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INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

CONSOLIDATED PROGRESS REPORT FOR 1972 ON NUCLEAR DATA ACTIVITIES IN THE NDS SERVICE AREA

ARGENTINA
AUSTRALIA
BRAZIL
BULGARIA
HUNGARY
INDIA
IRAQ
REPUBLIC OF KOREA
POLAND
ROMANIA
REPUBLIC OF SOUTH AFRICA
YUGOSLAVIA

September 1972

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

FOREWORD

This consolidated progress report for 1972 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 It is intended to encourage a closer relationship between Member States and provide for a wider circulation of unpublished progress reports from countries within the Nuclear Data Section service area.

The report is arranged alphabetically by country, and reproduces the content of each individual report as it was received by the INDC Secretariat. The original INDC report number assigned to each of the individual contributions is given in parentheses behind the country name in the Table of Contents. 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. A brief description of the facilities known to exist at each of these institutions is also given.

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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Progress Report on Neutron Nuclear Data in Argentina 1972

Argentine Atomic Energy Commission

Compiled by G.H. Ricabarra

PROGRESS REPORT OF REACTOR PHYSICS DIVISION

1.- ^{74}Ge and ^{76}Ge activation resonance integral.- (M.D. Ricabarra, R. Turjanski and G. H. Ricabarra).-

Measurement and evaluation of the activation resonance integral for ^{74}Ge has been completed and is going to be published in the Candian J. Of Physics with the following abstract: "Values of the reduced activation resonance integral relative to the thermal cross section, I'/σ_o of ^{74}Ge and ^{76}Ge were determined relative to gold by measuring cadmium ratios in a reactor spectrum.

A lithium-drifted germanium gamma ray spectrometer was used to resolve the activities of the samples.

The results for ^{74}Ge are $I'/\sigma_o = 1.514 \pm 0.031$ and $I' = 0.681 \pm .123$ barn with an assumed $\sigma_o = 0.45 \pm 0.08$ barn; for ^{76}Ge $I'/\sigma_o = 12.00 \pm 0.16$ and $I' = 1.992 \pm 0.359$ with and assumed $\sigma_o = 0.166 \pm 0.030$ barn.

The values obtained for I' are in serious disgreement with the values calculated with neutron resonances parameters and confirm previous results obtained in similar keV average resonance spacing isotopes.

Due to this fact a careful evaluation of keV neutron radiative capture cross section and resonance integral for ^{74}Ge was undertaken.

The evaluation and comparison with the experimental value of the resonance integral shows first that for nuclides with an average resonance spacing of keV the unresolved resonan-

ce integral has been seriously underestimated in many evaluations and second that between 10 keV and 100 keV resonance integrals calculated with smooth low resolution activation cross section give a better calculation of neutron captures than that obtained with neutron resonance parameters.

A preprint of this paper has been distributed as INDC (ARG) - 2/G.

2.- <u>^{146}Nd, ^{148}Nd and ^{150}Nd activation resonance integral</u>.- (M.D. Ricabarra, R. Turjanski and G.H. Ricabarra).-

In previous progress report (INDC(ARG)-1/G) has been pointed out the disagreement of our measurement with Breit-Wigner calculation made with resonance parameters of Karzhavina (Dubna). The evaluation has been enlarged now to include comparison and discussion with Alves (Saclay) Tellier (Saclay) and Migneco (Geel) resonance parameters obtained by time of flight measurements. Also a careful evaluation has been made of the unresolved resonance integral.

A preliminary report has been finished. The most important conclusion of this report is that first ^{148}Nd resonance integral is half of the previous recommended value and second that the radiative width which can be obtained of our resonance integral measurement is half of the value measured by Karzhavina TOF capture technique on enriched samples.

3.- <u>Additional comments about anomalous neutron thermal absorption of a heavy isotope</u>.- (M.D. Ricabarra, R. Turjanski and G.H. Ricabarra).-

A letter to the Editor of Nuclear Sci. and Eng. is transcribed for information of the International Nuclear Data Commitee.

Comment on a p-wave assigment to the 301 eV neutron resonance of Zirconium 96.

Fulmer et al [1] have arrived to the conclusion suggested by us in a previous work[2], that in order to explain the low thermal absorption cross section of ^{96}Zr the 301 eV neutron resonance will be required to be a p-wave resonance.

However Fulmer et al have overlooked that this p-wave assignement is not consistent with nuclear systematics. As this fact may have been overlooked by other readers of our previous paper, it is worthwhile to explain with more detail this point.

If we calculate the probable value of a neutron width for a p-wave resonance at 301 eV, using the values of-neutron widths measured for ^{94}Zr by Bartolome et al[3], we obtain Γ_{n1} (301eV) = 0.0014 eV.

Then the 301 eV. resonance (Γ_n = 0.23 eV) must be around 100 times stronger of what would be expected in order to be a p-wave resonance.

This seems to be hardly possible from the point of view of current knowledge of experimental p-wave neutron widths and from theoretical estimation and only one clear example has been given in the literature which may support the p-wave assignement

to the 301 eV. resonance of ^{96}Zr. According to Harvey and Fuketa[4] the 62 eV neutron resonance of ^{124}Sn is a p-wave resonance 100 times stronger than what would be expected for a p-wave resonance. Harvey and Fuketa suggested that the 62 eV resonance of ^{124}Sn is a 2p-1h doorway p-state resonance and found that its neutron width was comparable to those calculated by Shakin[5].

However an experimental value of I'/σ_0 (ratio of reduced resonance integral to the thermal cross section) obtained by us and reported in the Helsinki Conference [6], showed that this ratio was in agreement with the ratio calculated assuming that the 62 eV resonance of ^{124}Sn is an s-wave neutron resonance.

Another alternative explanation may be given to the anomalous thermal cross section of ^{96}Zr in terms of the theory of radiative capture of Lane and Lynn[7], in whick there is a possibility of multilevel interference effects in the radiative channels. A similar anomaly in the thermal capture cross section has been shown to occur in very light elements, but unlike heavier nuclei, these nuclei have very few final states, then partial anomalies due to interference effects in the radiative channels may appear in the total capture cross section. However for a heavier element as ^{96}Zr it is difficult to understand how this destructive interference effect may depress the thermal cross section by a factor of ten and no example has been found in the literature to support this explanation.

Finally, it is rather curious to see that a simple thermal activation cross section may present problems of interpretation by present knowledge of neutron physics, and suggests that ^{96}Zr may become a particular interesting element for a deeper analysis by nuclear physicists.

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4.- Resonance Integral of ^{112}Sn, ^{116}Sn, ^{122}Sn and ^{124}Sn.

(M.D. Ricabarra, R. Turjanski, and G.H. Ricabarra).-

The ratio of resonance integral to thermal activation-cross section of the isotopes ^{112}Sn, ^{116}Sn, ^{122}Sn and ^{124}Sn has been determined by measuring cadmium ratios in the central reflector of the RA-1 reactor.

The flux in the RA-1 reactor where the irradiations were made was large enough to allow the use of thin samples.

The activities were resolved with a Li-drifted Ge gamma ray spectrometer working on line with a computer.

Preliminary evaluation of data has been finished and work on evaluation and calculation of resonance integral is in progress.

5.- <u>^{100}Mo Resonance Integral</u>.- (M. D. Ricabarra, R. Turjanski, and G. H. Ricabarra).-

In our previous work (Can. J. Phys. 47, 2031 (1969) has been pointed out that the disagreement between measured and calculated resonance integral of ^{100}Mo could be explained if the radiative width recommended by BNL 325 or KFK 120 (EANDC) was too large by a factor of two or more.

However what could not be explained was the results of Baumann's boron filter experiments (AEC Research and Development Rept DP-817 Savannah River Laboratory) that showed that a significant fraction of the ^{100}Mo activation resonance integral was coming from energies much higher than that of the main captures resonance at 364 eV.

An estimation and calculation has been made of the resonance integral between 1 keV and 10 MeV using differential neutron capture or activation cross section and multigroup calculated reactor spectrum.

This preliminary evaluation confirms now the results of Baumann's boron filter experiments.

6.- <u>Further experiments on a new epithermal foil detector</u>.- (D. Waisman, M.D. Ricabarra, and G.H. Ricabarra).-

A report is in preparation for the calculation and self-shielding measurement of ^{96}Zr. This measurement was reported in previous progress report (INDC(ARG) - 1/G).

In addition bare and cadmium covered axial distribution of the activity of ^{97}Nb produced by neutron capture in ^{96}Zr has been determined inside the Reactor Argentino 1 (RA-1) together

with the distribution made with a conventional foil detector (indium).

Also a sandwich type of measurement has been made with the same detector an a reasonable agreement has been found with calculations.

All this experimental results will permit to propose a novel epithermal foil detector which will be better than previously used in the the same energy range.

PROGRESS REPORT ON THE ACTIVITIES OF THE NEUTRON AND REACTOR PHYSICS GROUP AT THE CENTRO ATOMICO BARILOCHE.-

M. J. Abbate, H.M. Antúnez, c. Castro Madero, L. Gatto Cauterucci, F. Kropff Moreno, J. Lolich and L. A. Remez.

INTRODUCTION

The activities of the Neutron and Reactor Physics Group at the Centro Atómico Bariloche (CAB) are centered around the use of the 30 MeV electron linear accelerator (LINAC) as a high intensity pulsed neutron source.

Three main lines of research are being carried out:

1.- Neutron time of flight spectra measurements.

2.- Neutron total cross sections measurements by transmission method.

3.- Neutron Die away experiments.

FACILITIES AND EQUIPMENT

The research work is performed using the following facilities:

1.- Electron linear accelerator, S-band, one section, 30 MeV energy, pulse width: 10nanosec - 1 µsec, peak current: 3Amp short pulse, 150 mA long pulse. Repetition rate up to 200 short pulses. It is being upgraded to two sections - 60MeV.

2.- An evacuated 17 m. flight tube in 4 sections with an adjustable diameter precollimator and a detector room. It is being extended to 65 m.

3.- An IBM/360 model 44 computer for on line data acquisition and processing, 128 Kbytes fast memory, two disc drives (1000 Kbytes capacity each), a 1627 plotter, a 2540 card punch and reader, a 1403 line printer, a high speed multiplexor channel with a 2701 data adapter unit with parallel data adaptors.

4.- A Laben TV60 time of flight coder with 125 µsec minimun channel width and 4096 channels, on-line with the IBM/360 model 44 computer.

5.- At present Li glass (6 and 7) detectors and miniature fission chambers are used. NE211 and He3 detectors are also available.

6.- Conventional instrumentations of the NIM type with several home-made special purpose units.

These facilities provide a present spectrometer resolution of approximately 7 nanosec/m. The extension of the flight path will improve it to 2 nanosec/m.

NEUTRON TIME OF FLIGHT SPECTRA MEASUREMENT.

Neutron spectra measurement in quasi infinite media of light water and pure and poisoned benzene are under way; the computational program system for on line data acquisition and "off line" data reduction has been developed. The experiments are to be compared with the DTF-IV transport code calculations.

NEUTRON TOTAL CROSS SECTION MEASUREMENTS.

Neutron total cross section measurements of Mylar ($C_{10}H_8O_4$) using the transmission method has been performed for energies between 0.007 eV and 20 eV with an accuracy less than 2%. The related computational program system has been developed. Similar experiment with heavy water is under way with an expected accuracy of less than 1%.

It is planned to start measurements in the KeV range in a near future.

NEUTRON DIE AWAY

Diffusion parameters of benzene for thermal neutron is almost through. The accuracy of the obtained values is higher than the previous published. The related computational program system has been developed.

The IALE Programme for Nuclear Spectroscopy Studies of Short-Lived Nuclei

Progress Report 1971

E.O.Achterberg, F.C.Iglesias, A.E.Jech+, E.Kerner, J.Mónico, J.A.Moragues+, D.Otero, M.L.Pérez+, M.A.Pinamonti, A.N.Proto, R.Requejo, J.J.Rossi, W. Scheuer, J.F.Suárez.

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The on-line system described briefly in the previous Progress Report has continued operating during 1971. A complete description of the experimental facility is being published [1].

Some minor modifications have been made on the system. A new collection chamber has been installed at the mass-separator exit providing improved access for the collection of activities for later off-line measurements. A beam deflection system has been added to allow fast cut-off of the activity reaching the collector, for half-life measurements and to enhance the activity of short-lived parent nuclides as compared to their daughter activities.

Two new Si(Li) detectors have been added to our facility during this year, one with 2 cm^2 area and 3 mm depletion depth, with 3.0 keV resolution, and another one with 0.5 cm^2 area and 15 mm depletion depth, with 7 keV resolution.

The analysing system has been expanded by the addition of a magnetic tape unit. Software modules developed for the on-line computer include a megachannel coincidence routine for use with the magnetic tape and a program for the operation of an IBM 29 card-punch unit through an appropriate interface. Data handling was facilitated by the development of a small γ-ray spectrum analysis routine [2] to be used on our 16K computer. Accurate energy calibrations are also performed on this machine.

The evaluation of the results of our internal-conversion measurements on the "heavy" fission peak has been concluded and the results are being published [3].

The work on ^{138}Xe decay has been completed with the measurement of low-energy γ-ray and X-ray spectra, and of γ-γ coincidences. A

new level scheme was constructed and the results have been submitted for publication [4].

In the study of ^{86}Br decay several new transitions have been assigned to the ^{86}Kr level scheme. Based on energy-sum relations and some prior coincidence results [5] a level scheme for ^{86}Kr was constructed including ∿99% of the γ-intensity, in good agreement with the one proposed in ref. 5. The results are being published [6].

New investigation to be taken up include: a) Precise measurement of ^{138}Xe decay intensities to use this activity for on-line efficiency calibration purposes; b) 143 mass-chain decays; c) ^{139}Xe decay; d) ^{91}Kr decay, and e) ^{93}Kr decay.

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Progress Report on Nuclear Data Activities in Brazil

Compiled by Silvio B. Herdade

May 1972

A. INSTITUTO DE ENERGIA ATÔMICA

Caixa Postal 11049 - Pinheiros
São Paulo, Brasil

1. IEA-R1 5 Mw Swimming Pool Research Reactor

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 includes: 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.

2. Resonant Nuclear Scattering of Gamma-Rays in the Energy Range (5-10 MeV).

G.G. Bianchini

Monochromatic photons obtained from thermal neutron capture reactions in the IEA-R1 reactor are utilized for the excitation of nuclear levels in the energy range 5-10 MeV, by means of the resonant nuclear scattering of gamma-rays.

Resonant events are obtained when one of the gamma lines of the incident spectrum coincides with a nuclear level in one of the nuclides contained in the target under study.

This method of exciting nuclear levels gives information on the following properties of nuclear levels: energy, spin, parity, total and partial level widths and statistical information on the widths and spacing of nuclear levels.

