average' beta energies for a G.M. Counter in ordinary geometry. From the resultant 'regular' curve, error factors could be determined down to very low average beta energy. Application has been made to determine different relative 14 MeV neutron cross sections of bromine (^{79}Br and ^{81}Br).

I. DEPARTMENT OF ATOMIC ENERGY, NEW DELHI

1. The effects of the Addition of a Neutron on Nuclear Properties* - Jyoti K.Parikh - In order to carry out the calculations for the odd and even isotopes of Ti, Cr, Fe and Zn, the Hartree-Fock-Bogoliubov formalism is developed for the odd nuclei. The blocking effects introduced by the odd nucleon is taken into account in the formalism. By comparing the results of the even-even nuclei one understands the effects of the addition of neutrons on the nuclear properties. The calculated binding energies, BE2 values, quadrupole moments and the neutron and proton pick up strengths compare very well with the experimental values. The possibility of obtaining the "equivalent deformation" for which the Nilsson levels correspond to the calculated single particle levels is discussed.

* To be published in Physical Review C.

2. A Study of V, Mn And Co Isotopes - Jyoti K. Parikh - The nuclei with odd proton are studied using the Hartree-Fock-Bogoliubov method. The binding energies, single particle spectra, quadrupole moments, BE2 values and the pick up strengths are calculated. By comparing the results of the neighbouring even nuclei one can study the sets of isotones. The nuclei with N = 26, (^{48}Ti, ^{49}V, ^{50}Cr, ^{51}Mn and ^{52}Fe)

N = 28, (^{50}Ti, ^{51}V, ^{52}Cr, ^{53}Mn ^{54}Fe and ^{55}Co) and

N = 30, (^{53}V, ^{54}Cr, ^{55}Mn, ^{56}Fe and ^{57}Co) are studied to

understand the effects of the addition of a proton on the deformation, Fermi surface, fluctuations of the proton separation energies, pair separation energies and the configuration mixing.

J. INDIAN INSTITUTE OF SCIENCE, BANGALORE

1. A Trapped-Electron Cold Cathode Ion Source For Mass Spectrometry - S. Swaminathan and V.S. Venkatasubramanian - A new type of ion source, based on the trapped-electron cold cathode discharge, first described by McClure (1) has been examined for its characteristics. The discharge with concentric cylinder geometry, operating without a magnetic field at voltages $\sim$ 2 KV, and pressure $\sim 10^{-5}$ torr, constitutes the mass spectrometer, and provides stable resolved-ion currents up to 10^{-8}A.

Energy spectra of positive ions extracted from this source have been obtained by a monitor at the exit of the electrostatic analyser. The ions are observed to gain considerable energy from the discharge, and the mean energy as well as the energy spread ($\sim$ 200V at FWHM) are consistent with the motion of the positive ion sheath from the wire anode.

Fragmentation patterns for several gases have been determined for this source by measurement of relative intensities of molecular, atomic and multiply-charged ion peaks, and conform to the pattern obtained for a glow discharge. While the energy spread necessitates double focussing, the strong steady ion beams and the absence of a heated filament and source magnetic field recommend this ion source for gas analysis.

1. G.W. McClusre-Appl. Phys. Lett., 12,235, (1963).

K. INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

1. Relation Between Life Time and Transit Time for Single Hole State - R. Shanta, - For single hole states if the life time is smaller than a certain critical value which is the hole transit time, significant change is produced in the momentum distribution. A simple relation exists between the life time and the hole transit time. The behaviour of the complex wave functions and the momentum distributions as the life time and the transit time are individually varied is also studied.

2. Hole States in Single Particle Knock-Out Reactions - R. Shanta - The hole states that are created in single particle knock-out reactions are physical states but have finite life time. The hole is moving in a complex potential the imaginary part of which is related to the width of the state and the hole energy and wave functions are complex. The influence of these features on the momentum distributions of the hole is studied for the knock-out of the 1s and 1p protons from ^{12}C and found to be rather insignificant. However it is interesting to note that the overlap integral in momentum space shows a significant change.

L. INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

1. Configuration Mixing in Vibrational Nuclei - R.Singh, G.K. Mehta and Y.R. Waghmare - The configuration-mixed wave functions for one-phonon and two-phonon 2^+ states have been obtained from the experimental energy spectra of various even-even vibrational nuclei. The reduced transition probabilities and electric quadrupole moments have been calculated which are compared with the available experimental data. The systematics of the configuration mixing for 2^+ states exhibit trends which can be used for inferring the ordering of single particle levels in the regions where it is not known.

2. The Energy Levels of ^{139}La, ^{141}Pr and ^{140}Ce from (n,n'γ) Studies - R. Singh and G.K. Mehta - The energy levels of ^{139}La, ^{141}Pr and ^{140}Ce have been investigated through the study of gamma rays resulting from (n,n'γ) on ^{139}La, ^{141}Pr and ^{140}Ce using a Ge(Li) detector. In addition to the well established levels at 166, 1218, 1256, 1422, 1538, 1684, and 1755 keV, the levels at 1206, 1384, 1480, 1560, 1578, 1718, 1820 and 1840 have been confirmed as the excited states of ^{139}La. Two new transitions 1820 $\rightarrow$ 166, and 1840 $\rightarrow$ 166 have been added to the level scheme. In ^{141}Pr, besides the levels at 145, 1115, 1128, 1128, 1295, 1435, 1452, 1520, 1650, 1780, 1809 and 1840 keV the levels at 1300, 1456, 1490, 1580, 1610, 1828 and 1857 keV have been confirmed. Moreover, definite

indications of the transitions 1128 $\longrightarrow$145, 1580 $\longrightarrow$ 1295, 1650 $\longrightarrow$ 1295 have been found in the deexcitation of ^{141}Pr, and the level at 880 keV is supported, but no indication is found for the level at 1350 keV. In ^{140}Ce, apart from the well-known levels at 1596, 1903, 2412, 2547, 2900, and 3122 the levels at 2083, 2108, 2348, 2464, 2481 and 2522 keV are observed, but no level is found at 3017 keV.

3. Decay of ^{63}Zn - C. Rangacharyulu, V.G. Jadhao, G.K. Mehta and R.M. Singru - The 38.4 mm decay of ^{63}Zn was investigated by ^{64}Zn (n,2n) ^{63}Zn reaction. The 4.2 cc Ge(Li) detector was used to record the gamma ray spectra. The half lives of all the gamma rays, were also measured. No evidence is found for the existence of gamma transitions of 684, 923-5, 1087, 1150, 1168, 1189 and 2048.6 keV energies reported by Borchert[1]. Also the gamma rays of 1573.3, 2082-1, 2780, and 3101 keV energies reported by Kiuru and Holmberg[2] as well as Borchert[1], were not observed. However the 2103 keV gamma ray reported by Borchert[1] but not indicated by Kiuru and Holmberg[2] is clearly observed in our measurement and indication is found for three new gamma rays at 1716, 1734, and 2773 keV. The detailed coincidence study is planned.

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4. Decay of ^{49}Cr(41 min), ^{189}W(11 min) And ^{164}Ho(37min) - B.V.N. Rao, A.K. Singhvi and G.N. Rao - The decay of ^{49}Cr (41 min) and ^{189}W(11 min) produced with 14 MeV fast neutrons leading to the levels of ^{49}V and ^{189}Re respectively are studied using the NaI(Tl) and Ge(Li) detector. Four gamma ray energies 57.5, 90.9, 174.4 and 611.8 keV were observed in the decay of ^{49}Cr. The half life of ^{49}Cr ground state is accurately measured to be 41.4 $\pm$ 0.2 min. Relative intensities and accurate energies are obtained. Further coincidence studies and the radio chemical separations in the case of ^{189}W are in progress to conclusively identify the gamma rays of ^{189}W.

The ground and isomeric state decay of ^{164}Ho produced from $^{165}Ho(n,2n)^{164}Ho$ is also being studied using Ge(Li) and NaI(Tl) spectrometers in coincidence.

M INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

1. Integrated Photodisintegration Cross Section (σ_{int}) For Nuclei - B.K. Srivastava - We extend our earlier model[1] for σ_{int} for nuclei in the ds shell to nuclei of higher mass number using the concept of cluster formation in nuclei. We find that σ_{int} calculations cannot distinguish between two internucleon potentials on account of the range-depth relationship for these potentials. Our model gives results in quite good agreement with those obtained by Levinger and Bethe[2].

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N. KURUKSHETRA UNIVERSITY, KURUKSHETRA, HARYANA

1. Ni^{58} Reaction Cross Sections For 14 MeV Neutrons Using Optical Model Potential - B.S. Wadhwa and R.K. Mohindra - For the interaction of 14.8 MeV (Lab. Energy) neutrons with Ni^{58} the cross-sections of the type (n,p), (n,n'), (n,α), (n, n'p), (n,2n), (n,n'α) and (n, n'γ) have been computed. A diffused edge optical model potential for the reaction cross-sections has been used. The results have been compared with the real square well potential. The spin dependence, shell and pairing energy effects in the various level density, formulae have been considered. The compound nucleus[1] and the direct interaction[2] contributions are calculated separately. The compound nucleus cross-sections are quite suitable for the direct comparison with the experimental cross-sections obtained from the activation techniques and the energy and angular distributions.

The spin and pairing energy corrections make the agreement worse. In this case of Ni^{58} the shell dependent Newton's level density formula using optical model potential gives the best comparisons with the experiments as shown in the Table. This case is in contradiction to Pai et al[3] who conclude from their recent analysis that any attempts to include shell effects in the calculation of such cross-sections distorts the results. The volume direct interaction cross-sections contributions are about 15 per cent.[4]

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TABLE I

Cross-section mbs.	L-L			NEWTON			DIRECT	EXPT	
	SQ.W.	OPT	Pair-ing	SQ.W.	SPIN OPT	OPT		MeV	mbs
σ_{np}	79	90	341	232	471	269	31.5	14.8 14.8 14.4 14.8	210±40 280±35 331±30 dir > 17
$\sigma_{n\alpha}$	38	296	403	25	335	191		14.1	125±16
$\sigma_{nn'}$	1303	1034	676	1163	613	960	174	14.0	1037 844
$\sigma_{n,n'p}$	266	233		219		109	11.8	14.0 14.1 14.8 14.4	220 160±40 150 320
$\sigma_{n,n'\alpha}$	1.5	65		1.2		33	4.0	14.1	30±6
$\sigma_{n,2n}$	98	47		64		24.3	2.8	14.0 14.0 14.4 14.4	41±12 21±2 38±4 36
$\sigma_{n,n'\gamma}$	937	689		878		794	155		

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2. Spin Assignments of Low Lying States in ^{93}Nb - H.C. Sharma - The ^{93}Nb nucleus has been studied by several workers[1-7] during the last few years. The spins and the energies of the low lying states of ^{93}Nb were obtained in these studies by different techniques and these did not appear to be unique. The most recent work (7) in particular revealed that the spins of the doublets at 808 and 960 keV were very much inconsistent with those made earlier. Thus we undertook the present investigations, firstly to obtain an over all consistent picture of the excited states in ^{93}Nb and secondly to find which of the various methods used for making spin assignments is more reliable. The results of this

work are given next in brief.

The partial ^{93}Nb(n,n') reaction yields were calculated on the basis of Moldauer's formalism[8] and then compared these with the observed ones[1,3,4]. The level scheme of ^{93}Nb and the optical model used in these calculations were taken from the recent work[4] and our earlier work[5]. This comparison has revealed very clearly that the most appropriate spin of the 809 keV state is $5/2^+$ and not $11/2^+$ as reported recently[7]. It was further found on the basis of the data[4] and the present calculations that the spins of the doublet (950;980) keV should not be different significantly i.e. ($13/2^+$, $11/2^+$) assignments of this doublet is unambiguously preferred to ($13/2^+$, $5/2^+$) assignments. It has been noted that the spin assignment technique based on Coulomb excitation plus weak coupling model[7] is not as sensitive to the spin's of the individual states as that based on (n,n') reaction data.