By utilizing photons produced in the thermal neutron capture in iron, targets of lead, nickel and cadmium

have been studied. Elastic resonant scattering has been observed at the energy 7.646 MeV for ^{62}Ni, and 7.632 MeV for ^{112}Cd. The lines emmitted in the excitation of these levels have been studied as well as the inelastic scattering for levels of lower energies.

For the elastic level of 7.279 MeV in ^{208}Pb, the following parameters have been determined from angular distribution experiments, self-absorption, and variation of the temperature of the target: spin (J), width (Γ), and spacing (ε) between the incident line and the resonant level. The following results have been obtained:
$J = 1$, $\Gamma = (0.4 \pm 0,1)$eV, and $\varepsilon = (7.8 \pm 0,5)$eV.

3. Measurement of the cross-sections for the reaction $^{238}U(\gamma,n)^{237}U$, in the energy range 6-10 MeV, by radiochemical techniques.

O.Y. Mafra, M.F. Cesar, C.Renner, S.Kuniyoshi and J. Goldemberg

The cross-sections for the reaction $^{238}U(\gamma,n)^{237}U$ are being measured, for monochromatic gamma-rays in the energy range 6-10 MeV, obtained from neutron capture in several materials at the IEA-R1 reactor, utilizing a method of radiochemical separation.

The activity of ^{237}U is determined by integrating the counts under one of its gamma lines measured with a Ge(Li) detector.

The irradiation is carried out close to the target used as source of monochromatic gamma-rays. The sample is protected with cadmium and parafin to avoid neutron induced reactions. The presence of ^{237}U has been identified by the spectrum and half-life (6.75h).

These cross-sections have been determined previously by indirect means, counting the total number of neutrons emmited by an uranium sample taking in account the known cross-sections for photofission. Uncertainties in the precision of this method lead us to the direct study of the reaction (γ,n) in ^{238}U.

4. Study of the de-excitation of ^{77}Se through the desintegration of (^{76}Ge + n).

M.A.N. de Abreu and J.M. Gualda

The analysis of the gamma radiation in the energy interval 10-2500 KeV emmitted in the de-excitation of ^{77}Se, resulting from the desintegration of ^{77}Ge; $^{77}Ge \xrightarrow[13h]{} {}^{77}As \xrightarrow[39h]{} {}^{77}Se$, has been carried out using a Ge(Li) detector with a resolution of 2.2 KeV. The nuclide ^{77}Ge was produced by thermal neutron capture in a sample of germanium enriched to 74% in the isotope of A = 76.

The existence of new low intensity lines: (62.4 KeV) in ^{77}Se, (60.0 KeV) in ^{77}As, and a doublet (51.4 KeV) in ^{77}Se is detected.

5. Influence of the finite thickness of the sources on the forms of the internal conversion lines observed in a beta-ray spectrometer.

Brigitte R.S. Pecequilo and A.A. Suarez

Using a magnetic sector type beta spectrometer built at the Instituto de Energia Atômica, measures have been carried out of ^{114}Cd internal conversion lines of several energies (K558, K651, K725, K805, K1134, K1209) for different target thicknesses (0.32 mg/cm^2, 0.8 mg/cm^2, 1.42 mg/cm^2, etc.).

The obtained conversion lines allowed us to obtain the functional dependence of the resolution and other parameters with respect to the energy and source thickness. By utilizing this result it is possible then, to calculate the intensities and energies experimentally obtained.

6. Experimental Reactor Physics

Facilities:

a) Pulsed neutron source, High Voltage Eng.Corp. Model

PN-400. Deuterons: energy 400 KeV, maximum current 150 μA. Neutron yield: 10^{10}n/s. Duty cycle: ~ 10%.

Equipment for utilization: 1024 channel and 256 channel analysers; Ge(Li) detector 40 cm^3, 2 KeV resolution; pneumatic transfer system for samples (transit time $\geq$ 1s).

b) Sealed neutron source Philips - SAMES.

c) Statistical chopper, to be installed in one of the neutron tubes of the IEA-R1 reactor. It is intended to be used at first for obtaining integral parameters for reactor physics and neutron transport theory.

B. INSTITUTO DE FÍSICA, UNIVERSIDADE DE SÃO PAULO

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1. 22 MeV Herb Pelletron Accelerator

1.1 Installation

The Pelletron system consists of 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 Neutron Physics with a time-of-flight system

A time-of-flight system was designed to obtain 1 nanosecond beam pulse with a basic repetition rate of 5.5 MHz. This rate may be reduced by factors of two until 0.34 MHz. Pulses of approximately 30 n.s. are obtained by chopping, are compressed by a klystron type buncher and chopped after acceleration to give the desired pulse width.

1.3 Research Program in Neutron Physics

The research program will be initiated by studying (^{3}He,n) reactions in ^{12}C and ^{16}O where yields are large and the characteristics of the system can be easily observed.

(^{3}He,n) reactions will also be studied with nuclei in the f-p shell and compound with results on analogous (^{16}O,^{14}C) reactions. The results will be interpreted in terms of current theories in pairing vibrations.

It is also planned to study the energy spectrum of neutrons obtained from heavy ion reactions and compare the results with current evaporation theories.

1.4 Research Program with heavy ions

Studies will be made of the one and two nucleon transfer reactions produced by heavy ions. Initially oxygen beams will be used.

A systematic study will be made of the elastic scattering of heavy ions by different isotopes of the same element in order to obtain information on the relative diffuseness and extension of the nuclear boundary.

2. Electrostatic Accelerator

2.1 Installation

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

2.2 Fast Neutron Cross Section Measurements of Some Rare Earth Nuclei

(to be submitted to "Nuclear Physics")

Measurements of neutron radiative capture cross sections have been made using a Moxon-Rae Detector and time of flight techniques. Cross section ratios to In were determined for Sm, En, Gd, Tb, Dy, Ho, Er, Yb, Lu and Ta for 30, 65, 165 and 300 keV neutron energies.

3. Electron Linear Accelerator

3.1 Description and Characteristics

The University of São Paulo electron linear accelerator is composed by two SLAC type section three meters long. Electron beam is supplied by a 100 KV pulsed electron gun at a repetition rate of 60 cycles per second. After prebunching and focussing the beam is accelerated up to 50 MeV by the two sections. An analysing magnet allows a beam with a resolution of 0.5% in energy and a current of

0.1 μA.

Redesign of the gun power supply and of the Klystron modulator, as well as installation of a second Klystron will allow a higher repetition rate (180 cps) and higher energy (70 MeV).

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

3.2 Electrodisintegration measurements in ^{35}Cl and ^{19}F

J.R. Moreira, E.Wolynec and G. Moscati

An analysis of the relative contribution of the different electromagnetic field multipoles to the excitation of some nuclear levels can be made by electrodisintegration studies.

The electron beam of the University of São Paulo LINAC is being used to induce reactions of the type (e,e',n) in several nuclides.

Targets have been chosen in which the reaction product can be analysed by means of its β^+ activity. The positrons are identified through the annihilation radiation using two NaI(Tl) crystals in coincidence.

In order to distinguish the reaction (e,e',n) from the reaction (γ,n) caused by the electron bremsstrahlung in the target itself, a pair of samples is irradiated with a lead radiator between them.

Preliminary results for C coincide with results found in the literature. Measurements relative to ^{35}Cl and ^{19}F are in progress.

3.3 Electron and bremsstrahlung-induced fission of ^{238}U

S.B. Herdade, I.C. Nascimento, J.D.T. Arruda Neto and J. Goldemberg

The cross-section ratio $\sigma(\gamma,f)/\sigma(e,f)$ has been determined using the electron beam of the University of São Paulo LINAC in the energy range 15 to 45 MeV.

Preliminary results have shown that this ratio is

approximately constant in this energy range. With these first results it was not possible to conclude if the transitions are of an electric dipole or of a magnetic dipole nature.

With the accumulation of more measurements, it is hoped that the above cross-section ratio will be determined with better precision.

The method utilized for the measurements is the one of counting fission fragment tracks in mica sheets.

4. Nuclear Spectroscopy

4.1 Isomeric formation ratio by Bremsstrahlung gamma rays on ^{89}Y $(\gamma,2n)$ ^{87}Y, and ^{89}Y $(\gamma,3n)$ ^{86}Y reactions

J.S. de Goes, O.A.M. Helene, V.R. Vanin, S.A.S.Vitielb, C.M. Faria, J.A. Guillaumon Filho e I.D. Goldman

Yttrium was irradiated at the electron beam of the "Acelerador Linear do Instituto de Física da Universidade de São Paulo". The measurements have been taken with a GeLi detector with 3KeV resolution at 662KeV, associated with a 4096 Multi-channel.

We have measured the half-life and characteristic transition to identify the isotope and the isomer. See table I and table III.

The experimental results show for ^{87}Y a slight in - crease of the isomeric ratio on relation $\Sigma_{9/2}^{+}/\Sigma_{1/2}^{-}$. We present the results in table II.

To ^{86}Y, the increase of the isomeric ratio $\Sigma_{8}^{+}/\Sigma_{4}^{-}$ is more pronounced, and that is consistent with the proximity of the low energy results to the reaction threshold, table IV.

The statistical Model, proposed by Huizenga and Vandenbosch, gives to the spin cutoff parameter $\sigma<3$ for ^{87}Y and $\sigma\simeq 4$ for ^{86}Y.

4.2 Isomeric Formation Ratio by Reactions (γ,xn) for ^{120}Sb, ^{104}Ag, ^{110}In and ^{178}Ta

J.S. de Goes, O.A.M. Helene, V.R. Vanin, S.A.S. Vitiello, C.M. Faria, J.A. Guillaumon Filho and I.D. Goldman

Antimony, silver, indium and tantalum were irradiated at the electron beam of the "Acelerador Linear do Instituto de Física da Universidade de São Paulo" with energies respectively of 38, 40, 39 and 40 MeV, producing the Bremsstrahlung in the sample.

The measurements have been taken with a GeLi detector with 3 KeV resolution associated with a 4096 Multichannel.

The isomeric state was determined by the half life and the characteristic transition (see Table V).

The isomeric formation ratio from high to low spin are shown in Table VI.

4.3 Energy Levels of ^{119}Sn

T. Borello, O. Dietzsch, E.W. Hamburger and C.Q. Orsini

The isotopes ^{111}Sn, ^{113}Sn, and ^{123}Sn have been studied in previous work. In this work the reaction $^{118}Sn(d,p)^{119}Sn$ has been studied with 17 MeV deuterons from the University of Pittsburgh Tandem. The protons analysed by a magnetic spectrometer, have been detected in nuclear emulsions. Fourteen spectra in scattering angles from 8° to 69° have been obtained. The analysis of these spectra allowed the identification of 47 energy levels up to an excitation of 4.5 MeV, and of their angular distributions. Nineteen of these energy levels have been observed for the first time. Comparisons of the angular distributions with the ones preview by the DWBA have furnished the values of ℓ. It is interesting to notice that a level with $\ell = 3$ appears at 1.056MeV, well bellow the energy one should expect on the basis of the shell model. Levels $\ell = 3$ at energies ~ 1 MeV appear also in the isotopes $^{113}S_n$, $^{121}S_n$ and $^{117}S_n$. Perhaps this level can be explained by the weak coupling of the phonon 2^+ with the quasi-particle $h^{11/2}$.

T A B L E I

$^{89}Y(\gamma,2n)\ ^{87}Y$

	Spin	half life	Measured Transitions
Ground State	$\frac{1^-}{2}$	80 h	388 KeV 483 KeV
Metastable State	$\frac{9^+}{2}$	14 h	381 KeV

T A B L E I I

Table of Isomeric Formation Ratio of ^{87}Y

Electrons energy	Ratio of high to low Spin	Previous results (a)
35,6 MeV	0,396	
38,0 MeV	0,426	
40,0 MeV	0,364	
42,0 MeV	0,485	
44,0 MeV	0,433	
46,0 MeV	0,473	
150 MeV*		0,42 ± 0.03
280 MeV*		0,42 ± 0.03

* bremsstrahlung

(a) W.B. Walters and J.P. Hummel - Phys. Rev. 150, 867 (1966)

TABLE III

$^{89}Y(\gamma,3n)^{86}Y$

	Spin	half-life	measured transitions
Ground State	4^-	14.6h	1078 KeV
Metastable State	8^+	46 m	208 KeV

TABLE IV

Table of isomeric Formation Ratio of ^{86}Y

Electron Energy	Ratio of High to Low Spin
35.6 MeV	0.0526
38.0 MeV	0.0789
40.0 MeV	0.0997
42.0 MeV	0.1380
44.0 MeV	0.1098
46.0 MeV	0.1490

TABLE V

ISOTOPE	REACTION	SPIN	HALF LIFE	MEASURED TRANSITIONS
^{102}Sb	$^{121}Sb(\gamma,n)^{120}Sb$	8^-	5.8d	1030 KeV
		1^+	15.9m	511 KeV
^{104}Ag	$^{107}Ag(\gamma,3n)^{104}Ag$	5^+ (ground-state)	30m	511 KeV. 555 KeV
		2^+	67m	556 KeV. 767 KeV e 938 KeV
^{110}In	$^{113}In(\gamma,3n)^{110}In$	7^+	4.9h	642 KeV, 658 KeV
		2^+	67m	658 KeV
^{178}Ta	$^{181}Ta(\gamma,3n)\ ^{178}Ta$	1^+	9.4m	511 KeV
		$(7,8,9)^-$	2.Ih	213 KeV, 326 KeV, 426 KeV

TABLE VI

TABLE OF ISOMERIC FORMATION RATIO OF IRRADIATED ISOTOPES

ISOTOPE	HIGH SPIN	LOW SPIN	RATIO OF HIGH TO LOW SPIN
^{120}Sb	8^-	1^+	0.080
^{104}Ag	5^+	2^+	0.130
^{110}In	7^+	2^+	1.035
^{178}Ta	$(7,8,9)^-$	1^+	0.183

C. CENTRO BRASILEIRO DE PESQUISAS FÍSICAS

Av. Wenceslau Braz, 71 - ZC-82
Rio de Janeiro, Brasil

1. Electron Linear Accelerator

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 radionuclide 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 in use for neutron time-of-flight experiments. Resonant neutron capture studies are in progress.

A pneumatic system (rabit), for irradiation of samples, is available. A high flux ^{235}U neutron source is planned for 1972.

2. Levels of ^{197}Pt and ^{197}Au populated by the decay of ^{197}Pt g.s and ^{197m}Pt.

S. de Barros, S. Calzavara and A. Tonati

The decays of ^{197}Pt and ^{197m}Pt have been studied by gamma-ray spectroscopy, using Ge(Li) detectors. Coincidences have been registered with the aid of a multiparameter analyser. The experimental results are compared with previous results obtained in decay and nuclear reaction experiments. The β branch, populating the 548.0 KeV [1], was not confirmed. A decay scheme coherent with our coincidence data is presented.