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O. M.S. UNIVERSITY, BARODA

1. A Coupled Channel Scattering Model in Extended R-Matrix Formalism - J.L. Dhar and S.K. Shah - Optical model phase shifts are injected to describe background scattering and approximate compound nucleus states are provided by a nuclear structure calculation. The model is applied to a S-wave scattering by C^{12} whose 0^+ and 2^+(4.45 MeV) excited state are considered explicitly.

The results are shown to be fairly insensitive to the values chosen for channel radii and a very few compound nucleus states give good results. A very good fit to the resonance in elastic cross-section is obtained.

2. Inelastic Proton Scattering by Deformed Nuclei - J.L. Dhar and S.K. Shah - Feshbach's projection operator formalism for nuclear reactions is particularised to describe inelastic scattering for a selected set of target excitations of light nuclei. A coupled channel calculation is performed for the selected open channel part of the wavefunction. The Hamiltonian for the closed channel part which contain a collective degree of freedom is diagonalised in a particle-hole basis in a deformed scheme. The contribution from the complicated excitations of the compound system is assumed to be small in the energy interval of present interest.

The calculated widths and total cross section for proton scattering by targets N^{15} and F^{19} agree reasonably well with the experimental data.

P. PHYSICAL RESEARCH LABORATORY, AHMEDABAD

1. Projected Spectra From Alpha-Clustered States With a Skyrme Interaction - S.B. Khadkikar - The states of good angular momentum are projected from equilibrium alpha-cluster configuration employing a density dependent Skyrme interaction. In particular the dependence of spacings in the projected spectra on the addition of a p-state repulsion is studied. It is found that the p-state repulsion which would be necessary for saturation in the case of density independent interaction leads to more spreading of the energy spacings, even though in this case large cluster separations are obtained. Calculations for the nucleus Be^8 have been done. It is seen that the effective "moment of inertia" is also sensitive to the way in which an effective interaction would saturate and could be used in addition to the information about single particle energies to pin down the relative amounts of odd-state repulsion and density dependence in the effective interaction to be used in the alpha-cluster calculations.

2. E2 Transition Systematics in the 1f-2p Shell : A Constraint on the Effective Interaction - K.H. Bhatt and S.K. Sharma - A dramatic feature of the experimental E2 transition systematics in the 1f-2p shell is the drop in BE2 (0→2) values when N or Z=28, the BE2 (0→2) values for the nuclei with N=26 and 30 being significantly larger than those for the N=28 nuclei.

An implication of this is that the intrinsic quadrupole moment for the N=28 isotope must be <u>smaller</u> than that for the N=26 or 30 isotope. As against this, the most consistent feature of the Hartree-Fock (HF) or Hartree-Fock-Bogoliubov (HFB) calculations carried out with various interactions has been that the quadrupole moments of the HF or HFB intrinsic states for the N=28 isotopes are considerably <u>larger</u> than that for the N=26 and 30 isotopes. In view of this contradiction, we have made an attempt to indicate that the experimental BE2 systematics can serve as a useful and sensitive constraint for modifying the effective interaction. A search is made for some simple modifications in the Kuo-Brown Interaction which would tend to make it satisfy this constraint.

3. <u>Pairing in D-S Shell</u> - Jyoti Parikh* and S.P. Pandya - Hartree-Fock-Bogoliubov calculations in d-s shell have been carried out by a number of authors, but usually only for N=Z even-even nuclei. We present here systematic results for nuclei with neutron excess viz., isotopes of O, Ne, Mg, Si and S. The welknown Kuo interaction has been used with single particle energies of ^{17}O. Only pairing between neutrons and between protons is taken into account. Sizable pairing effects have been seen for several nuclei. Generally proton HF gaps appear to decrease as neutron pairs are added. In ^{30}Si (prolate) only

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* Atomic Minerals Division, New Delhi.

neutrons exhibit pairing, whereas in ^{32}Si (prolate) only protons show pairing effects. In ^{24}Ne prolate solution shows pairing only for protons. For ^{26}Mg and ^{28}Mg HF solutions show prolate solutions to be lower in energy, whereas HFB gives oblate solutions slightly lower in energy. Inclusion of pairing can drastically alter the nuclear structure in such cases. HF solutions for ^{18}O and ^{20}O are found quite unstable to pairing effects, and HFB gives almost spherical shapes.

4. <u>A Study of Odd-Odd Nuclei in 1f-2p Shell</u> - A. Dhar and D.R. Kulkarni - Systematics of odd-odd nuclei of lower f-p shell are being investigated in the frame work of axially deformed configuration mixing calculations. We have obtained both prolate and oblate Hartree-Fock (HF) intrinsic band heads of different K values for these nuclei using the interaction of Kuo with and without the modifications suggested by McGrory et al[1]. It is observed that in most of the cases not only prolate solutions are lower in energy and very close to oblate ones, but also different K bands of a given deformation are close to each other. Moreover, the bands with $K=k_p+k_n$ come lower in energy than the ones with $K= k_p-k_n$. In all these cases HF single particle gap is quite small. We intend to diagonalize the Hamiltonian within the space of states obtained with various excitation of two odd nucleons. States of good-J

shall then be projected from the lowest energy intrinsic states with different values of K.

5. Improved HF Calculations for ^{28}Si - D.R. Kulkarni and S.P. Pandya - Axially deformed Hartree-Fock calculations have been done for nucleus ^{28}Si using three different interactions viz. a) Kuo's renormalized interaction, b) the interaction obtained by radical integral parameterization to fit the observed levels of nuclei of mass number A=18 to 20, c) the modified Kuo interaction obtained by McGrory and Wildenthal. The energies and transition probabilities of the good-J states projected from the lowest oblate and prolate HF intrinsic states are obtained. The agreement between the calculated results and the experimentally observed results improves gradually as we go from interaction a) to c), reflecting the interaction - dependence of these calculations. An attempt has been made to explain this result by carrying out in detail the radial integral analysis of these interactions.

6. Generator Coordinate Spectrum of ^{28}Si - D.R. Kulkarni and S.B. Khadkikar - The generator coordinate (GC) calculations based on projection from constrained Hartree-Fock (HF) state is applied to obtain T = 0, energy levels of ^{28}Si nucleus employing different effective interactions. It was observed that the response curve obtained using Kuo's renormalised interaction is quite stiff and therefore the GC calculations do not yield much improvement of the ground state band compared to the original

HF projected calculations which are in poor agreement with experiment. On the other hand the response curve for the kuo interaction as modified by McGrory and Wildenthal is quite soft indicating that HF projection alone may not be a good approximation even though it yields satisfactory agreement with experimental results. This has been investigated for various choices of the points selected for GC calculations. A comparison is made between the experimental and calculated spectra of energy levels upto $\sim$ 15 MeV excitation.

Q. PUNJAB UNIVERSITY, CHANDIGARH-14

1. The Governor Model of Gupta and Trainor and its Application to Nuclear Fission - Raj K. Gupta - Greiner and his collaborators have recently advanced a two-centre shell model and applied it successfully to the phenomena of fission. The fission of the nucleus is achieved by assuming the shrinkage of the middle of the nucleus such that it breaks up into two equal (or unequal), spherical or deformed parts. The model, however, does not seem to account for the fact that at low excitations whole of the nucleus does not participate in rotation - a result that forms the basis of our so-called Governor model. The fission process in this model can be looked at as the shrinkage of the central core such that more and more nucleons come out of the core and finally at fission the core reduces to zero and the nucleus gets divided into two parts. Calculations based on this physical picture are being carried out.

2. On the Peculiar S-shape Observed in the Rotational Spectra of Even Even Nuclei - Raj K. Gupta - Recent experimental data on the ground state rotational band of a deformed even even nucleus when represented by a moment of inertia vs. angular velocity (squared) plot, results in a peculiar S-shape. First report on such high spin ($I \sim 20$) states was published in April, 1971 where the resulting S-shape for Dy-160 was described "singular". However, very soon the S-shapes were observed for enough number of nuclei that in May, 1972 a full symposium on this subject was

organised in Stockholm. These points were analysed: (i) the phenomenology of this data by the use of rational fractions in terms of angular momentum, and (ii) the success of the variable moment of inertia. The variable moment of inertia model for the asymmetric shape of nuclei has been worked out which allows a simultaneous analysis of the data for both the ground state band and the γ-vibrational band.

3. Level Structure Studies in ^{75}As and ^{131}Xe - Nirmal Singh, S.S. Bhati, R.L. Dhingra and P.N. Trehan - Gamma ray energy and intensity determinations with considerable precision have been done in the decay of ^{75}Se and ^{131}I using 8 cm^3 Ge(Li) detector and ND512 channel analyser. In addition to this, directional correlation studies have been carried out for 121-279, 136-279 keV cascades in ^{75}As and for 284-80 keV cascade in ^{131}Xe. The directional correlation for the 326-177 keV cascade in ^{131}Xe is under study at present which will enable us to make a spin assignment to 341 keV level. Mixing ratios and transition probabilities have been calculated for some transitions in ^{75}As and ^{131}As and their comparison made with the single particle estimates.

4. Angular Correlation Studies in the Decay of ^{147}Nd - S.S. Bhati, Nirmal Singh, R.L. Dhingra, P.C. Mangal and P.N. Trehan - Gamma-gamma angular correlation studies for four cascades 197-398, 398-91, 319-91 and 440-91 keV have been

carried out in the decay of ^{147}Nd. The measured correlation co-efficients for these cascades are

$$W(\theta,197\text{-}398) = 1+(0.062\pm0.012)P_2(\cos\theta)$$
$$= +(0.070\pm0.021)P_4(\cos\theta)$$
$$W(\theta,398\text{-}91) = 1-(0.062\pm0.018)P_2(\cos\theta)$$
$$-(0.008\pm0.000)P_4(\cos\theta)$$
$$W(\theta,319\text{-}91) = 1+(0.107\pm0.008)P_2(\cos\theta)$$
$$-(0.005\pm0.015)P_4(\cos\theta)$$
$$W(\theta,440\text{-}91) = 1+(0.053\pm0.013)P_2(\cos\theta)$$
$$+(0.000\pm0.000)P_4(\cos\theta)$$

A spin assignment of $5/2^+$ has been made to the 490 keV level on the basis of angular correlations for the 398-91 and 197-398 keV cascades. Multipole admixtures in 197, 398, 319 and 440 keV gamma rays are found to be M1+(82±4)%E2, M1+(5±1.5)% E2, $M1(1.5\ ^{+1.0}_{-0.5})\%$ E2 and $M1+(25\ ^{+4}_{-3})\%$ E2 respectively. The comparison of calculated transition probabilities for various gamma rays have been made with single particle estimates.

5. <u>Internal Field of Hafnium Nuclei In a Feromagnetic Host</u> - B. Singh, A.K. Dhar and H.S. Hans - The integral reversed field method of perturbed angular correlations has been used to determine the induced magnetic field acting on hafnium nuclei embedded in nickel host. The spin precession of the $9/2^+$(208-keV) $9/2^-$(113-keV) $7/2^-$ $\gamma-\gamma$ directional correlation in ^{177}Hf was

used for the above purpose. The measurements on the internal field in cobalt host are in progress.

6. Magnetic Moment of the Second Excited State of ^{160}Dy - A.K. Dhar, B. Singh and H.S. Hans - The application of the perturbed angular correlation technique to a triple gamma cascade with an unobserved intermediate transition has been analysed. Using an external magnetic field of 16.5kOe, the rotation of the 299-682(unobserved)-197 keV cascade in ^{160}Dy has been determined as $\omega\tau = 0.024 \pm 0.003$. This corresponds to a magnetic moment $\mu(283\text{-keV}, {}^{160}Dy) = +1.36 \pm 0.20$, which is in agreement with the rotational level systematics of the deformed nuclei.

7. Core Excitation Effects in Nb^{91} Spectra - S. Shelly and R.K. Bansal - A complete microscopic calculation of isospin-excitation effects of the core on energy spectra has already been done[1] for the nuclea which consist of a closed neutron shell plus a proton in one of the empty shells. Formalism of the above calculation have been applied to the case of the nucleus Nb^{91} ($Zr^{90} + d_{5/2}$ (proton)). The single particle strength which is expected to be concentrated in one level in the absence of core excitation, is fragmented into $(2j + 1)$ pieces, where j is the angular momentum of the orbit to which the proton is added, thus giving rise to a fine structure in the spectrum.

R. PANJABI UNIVERSITY, PATIALA, PANJAB

1. Mixing of States with $\Delta N = \pm 2$ In Nuclear Spectra And The Transition-Probabilities - S.D. Sharma - The mixing of $\Delta N = \pm 2$ state through the particle part of the Hamiltonian for a deformed nucleus, is an important aspect in the study of nuclear dynamics. The present treatment is a theoretical approach to the study of this type of mixing in some of the deformed nuclei. The predictions of transition-probabilities between the H.O shells with $\Delta N = \pm 2$ are encouraging (especially in case of some of the odd-odd nuclei). Also the predictions of the spacings between band-heads with principal quantum numbers differing by two are tested with the experimental reports.

2. The Spectra, Static Moments and Transition Probabilities in Pr^{144} And Bi^{208} - S. D. Sharma - The region near Z = 57 is now believed to be deformed through the experimental investigations by Sheline et al. The symmetric core as well as asymmetric core collective model is applied to explain the static and dynamic properties and the best fit parameters are obtained on comparison with the experimental reports. The model is found to work reasonably well. The transition probabilities are found to follow the general trend in the C - rotational sequences. The effect of mixing the other nearby Nilsson states is studied. In case of Bi^{208} the results show

some improvements on addition of vibrational parts to the Hamiltonian. (There is somewhat deformation due to the additional odd-nucleons after the magic numbers.)

3. Saturation of Particle-Waves Effect of Band-Mixing on Moments of Inertia in Odd-A And Odd-Odd Nuclei - Jagaddeva Gargi and S.D. Sharma - In the study by Sharma and Davidson the saturation of particle-waves at a certain spin was shown to be a remarkable demarcation line for the cease of nucleonic contribution towards the spectrum. The fact has been justified using the pure rotational wave-function and the wave-functions including those of the additive nucleons. The study is carried on further through the investigations of the effect of band - mixing on moments of inertia, due to the coupling of necleons with the nuclear core. The results concluded in the study tally quite well with the experimental reports.

4. Effect of Nuclear Forces on Magnetic Moments of Odd-Odd Nuclei - S.D. Sharma - The effect of nuclear forces is studied in relation to the magnetic dipole moments of deformed odd-odd nuclei. The importance of study of magnetic moments in high lying members of C-rotational sequences (especially $K = 0^{\pm}$ bands, where the odd-even shift is observed) is emphasized. The observational data are poor. The results are analysed in case of available experimental reports. The approach is justified on physical grounds.

5. Empirical Behaviour of the (n,2n) Cross Sections For 14-15 MeV Neutrons - K.C. Garg and C.S. Khurana - The 14-15 MeV (n,2n) cross-sections are found to depend mainly on the asymmetry parameter and the Q-value. No shell effects are found to exist in the (n,2n) cross-sections. The total (n,2n) cross-sections in the high, intermediate as well as low Z-number are found to be well predicted by an empirical relation which takes care of the asymmetry parameter $\xi\left(\frac{N-Z}{A}\right)$, its square and the Q value.

S. UNIVERSITY OF DELHI, DELHI

1. Directional Correlations of Gamma-Gamma Cascades in ^{75}As - S.L. Gupta, M.M. Bajaj and N.K. Saha - Gamma-gamma directional correlations of the two weak cascades 136-66 and 66-199 KeV have been measured and analysed taking into account the interfering contributions of the strong neighbouring cascade 121-280 and 136-265 KeV. Measurements have also been made on the latter two cascades for this purpose. Inconsistencies existing in some of the measurements reported earlier have been pointed out. The present work settles the spin of the 199 KeV level as 1/2 and the spin values 3/2, 5/2 and 5/2 for the excited levels at 265, 280 and 401 KeV respectively. The quadrupole admixtures in the 66, 136, 265 and 280 KeV transitions have been estimated to be $(3.5\pm1.7)\%$, $(6.5\pm3.0)\%$, $(5.4\pm4.4)\%$ and $(13.5\pm6.5)\%$ respectively. The partial lifetimes and nuclear speeds of dipole and quandrupole components of the 136, 265 and 280 KeV radiations have been computed.

2. Nuclear Systematics of Speeds of Dipole and Quadrupole Transitions - The variation of the hindrance per unit nucleon with the energy of the E1, M1, E2 and M2 transitions has been studied. Some interesting regularities are observed and a general relation in terms of the energy of the transitions has been developed. This relation roughly covers almost all data reported so far, with a suitable adjustment of the parameters: inverse mass number coefficient and linear, square and

inverse energy coefficients. The variation of the E2 enchancement per nucleon with the energy of the gamma transition has also been studied in the odd-A spherical nuclei and a semi-empirical relation has been developed. Validity of the relations and the choice of parameters has been analysed.

T. UNIVERSITY OF POONA

1. A Modified Design of the Magnet for Microtron and Its Energy Error Free Orbits - M.R. Bhiday, V.C. Bhoraskar, R.K. Shalla and V.B. Asgekar - In the literature of microtron, calculations for field free space of the magnet are described with velocity correction, however, the momentum energy[1] correction was not effectively used. On applying the momentum energy correction to our proposed 20 MeV race-track microtron magnet, the calculated values of the field free space show a considerable discrepancy from those calculated with velocity correction. The computed values using magnetic field of 2 KG and radio frequency 3 GHz reveal that the field free space is to be reduced by 18.38% of the original for the first orbit and by 19.55% for the 21st orbit and similar modifications are necessary for the orbits in between. Deletion of the above mentioned correction will lead to a phase error of 61.55° for the first orbit which is sufficient to blow off the beam. Similarly reports are available which deal with the magnitude of the energy error associated with an orbit to maintain phase stability, however, no information was available to make any particular orbit, at will, error free. In this work, a technique is studied which enables to make any orbit of microtron error free, without affecting the phase stability.

1. Tech. Rep. 156, Illinois.

V. UNIVERSITY OF ROORKE, ROORKEE

1. Beta-Gamma Angular Correlation Coefficients for Allowed Beta Transitions and the Conserved Vector Current Theory - H.S. Dahiya and B.P. Singh - Experimental non-zero values of beta (allowed) gamma angular correlation coefficients (A_{22}) for the radiations from the decay of the following isotopes Na^{22}, Co^{56}, Co^{58}, Eu^{145}, Eu^{152}, Cs^{134}, Sb^{124}, Ag^{110m}, Co^{60}, Mn^{56} and Na^{24} are reported in the literature. In order to account these non-zero values of A_{22}, the contribution of 2nd order forbidden matrix elements in allowed beta transitions (referred by the factor ρ) are considered along with a model dependent factor 'η'. These contributions are made with and without Gell-Mann's Conserved Vector Current Theory for momentum type matrix elements. The plot of A_{22} versus ρ for various values of η for above mentioned $\beta-\gamma$ angular correlation are given and experimental non-zero values are discussed in this light.

2. Beta-Gamma-Gamma Angular Correlation Studies From the Decay of Rh^{106} - R.R. Sharma, H.S. Dahiya and B.P. Singh - One plastic scintillator (spectrometer) and two NaI(Tl) detector (spectrometers), all mounted in the plane of the table (two detectors, the plastic scintillator and one of the NaI(Tl) detectors are fixed perpendicular to each other and the third detector NaI(Tl) detector movable in opposite quadrant of the

two fixed detector) are used for coincidence and angular correlation studies of the β group of E_{max} of 2.4 MeV → gamma rays of 622 KeV or / and 610 KeV → 511.8 KeV from the decay of Rh^{106}. Angular correlation studies of β -group of E_{max} of 2.4 MeV and gamma rays of 610 KeV + 622 KeV and gamma-gamma angular correlation ~~correlation~~ studies of gamma rays selecting gamma rays in the combined photo peaks at (610 KeV + 622 KeV) are also done.

The results are analysed in order to account the doublet at 1.1278 KeV and 1.1333 KeV in Pd^{106}. The multipolarity of gamma transitions are obtained.

V. VIKRAM UNIVERSITY, UJJAIN, MADHYA PRADESH

1. T = 1 Effective Potential in sd Shell - S.C. Gupta and K.P. Joshi - Equivalent potentials have been derived by reproducing the radial integrals of the effective interaction of Cohen et al. An earlier paper by Dikshit describes the equivalent potentials which have attractive core with repulsion at intermediate range and with attractive tails. Our analysis shows that with the proper choice of the parameters one can obtain effective potentials which are in agreement with the accepted view. It is found that the renormalisation of the free nucleon-nucleon potential in finite nuclei appears to dilute and flatten the repulsive core.

2. A Simple Equivalent Potential From Yale Interaction - K.P. Joshi - An equivalent potential of the form, central plus tensor forces, has been derived from the realistic Yale interaction. The radial shape of a single Yukawa suffices in all but s-states where a sum of two Yukawa shapes are necessary. The parameters of the equivalent potentials have been determined by best fitting the relative matrix elements of the Yale interaction. The derived equivalent potential is compared with the purely phenomenological potentials used by various authors. Remarks are made about the nature of the effective interaction in nuclei.

3. Single Particle Energies and Binding Energy of ^{16}O And Effective Interactions - Gopal K. Upadhyay and K.P. Joshi - Effective interactions in sd shell region in widespread use for nuclear spectroscopic calculations are compared in respect of the single-particle energies and binding energy of ^{16}O. Both types of effective interactions-purely phenomenological and those derived from the realistic potentials have been used. The latter potentials are derived by best fitting the relative matrix elements of the realistic interactions, yale and sussex. No effective potential reproduces both the quantities though the potentials derived from the realistic interactions fare much better.

W. VISVA-BHARATI UNIVERSITY, SANTINIKETAN, WEST BENGAL

1. A Perturbation-Theoretic Approach to the Woods - Saxon Potential - D. Chattarji and M.N. Sinha Roy - It is shown that the Woods-Saxon (WS) potential can be written in the form

$$V_{WS}(r) = - V_o/(1 + e^{r-R/a}) = -V_o + f(r), \qquad (1)$$

where

$$f(r) = \sum_n a_n L_n(r). \qquad (2)$$

$L_n(r)$ are Laguerre polynomials and the coefficients a_n are such as to ensure rapid convergence of the series. Also,

$$f(r) \longrightarrow V_o \quad \text{for} \quad r \gg R, \qquad (3)$$

so that $V_{WS}(r)$ may be regarded as a square well plus a perturbation term. Eq.(1) permits us to expand the solution of the Schrodinger equation for the WS potential in terms of the much simpler solutions of the square well problem. Coefficients of this expansion have been obtained explicitly.

X. GOVERNMENT ENGINEERING COLLEGE, BILASPUR

1. Statistical analysis of (α,n) Reaction Products - S. Roychoudhury - The neutron spectra produced by $Fe^{56}(\alpha,n)$ and $Cu^{63}(\alpha,n)$ reactions have been studied for alpha energies between 11.5 and 22.7 Mev. The analysis of the angular distribution is performed on the basis of spin dependent statistical theory of nuclear reactions. Calculations were performed with several energy independent values of moment of inertia as well as energy dependent values. The computed distributions have been compared with the experimental results for (α,n) reactions and, are in agreement with the experiment. The analysis indicated that nuclei at high excitations have rigid moment of inertia.

Y. GOVERNMENT POST GRADUATE COLLEGE, PANNA

1. Effective Density of Rotating Nucleons and Moment of Inertia calculations for Deformed Nuclei - D.S. Rai - Following the 'Governor Model' of Gupta and Trainor, an expression for effective density of rotating nucleons is derived. Using experimental values of effective moment of inertia and deformation parameter, effective densities for deformed nuclei in the regions 152 A 190 and A 222 are calculated and are found to be 0.95 and 1.2 respectively. On the basis of the same model, a simple and new expression for the effective moment of inertia of even-even deformed nuclei has been derived. The derived expression gives satisfactory agreement with experimental values.