(1) E.Bashandy and M.Migahed, Annalen Physik, 7 (1967) 152.

3. Decay of ^{197}Ir

S.Calzavara, S. de Barros, A.M. Gonçalves

The ^{197}Pt transitions following the decay of ^{197}Ir have been investigated with a Ge(Li) detector. A new decay scheme for ^{197}Ir is presented, including four gamma-rays: (877.6 ± 0,3)KeV, (938.0 ± 0,3)KeV, (1049.6 ± 0,3)KeV, and (1341 ± 0,3)KeV, not previously detected.

Spin and parity assignements for excited levels of ^{197}Pt and for the ground state of ^{197}Ir have been proposed. The observed level structure has been compared with the ones obtained from nuclear models.

4. Neutron-Capture Gamma-Ray Spectroscopy in ^{76}As.

N.Lisbona, A.M. Gonçalves and S.de Barros

Gamma-rays from excited levels of ^{76}As have been detected in a time-of-flight spectrometer by single and coincidence counting. The detectors used were NaI(Tl) (8cm diameter x 8cm height) and (12x12 cm^2 area x 10cm height). 23 resonances have been analysed in the energy interval 20 to 1450 KeV. The 307.7 KeV and 578.8 KeV resonances correspond to new levels of ^{76}As, and the 498.0 KeV and 8720,0 KeV resonances confirm the levels that caused disagreement in previous measurements [(1)(2)]. An extension of the Coceva et al [(3)] method to odd-odd nuclei, allowed us to make several spin assignements in the resonance energy interval 0 to 1000 KeV. The consequences of the extension of this method are discussed. The indication of the variation with spin of the S-wave neutron density function, in the direction $S(I + \frac{1}{2}) > S(I - \frac{1}{2})$, is confirmed.

(1) J.B. Gard, et al, Phys.Rev. 136, B 177 (1964)
(2) J.Julien, et al, Phys.Lett. 10, 86 (1964)
(3) C.Coceva, et al, Nucl.Phys. A 117 (1968) 586-614

5. Transparencies of Complex Nuclei to Photoproduced Pions and Recoil Nucleons.

H.G. de Carvalho, J.B. Martins, O.A.P. Tavares and R.A.M.S. Nazareth (Centro Brasileiro de Pesquisas Físicas - Rio de Janeiro); V. di Napoli (Instituto di Chimica Generale ed Inorganica dell'Università - Roma).

Lettere Al Nuovo Cimento, Vol. 2, N.22 (1971)

In the high-energy photonuclear research it is very important to study the probability that a pion and/or a recoil nucleon produced by the interaction of a high-energy photon with a complex nucleus, escape from the nucleus without any interaction, i.e. the transparency of the nucleus to the photopions and recoil nucleons.

The present paper reports the calculation of transparencies for pions and recoil nucleons originated by interaction of high-energy photons with complex nuclei (energy range: 0.3 - 1.0 GeV).

6. Alpha Activity of ^{209}Bi

H.G. de Carvalho and M.de Araujo Penna
To be published in "Lettere al Nuovo Cimento"

The nuclide ^{209}Bi has a magic number of neutrons (126) and one proton more than magic (83). This particular shell structure imposes restrictions on the usual methods for calculation of the alpha-decay half-life. The alpha-decay of ^{209}Bi to the ground state of ^{205}Tl leads to a large spin and parity change, adding strong hindrance to the process. The extremely low activity is far out of the ordinary experimental methods for alpha-radioactivity measurements which have been unsuccessfuly used by many authors. The present paper reports the result of the alpha-decay half-life of ^{209}Bi obtained from theoretical considerations taking into account all hindering factors of ^{209}Bi decay, and establishes a new lower limit for the experimental half-life.

7. Nuclear Ground-State Structure and Beta-Decay

L. Tauhata, M. Binderly Gaspar and A. Marques

Nuclear ground state wave functions are generated through modern computational methods and used for calculations of relevant data in beta-decay. The results are checked against life-times and beta-ray energy

spectrum accurately measured with solid-state detectors and yield information either upon the wave functions or weak interaction coupling constants.

8. Compensation for the Gamma-Ray Energy Dependence in Delayed Coincidence Measurements with NaI(tl) Detectors

A. Marques

A method is developped for the accurate time balance of the two channels of a delayed coincidence device which can allow for time delays generated in the crystal detectors. Short life-time measurements ($< 10^{-10}$s) are envisaged.

9. Mass Formula for Super-Heavy Elements

T. Kodama

A theoretical mass formula for super-heavy elements is under development.

10. Quadrupole Moment of the First Excited 3/2-Level of Ru^{99}

D. Grienzburger, J. Danon in Collaboration with W. Potzel, F. Wegner and U. Zahn (Technische Höschule Munchen)

Electric field gradients are calculated in Rutenium molecular complexes whose quadrupole interaction has been measured by Mössbauer spectrometry method. The quadrupole moment for that state is derived.

D. PONTIFÍCIA UNIVERSIDADE CATÓLICA, DEPARTMENT OF PHYSICS

Rio de Janeiro ZC-20, Brasil

1. Van de Graaff Accelerator

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 intensity.
The accelerator is expected to be operational in September 1972.

2. The Level Spectra of Nuclei with $51 \leq Z \leq 61$ and the Intermediate-Coupling Model.

A.G. de Pinho, I.V. Goldstein and J.M.F. Jeronymo
Published in: An.Acad.Bras.Ciên. (1971), 43 (1)

The properties of the low-lying levels of many odd-mass nuclei with $51 \leq Z \leq 61$ were studied in the framework of the unified (intermediate-coupling) model. Energies, magnetic dipole and electric quadrupole moments, transition probabilities and spectroscopic factors were calculated and compared with the experimental values. Up to three phonons and four shell model orbits were considered in the calculation of the positive parity states. The A-dependence of the adjustable parameters of the model was examined.

3. Level Scheme of ^{211}Bi

E.F. da Silveira, A.G. de Pinho and C.V. de Barros Leite
Published in: An.Acad.Bras.Ciên. (1971), 43 (1)

The decay scheme of ^{211}Pb was reinvestigated by means of Ge(Li) singles and coincidence techniques giving rise to the addition of two new levels to the known level scheme of ^{211}Bi. A total of 31 transitions were observed following the decay of ^{211}Pb and its descendents and 21 of these

transitions were accomodated in the level scheme of ^{211}Bi. Energies and relative intensities of all the transitions were determined as well as some internal conversion coefficients. The resulting level scheme was compared with a calculation where only the $(\pi\ 1h\ 9/2)^1\ (\nu\ 2g\ 9/2)^2$ configuration was considered and the levels were calculated by using only experimental information about the interaction of two neutrons in 2g 9/2 neutron and a h 9/2 proton (from ^{210}Bi). No adjustable parameter was present and some impressive results were attained.

4. Experimental Determination of Relative Radiative Decay Rates of Vacancies in the K Shell.

A.G. de Pinho
Published in: Physical Review A, 3 (1971) 905

A high-resolution Ge(Li) X-ray spectrometer was used for measuring relative radiative decay rates of vacancies in the K shell of the following atoms: Au, Hg, Tl, Pb, Bi, Rn, Ra, Th, and U. In the most favorable cases, the X-rays following the filling of a K vacancy by L_{II}, L_{III}, M_{II}, M_{III}, M_{IV}, M_V, N_{II}, N_{IV-V} and O_{II-III} electrons were observed and measured. The results were compared with recent relativistic calculations carried out by Scofield.

5. $\frac{1}{2}^+$ Ground States of C_s^{127} and C_s^{129}

I.V. Goldstein and A.G. de Pinho
Published in: Physical Review C, 4 (1971) 653

The nature of the $\frac{1}{2}^+$ ground states of the light isotopes of cesium is discussed in the framework of the unified model. These states are well reproduced by the Nilsson model for oblate shapes, as well as by the intermediate-coupling version of the unified model.

6. Enhanced Low-Energy E2 Transitions in the Odd-A Isotopes of Sb, I, C_s and Pr.

I.V. Goldstein and A.G. de Pinho
Published in: Canadian Journal of Physics, 49 (1971) 1794

The intermediate coupling version of the unified model was used to calculate E2 transition rates in some odd-mass isotopes of Sb, I, C_s, and Pr. The observed enhancement of these transitions is reproduced and regular variations of the transition probabilities in groups of neighboring isotopes are explained.

7. Levels of the Odd Mass Isotopes of Sb and I and the Unified Model

I.V. Goldstein and A.G. de Pinho

A description of the low-lying positive parity levels of the odd mass isotopes of Sb and I is presented on the basis of the intermediate coupling approach of the unified model. Such analysis helps to understand many properties of those levels since a rather satisfactory agreement with experimental data is reached.

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

F.M. Smolka and A.G. de Pinho

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 assignement of gamma-rays with energies up to 2.05 MeV. Spin and parity assignements were made for all levels. The resulting level scheme is compared with predictions of theoretical calculations.

E. INSTITUTO DE ENGENHARIA NUCLEAR

Cidade Universitária, Ilha do Fundão
Rio de Janeiro, Gb - Brasil

1. Reactor Engineering Division

1.1 Brazilian ARGONAUTA Research Reactor

Designer: Argone National Laboratory, USA
Built by: Mecânica CBV Ltda., Rio de Janeiro, Brasil
Owner and operator: Comissão Nacional de Energia Nuclear
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 - $0,57 \times 10^{11}$ n/cm^2.s
peak thermal - $1,20 \times 10^{11}$ n/cm^2.s
peak fast - $0,65 \times 10^{11}$ 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.

1.2 Resonance scape probability for the Argonauta reactor

A sandwich made with uranium foils (depleted in ^{235}U) and representative sections of the fuel under study is irradiated in the reactor core, and the activity of ^{239}U or ^{239}Np is measured.

1.3 Neutron cross-section measurements in the energy range 0.001 eV - 1.0 eV, with a crystal spectrometer

The resolution function for the IEN crystal spectrometer has been calculated, as well as the effect of the 2nd order contamination for the planes (111) of an aluminum crystal. Initially, to evaluate the influence of these effects in resonance measurements, the Iridium

resonance at E_o = 0,654 eV has been considered, using a Tellurium resonant filter to eliminate the 2nd order contamination.

The theoretical curve for the resonance has been calculated by the Breit-Wigner formula, taking in account the Doppler broadening for room temperature. This curve has been affected by the estimated resolution function, and corrected for 2nd order contamination. The theoretical curve agrees with the experimental results.

The ^{176}Lu resonance in the thermal region has been measured, and the following parameters were obtained:

$$E_o = (0{,}141 \pm 0{,}002)\,eV$$

$$\sigma_o = (13550 \pm 70)\,b$$

$$2g\,\Gamma_n^o = (0{,}230 \pm 0{,}005)\,MeV$$

$$\Gamma\gamma = (59 \pm 1)\,MeV$$

1.4 Neutron generator

Model: Texas Nuclear 9905

Neutron production: $^3_1H(d,n)^4_2He$, $^2_1H(d,n)^3_2He$

Maximum neutron flux: ~ 10^9 n/cm^2.s

Pulsed operation: 1 to 5 pulses/s; pulse width: 0.1 μs to 10 ms.

Additional equipment: pneumatic system for sample transfer; 2 photomultipliers coupled at 180°; 400 channel analyser.

Data output: paper tape puncher, card puncher, graph recorder.

Utilization: activation analysis; study of diffusion and moderation parameters in several media; cross-section measurements; graduate education.

1.5 Measurement of the thermal neutron diffusion parameters in water spherical systems by the pulsed neutron source method.

The decay constants of the thermal neutron flux have been measured in 20 spheres, varying the buckling in the range $0.024 \leq B^2 \leq 1{,}37$. A careful analysis has been made of the problems that influence the measurements of

the decay constants and the determination of the diffusion parameters, namely: the presence of epithermal neutrons, the variation of background, the influence of shielding, the contamination by harmonics, the behaviour of the extrapolated distance, the influence of the detector utilized, the weights adopted in the analysis of the experimental curves, etc. The results have been normalized for 26.5°C.

The fits of the curve

$$\lambda = V\Sigma_a + D_o B^2 - CB^4 + FB^6 + \ldots$$

with 3 or 4 parameters gives, respectively:

$$V\Sigma_a = 4882 \pm 10 \ (s^{-1})$$
$$D_o = 36550 \pm 94 \ (cm^2 \ s^{-1})$$
$$C = 3930 \pm 130 \ (cm^4 \ s^{-1})$$

and

$$V\Sigma_a = 4879 \pm 12 \ (s^{-1})$$
$$D_o = 36620 \pm 185 \ (cm^2 \ s^{-1})$$
$$C = 4120 \pm 530 \ (cm^4 \ s^{-1})$$
$$F = 140 \pm 370 \ (cm^6 \ s^{-1})$$

1.6 Measurement of the diffusion parameters in "Dowtherm A"

The decay constants of the thermal neutron flux have been measured in 9 spherical systems of "Dowtherm A", in the buckling range $0{,}044 \leq B^2 \leq 0{,}468$.

The fit of the curve: $\lambda = V\Sigma_a + D_o B^2 - CB^4$, where the values have been normalized for 20°C, gave the results:

$$V\Sigma_o = 2896 \pm 66 \ (s^{-1})$$
$$D_o = 51657 \pm 769 \ (cm^{-2} \ s^{-1})$$
$$C = 23635 \pm 1823 \ (cm^{-4} \ s^{-1})$$

2. Nuclear Physics Division

2.1 Variable Energy Cyclotron

A CV-28 cyclotron from the Cyclotron Corporation is

scheduled to start operation in June 1973. This accelerator will deliver over 50μA of external beams of protons from 2 to 24 MeV, deuterons from 3 to 14 MeV, $^{3}He^{++}$ from 5 to 38 MeV and $^{4}He^{++}$ from 6 to 28 MeV. He vier ions can also be accelerated. Production of neutron deficient radionuclei for medical uses will be a pratical application of the cyclotron. Research on nuclear spectroscopy, neutron physics, activation analysis, radiation damage, nuclear reactions, will be stimulated. The housing of the cyclotron will be a 1500 m^2 building with Physics and Chemistry laboratories, and a 400 m^2 experimental area.

With a view on future applications of the variable energy cyclotron of the Instituto de Engenharia Nuclear, data was compiled on the following items:

a) neutron deficient radioisotopes for medical uses
b) charged particle activation analysis
c) fast neutron production by charged particles

2.2 Search for New Transitions in the Decay of ^{164}HO

A search for transitions from the 1^+ ground state of ^{164}Ho to the $2'^+$ gamma-vibrational states of ^{164}Dy and ^{164}Er was undertaken. A transition to the 760 keV $2'^+$ level of ^{164}Dy with log ft = 8.0 was found. For the transition to the 860 keV ^{164}Er $2'^+$ level, only a lower limit was found (log ft = 7.6). The results are discussed in terms of the multiple quasi-particle-pair interpretation of the gamma vibrations.

2.3 The Decay of ^{58}Cu

The energies and relative intensities of the γ-rays and the relative intensity of the annihilation radiation from the decay of ^{58}Cu have been measured. Levels at 444.9 keV and 4538.3 keV in ^{58}Ni were found to be populated in this decay. The intensity of the β^+-feeding of the 3584.9 keV level was found to be < 0.1%.

2.4 Gamma-ray Spectroscopy of the Thorium Active Deposit

The decay schemes of ^{212}Pb, ^{212}Bi, ^{212}Po and ^{208}Tl

members of the Thorium Active Deposit, were studied. In the γ-ray spectra obtained with Ge-Li detectors, forty-four γ-ray transitions were observed of which six, with energies 145.9, 164.2, 205.4, 227.5, 290.4 and 4[illegible]3.3 keV, not seen before, and two, with energies 927.6 and 982.9 keV were found simultaneously with other workers. A systematic separation of ^{212}Pb, ^{212}Bi and ^{208}Tl nuclei using AMBERLITE IR-120 and IRA-401 ion exchange resins as well as using recoil methods, showed that the two last mentioned γ-rays belong to ^{208}Tl decay. The 227.5 keV line was attributed to the β-decay of ^{212}Bi, based on the separations and also considering the α -particles intensities feeding the ^{208}Tl levels. The 205.4 and 290.4 keV γ-rays belong to the decay of ^{208}Tl as deduced from difference in the energy of levels in ^{208}Pb.

2.5 Some Applications of Coincidence Methods in Nuclear Spectroscopy

After setting up and studying some characteristics of the coincidence system, coincidence measurement in ^{208}Pb (gamma-gamma) and in ^{212}Po and ^{208}Tl (alpha-gamma) were performed. Three new gamma-ray transitions with energies 657,2 keV, 668,2 keV and 836,0 keV were found to be in coincidence with 2614 keV line. A 598,5 keV gamma-ray coincident with the 8,78 MeV α particles was confirmed in the decay of ^{212}Po. These transitions do not fit in the known decay schemes. Gamma-rays of 146,1 keV, 165,6 keV, 493,3 keV and 620,0 keV were seen in coincidence with α particles from the decay of ^{212}Bi. The energy measurement of this last transition is more accurate than measured before.

Progress Report on Nuclear Data Activities in Bulgaria

Compiled by E. Nadjakov

May 1972

PROGRESS REPORT

Bulgaria 1971

All the activities are going on at The Institute of Physics with Nuclear Research Centre, Bulgarian Academy of Sciences, Sofia.

I. Neutron nuclear data

1. Three-group spatial and energy neutron distributions in the reactor on their passing through iron and lead neutron ducts. (T.Troshev, V.Hristov, T.Apostolov).

The carried out investigations are concerned with homogeneous and non-homogeneous neutron ducts with diameters of 100 mm, placed in water medium. Iron and lead neutron ducts, as well as ducts with periodical non-homogenities of paraffin or air included in these materials have been investigated. Miniature threshold corona counters containing B and ^{238}U have been used in carrying out the experiment.

Values of diffusion lengths in water-surrounded neutron ducts, avaraged along the neutron duct:

Neutron duct material	For neutron energy			
	>3 MeV	>1.3 MeV	0.4 eV - 10keV	Epithermal and thermal neutrons
iron	8.8	7.9	11.0	11.3
lead	10.9	8.4	6.7	6.8
iron+paraffin	-	6.4	7.5	7.6
iron+air		12.4	11.8	13.6
lead+paraffin	-	5.6	5.7	6.0
lead+air	-	9.8	8.0	9.5

2. Development of nondestructive methods for measuring the plutonium by means of neutron coincidence technique. (A.Trifonov, V.Hristov, T.Dragnev).

A handy portable device for measuring the quantity of plutonium in the waste fission materials from uranium industry and power reactors, as well as in the uranium containing water-water reactors has been worked out and its characteristics studied. A non-destructive method on the basis of neutron coincidence technique has been applied.

The device contains the following new elements: ordinary water as a moderator, which makes the container portable - weight 3 kg or 30 kg in working position; a possibility for measuring samples of big volume (up to 5 l); detectors of a new type - corona counters for neutrons with helium-3 or boron-10 with better characteristics compared to other detectors. The possibility for parallel coupling of a great number of corona counters by means of logic elements has been studied.

The estimates show that by means of this method quantities of plutonium-240 of the order of 100 mg can be determined. The work is carried out according to a contract with IAEA - Veinna.

3. Parameters of the intermediate structure of neutron induced fission in ^{239}Pu in the energy region 0 - 2000 eV (N.Ianeva).

Evaluation of data, obtained at the pulsed reactor IBR-30 in Dubna, is performed. This work is now in progress.

II. Non-neutron nuclear data

1. A group (J.Jelev, B.Amov, et al) has studied the radioactive decay of neutron deficient isotopes, obtained on the 660-MeV

proton accelerator of JINR - Dubna. The investigations are as follows: gamma-spectra - with Ge(Li) spectrometers; conversion electron spectra - with a low-background beta spectrometer with double twofold focusing at an $\pi/\sqrt{2}$ angle and a semiconductor Si(Li)-spectrometer; gamma-gamma coincidences - with two Ge(Li)-spectrometers.

a) ^{122}J, $T_{1/2}$ = 35 min (B.Amov et al, Theses of reports - 12th Conference on nuclear spectroscopy... and theory of deformed nuclei, Dubna, 22-25.6.1971, p.74).

The gamma-ray spectrum from the decay of ^{122}Xe ($T_{1/2}$ = 20h) in equilibrium with ^{122}J, purified at a mass separator, has been investigated. The following gamma transitions: 953, 1037, 1357, 1793, 1940 and 2312 keV, earlier attributed to ^{122}J, have not been observed. Ten new gamma transitions have been found: 706(0.2); 721(0.1); 1131(0.1); 1181(0.15); 1235(0.06); 1640(0.09); 1682(0.11); 1788(0.07); 2205(0.04) and 2943(0.01) keV. The relative intensities of gamma transitions, the 564 keV transition assumed to be 100 units, are given in brackets.

b) ^{132}La, $T_{1/2}$ = 4.5h and ^{132m}La, $T_{1/2}$ = 25 min (B.Amov et al, Izvestia AN USSR, Ser.Fiz.35, 2266 (1971)).

Conversion electron intensities and internal conversion coefficients of 18 transitions at the decay of ^{132}La have been determined. According to this, quantum characteristics have been assigned to several states of ^{132}Ba: 1685 keV (2^+, 3^+), 1728 (4^+), 2854 (2^-, 3^-), 3155 (1^-, 2^-), 3217(2^-, 3^-), 3423 (2^-, 3^-), 3492 (2^-, 3^-), 3562(1^-, 2^-), 3633 (1^-, 2^-), 3662 (1^-, 2^-). On the basis of gamma-gamma coincidences 3 new excited levels are suggested: 1503 keV (0+); 1511 keV (3^+); 2026 keV (4^-, 5^-). The earlier in-

troduced levels 1546,1667 and 2077 keV have not been confirmed.

c) ^{133}La, $T_{1/2}$ = 4.0h (S.Avramov, B.Amov, et al, Program and theses of reports-21st annual conference on nuclear spectroscopy and nuclear structure, part I, Moscow 27.1. - 4.2.1971, p.77; Theses of reports-12th conference on nuclear spectroscopy and theory of deformed nuclei, Dubna, 22-25.6.1971, p.83).

The gamma-ray transition intensities for the decay of ^{133}La, purified at a mass separator, have been determined. On the basis of these data and others' data for the conversion electron intensities, the internal conversion coefficients for a number of transitions have been evaluated. From transition intensity balance the population of the levels and the values of the matrix elements have been calculated. Quantum characteristics have been assigned to the following levels in ^{133}Ba: 578.6 keV ($5/2^+$, $7/2^+$), 631.4 ($3/2^+$, $5/2^+$), 677.1 ($5/2^+$, $7/2^+$), 1114.4 ($5/2^+$, $7/2^+$). Most of the earlier introduced levels have been confirmed using gamma-gamma coincidences.

d) ^{194}Tl, $T_{1/2}$ = 33 min (B.Amov et al, Preprint JINR, Dubna, P6-6250 (1972)).

The gamma-ray and conversion electron intensities of a number of transitions in the decay of ^{194}Tl, purified at a mass separator have been determined. 19 new transitions have been observed. The internal conversion coefficients of some of them and the quantum characteristics of a number of levels have been determined. Eight new excited states of ^{194}Hg are suggested: 1292.5 keV (3^+), 1468.5(3^+), 2165.8(5^-, 6^-), 2180.0 (4^-, 5^-), 2260.0, 2264.7(4^-, 5^-), 2374.8 (6^-), 2463.8 (6^-).

2. A group (E.Nadjakov et al) has studied the decay of nuclei obtained on the Dubna heavy ion accelerator U-300. New isotopes have been identified by means of radiochemical methods

and of excitation functions after measurement of the decay of their gamma spectra and of the gamma spectra of their daughter products on Ge (Li) spectrometers.

a) The new isotopes ^{181}Ir, $T_{1/2} = 10 \pm 2$ min; ^{180}Ir, $T_{1/2} = 6.5 \pm 1.5$ min; and ^{179}Ir, $T_{1/2} = 4 \pm 1$min have been identified. (E.Nadjakov, B.Bochev et al, Izvestia Akad.Nauk USSR, Ser.Fiz. 35, 2202 (1971)).

b) The new isotopes ^{171}W, $T_{1/2} = 9.0 \pm 1.5$ min and ^{170}W, $T_{1/2} = 4 \pm 1$ min have been identified. (E.Nadjakov, B.Bochev et al, Izvestia Akad.Nauk USSR, Ser.Fiz. 35, 2207 (1971)).

3. A group (E.Nadjakov et al.) has developed the recoil - distance Doppler-shift method for nuclear level lifetime measurements (picosecond range) on the Dubna heavy ion accelerators U-300 and U-300 + U-200. (B.Bochev et al, preprints JINR P6-6229, Dubna 1972; P7-6415, Dubna 1972).

The lifetimes $T_{1/2}$ of the ground-state rotational bands in ^{164}Yb and ^{162}Yb have been measured:

Transition	^{164}Yb Energy keV	^{164}Yb $T_{1/2}$ psec	^{162}Yb Energy keV	^{162}Yb $T_{1/2}$ psec
2 → 0	123.5	882 ± 88	166.5	387 ± 53
4 → 2	262.8	29.9±30	320.5	7.4±3.4
6 → 4	375.0	5.2±0.7	436.0	5.9±2.6
8 → 6	462.8	1.6±0.5	521.7	-
8 → 6*		4.9±1.0		13.6±3.7

* Time interval from reaction to transition.

Measurements on other nuclei are in progress.

May 1972

Liaison Officer to the INDC for Bulgaria:
Emil Nadjakov
Institute of Physics with Nuclear
Research Centre
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Sofia 13, Bulgaria

Progress Report on

Nuclear Data Activities in Hungary

Institute of Experimental Physics
Kossuth University, Debrecen

Hungarian Academy of Sciences
Institute of Nuclear Research, Debrecen

Hungarian Academy of Sciences
Central Research Institute for Physics, Budapest

INSTITUTE OF EXPERIMENTAL PHYSICS,

KOSSUTH UNIVERSITY

DEBRECEN

NUCLEAR DATA PROGRAM AT THE INSTITUTE OF EXPERIMENTAL PHYSICS, KOSSUTH UNIVERSITY, DEBRECEN

Though the main purpose of this Institute is physics education, there is a considerable activity in the field of fast neutron physics. In addition to the experimental measurement of neutron data, some evaluation work is in development, too.

EXPERIMENTAL FACILITIES

1./ 800 kV /40 μA/ Open-air type Van de Graaff generator;

2./ 200 kV /2 mA/ neutron generator /home made/;

3./ 180 kV /1.2 mA/ Activatron-111 neutron generator /IAEA/;

4./ Associated-particle system for ^{3}He and ^{4}He; this can be mounted onto any of the neutron generators;

5./ Pneumatic transport system for quick automatic sample transfer;

6./ Pu-Be neutron sources from 0.5 Ci to 5 Ci;

7./ 25 cm^{3} Ge-Li detector with cryostat /IAEA/;

8./ 4000 channel DIDAC /Intertechnique/ analyser; three 100 - channel analysers;

9./ Tally tape perforator /IAEA/, printer, tape-reader, X-Y plotter, spectrum-stabilizer;

10./ Lorenz telex with tape-punching and punched tape reading units in five-hole CCIT code /Hungarian Atomic Energy Committee/;

11./ ^{6}LiJ /Eu/ crystal /IAEA/ spectrometer;

12./ ^{3}He proportional counter;

13./ Low-background proportional counter for the measurement of weak beta and/or gamma rays, e.g. tritium, with a sensitivity of a few pCi;

CROSS SECTIONS FOR THE $^{113}In/n,n'\gamma/^{113}In$ AND $^{103}Rh/n,n'\gamma/^{103m}Rh$ REACTIONS

/n,n'γ/ cross sections leading to metastable states have been measured for ^{113}In at 2.8 MeV and 14.7 MeV as well as for ^{103}Rh at 14.7 MeV neutron energies; the results are 260 ± 25 mb, 66 ± mb and 289 ± 25 mb, respectively. The conversion coefficient has been deduced for the decay of ^{103m}Rh: $\alpha_K = 123 \pm 14$.

INVESTIGATION /n,t/ CROSS SECTIONS FOR 14 MeV NEUTRONS

Using a low-background proportional counter /see item 13. of facilities/ measurements of /n,t/ cross sections are in progress for A < 100 nuclei. The irradiated samples are outgassed in a special heating system, and the tritium gas produced lead into the proportional counter. In order to avoid the background an electronic pulse shape discrimination system has been developed; this proved to be more effective than the conventional anti-coincidence shielding. This means that the investigations can be extended to low /n,t/ cross sections, i.e. to targets with higher mass numbers. At present /n,t/ cross sections were measured for Be, B, Fe, Ni, and Cu at 14.7 MeV neutron energy.

^{238}U FISSION YIELD MEASUREMENTS WITH Ge/Li/ DETECTOR FOR 14 MeV NEUTRONS

In order to study the yield of fragments from a fission process with low cross section, the direct measurement of gamma-spectra of thick samples irradiated by 14 MeV neutrons was undertaken, without any chemical separation or application of recoil effects. For neutron induced fission of ^{238}U the cumulative yields /relative to that of ^{140}Ba/ of ten isotopes were determined using a Ge/Li/ detector and a thick uranium target.