Previous reports published by the Indian Nuclear Data Group (INDG) :-

1. A.E.E.T./NP/10	Progress report on Nuclear data activities in India-I	1964
2. A.E.E.T. -227	Nuclear Data measuring facilities in India	1965
3. A.E.E.T. -228	Progress report on nuclear data activities in India-II	1965
4. A.E.E.T. -227	Progress report on nuclear data activities in India-III	1966
5. B.A.R.C. -305	Progress report on Nuclear data activities in India-IV	1967
6. B.A.R.C. -401	Progress report on Nuclear data activities in India-V	1969
7. B.A.R.C. -474	Progress report on Nuclear data activities in India-VI	1970
8. B.A.R.C. -553	Progress report on Nuclear data activities in India-VII	1971
9. B.A.R.C. -614	Progress report on Nuclear data activities in India-VIII	1972

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Progress Report on Nuclear Data Activities in Korea

Compiled by

M. Cho

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN KOREA

Compiled by M. Cho

Liaison Officer of INDC,

Reactor Physics Lab., Korea Atomic Energy Research Institute

* Measurement of Isomeric Ratios for Thermal Neutrons

Hae-ill Bak

Seoul National University

Huhn Jun Kim and Chul Lee

Korea Atomic Energy Reseach Institute

Isomeric ratios were measured for the capture of thermal neutron by ^{79}Br, ^{80}Se, ^{103}Rh, ^{115}In and ^{133}Cs as well as those of epi-cadmium neutron by ^{79}Br, ^{80}Se and ^{133}Cs, The measurements were performed by analysing decay curves obtained by γ-ray spectrometry after irradiation. The counting efficiency curve was determined by using the calibrated standard sources with overall uncertainties of about 1%. Isomeric ratios, given in σ high spin/(σ high spin+ σ low spin), of $^{80,80m}Br$, $^{81,81m}Se$, $^{104,104m}Rh$, $^{116,116m}In$ and $^{134,134m}Cs$ produced by thermal neutron activation were found to be 0.21 ± 0.01, 0.14 ± 0.02, 0.12 ± 0.02, 0.69 ± 0.07 and 0.058 ± 0.004, respectively, Those values of $^{80,80m}Br$, $^{81,81m}Se$, and $^{134,134m}Cs$ produced by epi-cadmium neutron were found to be 0.19 ± 0.02, 0.29 ± 0.02 and 0.074 ± 0.011, respectively. The experimental values obtained were compared with the theoretical values deduced from the statistical model. There were the general agreements between the theory and the experiment.

* Scattering Effectiveness of Monoenergetic Neutrons in the Various Shielding Materials

Young Soo Yoo

Korea Atomic Energy Research Institute

In neutron shielding, the scattering effect is equally important as the attenuations in shielding materials. In the present study, the scattered dose equivalent was measured using a Rem counter for water, paraffin, borated paraffin, ordinary and heavy concrete, lead, iron, and tissue equivalent material in three different angles; 45°, 90°, and 135°, respectively.

The measurements were performed for the neutron, having the energies of 0.5, 1, 2, 5, and 18 MeV, which are produced from the Van de Graaff accelerator.

The scattered dose equivalent ratios were increased with increasing the thickness of scattering materials and saturated at a certain thickness although they were different from one to other materials under study. The ratios were large for lead and iron while they were small for the hydrogen containing materials such as water and paraffin etc.

* Current Status of KAERI

May 1972, TRIGA MARK III reactor (2 MW) reached its criticality and installation of the facilities for neutron physics experiments are in progress.

Van de Graaff and FCA project reported in previous progress report (INDC(KOR)-1/G) were held over until a date to be fixed.

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STATE COMMITTEE FOR NUCLEAR ENERGY

PROGRESS REPORT

ON NUCLEAR DATA IN ROMANIA

during the year 1972

Compiled by

S. RAPEANU, H. TOTIA

BUCHAREST, 1973

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N O T E

This annual report contains two parts:

- a general view on the neutron physics experiments carring on, facilities for neutron physics measurements as well as the activity regarding the preparation of a library of microscopic data evaluated by the Institute for Atomic Physics and group constants calculated by the Institute for Nuclear Technology;

- individual reports concerning certain results for nuclear data in the field of thermal and fast neutrons.

The individual reports are not intended to be complete or formal. Consequently, they must not be quoted, abstracted or reproduced without the permission of the authors.

SHORT REVIEW ON NUCLEAR DATA ACTIVITIES

Due to the special requirements imposed by the up-to-date technology and power production, a vast plan of scientific research in physics and nuclear technology has been worked out in the Socialist Republic of Romania.

According to the National Nuclear Plan Programme various nuclear technological and scientific fields are in a steady development among which a particular place is held by the experimental and theoretical problems concerning nuclear data for reactors.

In full agreement with the importance of the nuclear data in the nuclear power development, a laboratory working on this theme has been founded, which the greatest part of the activities in this field within the Romanian nuclear research Programme. There are some other laboratories as well belonging to the Institute of Atomic Physics and the Institute for Nuclear Technologies, carrying on their activities on these subjects.

In order to reach their aim, the research scientists are oferred a wide range of equipment and have at their disposal the computer centre. Here are in short, the main existing facilities for the works regarding nuclear data problems:

- the VVR-S nuclear reactor operating with 10% enriched U, and using water as a moderator. Its present power is of 3.5 MW, and has a thermal flux of 2.10^{13} n/cm^{2}sec. (These characteristics will be improved with the time, by employing certain new fuel cans of the IRT-M type). The reactor has nine horizontal channels, a thermal column and 37 vertical channels.

The most important research equipment available at the reactor consists in crystal and time-of-flight spectrometers, monochromators

and neutron-selectors, a diffractrometer and a neutron-polarizer.

- a U-120 type cyclotron which can accelerate charged particles at different energies (from 3 to 13 MeV in case of protons, 6 - 13 MeV for deuterons and 12 - 20 MeV for α particles).

- the Van-de-Graff electrostatic accelerator of the Tandem type, model FN-15 (USA), which can accelerate protons at an energy of 4 - 15 MeV, producing a beam of a 5 mm diameter and 4 - 8 μA intensity.

- 3 betatrons, having a maximum accelerating energy of 8,15 and 25 MeV.

- a linear accelerator for electrons of a 2,2 - 3,1 MeV energy.

- several other neutron generators (both native and imported) and a γ source of cobalt-60 having a 10,000 Curie activity.

- different types of lasers (with Helium-Neon, CO_2, ionized argon or Cd vapours).

- two subcritical assemblies, one of them with enriched U-graphite and the other with natural U-water and a zero power reactor with enriched U-light water.

- two "on-line" computers for various experimental facilities of the PDP-8/1 and PDP-15/20 types.

- an electronic computer of the IBM-370/135 type, having soon a memory of 192 K bytes, with working capacity on a virtual memory of 512 K bytes, and equipped with various periferials (line-printer, disk, magnetic types and card-readers).

- γ, β spectrometers Mössbauer, nuclear magnetic resonance and spin electronic resonance spectrometers.

The main activities in the nuclear data field from Romania will be further presented:

I. The activity carried on in the nuclear data laboratory from the Institute of Atomic Physics

This activity follows two important directions of development, namely: a theoretical and an experimental one.

1. The Theoretical Activity

The main activity consists in forming a national library of evaluated microscopic nuclear data. The DANEM adjusted shape for data storage represents an adjustment of the ENDF/B system to our present possibilities and needs at the same time, the code system necessary for library use, has been also worked out (storage, retrival, checking, fitting codes and plots). At present, the library contains evaluated data received from INDC-IAEA (the KEDAK data, some other data from UKNDL and ENDF/B).

For the time being, the laboratory activity is being carried on in three directions:

- to have a permanently up-to-date the data library, by introducing the newly received or their own data and by producing the latest possible shape for the storage and the connected codes (wishing to achieve an integral adoption of the original ENDF/B system).

- to compilate and evaluate a neutron microscopic data. Initially, this activity was limited to some iron isotopes and only to some of the data types. In the future, this activity will develop even more, including problems of a particular interest, mentioned by INDC.

- to draw up certain codes and computation methods for the multigroup constants, required in the calculations of the rapid and thermal reactors of a nation interest.

At the same time, an activity of adjusting the multigroup constant sets will be initiated, based on a comparison between the results of the reactor theoretical calculations and the results of various reactor integral experiments.

2. The Experimental Activity

There have been carried on various scattering experiments and determinations of the scattering law for thermal neutrons, on various liquids at low temperatures, as well as on metals (solid and liquid) and alloys, by employing the technique of crystal and time of flight spectrometry.

The number of these experiments will increase, including some other substances of real interest for nuclear reactors. At the same time, the working field will become ever larger, due to the measurements. That will be made, by means of the tandem accelerator and of the cyclotron. Consequently, important measurements will be carried on, for those materials, for which the evaluation activity of microscopic data will be effected.

II. The Theoretical and Experimental Activity in the Nuclear Field, Carried on in Some Other Laboratories in the Institute for Atomic Physics

By employing the VVR-S reactor,various neutron physics measurements are carried on, for both thermal and rapid neutrons.

Determinations of hiperfine atomic structures by means of lasers are also under way.

Different studies on fotonuclear reaction are also carried on. by the help of the 25 MeV betatron (the fine structure of the gigantic resonance in fotoneutronic reactions, the cross section of the fotofission, etc.).

As for as the field of nuclear physics at law energies is concerned, various neutron nuclear reactions are being studied (such as: the ^{239}U fission) as well as non-neutron nuclear reactions (α particle reactions, protons, deuterons). Determinations of the statistical parameters of the residual nuclei from the reactions, have been also effected (n,γ); the productivity of rapid neutrons resulting from charged particle reactions, have been also measured.

Using the β—magnetic, gamma and Mössbauer spectrometers, determinations of the nuclear level diagrams have been also carried out.

Some theoretical evaluations of the ^{239}Pu fission section for rapid neutrons, have been also made. Important studies on the nucleus theory have been made as well (nuclear models, nuclear structure problems, nuclear reaction mechanisms).

In the future, the problems regarding the experimental research work, carried on by means of the tandem and cyclotron, will be further developed, by covering certain important problems in the range of low energies (unresolved resonances, fission sections, etc.).

A particular attention will be paid to the problems set up by INDC - measurements and evaluations for the materials required by IAEA.

Last but not least, we should also mention the importance of our collaboration with IAEA-INDC both in the reciprocal exchange of compilated and evaluated data, as well as in pointing the most important research problems in the nuclear data field.

$^{240mf}Pu$, $^{241mf}Cm$ AND $^{243mf}Bk$ FISSION ISOMER EXCITATION FUNCTIONS IN ALPHA-PARTICLE INDUCED REACTIONS

I.Vîlcov, N.Vîlcov, Yu.P.Gangrsky*, M.Marinescu
A.A.Pleve*, D.Poenaru, I.F.Harisov*

The purpose of the work was to measure the excitation functions of the /α,2n/ reactions leading to the $^{240mf}Pu$, $^{241mf}Cm$ and $^{243mf}Bk$ fission isomers in order to obtain their excitation energies.

The experiment has been performed at the I.A.P. Cyclotron by using the fission-in-flight technique /figure 1/. The delayed fission fragments emitted in flight by the recoil nuclei knocked-out of the target 1 by the bombarding alpha-particles are registerred by the mica annular detector 2. The small step energy variation of the incident beam is achieved by using an aluminium absorber 6. The target, the absorber and the detector are placed on the same mounting 7. A silicon surface-barrier semiconductor detector 8 is used for the measurement of the energy of alpha-particles scaterred by a thin carbon foil 5. A circular mica detector 3 counting the prompt fission fragments emitted by the target and a Faraday cup 4 are used for monitoring purposes.

The radial distribution of the delayed fission fragments registerred by the annular mica detector depends on the fission isomer life-time. The obtained fission isomers were identified by their life-times /see figure 2,1-$^{240mf}Pu$, $T_{1/2}$=3.8 ns; 2-$^{241mf}Cm$, $T_{1/2}$=15 ns; 3-$^{243mf}Bk$, $T_{1/2}$=2 ns/.

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*Joint Institute for Nuclear Research, Dubna, USSR

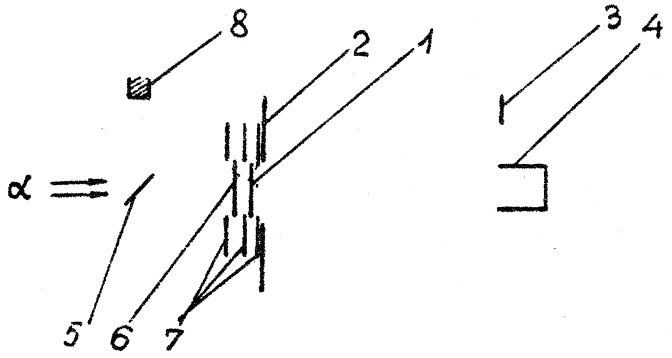

Fig. 1.

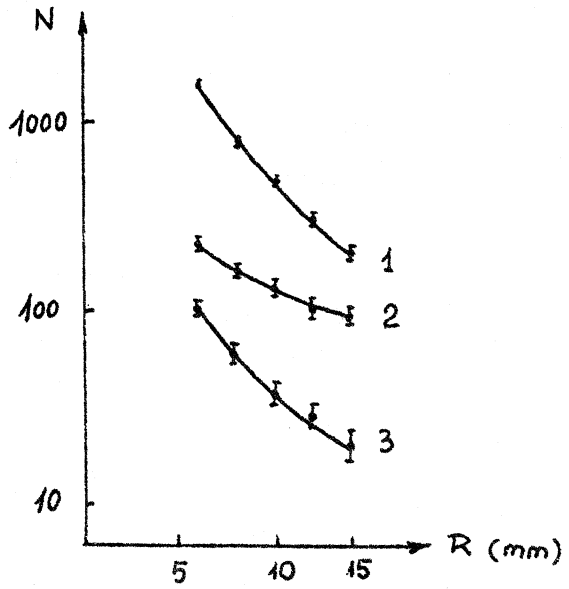

Fig. 2.

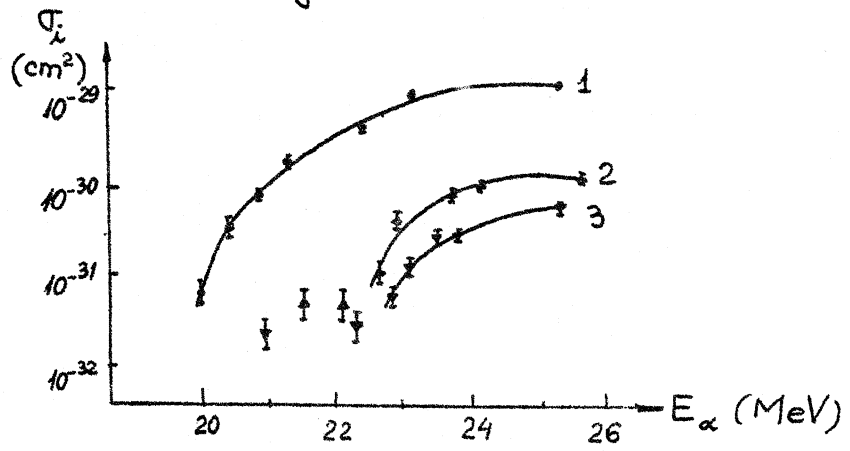

Fig. 3.

The $^{240mf}Pu$, $^{241mf}Cm$ and $^{243mf}Bk$ fission isomer cross-sections versus alpha-particle energy are shown in figure 3. The errors in the cross-sections measurement do not exceed 10% for the relative values and 30% for the absolute values. The accuracy of the alpha-particle energy measurement is of about 100 Kev.

From a fit to the above excitation functions the following values of the fission isomer excitation energies were obtained:

$^{240mf}Pu$ _____ E_{is}=2.5±0.2 Mev

$^{241mf}Cm$ _____ E_{is}=2.6±0.2 Mev

$^{243mf}Bk$ _____ E_{is}=2.2±0.2 Mev

A detailed paper concerning this experiment has been published in Yadernaja Fizika 16, 454 /1972/.

THE EFFECTIVE CROSS SECTION OF ^{165}Ho (γ,xn) REACTION

D. Catana, G. Baciu, V.I.R.Niculescu and C. Iliescu

The cross section of ^{165}Ho (γ,xn) reaction has been obtained from the (γ, total neutron) yield curve measurement with a 100 kev bin, in the range from threshold up to 23 MeV. The analysis of the yield curve is based on the least structure solution, using the thick target forward direction bremsstrahlung spectrum.

The measurements of the yield curve have been performed at the 25 MeV I.A.Ph. betatron. The bremsstrahlung end point energy could be changed from cycle to cycle with a constant increment, and photoneutrons were measured between radiation pulses, using a Halpern type detector.

In order to carry out the analysis of the yield curve with a thick target forward direction bremsstrahlung spectrum, a collimator with an angular aperture 2α=12 angular min was used.

The obtained cross section of $^{165}Ho(\gamma,xn)$ reaction is given in fig.1. In the same figure is given the computed total photoabsorption cross section based on $(\gamma,2n)$ cross section results of Fultz et al (Phys. Rev. 179, 1194 (1969)).

The experimental absorption cross section is compared with the computed cross section in the frame of the dynamic collective model and with the cross section computed using Nilsson level scheme.

The predictions of the two models are compared with the experimental results reported by Fultz et al. for oriented Ho nuclei. For the computation of the cross section in the Nilsson model, we used a constant width of 1 MeV and 2 MeV, for transitions obeying to $\Delta k=0$ and to $\Delta k=\pm 1$ selection rules, respectively. The results are shown in fig.2.

The integrated cross sections are summarised in the table 1. If we define two average energies E_1 and E_2 belonging to $\Delta k=0$ and $\Delta k=\pm 1$ transitions and the two widths Γ_1 and Γ_2 as the mean-root-square deviation of the energy transitions against E_1 and E_2, the cross section can be aproximated by a sum of two Lorentz lines. The results are given in table 2 together with the parameters of Lorentz lines which fit other experimental absorption cross sections.

Table 1 Integrated Cross Sections

	σ_0 mb MeV	σ_1 mb	σ_2 mb Mev^{-1}
a	2.51	166	11.56
b	2.79 ± 0.25	194 ± 14	14 ± 1
c	2.60 ± 0.21	178 ± 15	12.8 ± 1.5
d	2.59	165	12.3

a - Phys. Rev. 185, 1576(1969); b - Nucl. Phys. A 121, 463(1968); c - present experimental work; d - theory.

Table 2 Parameters of the Lorentz Lines

	E_1	Γ_1	σ_1	E_2	Γ_2	σ_2	$\int\sigma_2 dE/\int\sigma_1 dE$
a	12.28	2.57	214	15.78	5.00	246	2.24
b	12.07	2.7	250	15.62	4.8	295	2.03
d	12.15	2.49	203.7	15.61	4.66	245.1	2.25

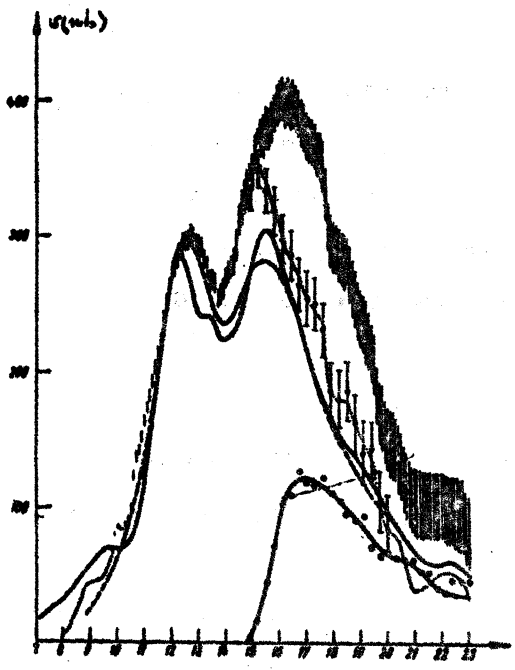

Fig.1 The $^{165}Ho(\gamma,xn)$ cross section (|)-experimental cross section; ($\frac{1}{2}$)-(γ,total neutron)-(⊙)(γ,2n); (...)-the difference between (|) and (γ, 2n) solide line;(—)-present computotal photoabsorption cross section; (---)-dynamic collective model results.

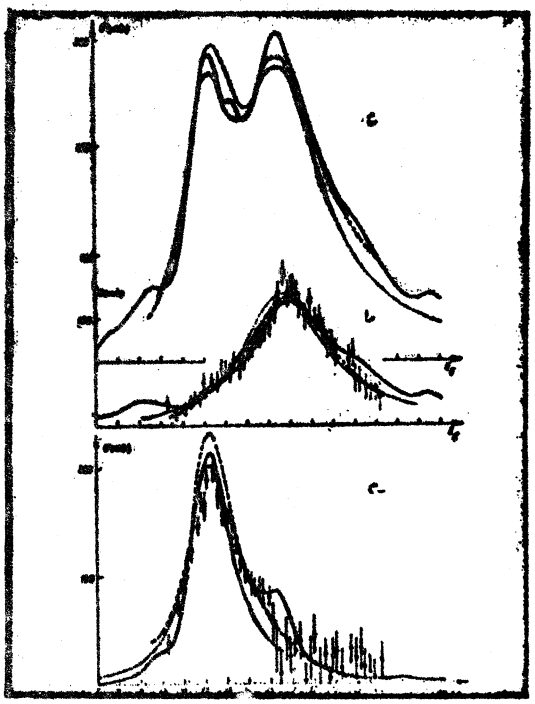

Fig.2 Present computed El photoabsorption cross section (—); Lorentz lines with parameters from table 2(d)(....); dynamic collective model results (---); experimental points (Phys.Rev. 179,1194(1969))($\frac{1}{2}$); a-σ_1; b-$\frac{1}{2}\sigma_1$; c-$\sigma=\sigma_1+\sigma_1$.

STATISTICAL PARAMETERS FOR TWO Tb ISOTOPES FORM $^{156}Gd(p,n)$ ^{156}Tb AND $^{157}Gd(p,n)$ ^{157}Tb REACTIONS

E.Trutia and R.Dumitrescu

The aim of the present work was the determination of some statistical parameters used in cross section calculations for rapid neutrons.

In the recent years, yttrium and its compounds have found a lot of uses in the nuclear industries [1]. The yttrium oxide habitually contains impurities of rare earths as: Gd, Tb, Dy, Ho and Er so that the knowledge of their properties, under all the aspects is of great importance. For this reason we found the study of the Gd(p,n) Tb reaction interesting.

The information concerning nuclear level densities was obtained from the study of the statistical emission of the neutrons resulting from $^{156}Gd(p,n)$ ^{156}Tb and $^{157}Gd(p,n)$ ^{157}Tb reactions with the aid of time of flight method [2].

The spectral data were fitted to the statistical model of the compound nucleus. The analysis was made on the energy spectra of the emitted particles at 130^{o} angle, so that the statistical emission should not be influenced by the contribution of some non-compound processes. For the some reasons the bombardment energy was chosen sufficiently small, that is 7,627 MeV.

The values of the a and T parameters of the two isotopes are in good agreement with the values of these parameters obtained for other elements situated in the same mass region from the neutron and proton resonances [3], [4].

The results are indicated in the table I

Table I

Element	Parameter	
	a (MeV^{-1})	T (MeV)
^{156}Tb	22,7 ± 4,7	0,479 ± 0,021
^{157}Tb	24,6 ± 0,4	0,505 ± 0,005

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THE USE OF CUBIC SPLINE FUNCTIONS IN NUCLEAR DATA PROCESSING

N.Deciu, S.Răpeanu

Spline functions represent a class of picewise polynomial functions which satisfy certain conditions regarding continuity of the function and its derivates /1, 2, 3/; we took into account these functions with a view to experimental data processing.

The property of cubic spline interpolation offers substantial advantages. It avoids the undulatory behaviour that commonly occurs when experimental data are fitted with analytic functions.

A Fortran Program has been written for ICL-1905 computer which is able to interpolate, differentiate and numerically integrate the experimental data.

A scattering spectrum of cold neutrons on the liquid benzene /4/ and a set of interpolated data for the elastic scattering cross-sections on ^{238}U in the range energy 10.6 - 21.5 eV are presented in Fig.1. The program and details are given in paper /5/.