AVERAGE CROSS SECTIONS FOR Pu - ALFA - Be NEUTRONS: LOW ENERGY NEUTRONS FROM ALFA-N SOURCES

Average activation cross sections for a number of elements were determined using unmoderated neutrons from Pu--Be and Po-Be sources. Applying threshold detectors it was found that 10% of Pu-Be neutrons is emitted in the energy intervals from 10 keV to 100 keV. Neutron spectra from $PuBe_{13}$ sources of different dimensions are the same within the interval 0.5 Ci and 5 Ci; the majority of neutrons below 2 MeV come from the multibody break up of ^{13}C.

EVALUATION OF /n,2n/ CROSS SECTIONS AT 14.7 MeV

On the basis of experimental data and N-Z systematics most probable /n,2n/ cross section values were calculated for isotopes and elements. The present cross sections were compared with those given by empirical formulas.

DESCRIPTION OF FAST NEUTRON CROSS SECTIONS BY A SEMICLASSICAL MODEL

The applicability of a simple, semi-classical optical model to the description of nonelastic and integrated elastic neutron cross sections was investigated at 14 MeV, and found to be justified. Using the nonelastic cross sections, nuclear radius parameters were determined; their magnitude and A-dependence is close to that of the electromagnetic r_o-values.

PLANS FOR THE FUTURE

Practically all of the above-mentioned topics will be continued in the next year;

/n,t/ cross section measurements to higher A-values; cross section measurements on fuel and structural materials using ^{252}Cf neutron source /fission spectrum/; investigations on the mass and charge distribution of fission fragments;

neutron diffusion and cooling in moderators; low-energy charged particle cross section measurements with fusion and astrophysical interest;

compilation and evaluation work to find best values of several measurements, simple empirical expressions describing microscopic cross sections, search for systematics.

INSTITUTE OF NUCLEAR RESEARCH

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DEBRECEN

L-SUBSHELL, M- AND N- SHELL INTERNAL CONVERSION RATIOS THE 391,7 keV ISOMERIC TRANSITION OF ^{113}In

A. Kövér, D. Berényi, J. Csongor[x]

In press in Zeitschrift für Physik

The L_I, L_{II} and L_{III} as well as the M and N internal conversion lines from the 391,7 keV 100 min isomeric transition of ^{113}In have been studied and the ratios of the conversion coefficients determined in a special permanent magnet beta-ray spectrograph of 75 cm maximum radius.[1/] The multipolarity of the transition have been stated to be M4 comparing the obtained $L_I/L_{II} = 6,7 \pm 1,3$ and $L_I/L_{III} = 4,9 \pm 0,8$ ratios with the theoretical calculations [2-4/]. The possible maximum E5 admixture on the basis of our experimental data has been calculated by a computer program[5/]. The L/M as well as the L/N and M/N ratios show a good agreement with the corresponding theoretical values including the recent results of the calculations for the N shell[6/].

1. J.Schadek, D. Berényi and F. Illés, Atomki Közlemények 3 /1961/ 105
2. M.E.Rose, "Internal Conversion Coefficients." North-Holland Publ. Co., Amsterdam, 1958.
3. L.A.Sliv's and I.M. Band's values from K.Siegbahn, "Alpha-, Beta- and Gamma-Ray Spectroscopy, Vol.2. North-Holland Publ. Co. Amsterdam, 1965.
4. R.S.Hager and E.C.Seltzer, Nuclear Data 4A /1968/ 1.
5. H.J.Hennecke, J.C.Manthuruthil and O.Bergman, and C.R.Cothern, Phys.Rev. 159 /1967/ 955
6. O.Dragoun, Z.Plajner and F.Schmutzler, Nuclear Data A9 /1971/ 119

[x] Institute of Pathophysiology, Medical University, Debrecen, Hungary

THE $^{23}Na/d,p/^{24}Na$ REACTION AT DEUTERON ENERGIES 670 AND 620 keV

A. Valek

To be published in Acta Physica Acad. Scient. Hungaricae

The angular distributions and absolute cross-sections of proton groups p_o, p_1, p_2, p_3+p_4 and p_5+p_6 from the reaction $^{23}Na/d,p/^{24}Na$ have been measured at E_d = 670 and 620 keV. Deuterons were accelerated by the cascade generator of ATOMKI, Institute of Nuclear Research, Debrecen, Hungary and protons were detected by a semiconductor detector. The angular distributions were obtained asymmetrical about 90°. The total cross-section data, listed in Table I, have the errors in general about 25 %.

Table I.

Energy /keV/	Cross-section of groups /μb/				
	p_o	p_1	p_2	p_3+p_4	p_5+p_6
670	27	24	30	113	70
620	18	8.5	13	47	19

The experimental data have been analysed in terms of Legendre polynomials and DWBA method, used optical potential parameters from [1,2]. The DWBA calculations reproduced the angular distributions of proton groups p_3+p_4 and p_5+p_6, while it did not give good results in the case of p_o, p_1 and p_2. The analysis of our experimental results suggests, that at low bombarding energies in this reaction both the compound nucleus and the direct interaction mechanism simultaneously exist, and in the case of p_3+p_4 and p_5+p_6 the contribution of the direct interaction is predominant.

Our results are in agreement with the conclusions given by El-Behay et al. [3].

1. F.G.Perey, Phys.Rev., 131, 745, 1963.
2. A.Gallmann et al. Nucl.Phys., 88, 654, 1966.
3. A.Z.El-Behay et al., Nucl.Phys., 74, 225, 1965.

INVESTIGATION OF THE $^{14}N/d,p/^{15}N$ AND $^{14}N/d,\alpha/^{12}C$ REACTIONS BELOW THE COULOMB BARRIER

I. Hunyadi, L. Meskó, B. Schlenk, A. Valek and M.H.S.Bakr[x]
To be published in Acta Physica Acad.Scient.Hungaricae

The study of $^{14}N/d,p/^{15}N$ and $^{14}N/d,\alpha/^{12}C$ nuclear reactions is in progress at the cascade generator of ATOMKI, Institute of Nuclear Research, Debrecen, Hungary. The angular distributions of $p_o, p_1+p_2, p_3+p_4, p_5$ and α_o, α_1 groups were measured by semiconductor detector at E_d = 626, 576, 475, 374 and 324 keV energies on thin adenine target. The excitation functions of the above mentioned groups were measured at 90° in the energy range E_d = 310 - 640 keV using gaseous target method. The obtained differential cross-sections varied smoothly with the bombarding energy, no resonance behaviour was observed. The angular distributions of the proton groups were analysed in terms of Legendre polynomials. The shape of them are asymmetrical about 90°, in general, slightly vary with the deuteron energy. The measured absolute total cross--section data of the proton groups are shown in Table 1. The estimated errors are less than 20 %.

Table 1

Energy /keV/	Cross-section of proton groups /μb/				
	p_o	p_1+p_2	p_3	p_4	p_5
626	1210	2000	860	3240	9050
576	780	1080	550	2100	6450
475	341	395	215	820	2800
374	76	86	37	142	580
324	25,1	26,6	12,2	46	201

[x] *Atomic Energy Establishment, Cairo, Egypt*

The DWBA analysis and the theoretical evaluation of the experimental data of proton groups are going on.

The groups α_2 and α_3 leading to the second and the third excited levels in the residual nucleus ^{12}C could not be measured using the same semiconductor detector technique because of the intense proton groups from other competing /d,p/ reactions on ^{14}N, ^{16}O and ^{12}C. Solid state track detectors [1] were used to measure the angular distributions of the groups $\alpha_o, \alpha_1, \alpha_2$ and α_3 at incident deuteron energies E_d = = 350, 510 and 650 keV. The measured absolute total cross sections of the α groups are given in Table 2. The absolute errors are less than 20%.

Table 2

Energy /keV/	Cross-sections of alpha groups /μb/			
	α_o	α_1	α_2	α_3
650	1048	3283	181	3587
510	322	991	61.9	1103
350	19.0	74.3	5.63	66

The shape of the measured angular distributions does not change in the investigated energy region. The strong forward peak in the angular distirubtions of the group α_o and the relatively low cross section of the group α_2 demand detailed treatment which is now in progress.

[1] L. Meskó, B. Schlenk, G. Somogyi and A. Valek, Nucl. Phys., A130, 449 1969

CENTRAL RESEARCH INSTITUTE FOR PHYSICS

OF THE HUNGARIAN ACADEMY OF SCIENCES

BUDAPEST

THE MAGNETIC FIELD AT TUNGSTEN NUCLEI IN IRON

J.A. Cameron[x], *L. Keszthelyi, G. Mezei, Z. Szőkefalvi-Nagy and L. Varga*

Published in Canadian Journal of Physics

Larmor precession of the first 2^+ states of ^{182}W and ^{184}W has been observed in an iron alloy containing 5 atom percent W. The levels were Coulomb excited with 2.5 MeV protons. The hyperfine energy in ^{182}W is the same as that found by Mössbauer absorption. The variation of the field up to $300^{o}K$ is less than 6%. A comparison of g factors measured by hyperfine field and external field suggests the existence of a hyperfine anomaly.

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[x]On leave from McMaster University, Hamilton, Ontario, Canada

MAGNETIC MOMENTS OF THE 295 keV AND 357 keV STATES OF ^{103}Rh

L. Keszthelyi, I. Demeter, Z. Szőkefalvi-Nagy, L. Varga and G. Mezei

To be published in Nucl. Phys.

The g-factor of the 295 keV and 357 keV excited states of ^{103}Rh measured by Coulomb excitation in Fe-Rh alloy were found to be 0,28 ± 0,20 and 0,54 ± 0,05, respectively. The cascade decay of the 357 keV level was carefully taken into account in the evaluation of the 297 keV energy data.

g-FACTORS OF THE 211 AND 240 keV STATES OF ^{195}Pt

L. Varga, I. Demeter, L. Keszthelyi, G. Mezei, Z. Szőkefalvi-Nagy

Published in Phys. Rev.

The statistical accuracy of earlier results was improved by new measurements on $Fe_{72,5}Pt_{27,5}$ and $Fe_{50}Pt_{50}$ targets. In re-evaluating the data, corrections were made for beam bending and beam shift and new data regarding the decay scheme of ^{195}Pt were taken also into account. The g-factors of the 211 and 240 keV states of ^{195}Pt were found to be 0,104 ± 0,021 and 0,146 ± 0,019, respectively, in disagreement with current theoretical predictions. The value of the strength of the hyperfine magnetic field at Pt nuclei in the $Fe_{72,5}Pt_{27,5}$ alloy is in agreement with static measurements, it is -870 ± 60 kGauss for $Fe_{50}Pt_{50}$ alloy.

CORRELATION OF THE PARTIAL RADIATIVE AND NEUTRON WIDTHS IN THE $^{163}Dy/n,\gamma/^{164}Dy$ REACTION

L.S. Danelyan[x], A.M. Demidov[x], S.V. Krupin[x], S.K. Sotnikov[x], A. Zarándi, B. Kardon, L. Szabó, Z. Seres

ZhETF 62, /1972/ 425

The gamma-ray spectra in the $^{163}Dy/n,\gamma/^{164}Dy$ reaction are investigated with a Ge/Li/ spectrometer. A number of phenomena of non-statistical nature are observed: correlation between the reduced radiative and neutron widths and between various partial radiative widths. The absolute mean reduced partial width is greater than any of those predicted by various models or based on the experimental data for other nuclei. The degree of freedom of the partial width distribution to the ground rotational and γ-vibrational band is $\nu = 2 \pm 0.5$.

x Kurchatov Institute of Atomic Energy, Moscow

EFFECTS OF LEVEL STRUCTURE ON THE INTENSITY OF PARTIAL RADIATIVE TRANSITIONS IN THE $^{155}Gd/n,\gamma/^{156}Gd$ RESONANCES

L.S. Danelyan[x], *B. Kardon, S.K. Sotnikov*[x]

ZhETF, 62, /1972/ 1228

Intensity of the partial radiative transitions in resonances of the $^{155}Gd/n,\gamma/^{156}Gd$ reaction are studied by means of a Ge/Li/ -spectrometer. The correlation observed between the widths for transitions to levels of the ground state rotational band and the reduced neutron widths are discussed from the point of view of a semi-microscopic nuclear model.

[x] *Kurchatov Institute of Atomic Energy, Moscow*

THE INFLUENCE OF QUANTUM NUMBER K ON THE INTENSITY OF PARTIAL GAMMA TRANSITIONS FROM THE $^{177}Hf/n,\gamma/^{178}Hf$ REACTION AT THE NEUTRON RESONANCES

L.S. Danelyan[x] *and B. Kardon*

To be published

The study of neutron capture gamma-ray spectra at the neutron resonances gives information on the highly excited nuclear levels. With the use of a lithium drifted germanium detector the partial radiations were measured at the neutron resonances with spin $J = 4^-$ up to a neutron energy of 100 eV, to the low-lying levels with different K quantum number.

[x] *Kurchatov Institute of Atomic Energy, Moscow*

THERMAL NEUTRON CAPTURE GAMMA-RAY STUDIES OF NATURAL Xe

B. Kardon, I.A.A. Manuaba, P. Gróz

Report KFKI-71-46

The gamma radiations following thermal neutron capture in natural xenon have been studied using a Ge/Li/ spectrometer at WWRS type research reactor. Solid XeF_2 was used as the target. The gamma-ray energies and intensities of 145 transitions in the energy range 0,2 - 9,3 MeV were determined. The energies have been obtained with an accuracy ranging between 0,1 keV for intense transitions and 5 keV for very weak transitions. The neutron separation energies of ^{130}Xe and ^{132}Xe have been deduced to be 9300,7 $\pm$ 1,8 keV and 8940,6 $\pm$ 1,1 keV, respectively.

MEASUREMENT OF GAMMA-RAY SPECTRA FROM THE SPONTANEOUSLY FISSIONING ISOMER OF ^{236}U

A. Lajtai, L. Jéki, Gy. Kluge and I. Vinnay

Measurements are in progress to detect gamma-ray transitions preceding spontaneous fission of the isomeric state of ^{236}U. The energy spectra between 200 keV and 1 MeV of gamma rays from $^{235}U/n_{th}$,gamma f/ reaction are studied to observe single lines corresponding to prefission gamma decays, using a fast-slow coincidence system. The gamma rays were detected with a 30 cm^3 Ge/Li/ detector, the fission fragments with a gas scintillation counter.

ENERGY SPECTRA OF NEUTRONS FROM /n,n'/ AND /n,2n/REACTIONS

Gy. Kluge and L. Jéki

Report KFKI-72-17

Energy spectra of neutrons from /n,n'/ and /n,2n/ reactions induced by 14 MeV neutrons have been calculated in terms of the original Weisskopf model for a number of target nuclei. The results of the calculations which avoid the usual approximations show very good agreement with the experimental data.