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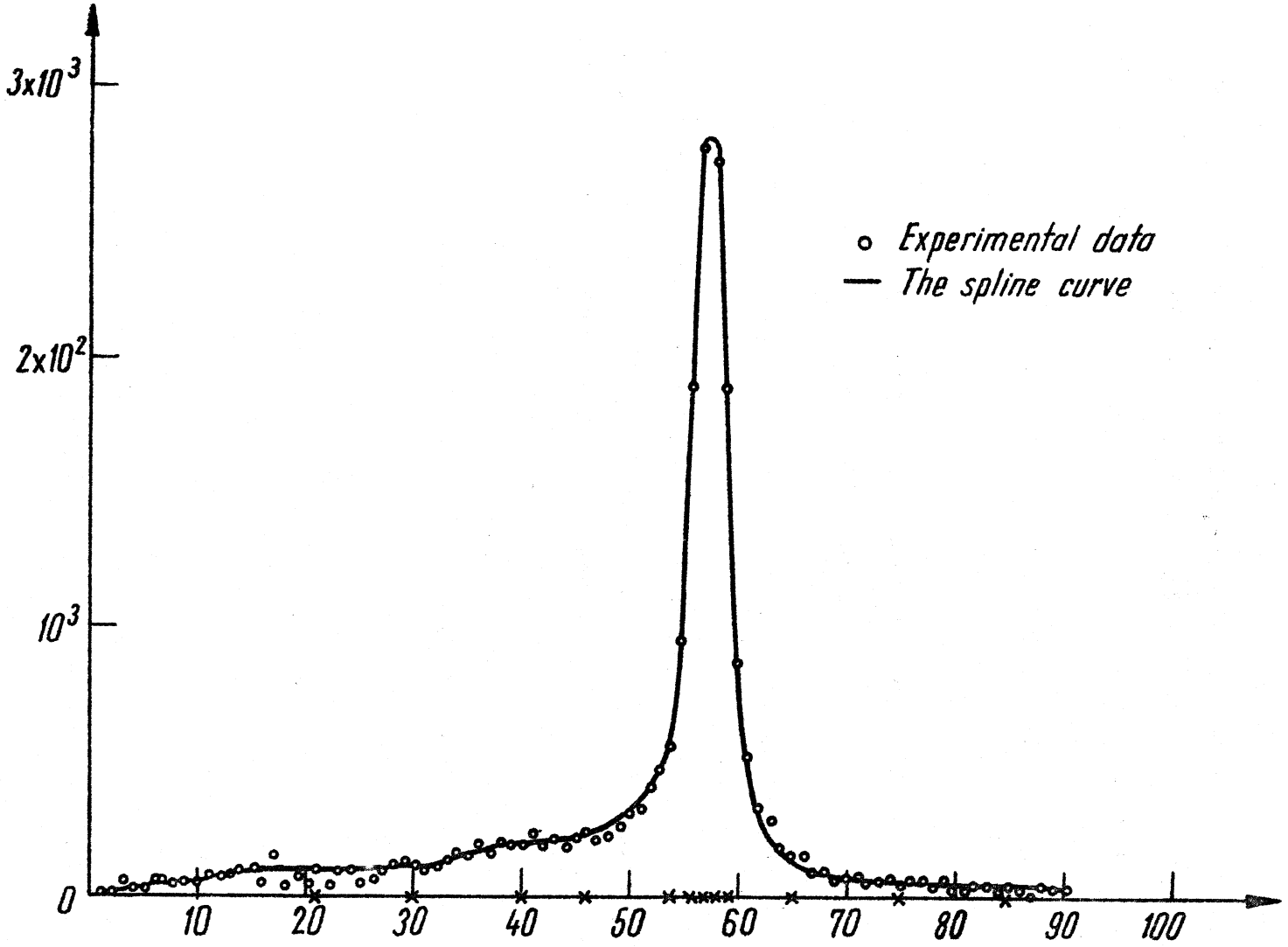

Fig.1. Scattering spectrum of cold neutrons on the liquid benzen
x) Positions of the knots

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THE THERMAL NEUTRON CROSS SECTION FOR Zr

H.Teutsch, I.Pădureanu

The present paper presents the cross section for thermal and cold neutrons for Zr.

The measurements have been carried on by means of a time of flight spectrometer, in two variants, namely: a) monocromator crystal-chopper with curved slits, b) Berilium filter, cooled at the temperature of the liquid N - chopper with curved slits.

The data have been compared with the evoluated data from the UKNDL British library and with the data published in BNL 325.

Examples:

λ=2.05 A T=25°C

σ_t=6.04 b - according to the present measurements

σ_t=6.20 b

σ_t=5.90 b

In figure 1, the obtained data for Zr, at a temperature of 25°C, in comparison with the data obtained from UKNDL and BNL-325 for the incident neutron wave lengths in the range of 4÷7 Å are presented.

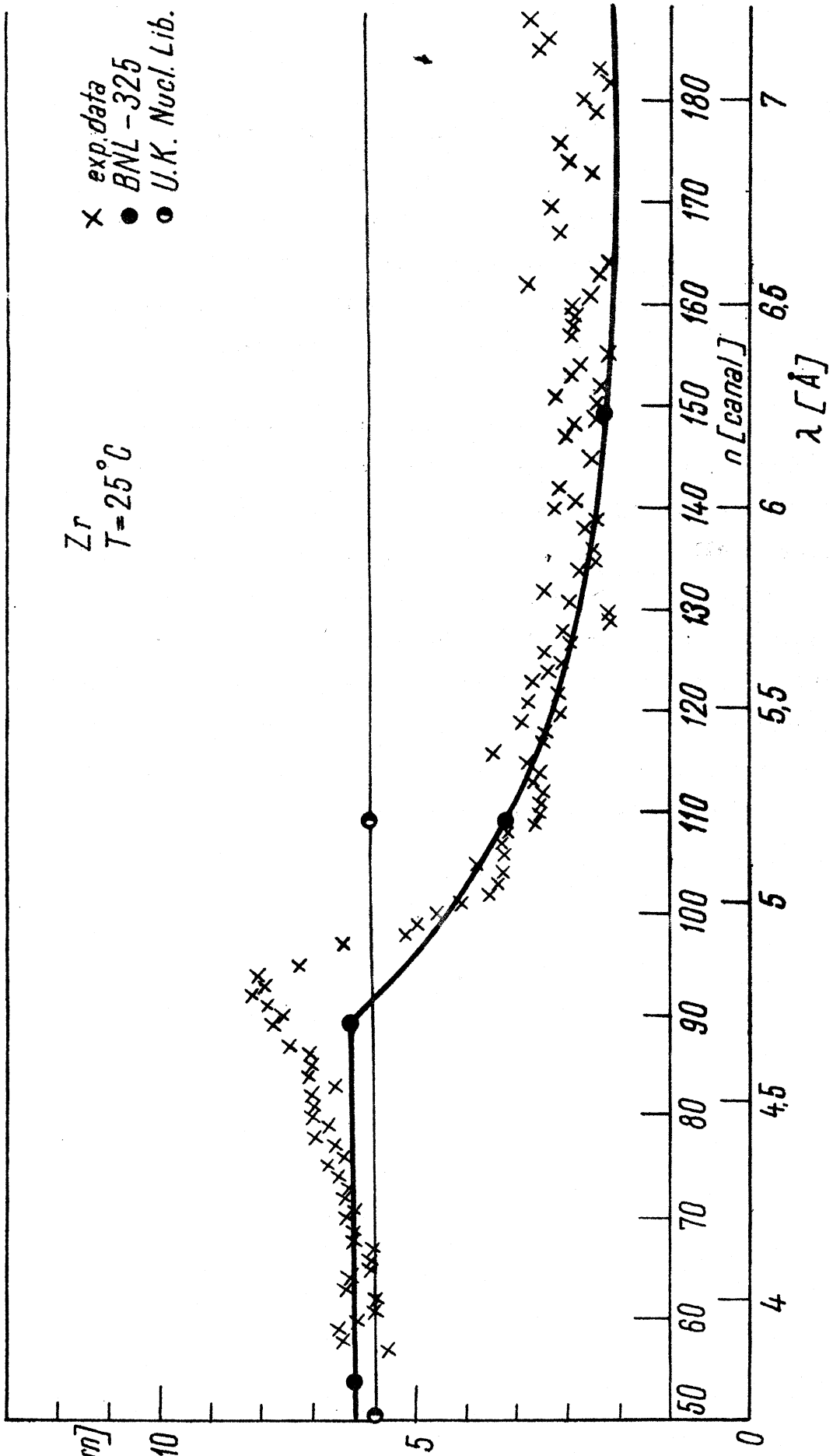
Zr
T=25°C
× exp.data
● BNL-325
◐ U.K. Nucl. Lib.
[barn]
10
5
0
50 60 70 80 90 100 110 120 130 140 150 160 170 180
n [canal]
4 4,5 5 5,5 6 6,5 7
λ [Å]

Fig. 1.

THERMAL NEUTRON SCATTERING IN LIQUID Al-Si AND Al-Zn ALLOYS

V.Tarină, D.Gelberg (Institute for Atomic Physics - Neutron Physics Laboratory)
I. Cosneanu (Research Institute for Machine Building, Bucharest, Romania)

Thermal neutron elastic scattering measurements in intermetallic compounds in liquid state have been carried. Giving informations on the dimensions of the coordination shells, on their modifications introduced by alloying and on the interatomic potential, the studies of the liquid state structure prove the evidence of the stable atomic conglomerates. The experimental measurements of thermal neutron elastic scattering in Al, Al-Si and Al-Zn have given the structure factors of these systems in the range of the wave-vector transfer $1 \div 9$ $\mathring{A}^{-1}$. The radial density functions in these liquid systems were obtained by Fourier inversion of the intensity functions.

A NEUTRON SCATTERING STUDY OF MOLECULAR MOTIONS IN TOLUENE ADSORBED ON η–ALUMINA AND ON CHROMIA SUPPORTED ON η–ALUMINA

S.Todireanu (Institute for Atomic Physics Neutron Physics Laboratory), Ala Nicolescu, M.Dardan, I.V.Nicolescu (Institute of Physical Chemistry - Bucharest, Romania)

Double differential cross sections measurements of cold neutron scattering in toluene adsorbed at several temperatures on η–alumina and on chromia supported on η–alumina were performed. An inelastic peak assigned to the torsional vibration of methyl group was observed and the high jump of the potential in the harmonic approximation was derived to be about 6.3 kcal./mol. Increasing the temperature, the intensity of the inelastic peak decreased and disappeared practically in the spectra of toluene, at temperatures higher than 550°C.

REP. IFA NR-48-1973

TWO-CHANNEL-MULTILEVEL CALCULATION OF THE ^{235}U NEUTRON FISSION CROSS SECTION

I.M.Mihăilescu, M.Petrașcu

Using the Reich-Moore formalism[1] the ^{235}U fission cross-section is calculated for low energy neutrons. A single neutron channel, two fission channels and many capture channels are taken into account. The contribution from two bound levels and from nine resonance levles at positive energy of the same spin and parity, which interfere, is considered. The computed fission cross-section values are compared with those obtained by assuming a single fission channel[2] and with experimental data.

References

[1] C.W.Reich, M.Moore: Phys.Rev. 104, 483 (1965)

[2] I.M.Mihăilescu, M.Petraşcu: Rep. IFA Nr-41-1972

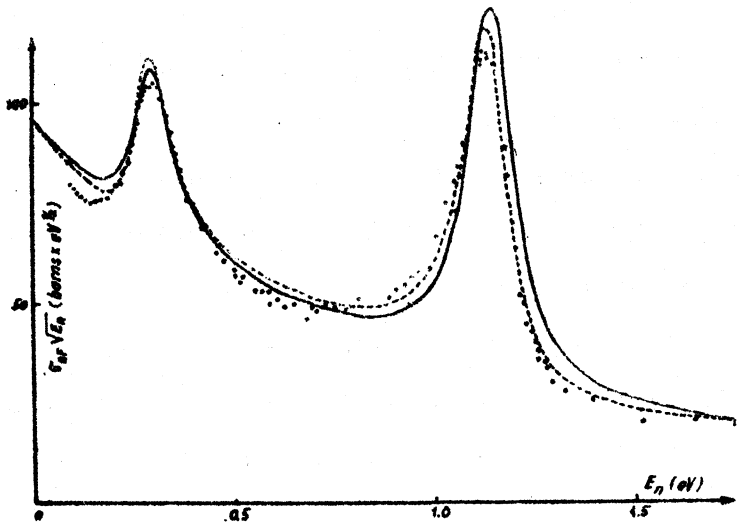

Fig.1 The multilevel neutron fission cross-section curves for ^{235}U.