PROMPT FISSION NEUTRON SPECTRA

Gy. Kluge

Report KFKI-71-55

Some of the main features of the present theoretical understanding of the fission neutron spectra are discussed. The effect of a possible center-of-mass anisotropy and the validity of Terrell's T/ν/ relation are discussed. Results of some calculations on the prompt neutron spectra are given.

ON THE EMISSION OF PROMPT FISSION NEUTRONS

Gy. Kluge

Physics Letters 37B/1971/217

Different approaches, including a detailed cascade calculation of the centre of mass spectra of fission neutrons emitted from the individual fragments of spontaneous fission of ^{252}Cf, are compared in the determination of the total energy and angular distributions of fission neutrons. The existence of scission neutrons is questioned and the corrections arising from the form of the approach are discussed.

/n,2n/ CROSS SECTIONS ON Nb AND Mo NUCLEI

L. Jéki and Gy. Kluge

Submitted to the Journal of Nuclear Energy

Niobium and molybdenum are key structural materials in proposed designs for a D-T fusion reactor blanket, but implementation of such plans is hindered considerably by the lack of accurate cross-section values and energy distributions of neutrons in the /n,n'/ and /n,2n/ reactions of these elements. These data have been obtained by recently advanced calculation methods.

REMARKS ON THE EXISTENCE OF RETARDED NEUTRONS IN FISSION

L. Jéki, Gy. Kluge, A. Lajtai

Report KFKI-71-35

New measurements on the fine structure of the fission neutron spectrum are critically discussed.

UNFOLDING NEUTRON SPECTRA FROM ACTIVATION DATA

A. Fischer, L. Turi

The neutron spectra are unfolded from activation data by the code RFSP [1]. The main problems which are now investigated are connected with the compilation of reliable activation cross section data for the detector foil materials. The new cross section data are continuously incorporated in the cross section library of the code. Preliminary results show, that some discrepancies discovered in connection with the use of this method are probably due to incorrect detector cross section data.

[1] A.Fischer, L.Turi: Report KFKI-71-22

COMPILATION OF MUFT-TYPE MULTIGROUP CONSTANT LIBRARY

P. Vértes

Since the last Progress Report /1971/ little has been done as the compilation of new multigroup constant library concerned. What is going on now is a thorough check of the new compilation /on which it was reported in the Progress Report of last year/ by using it for the calculation of multigroup neutron spectra and by comparison of the calculated spectrum indices and other important parameters with experimental results. It is found that this new compilation represents an important improvement with respect to our old group constant library.

Progress Report on Nuclear Data Activities in India

Compiled by M. Balakrishnan

May 1972

INDIAN NUCLEAR DATA GROUP

Members

1. M. Balakrishnan (Secretary)		: Nuclear Physics Division, BARC
2. V.C. Deniz		: Reactor Engineering Divn., B.A.R.C.
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
6. B.P. Rastogi		: Reactor Engineering Divn., BARC
7. N.S. Satyamurthy		: Nuclear Physics Division, B.A.R.C.
8. N.C. Bhattacharya	(Co-opted)	: Variable Energy Cyclotron Project
9. S.B. Garg	"	: Reactor Engineering Division, BARC
10. M.C. Joshi	"	: University of Bombay
11. S.K. Mitra	"	: Tata Institute of Fundamental Research.
12. M.P. Navalkar	"	: Nuclear Physics Division, BARC
13. P.K. Patwardhan	"	: Electronis Division, BARC

Preface

The eighth progress report on Nuclear Data Activities in India covers the work done during the year 1971. A part of the work given in this report has been presented at the Nuclear Physics and Solid State Physics Symposium held at Bombay during February 1972.

The total number of CINDA entires sent to the Nuclear Data Section of the International Atomic Energy Agency during the period of the report is 160. The liaison activity with Computer Programme Library (CPL) of European Nuclear Energy Agency was continued.

A major event of the year was the holding of the Fourth International Nuclear Data Committee(INDC) Meeting in Bombay. About twenty participants from outside India, comprising committee members, scientific advisers and observers attended the meeting in addition to the participants from India. A highlight of this meeting was a one day Topical Conference on "Neutron Induced Fission". Work done in India as well as in many other countries abroad on this subject was reported and discussed at the conference. Proceedings of this topical conference have been brought out as INDC Report, INDC-7/U.

The progress report on new facilities for research is as follows:

a) Zero energy fast reactor

A significant development in the fast reactor technology is the zero energy fast reactor, built at BARC. A plutonium

fuelled zero energy fast reactor was made critical at the Bhabha Atomic Research Centre, Trombay at 0915 hours, on May 22nd 1972. The reactor has a three litre core and uses about 180 plutonium oxide fuel pins of 1 cm diameter. The critical mass is 21.6 kgs of plutonium. The core is reflected by thick copper and steel on all sides. Primary control is by the insertion / withdrawal of the core vessel into / out of the massive reflector. In addition molybdenum reflector safety and control rods are available.

For quick shutdown in the event of a rapid rise of neutron flux, the core which is held normally by electromagnets drops out of the reflector assembly, simultaneously six molybdenum safety rods are ejected out of the assembly with an initial acceleration of over 15g by means of compressed springs. The neutron instrumentation consists of three neutron pulse channels and five ^{10}B coated ion chamber-channels with the usual high level and period trip initiating elements.

b) <u>The pulsed fast reactor</u>

The Trombay zero energy fast reactor is a mock up of proposed repetitively pulsed fast reactor (PFR) to be built at the Reactor Research Centre being set up at Kalpakkam, near Madras city, in Tamil Nadu. Experiments towards optimising the physics characteristics of the PFR would commence soon after the initial commissioning tests on the zero energy fast reactor are completed.

c) The construction work on the 224 cm. variable energy cyclotron (VEC) has made all round progress during the year, as per schedule. Casting of steel for the 250 tonne magnet has been completed at the Heavy Engineering Corporation Ranchi and the final machining is under way. The magnet coil fabrication has started at the Heavy Electricals India Ltd., Bhopal. The fabrication of other components is being done at the Bhabha Atomic Research Centre Bombay. Plans for a 160° analysing magnet and a TDC-16 (Trombay Digital Computer-16) on line computor have been finalized and tendering is in progress. The VEC building is nearing completion and movement of staff to Calcutta has started. The users' committee for physics is formulating plans for utilization of the cyclotron. Users' committees for chemistry and biology have been formed. The cyclotron is expected to go into operation in 1974.

d) At the Panjab University, Chandigarh, the building for the 6 MeV variable Energy Cyclotron is complete. Installation of the cyclotron is in progress.

A.S. Divatia
Convenor
Indian Nuclear Data Group

A. BHABHA ATOMIC RESEARCH CENTRE, TROMBAY, BOMBAY 85

1. Studies on Analog States in ^{33}Cl by Isospin-Forbidden Resonances in the reaction $^{32}S(p,\gamma)^{33}Cl$ - M.A. Eswaran, M. Ismail, N.L. Ragoowansi and H.H. Oza - Nuclear Physics Division - The residual positron activity between bursts of a mechanically chopped beam has been used to measure the yield of the reaction $^{32}S(p,\gamma)^{33}Cl$ systematically in the bombarding energy range E_p = 3.36 to 5.41 MeV. Two, T = 3/2 states in ^{33}Cl at E_p = 3.371 ± .005 MeV, E_x = 5.550±.007 MeV and at E_p = 5.232±.006 MeV E_x = 7.402±.008 MeV have been located and their absolute resonance strengths determined. Each of these resonances was narrower than the estimated 2 keV spread in the proton beam. These two states are interpreted as the analogs of the ground and the second excited state of ^{33}P with J^{π} , $1/2^+$ and $5/2^+$ respectively. γ-decay of the lower resonance, investigated with a Ge(Li) detector shows $>$ 88% and $<$ 12% branchings to the first excited state and ground state of ^{33}Cl respectively. The M1 strength of these transitions are compared with those obtained from beta analog transitions and with the theoretical predictions based on the many-particle shell model calculations.

2. A Study of the Reaction $^{64}Ni(p,p)^{64}Ni$ in the Range 3.150 to 4.050 MeV - M.K. Mehta , A.S. Divatia, S.K. Gupta and S.S. Kerekatte - Nuclear Physics Division - Elastic scattering of protons from ^{64}Ni targets has been studied with fine resolution (2.5 - 5 keV) in the bombarding energy

range from 3.15 to 4.05 MeV. Yields are measured at laboratory angles of 89°, 125°, 140° and 165°. The first three angles correspond to zeroes of Legendre Polynomials of first second and third order. The excitation functions exhibit a large amount of fine structure together with two regions of relatively stronger anomalies. These anomalies are correlated with stronger structure seen in our earlier $^{64}Ni(p,n)^{64}Cu$[1] experiment and are identified as levels in the compound nucleus ^{65}Cu which are isobaric analogues of the loylying levels in ^{65}Ni.

1. S.S. Kerekatte, S.K. Gupta and A.S. Divatia
Proc. of Nucl. Phys. and Solid State Phys. Symposium (1970), Madurai, p. 45.

3. <u>Excitation Function for the Gamma-Ray Yields from Alpha Particle Bombardment of ^{19}F in the Range 3.5 to 4.7 MeV</u>

- M. Balakrishnan, M.K. Mehta and A.S. Divatia - Nuclear Physics Division - Gamma rays from alpha particle bombardment of ^{19}F targets have been detected in 35 c.c. GeLi detector. Gamma rays going to the first and the second excited state at 110 and 197 keV in ^{19}F have been identified. A gamma ray of 1.277 MeV corresponding to the first excited state in ^{22}Ne is also observed. Excitation functions for all these gamma rays are measured in the bombarding energy range from 3.5 to 4.7 MeV in 5 keV steps. The structure observed is interpreted in terms of the resonances corresponding to the levels in the compound nucleus ^{23}Na. The data are correlated with our earlier

results from a study of $^{19}F(\alpha,n)^{22}Ne$ reaction[1].

1. K.K. Sekharan, M.K. Mehta and A.S. Divatia Proc. Nucl. Phys. & Solid State Phys. Symp. (Calcutta) Vol. II(1965) p. 199.

4. <u>Calculation of the Effect of Fission Fragment Anisotropy on the Measured Prompt Neutron Energy and Angular Distributions</u> - N.N. Ajitanand and S.S. Kapoor - Nuclear Physics Division - The laboratory angular and energy distributions of the prompt neutrons have been calculated for fast neutron induced fission when the fragment angular distribution is forward peaked of the form $(1 + A_2 P_2 (\cos \theta)$. The results of these calculations are presented for various values of the fragment anisotropy for the case of fragment detection in 2π geometry. Typically, for 30% fragment anisotropy the average laboratory neutron energy is increased by about 2% at 0° and decreased by about 1.5% at 90° as compared to the case of isotropic emission of fragments. The corresponding neutron anisotropy is about 7% and varies linearly with the fragment anisotropy. The measured average number of neutrons should therefore be corrected for the fragment anisotropy effects since very accurate values of $\bar{\nu}$ are required for the estimation of breeding ratios in fast breeder reactors.

5. <u>Energy and Angular Distributions of Long Range Charged Particles in Thermal Fission of U^{235}</u> - D.N. Nadkarni,

S.K. Kataria, S.S. Kapoor and P.N. Ramarao - Nuclear Physics Division - The energy distributions of the long range charged particles (LRCP) emitted in the thermal fission of U^{235} were simultaneously measured with the same semiconductor detector for the cases when the average angle between the direction of LRCP and the fission framgnets were 90°, 46°, 25° and 11°. The data were analysed by the numerical montecarlo method to take into account the effects of the finite size of the source and the various detectors, and the following conclusions are drawn: i) For the total LRCP energy range the assumed Gaussion shape for the angular correlation functions is only valid for the angular region of 50° about the fission axis. For example at the angle of 11°, the measured fractional LRCP yield is (.031$\pm$.007) as compared to the value of (0.002 $\pm$ .001) expected for Gaussion shape (ii) It is found that the width parameter of the angular correlation function is nearly constant in the energy range of 12-20 MeV, while it increases sharply for LRCP energies $E > 20$ MeV. The angular distribution essentially becomes isotropic for $24.5 < E < 26.5$ MeV and indicates a minimum at 90° for $E > 26.5$ MeV. These results indicate that a small fraction of LRCP, with a mean energy significantly higher than the average is emitted with a forward peaked angular distribution. It is suggested that this component is the result of evaporation from excited fragments in competition with neutrons.

6. <u>Studies on Highly Asymmetric Binary Fission :</u>

<u>Fission of Uranium with Reactor Neutrons</u> - V.K. Bhargava, V.K. Rao, S.G. Marathe, S.M. Sahakundu and R.H. Iyer - Radiochemistry Division - Preliminary results have been obtained of a programme of work aimed at defining precisely the nature of the mass distribution in the highly asymmetric binary fission of heavy elements from a radiochemical investigation of the reactor neutron induced fission of natural uranium. The cumulative fission yields of five nuclides vis. ^{66}Ni, ^{67}Cu (on the lighter) and ^{172}Er, ^{175}Yb and ^{177}Lu (on the heavier mass regions) were measured relative to ^{99}Mo (taken as 6.2%) using stringent radiochemical separation procedures. The measured yields are [7.5±0.8] x 10^{-6}%; [6.2±3.0]x10^{-6}%; [4.7±2.5]x 10^{-6}%; [4.0±2.0]x 10^{-6}%; [2.7±1.4]x 10^{-6}% for ^{66}Ni, ^{67}Cu, ^{172}Er, ^{175}Yb and ^{177}Lu respectively. The values reported for ^{175}Yb and ^{177}Lu are considered at present as upper limits in view of the extremely low activities observed and the uncertainties in the impurity contributions.

From a comparison of the present data with those available in the literature (although the reported measurements are limited to A $<$ 161 only), there appears to be a strong tendency for the yields to increase rapidly with increase in the asymmetry of the split as well as excitation energy of the compound nucleus.

7. <u>An Alternative Method to Strutinsky Prescrition for Determining Nuclear Ground State Shell correction</u> - V. S. Ramamurthy, S.K. Kataria and S.S. Kapoor - Nuclear Physics Division - The strutinsky method of determing the ground state shell correction requires the generation of an average single-particle level sequence which retains the long range behaviour while smearing the local fluctuations of the single particle level sequence. Mathematical prescriptions for the generation of the uniform level scheme have been given by strutinsky and Nilsson and some inadequacies of these prescriptions have been noticed. In this work, we present an alternative method for the determination of the ground state shell correction on the basis of a miscroscopic calculation of the excitation energy dependence of the thermodynamic entropy of a nucleus without reference to any artificially generated average level schemes. The calculation of the shell correction versus nuclear deformation on the basis of the present method is shown to lead to the familiar double-humped fission barrier for nuclei in the actinide region.