— two-fission channel-multilevel fit.

--- single-fission channel-multilevel fit.

... experimental points.

REP. IFA NR-46-1973

MULTILEVEL CALCULATION OF THE ^{235}U NEUTRON FISSION CROSS SECTION USING THE RANK ANNIHILATION METHOD

I.M.Mihăilescu, M.Petraşcu

Using the rank annihilation method for inverting the level matrix, a theoretical calculation of the ^{235}U fission cross-section is presented. A single neutron channel, a single fission channel and many capture channels are taken into account. The ^{235}U fission cross-section computed with a FORTRAN IV program, are compared with those obtained using the Reich-Moore multilevel formula[1]. Using the same resonance parameter, a good fit is obtained.

References

[1] I.M.Mihăilescu, M.Petraşcu: Rep. IFA Nr-41-1972

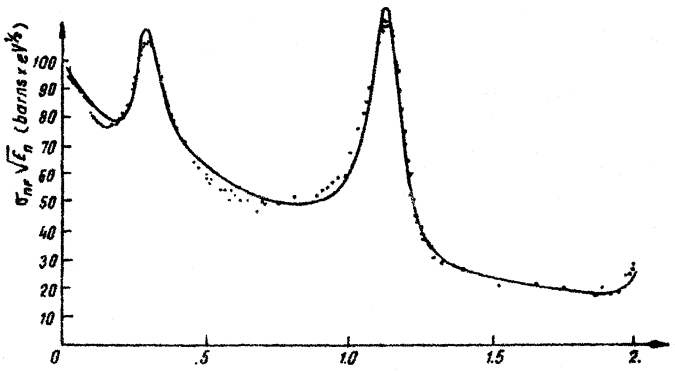

Fig.1 Multilevel neutron fission cross-section curves for ^{235}U, calculated for one fission channel using:

—— the rank annihilation method

---- the Reich-Moore formula experimental points are shown

Title	NEUTRON TOTAL CROSS SECTION MEASUREMENT OF Zr IN THE CUT--OFF REGION (1,5÷5,5 meV)
Author	S.Răpeanu, H.Teutsch, I.Pădureanu
Institute	Institute for Atomic Physics, Bucharest, Romania
Exp-year	1973
Facility	Time-of-flight spectrometer: cooled Be-filter, chopper with curved slits
N-source	VVR-S-reactor
Detector	4 banks of 19 $B^{10}F_3$ counters
Standard	Absolute
Method	Transmission
Part-det.	Neutrons
Geometry	2,1 m flight-path from sample to detector. Rezolution in time-of-flight 3,5%.

Zr

E [meV]	σ_{tot} [barn]	E [meV]	σ_{tot} [barn]	E [meV]	σ_{tot} [barn]
5,510	5,88	3,172	3,50	2,059	1,87
5,298	6,34	3,079	3,26	2,010	1,55
5,097	5,98	2,989	2,62	1,962	1,93
4,908	5,97	2,904	2,63	1,917	2,13
4,729	6,10	2,822	2,94	1,873	2,28
4,559	6,28	2,743	2,55	1,830	2,82
4,399	6,50	2,668	2,57	1,789	2,54
4,247	6,69	2,595	2,34	1,749	1,94
4,102	6,88	2,526	1,76	1,710	2,19
3,965	6,90	2,459	1,92	1,673	1,66
3,835	7,19	2,395	1,41	1,637	1,51
3,711	7,71	2,334	1,34	1,602	1,71
3,593	8,05	2,275	1,70	1,568	2,79
3,480	8,29	2,218	1,16	1,536	4,05
3,373	5,51	2,163	1,32	1,504	3,08
3,270	4,11	2,110	1,60	1,473	2,84

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Progress Report on Nuclear Data Activities in the Republic of South Africa

Compiled by

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REPUBLIC OF SOUTH AFRICA

PROGRESS REPORT TO THE INDC

1972

Compiled by D. Reitmann

1. Southern Universities Nuclear Institute, Faure, Cape Province

Major facilities include a 5,5 MV van de Graaff accelerator with terminal pulsing and bunching as well as a computer-based data acquisition and processing system. The research program covered a wide variety of projects in basic and applied nuclear physics, of which the following are most relevant to the field of neutron data:

1.1 The level structure of Nb from (n,n'γ) measurements

I.J. van Heerden, W.R. McMurray and R. Saayman

Excitation curves for inelastic neutron scattering from ^{93}Nb obtained from (n,n'γ) measurements were compared with the predictions of the statistical compound nuclear model[1,2]. Level energies, spins and decays were deduced.

The results of the present experiment as well as those of recent Coulomb excitation studies[3,4], have been interpreted in terms of a unified model using intermediate coupling of a 1g $^{9}/2$, 1g $^{7}/2$ and 2d $^{5}/2$ proton to the vibrational spectrum (up to two phonons) of the ^{92}Zr core.

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1) W. Hauser and H. Feshbach, Phys. Rev. 87 (1952) 366

2) P.A. Moldauer, Rev. Mod. Phys. 36 (1964) 1079

3) F.D. Bond, Progress Report, Department of Physics Stanford University (1971) 98

4) P.H. Stelson, R.L. Robinson, W.T. Milner, F.K. McGowan and M.A. Ludington, Bull. A.P.S. 16 (1971) 619

It is shown that the five lowest excited levels of positive parity can be considered to form an excited-core multiplet, mainly arising from the coupling of the 1g $^{9}/_{2}$ proton to the 2^{+} one-phonon state of ^{92}Zr. Higher-lying energy levels are also predicted. From the extracted core-particle wave functions some electromagnetic properties of ^{93}Nb have been calculated and compared with the measured values.

These results have been submitted for publication in Zeitschrift für Physik.

1.2 The level and decay schemes of ^{232}Th and ^{238}U

W.R. McMurray and I.J. van Heerden

The results obtained from studies of (n,n') and (n,n'γ) reactions on ^{232}Th and ^{238}U have been analysed in terms of level and decay schemes[1]. Work is continuing on the determination of (n,n') cross sections for levels in ^{232}Th (ref.[2]). All the existing information for the levels of ^{238}U, including measurements of the ^{238}U(d,d) reaction[3], have been combined in the assignment of collective bands and J^{π} values to the levels in ^{238}U. The deduced level scheme has been used in Hauser Feshbach calculations[4] of the expected inelastic neutron scattering cross sections for these levels. The calculated cross sections give a good fit to the observed (n,n') cross sections[5] except for the two levels at 950,3 and 966,3 keV excitation. An attempt will be made to eliminate this disagreement.

1.3 The levels of ^{75}As and their decay gammas

P.J. Celliers and W.R. McMurray

The levels of ^{75}As have been studied using the (n,n'γ) reaction. Some results have already been reported[6,7]. A detailed level and decay

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1) W.R. McMurray and I.J. van Heerden, Z. Physik 263 (1972) 289
2) W.R. McMurray et al., SUNI Annual Report (1971), item 2.1.2
3) A.T.G. Ferguson and B. Elbek, private communication
4) Hauser Feshbach programme by D. Wilmore, AERE
5) E. Barnard et al., Nucl. Phys. 80 (1966) 46
6) P.J. Celliers and W.R. McMurray, SUNI Annual Research Report (1971), item 2.1.3
7) R.M. Wilenzick et al., Phys. Rev. C4 (1971) 2126

scheme has been extracted incorporating 54 decay gammas from 32 levels up to an excitation of 1872 keV in ^{75}As. Many new levels are observed in the present work. The application of Hauser Feshbach analysis to the deduced neutron inelastic scattering cross sections is not yet complete.

1.4 Polarizations in n-p scattering at 16 and 22 MeV

D.T.L. Jones and F.D. Brooks

The polarizations in n-p scattering at 16 and 22 MeV were studied using polarized neutrons from the $T(d,n)^4He$ reaction. The technique used the anisotropic scintillation properties of anthracene monocrystals as a tool for measuring the LR-asymmetry of proton recoil associated with n-p scattering.

The Δ^P_{LS} and Δ^D_{LS} phase parameters derived from the polarization measurements are: $(0.52 \pm 0.07)^o$ and $(0.02 \pm 0.06)^o$ respectively at 16 MeV; and $(0.96 \pm 0.04)^o$ and $(0.13 \pm 0.02)^o$ respectively at 22 MeV. These results show a preference for the Livermore LRL-X phase parameter solution at 16 MeV and for the Yale-Buffalo Y-IV solution at 22 MeV.

1.5 Polarization in n-d scattering for 5-22 MeV neutrons

Mary Steinbock, F.D. Brooks, S.A.R. Wynchank and I.J. van Heerden

A scintillation polarimeter similar to that used to study the polarization in n-p scattering (see preceding item) is now being used to study the polarization in n-d scattering. The polarimeter in this case is based on a deuterated anthracene crystal instead of an anthracene crystal.

The anisotropic scintillation properties of the deuterated crystal have been studied using 8 MeV neutrons from the D(d,n) reaction and found to be similar to those of normal anthracene crystals. Data have been taken for polarization measurements at E_n = 7.5 MeV using polarized neutrons from the $^9Be(\alpha,n)^{12}C$ reaction. These data are now being analysed. The experiment will eventually be extended to other neutron energies in the range 5-22 MeV.

1.6 Cross sections for the D(n,2n) reaction at 8–22 MeV

G. Pauletta and F.D. Brooks

The cross section for the D(n,2n)H reaction has been measured at incident neutron energies in the range 8 to 22 MeV. The experimental method was based on the use of a deuterated benzene scintillator as both target and detector of the reaction products. Pulse shape discrimination techniques were used to discriminate between protons from the D(n,2n) reaction and recoil deuterons from elastic scattering. The discrimination between protons and deuterons was effective down to proton energies of ~3 MeV.

At each incident neutron energy the observed energy distribution of breakup protons was extrapolated down to zero proton energy by comparison with phase-space distributions. The ratio R of the elastic and breakup cross sections was then obtained by integrating the corresponding energy distributions and the breakup cross section was obtained by dividing the total cross section by (1 + R).

The cross section data agree well with previous measurements at 8 and 15 MeV[1,2].

At higher energies, where no other measurements have yet been reported, they lie closer to the extrapolation by Horsley[3] than to Sloan's theoretical predictions[4] based on the model of Aaron, Amado and Yam[5].

---

1) M. Holmberg, Nucl. Phys. A129 (1969) 327

2) V.J. Ashby, H.C. Catron, L.L. Mewkirk and C.J. Taylor, Phys. Rev. 111 (1958) 616

3) A. Horsley, Nucl. Data A4 No. 4 (1968)

4) I.M. Sloan, Nucl. Phys. A168 (1971) 211

5) R. Aaron, R.D. Amado and Y. Yam, Phys. Rev. 140 (1965) B1291

2. Physics Division, Atomic Energy Board, Pelindaba, Transvaal

Facilities used for neutron physics research include the 20 MW research reactor, Safari I, and a pulsed 3 MV van de Graaff accelerator equipped with terminal bunching and a CDC 1700 on-line computer.

2.1 Neutron capture reactions

M.A. Meyer, C. Hofmeyr, B.C. Winkler and J.P. Siegling

The tangential thermal beam tube in the reactor was used to study the neutron-conducting properties of a copper micro-wave waveguide. Addition of another bismuth crystal to beamtube No. 1 reduced the gamma-ray background considerably, and measurements on gamma spectra produced by neutron capture were resumed by first recording a number of known spectra. Coincidence and angular correlation measurements were commenced in an attempt to determine the spins of some low-lying levels in ^{71}Ge.