8. <u>Evidence for the Persistance of Shell Effects on the Saddle Point Deformation of $^{201}_{81}$Tl</u> - V. S. Ramamurthy and S.S. Kapoor - Nuclear Physics Division - Evidence for the existence of a significant positive shell correction near the highly deformed saddle point of the light fissioning nucleus $^{201}_{81}$Tl is presented on the basis of an analysis of

the available data on Γ_f / Γ_n versus the excitation energy for this nucleus. For the calculation of the neutron emission width Γ_n, the level densities of the residual nucleus were obtained on the basis of a microscopic calculation using a realistic shell model single particle energy level scheme. Bohr-wheeler Transition state theory was applied for the calculation of the fission width Γ_f. A value of +2.4 MeV is obtained for the shell correction at the saddle point deformation of this nucleus giving rise to a value of 15.4 MeV for the Liquid Drop Model (LDM) fission barrier. This result has important implication on the determination of the coefficients of the semiemplrical mass formula of Myer-Swiatecki where the LDM fission barrier of this nucleus is an important input parameter.

9. <u>Further Calculations on the Distribution of Fragment Mass and Charge in Fission</u> - V. R. Ramamurthy - Nuclear Physics Division - Calculated distributions of fragment mass and charge in high energy fission of the light nuclei ^{186}Os, ^{201}Tl, ^{213}Pb and ^{213}At on the basis of the stochastic Theory of fission are analysed. Since in these cases, fragment shell structures do not significantly influence the final mass and charge distributions, the theory can be applied without the use of any free parameters. The results have been compared with the experimental distributions obtained for these nuclei and also with the corresponding distributions calculated on the basis of the Liquid Drop Model. Calculations have also

been carried out for the case of low energy fission of the Fermium isotopes ^{254}Fm and ^{258}Fm. It is shown that for ^{254}Fm fission is asymmetric, while it is symmetric for ^{258}Fm fission, as observed experimentally.

10. Angular Momentum Effects in the Elastic Scattering of ^{16}O from Calcium Isotopes - A Calculation - M. K. Mehta - Nuclear Physics Division - The dependence of the imaginary part of the optical potential for heavy ions on complex nuclei has been established by the FSU group[1] on the basis of the maximum angular momentum that can be carried away in the exit channel consisting of an alpha particle plus the residual nucleus. The University of Washington group[2] suggested that the direct alpha particle transfer is a more critical channel which affects the angular momentum dependence of the imaginary potential. The ^{16}O scattering from calcium isotopes is examined from this point of view starting with the FSU optical potential. The results indicate that although no drastic effects are expected, the scattering from ^{40}Ca will be more sensitive to angular momentum effects than that from ^{44}Ca.

1. R.A. Chatwin et al Phys. Rev. C1(1970)795

2. R.W. Shaw, R. Vandenbosch and M.K. Mehta, Phys. Rev. Letts. 25(1970)457.

11. Detailed Analyses of the $^{7}Li(p,pt)^{4}He$ Reaction - A.K. Jain and N. Sarma - Nuclear Physics Division - This

reaction $^{7}Li(p,pt)^{4}He$ has been analysed using completely antisymmetrized cluster model wave functions and distorted wave impulse approximation (DWIA). The inter cluster wave function used has an exponential asymptotic behaviour corresponding to the α -t separation energy. The calculations reproduce both the magnitude and shape of the angular correlation data at 156 MeV. It is very encouraging to note that the same formulation fits the data at 55 MeV as well. No free parameters are introduced in these analyses.

12. <u>Model Studies on a Half GEV cyclotron</u> - A. Jain and A.S. Divatia - Nuclear Physics Division - A simple analytical technique for shaping the contours of AVF cyclotron sectors developed earlier[1] has been tested by designing and constructing an electron analogue of a high energy proton cyclotron. Since 255 Kev ($\frac{1}{2}$ $m_e c^2$) electrons have the same mass increase as 470 MeV (2 $m_p c^2$) protons, an electron cyclotron presents equivalent high energy proton cyclotron orbit stability problems. The spiral sectors designed and constructed for the electron analogue were fixed to the pole pieces of a 30 cm diameter electromagnet. The median plane magnetic field $B(r,\theta)$ of this electron cyclotron magnet was measured using a Hall-probe. The field was smoothened by the method of least squares. The orbit properties under operating conditions were then obtained by a Runge-Kutta numerical integration of twelve simultaneous differential equations of motion in the measured field $B(r, \theta)$ by a digital computer, using the

orbit code ORBIT. The exact orbit properties of this $\frac{1}{2}$ me^2 cyclotron are compared with those predicted by the design theory.

1. A. Jain and A.S. Divatia, Proc. of NP and SSP Symposium, Madurai 1970, Vol 2, P.579.

13. A Fast Neutron Time-of-Flight Spectrometer for use in Neutron Gamma Ray Coincidence Experiments - N.L. Ragoowansi and M.A. Eswaran - Nuclear Physics Division - For use in neutron gamma ray coincidence experiments in nuclear reactions a fast neutron time-of-flight spectrometer arrangement has been set up. A plastic scintillator mounted on XP1040 photo-tube is used for neutron detection and NaI(Tl) scintillation counter is used for gamma rays. The main part of the system is a transistorised time-to-amplitude convertor which is built based on the circuitry published in reference (1). This incorporates in addition to the time-to-amplitude convertor, a fast coincidence arrangement which triggers the T.A.C. enabling the timesorter to be operated by only the coincident events Using neutron gamma ray coincidences from the reaction 9Be $(\alpha, n\gamma)^{12}C$ from Am-α-Be source, the performance of the above system has been checked employing various flight paths. The usefulness of this system in general coincidence experiments for recording random and true plus random spectra simultaneously is also studied.

1. R. B. Tomlinson and R.L. Brown, IEEE Trans. on Nuc. Sci, April, 1964 p.28.

14. <u>A New Plastic Track Detector</u> - D.K. Sood - Nuclear Physics Division - Charged particles traversing an insulating medium leave a radiation damage trail which can, often, be selectively attacked by a suitable chemical reagent to produce tracks visible under an optical microscope. Several solid state track detectors such as mica, glasses and plastics have been developed and used extensively. Each detector is characterised by a critical energy loss rate (dE/dx)-crit below which no tracks are registered. Thus most of the detectors proposed so far could record ions heavier than α-particles. We have developed a new plastic (Cellulose triacetate) detector capable of registering protons of energy as low as 50 keV. The response of this detector to 400,300, 200, 100 and 50 keV protons; 5.48 MeV, 400 and 200 keV alphas; 3 300 keV N^+ ions and 300 keV Kr^+ ions has been studied. The diameter of the tracks is found to increase with etching time (6N NaOH at 60°C) and with dE/dx of the incident particle. It is shown that the detector possess rather good particle identification characteristics which make it suitable for a wide range of applications in nuclear physics, solid state physics and astrophysics.

15. <u>High Resolution Si (Li) Spectrometer and its Analytical Applications</u> - Madan Lal and S.S. Kapoor - Nuclear Physics Division - A high resolution multichannel x-ray spectrometer employing a cooled 30 mm^2 x 3 mm Si(Li) detector and a cooled FET preamplifier in the charge sensitive mode, has been

set up in this laboratory. The present energy resolution of the system corresponds to about 400 ev and efforts are being made to improve this resolution further. The various factors, crucial to the attainment of high resolution will be discussed. The present energy resolution is good enough to discriminate K x-rays of any two adjoining elements of $Z > 20$. This set up is now being used for rapid, nondestructive simultaneous analysis of all the elements ($z > 20$) in any given sample. Several new areas of applications to which this set-up can be put to, are being studied.

16. <u>Second Order Spherical Aberrations due to a Dipole Magnet</u> - N.C. Bhattacharya, R.C. Sethi, R.K. Bhandari and A.S. Divatia - Nuclear Physics Division - Spherical aberrations due to radial and axial divergences are the most important for a dipole magnet in a beam optical system. They have been calculated including the extended fringing field effect in the most general case i.e. with non-normal entry and exit and non-identical curvatures at the two faces of the magnet. The computation has been done according to Brown's formulation of second order matrices for various elements in a beam transport system. It has been shown that other parameters remaining constant, these aberrations are linear functions of the curvatures at the two faces. Expressions have been derived for the radii of curvature required to eliminate them.

In the special case of normal entry and exit, identical radii of curvature, relationship between the radii of curvature and the field index n has been presented graphically.

In the case of the analyzing magnet for the 224 cm. Variable Energy Cyclotron, having field index $n = \frac{1}{2}$ and normal entry and exit, the sum of the radial aberrations due to radial and axial divergences is independent of the radii of curvature and hence it is impossible to eliminate both the aberrations simultaneously.

17. <u>Effect of Magnating Field Errors on Orbit Properties in Cyclic Accelerators</u> - A Jain - Variable Energy Cyclotron Project - An orbit code for finding stability properties of equilibrium orbits in cyclic accelerators has been developed. The twelve first order simultaneous differential equations of motion described by Gordon and Welton[1] are numerically integrated simultaneously by a four point Runge-Rutta process in the measured magnetic field $B(r,\theta)$. Three versions of the code are available: The input magnetic field is given i) on a polar grid, ii) as a table of fourier co-efficients and iii) in an analytical form. The merits of the code and some recent applications have been described. It is theoretically difficult to correlate the errors in the measured field $B(r,\theta)$ with the final orbit properties. The problem has been studied numerically with the orbit code by deliberately introducing a known statistical error in an otherwise smooth field $B(r, \theta)$.

The effect (on orbit properties) of neglecting higher order terms in the fourier series representation of an azimuthally varying field has also been studied.

1. M. M. Gordon and T.A. Welton, ORNL-2765.

18. Measurement and Evaluation of the Fringing field Effects in A 2 CM. Quadrupole Magnet - R.C. Sethi, A. Jain and A.S. Divatia - Nuclear Physics Division - To evaluate the fringing field effects of the quadrupole magnet for the 224 cm. Variable Energy Cyclotron, a jig has been constructed to map the field of a 2 cm. aperture quadrupole magnet,using a Hall-probe. The magnetic centre of the magnet has been found graphically. The field gradient in the fringing field zone and inside the magnet has been mapped. Non-linearity of the field gradient and deviation from the ideal field gradient have been studied as functions of current and radius of aperture.

Fringing field effects have been measured in terms of change in length of the quadrupole magnet. The variations of this change in length have been obtained as functions of current and radius of aperture. The exact trajectory of a charged particle through the actual quadrupole field (fringing+main) has been traced numerically and the aberration has been calculated and compared with the hard-edge model approximation. The whole date has been smoothened by the method of least squares.

19. Meam Dynamic Stability Studies for the 224 CM Variable Energy Cyclotron - A. Jain and A.S. Divatia - Nuclear Physics Division - Given the input magnetic field B(r, θ) for a specific particle and energy in a cyclotron, the variation of the betatron frequencies (ν_r and ν_z) with the radius, the most important orbit stability characteristic, can be computed exactly by orbit integration codes. If the beam is to remain stable, this variation of ν_r and ν_z should not cross a "resonance" on the $\nu_r - \nu_z$ graph throughout the acceleration history of the particle.

The orbit properties for the entire spectrum of particles to be accelerated by the variable energy cyclotron have been computed and mapped. Important conclusions based on these beam dynamic stability studies are discussed. It is found that the present maximum proton energy which is 60 MeV could be raised to only 70-80 MeV, when we strike the $\nu_r - \nu_z = 1$ linear coupled resonance. With the present sector shapes, vertical beam stability also vanishes after this energy. It appears possible to achieve a maximum energy of 130 MeV for protons provided the sectors are redesigned.

20 Radial Motion Studies in the Central Region of the 224 cm Variable Energy Cyclotron - R.K. Bhandari, N. C. Bhattacharya and A.S. Divatia - In order to achieve good extraction efficiency in a cyclotron, it is necessary to have well centred orbits and high phase space density at the entrance of the deflector. These conditions are met

primarily by proper positioning of the ion source and the puller electrode in the central region where the electric field plays a domant role.

Particle orbits and orbit centre points have been calculated to determine the effect of the central region parameters - ion source position, puller electrode position, puller electrode angle, initial radial divergence and the magnetic field on the radial motion of the particles in the median plane, using the program PINWHEEL, obtained from Berkeley and adapted to CDC-3600 computer at TIFR. The necessary electric potential distribution in the central region has been measured by the electrolytic tank method, using a half scale copper model of the central region, incorporating the ion source, the puller electrode and the dee. The potential was obtained on an X-Y grid in the median plane using Type 547 Tektronix oscilloscope. Absolute accuracy in voltage measurement at any point on the water surface is $\pm$ 5%.

21. <u>Conversion Electron Studies Following ^{79,81}Br(p,n) ^{79,81}Kr Reactions</u> - Y.K Agarwal*, C.V.K. Baba**, M. G. Betigeri, S.M. Bharathi*, B. Lal and N.G. Puttaswamy*** - Nuclear Physics Division - The low lying states of ^{79,81}Kr

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isotopes resulting from $^{79,81}Br(p,n)$ reactions at $E_p = 5$ MeV have been investigated using a six-gap β-spectrometer and Ge(Li) detector. Conversion coefficients of transitions involving levels upto 532 keV in ^{79}Kr and 395 keV in ^{81}Kr have been measured and the corresponding multipolarities are assigned.

22. Critical Facility of the Pulsed Fast Reactor

- P.K. Iyengar, K. Chandramoleshwar, S.K. Kapil, T. R. Krishnamurthy, V.R. Nargundkar, C.S. Pasupathy, A.K. Ray, S.N. Seshadri, M. Srinivasan and K. Subba Rao - Nuclear Physics Division - The paper briefly describes the salient features of the Critical Facility of the proposed Pulsed Fast Reactor. The critical facility is the first Indian Fast Reactor and is located at Trombay.

The critical assembly has a three litre PuO_2 core. Melybdenum is used as axial reflector and copper and iron blocks are used as radial reflectors. Free fall of the core in addition to the ejection of molybdenum safety rode forms the main reactor protection feature.

Neutron detectors distributed in andaround the assembly provide the neutron level information for reactor control. Coarse and fine control rods are available for reactivity adjustment.

23. <u>Kinetics of the Pulsed Fast Reactor Critical Assembly with Temperature Feedback</u> - S. Das and M.Srinivasan - Nuclear Physics Division - The kinetic response of the PuO_2 fuelled pulsed fast reactor critical assembly to ramp reactivity inputs in the range of 10 ¢/sec to 10 $/sec has been studied in connection with the safety evaluation of the system. The presence of even a small but prompt negative temperature feedback coefficient of reactivity is shown to play a significant role by increasing the time available for the safety system to act. Estimates have also been made of the time spreads in the melting of the various fuel pins of the core in the event of a hypothetical prompt excursion incident.