2.2 Scattering of fast neutrons

E. Barnard, J.A.M. de Villiers, J.G. Malan, D. Reitmann and P. van der Merwe

The investigation of the elastic and inelastic scattering of fast neutrons from manganese was completed. Good agreement was obtained between the data and theoretical calculations. This work was accepted as a contribution to the international conference in Hungary[1]. The energy levels excited in the holmium nucleus by inelastic neutron scattering were studied in detail by means of neutron and gamma spectroscopy. This work has been published[2]. The results from a complete set of measurements on total cross sections as well as elastic and inelastic scattering of fast neutrons from rubidium have been accepted for publication in Zeitschrift für Physik, Earlier results from similar measurements on caesium were compared with detailed calculations.

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1) Int. Conf. on Nuclear Structure with neutrons, Budapest, 1972, contribution B-22

2) Z. Physik 257 (1972) 137

3. Physics Department, University of Pretoria, Pretoria

An upgraded 2 MV van de Graaff accelerator is used mainly for investigating deuteron- and proton-induced reactions in light nuclei. Some typical results for absolute cross section measurements on ^{9}Be are presented below. Experimental uncertainties are estimated to be about 5%.

Table I : Absolute differential cross sections for $^{9}Be(p,\alpha)^{6}Li$ at 90^{o}(lab).

E_p (lab) (MeV)	$\frac{d\sigma}{d\Omega}$ (lab) (mb/ster)
0.6	11.4
0.7	12.4
0.8	12.1
0.9	15.3
1.0	12.6
1.1	12.2
1.2	10.9
1.3	7.6
1.4	3.7
1.5	3.7
1.6	4.5
1.7	4.9
1.8	5.1
1.9	5.4
2.0	5.6
2.1	5.7
2.2	5.5

Table II : Absolute cross sections in laboratory system at 140^{o}

E_d (MeV)	$^{9}Be(d,p_0)^{10}Be$ (mb/ster)	$^{9}Be(d,p_1)^{10}Be$ (mb/ster)
1.0	0.91	0.69
1.1	0.89	0.77
1.2	0.88	0.89
1.3	0.89	1.04
1.4	0.84	1.26
1.45	0.74	1.31
1.50	0.82	1.42
1.55	0.81	1.49
1.6	0.77	1.55
1.7	0.74	1.64
1.8	0.74	1.67
1.9	0.79	1.66
2.0	0.73	1.58
2.1	0.68	1.54
2.2	0.63	1.48
2.25	0.56	1.45
2.3	0.57	1.65
2.35	0.53	1.50
2.4	0.50	1.44
2.5	0.44	1.38
2.6	0.38	1.33
2.7	0.36	1.29
2.8	0.33	1.25

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Progress Report

on Neutron and Non-neutron nuclear data

Yugoslavia

Compiled by
I. Šlaus
Institute "Rudjer Bošković"
Zagreb, July 1973

Laboratories in SFR Yugoslavia working in the field of neutron physics research

Institute "Rudjer Bošković", Zagreb:

Department of Nuclear and Atomic Physics
Chairman Prof.Dr.P. Tomaš

Department of Theoretical Physics
Chairman Prof.Dr.G. Alaga

Laboratory for Nuclear Chemistry
Head Prof.Dr.P. Strohal
(this is in the Department for the Oceanographic research)

Department for Physical Chemistry
Chairman Dr.M. Vlatković

Institute "Boris Kidrič", Vinča

Department of Physics
Chairman Prof.Dr.B. Lalović

Institute "Jožef Stefan", Ljubljana

Department of Physics
Chairman Prof.Dr.D. Jamnik

I. NEUTRON PHYSICS RESEARCH

i) Multiparticle breakup reactions:
$^{12}C(n,\alpha\alpha\alpha)n$, $^{6}Li(n,d\alpha)n$, $^{7}Li(n,t\alpha)n$ - B. Antolković, Institute "Rudjer Bošković"

ii) Isomeric cross section ratios for (n,p) reactions in Te isotopes -
- S. Lulić and M. Dikšić, Institute "Rudjer Bošković"
(FIZIKA 4 Suppl. (1972) p.61)

iii) Thermal Neutron Capture Gamma Rays from Lantanum -
- J. Simić, B. Lalović, S. Koički, I. Slavić, M. Stojanović and M. Bogdanović, Institute "Boris Kidrič"

Complex decay scheme of lantanum has been studied by Ge(Li) spectrometers, as well as by coincident Ge(Li)-Ge(Li) and Ge(Li)-NaI(Tl) systems. A number of new gamma-ray transitions has been found and new decay scheme has been proposed.

iv) Gamma Rays from Thermal Neutron Capture on Eu^{151} -
- S. Koički, V. Ajdačić, B. Lalović and I. Slavić, Institute "Boris Kidrič"

Highly excited Eu^{152} nuclei emits many gamma rays (above 2,000 in the range of 0-600 keV). Decay scheme of Eu^{152} is very complex and known rather poorely. By the use of a transition via the metastable (400 nanosec) state, with delayed coincidences obtained with the Ge(Li)-NaI(Tl) system, some atempts have been made in finding the connections between low and high energy gamma-rays.

v) The Application of Rid in Albedo Type Measurements -
- S. Koički and V. Ajdačić, Institute "Boris Kidrič"

Newly developed system of NaI(Tl) spectrometer which utilizes slow and fast light components (Nucl.Instr. May 1973) has been applied for the measurements of scattered gamma radiation. By the analysis of scattered gamma-rays (intensities and average energies) the change of density of different materials have been followed.

vi) Cross sections for (n,^{3}He) and (n,t) reactions induced by 14.6 MeV neutrons -
- M. Dikšić, P. Strohal, I. Šlaus, Institute "Rudjer Bošković"
(to be published in J.Inorg.Nucl.Chemistry, 1973)

Table 1.
Cross sections for (n,^{3}He) reactions

Target nucleus	Residual nucleus	cross section (mb)	values of other authors	Ref.
^{31}P	^{29}Al	222±100	700 500	1 2
^{41}K	^{39}Cl	848±320	2500	1
^{55}Mn	^{53}V	800±320	2000-6000 50 420	2 3 1
^{59}Co	^{57}Mn	62±30	25 1000-3000 100	3 2 1
^{63}Cu	^{61}Co	113±40	3200±1100 80	4
^{71}Ga	^{69}Cu	66±20		

Table 1. cont.

^{75}As	^{73}Ga	578±200	3000-7000 510 500	2 1 3
^{96}Zr	^{94}Sr	136±50		
^{93}Nb	^{91m}Y	17.9±9.0	60	8
^{103}Rh	^{101}Tc	16±7	1500-3500 1.2±1 2.0±0.6 90 0.4 19	2 5 6 1 7 3
^{109}Ag	^{107}Rh	23±10		
^{115}In	^{113}Ag	33±15		
^{130}Te	^{128}Sn	15±8		
^{187}Re	^{185}Ta	4+3		

Table 2.

Target nucleus	Residual nucleus	cross section (mb)	values of other authors	Ref.
^{32}S	^{30}P	154±70	4±1 20±5 7.5±9 2200±11%	9 10 11 12
^{40}Ca	^{38}K	310±180	20000±20% 100	12 10
^{54}Fe	^{52m}Mn	351±150	600±100	13
^{64}Zn	^{62}Cu	33.7±10	100	9
^{89}Y	^{87}Sr	15.4±10		

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1) E.T. Bramlitt, R.W. Fink, D.G. Gardner and A. Poularikas, Phys.Rev. 125 (1962) 297
2) I. Kumabe, A.D. Poularikas, I.L. Preiss, D.G. Gardner and R.W. Fink, Phys.Rev. 117 (1960) 1568
3) Brookhaven National Laboratory Report BNL 325 (TID-4500)
4) H. Pollehn and H. Neuert, Z. Naturforschung 16a (1961) 227
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6) L. Husain, A. Bari and P.K. Kuroda, J. Inorg.Nucl.Chem. 30 (1968) 3145
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8) E.T. Bramlitt and R.W. Fink, Phys.Rev. 131 (1963) 2649
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12) C.S. Khurana and I.M. Govil, Nucl.Phys. 69 (1965) 153
13) D.M. Chittenden II, D.G. Gardner and R.W. Fink, Phys. Rev. 122 (1961) 860

vii) Pre-equilibrium processes in (n, α) and (p, α) reactions - - R. Čaplar and P. Kulišić, Institute "Rudjer Bošković

viii) Measurements of (n,2n) cross sections - - E. Holub, N. Cindro, P. Kulišić, Institute "Rudjer Bošković"

II. NON-NEUTRON NUCLEAR DATA

i) Study of three nucleon systems. This work is done in collaboration with University of California, Los Angeles; IKO, Amsterdam and Naval Research Laboratory, Washington D.C.

We have recently compared the D(p,2p)n data with the Amado model using three different S wave separable N-N interactions:

a) Potential 1: $a^s_{np} = -23.68$ fm, $r^s_{np}=2.67$ fm, $a^s_{pp}=-7.76$ fm, $r^s_{pp}=2.86$ fm; $a^t_{np}=5.4150$ fm, $r^t_{np}=1.75$ fm

b) Potential 2: $a^s_{np}=a^s_{pp}=-23.78$ fm, $r^s_{np}=r^s_{pp}=2.67$ fm, $a^t_{np}=5.4229$ fm, $r^t_{np}=1.76$ fm

c) Potential 3 which fits the p-p 90° differential cross section up to 70 MeV, and the n-p 90° differential cross section up to 50 MeV. We conclude:

1) all three potentials give in general a satisfactory qualitative fit to the data which cover the QFS region from $40 \leq \theta_{34} \leq 90^\circ$ as well as several angle pairs away from QFS.
2) Potential 1. predicts a consistently lower absolute cross section, while Potential 2. tends to overestimate it.
3) None of the three potentials are able to fit the experimental QFS angular distribution at 23 MeV and 45 MeV. Three theoretical angular distribution differ by a practically constant factor.
4) The difference between breakup cross sections predicted by different potentials is frequently larger than the difference between predicted free N-N cross sections.
5) Interference effects between p-p, n-p_s and n-p_t amplitudes are very significant. An interesting example is for $\theta_3=60^\circ$, $\theta_4=80^\circ$, which is far from QFS and FSI, where two different potentials 1 and 2 predict an almost identical breakup cross section (within 2%) while 3 differs by 30%.

ii) Study of few nucleon systems is also done in collaboration with above mentioned institutions.

iii) The reaction $^{7}Li(d,\alpha\alpha)n$ at E_d=180 keV was investigated using both $\alpha-\alpha$ and α-n coincidence techniques. The reaction proceeds predominantly as a sequential decay through ^{5}He g.s. In case of α- n coincidence measurement, the fit to the data can be improved by adding a contribution of a direct 3-body breakup. -J. Hudomalj and P. Tomaš, Institute "Rudjer Bošković".

iv) The study of the reaction ^{3}H ($^{3}He,\alpha p)n$ and $^{3}H(^{3}He,d)\alpha$ is in progress at E_{inc} up to 600 keV. These reactions are of general interest in astrophysics being connected with the neutrino puzzle. The preliminary data from the reaction $^{3}H(^{3}He,d)\alpha$ indicate the validity of the Barshay-Temmer theorem of the isospin conservation. - D. Rendić, V. Pečar, P. Tomaš, Institute "Rudjer Bošković".

We have also studied in collaboration with UCLA and UC Davis groups the reactions $^{12}C(d,^{7}Be)^{7}Li$ and $^{10}B(\alpha,^{7}Li)^{7}Be$ at several energies between 30 and 40 MeV. - I. Šlaus, Institute "Rudjer Bošković".

v) The energy spectrum of the two-quanta e-γ emission in ^{113}In (internal Compton effect) has been measured. The value of B_K integrated over photon energies from 32 to 170 keV at $\Theta_{av}=35^{\circ}$ is $(3.5\pm0.4)\cdot10^{-2}sr^{-1}$, and for $B_{LM} = (3.2\pm0.4)\cdot10^{-2}sr^{-1}$. B_i is defined as a ratio of probabilities for the emission of the e-γ pair from the i-shell and the i conversion coefficient. - Z. Krečak, K. Ilakovac, M. Jurčević, Institute "Rudjer Bošković".

III. NUCLEAR DATA RELEVANT FOR APPLICATION OF RADIOISOTOPES IN MEDICINE, BIOLOGY AND OTHER FIELDS

i) Production of ^{67}Ga - M. Vlatković, S. Kaučić, G. Paić and B. Vekić, Institute "Rudjer Bošković".