24. <u>D.C. Channels For Control of Fast Criticality Facility</u> - V.A. Pethe, Rishi Kumar, A.A. Patankar, N. C. Rathod, M.D. Ghodgaonkar and S.A. Gogate - Electronics Division - Three types of direct current channels were developed and tested in Zerlina. All the channels use silicon devices and use function block type of construction. Two complete channels required only 5¼" x 19" panel space. All the preset controls are inside the function blocks whereas the output of the blocks can be monitored from the front panel select switch.

Current amplifiers can sense 10^{-13} amp. Period Meter has a variable response time from 10 sec at 10^{-11} amp. to 0.6 sec. at 10^{-4} amp.

The channels (Linear, Log-Safety and Period) were tested in Zerlina. The results clearly indicate that overlap between pulse and D.C. channels is more, indicating that these channels respond at low flux levels. Period channels are immune to outside pickups inspite of good response over a very wide dynamic range.

25. <u>Physics Design Aspects of a Pulsed Fast Reactor</u> - V.R. Nargundkar - Nuclear Physics Division - Preliminary physics design aspects of a 30 Kw aircooled, reflector pulsed fast reactor have been considered. Assuming the basic parameters η, α, ν and ϵ_0 the pulse width θ, peak power Pm, background power Po, maximum prompt reactivity ϵ mo etc. are calculated. The criteria for stable operation and control of the reactor are analysed.

Heat transfer calculations have been done to estimate cooling requirements and maximum fuel temperature.

The information generated has been found useful in the design of the critical facility of the pulsed fast reactor.

26. <u>Calculation of Keff for Bare Cylinder and Hexagonal Geometries</u> - B.K. Godwal, K. Subbukutty and S.B.D. Iyengar - Nuclear Physics Division - It is known that Keff of a system depends on the geometry. In order to investigate this dependence on geometry, calculations of Keff for bare cylinder and hexagonal geometries have been done by Monte Carlo Method.

27. Exploitation of Information Content in Second Moment of Count Rate During Approach-to-Critical Experiments - M. Srinivasan, K. Subba Rao, T.K. Basu - Nuclear Physics Division- The average count rate of a neutron detector placed in a multiplying assembly has been used traditionally as a measure of the subcritical multiplication of the system. A plot of inverse counts versus fuel loading has indicated the critical dimensions or loading of large heavy water power reactors down to the smallest fast critical assembly. However the basic drawback of the inverse counts method remain namely that the constant of proportionality between ΔK_{eff} and inverse counts is unknown. During the intermediate stages of the approach-to-critical experiment for example, the exact keff of the system is not known.

The feasibility of deriving the absolute degree of subcriticality and other useful reactor parameters by exploiting the information content in the second moment or standard deviation of the count rate of the detectors have been explored.

28. Maximisation of Desired Activity Against Interfering Activities in Threshold Reactions - O. P. Joneja, D. V. S, Ramakrishna and M.P. Navalkar - Nuclear Physics Division - The study of fast neutron flux and spectra in reactors using threshold detectors requires the measurement of reaction rates. The reaction rates are generally obtained by observing the activity of the product nucleus of a threshold reaction. Thus the

accuracy of flux measurement demands on the knowledge of the disintegration rate of the desired activity. Apart from the counting statistics and low energy gamma counting in a decay scheme, interference due to impurities in the irradiated sample also presents difficulties. A method based on maximisation of desired activity against interfering activities has been described with special reference to detectors which are commonly employed for fast neutron flux and spectrum measurements.

29. Neutronic Measurements Proposed in Fast Breeder Test Reactor - R. Shankar Singh - FBTR Design Group, Reactor Research Centre, Kalpakkam, Tamil Nadu - Certain neutronic measurements need to be performed when a reactor is brought to first criticality and before it is taken to full power. These include the neutron spectrum and flux measurements in various regions of the reactor in terms of different reaction rates and spectral indices etc. For Fast Breeder Test Reactor (FBTR)the objectives of such measurements, the types of measurements, the special apparatus required for them, the different kinds of neutron detectors required and the expected results from them, are analysed.

30. Measurement of Fast Fission Ratios in Natural UO_2 Clusters - H.K. Jain and V.C. Deniz - Reactor Engineering Division - The fast fission ratios, δ_{28} were measured for 7, 19 and 37 - rod UO_2 clusters with D_2O, air, H_2O and polystyrene moulds as "coolant" in Zerlina reactor. The measurements were made by comparing the fission product gamma ray

activities of depleted and natural uranium foils irradiated together inside the experimental cluster. The calibration factor P(t) was determined by measuring La^{140} 1.60 MeV fission product gamma ray activity.

The details of the experimental technique and the method of analysis, including corrections, are analysed. The experimental results are compared with theoretically calculated values using the computer code EPSICH.

31. <u>Inverse Kinetics Analysis of Power-Time Trace Data of Heavy Water Reactors</u> - M. Srinivasan - Nuclear Physics Division - The long half lives of delayed photo neutrons has been a hindrance in reactivity calibration experiments based on stable period measurements, in the case of D_2O moderated reactor systems. With the availability of large fast digital computers it is now possible to dispense with the concept of asymptotic period and inhour relation and deal directly with the basic reactor kinetic equations in the analysis of experimental data. In this approach the experimentally recorded reactor neutron level variations is analysed using a computer program to yield the input reactivity driving function. The advantages of this technique inthe context of D_2O reactor system are studied along with some experimental results

32. <u>Neutron Scattering Cross Section for Liquid Methane</u> - K.R. Rao and B.A. Dasannacharya - Nuclear Physics Division - The differential scattering cross section for neutron scattering from liquid methane has been measured using 4.1Å neutrons at CIRUS for scattering angles in the range of 15° to 90°. A theoretical model in which simple diffusion and hindered rotation characterised dynamics of molecules in the liquid, gives fairly good agreement with experimental results. However the data had not been corrected for multiple scattering and there were some discrepancies. In this work, the multiple scattering in the liquid corresponding to geometrical conditions of the experiment has been studied. The intensity ratio of secondary to primary scattering is found to vary from about 0.5 to 0.3 for scattering angles 30° to 90° in the inelastic region for a specimen of thickness 0.1 cm. When this correction is taken into account the agreement between experimental data and theoretical results is improved significantly. Cross section corrected for multiple scattering is obtained.

B. TATA INSTITUTE OF FUNDAMENTAL RESEARCH, BOMBAY-5.

1. Analogue States in ^{13}C, ^{19}F and ^{31}P - M.R. Gunye and C.S. Warke - The analogue states in ^{13}C, ^{19}F and ^{31}P are studied. Results in multishell configuration space are compared with those obtained from shell-model calculations and with the experimental data.

2. Spins of the Lowlying Levels in ^{75}Se - B. Lal and Baldev Sahai - The levels in ^{75}Se have been investigated by $^{75}As(pn,\gamma)^{75}Se$ reaction. The angular distribution of various ground state and cascade gamma-ray transitions from the low lying levels in ^{75}Se have been measured near their respective thresholds. Using the Hauser-Feshbach formalism of statistical theory of nuclear reactions, the spins of some of the low-lying levels in ^{75}Se have been determined from the anisotropies observed in the angular distribution of corresponding transitions.

3. Hyperfine Fields of as in Ferromagnetic HOST - R.C. Chopra and P.N. Tandon - Hyperfine field of As in Ni host has been measured using the Perturbed Angular Correlation technique. Radioactive ^{75}Se was implanted in Ni using a mass separator. The 121-280 keV gamma-gamma cascade was used in the measurement. The angular correlation of this cascade was measured using a 20 cc Ge(Li) - 2" x 2" Na(Tl) coincidence system, which gave $A_2 = -0.32 \pm 0.03$ without correcting for

geometry. The quantity 'R' was measured with detectors kept at 135°, in a polarising field of 1.2 KG provided by an electromagnet. The results obtained are R = 0.027 ± 0.007, $\omega\tau$ = 0.026 ± 0.007 and H_{hyp} = 41 ± 13 KG. Measurements on other ferromagnetic hosts are in progress.

4. <u>The 158 keV Level in ^{117}Sn</u> - R.C. Chopra, R.R. Hogangdi and P.N. Tandon - The half-life of the 158 keV level in ^{117}Sn has been measured to be $T_{1/2}$ = 0.32 ± 0.02 ns using delayed coincidence technique. The angular correlation of the 560-158 keV gamma rays through this level is measured to be A_2 = -0.08 ± 0.03. Measurements for the magnetic moment of this state are in progress.

5. <u>Decay of Np^{239} To Pu^{239}</u> - K.P. Gopinathan, A. P. Agnihotry, P.N. Tondon, H.C. Jain and S.B. Patel - The gamma spectrum of Np^{239} has been studied by a 20 cc Ge(Li) detector. The Np^{239} was produced by irraditation of natural Uranium in the APSARA reactor at Trombay followed by chemical separation in carrier-free form. The energies (and relative intensities) of the well resolved gamma rays were found to be 61.46 keV (18), 106.14 keV '636), 209.8 keV (29),228.2 keV (100), 277.6 keV (115), 285.5 keV (6.5), 315.9 keV (13), and 334.3 keV (16). Angular correlation measurements using both liquid and solid sources gave results in agreement with each other. The

weighted mean values were:

Cascade	A_2	A_4
106.14 - 228.2 keV	-0.023 ± 0.005	+0.010 ± 0.007
106.14 - 227.6 keV	-0.0080± 0.0037	+0.0087± 0.0070

After correcting for the contributions from interfering cascades and assuming that the 106.14 keV transition is pure E1 the analysis of the results gave the E2/M1 mixing ratios of the transitions : δ 228.2 = -0.22 ± 0.06 and δ 277.6 = +0.21 ± 0.02. The half lives of the 391.6 and 285.5 keV levels were measured by means of a time-to-pulse height converter and were found to be 192 ± 8 ns and 1.12 ± 0.06 ns respectively. Further work is in progress.

6. <u>High Resolution Study of Transitions in ^{144}Pr</u> - K.G. Prasad and A.K. Bandyopadhyay - The gamma-ray and conversion electron intensities in the decay of ^{144}Ce ^{144}Pr have been deduced using a high resolution Ge(Li) detector and a double focussing beta-ray spectrometer. The K-conversion coefficient and the L subshell ratios of the 80 keV transition have been determined accurately. The implications of these results on the multipolarity of the 80 keV transition are analysed.

7. <u>High Resolution Internal Conversion Measurements in the Decay of Lu^{177m} and Yb^{177}</u> - K. P. Gopinathan, A. P. Agnihotry and S.B. Patel and M.C. Joshi, University of Bombay, Bombay and M. S. Bidarkundi, I.I.T., Powai, Bombay - The internal conversion electron spectra from the decay of Lu^{177m} and Yb^{177} have been studied by a double-focusing electron spectrometer at a resolution of 0.1%. The K conversion coefficients and the K and L subshell conversion ratios were determined from the measurements. Transitions of energy 66.1 and 83.8 keV were found to be E1 from the L subshell conversion ratios. The E2 contents of the intraband M1+E2 transitions as determined from the L subshell ratios are : 10.531 keV (10%); 128.6 keV (15%); 153.3 keV (9%); 204.1 keV (11%); 214.5 keV(35%); in the $K = 9/2^+$ (624) band in Hf^{177}; 112.95keV (90%) in the $K = 7/2^-$ (514) band in Hf^{177}; 121.63 keV(23%) in the $K = 7/2^+$ (404) band in Lu^{177}; and 138.4 keV (3%) in the $K = 9/2^-$ (514) state in Lu^{177} was found to be weakly excited in the decay of Lu^{177m}. The results are analysed with reference to the rotational model of the nucleus

8. <u>Penetration Effects in Internal Conversion of Transitions in Lu^{177} and Hf^{177}</u> - K.P. Gopinathan and A. P. Agnihotry - Internal conversion coefficients of the hindered E1 transitions in Lu^{177} and Hf^{177} have been measured with an electron spectrometer at 0.1% resolution and a 20 cc Ge(Li) gamma ray spectrometer. The experimental conversion coefficients are given below. The theoretical values for E1

without penetration effects are given in parenthesis.

E (keV)	K	L_1	L_{11}	L_{111}
Lu^{177} 150.4	0.44±.040 (0.100)	0.102±.010 (0.011)	0.041±.004 (0.00228)	0.0053±.0008 (0.00245)
Hf^{177} 55.14	-	12.4±2.7 (0.125)	1.36±.45 (0.058)	0.24±.22 (0.074)
Hf^{177} 71.7	-	0.118±.019 (0.071)	0.088±.018 (0.026)	0.080±.16 (0.031)
Hf^{177} 208.32	0.052±.0015 (0.046)	0.0111±.0004 (0.0063)	0.0030±.0004 (0.0009)	0.00257±.0004 (0.0009)
Hf^{177} 321.4	0.166±.016 (0.0155)	0.0426±.006 (0.0018)	0.0175±.007 (0.00024)	0.0145±.008 (0.00022)

From the analysis of the results, allowing for any M2 admixture, the penetration nuclear matrix elements are determined and discussed in terms of the structure of the levels involved.

9. <u>Electromagnetic Transitions in ^{186}W, $^{186,188}Os$</u> - B.M. Subba Rao - In view of the current interest in transitional and vibrational nuclei, branching ratios of γ-rays from the 2'+ levels in $^{186,188}Os$ are measured with a Ge(Li) spectrometer. These are found to be lower than the corresponding Kumar-Baranger theoretical predictions by a factor of about 3 while they are in good agreement with the earlier Davydov-Filippov and Davydov-Rostovski non-axial nuclear models.

The ratio of the amplitudes of multiples mixture, (E2/M1), of the 630 keV transition is found, from the 630 keV → 137 keV directional correlation, to be + $16^{+24}_{-6.4}$ in agreement with both the above nuclear models (| 14.6 |) and the microscopic theory (+14.7). The two pure E2 transitions of 122.6 keV (186W) and 137.2 keV (^{186}Os) have been of continuing interest, for their internal conversion coefficients. Here, K, L_1, L_2, L_3 M and (N+(O)+P_1) conversion coefficients of these transitions are determined with an iron yoke double focussing β -ray spectrometer and are found to be in good agreement with the improved post-1968 theoretic theoretical calculations.

10. <u>Beta-Gamma Circular Polarization Correlation in ^{148}Pm</u> - H.C. Padhi and S.K. Mitra - The beta-gamma circular polarization correlation of 1020 keV beta and (915 + 1465) keV gamma-rays in the decay of 5.4 days ^{148}Pm was measured. The measured asymmetry parameter A, the Fermi matrix element M_F and the isospin impurity coefficient α which accounts for the Fermi matrix component in the allowed mixed beta-decay are:

$$A = 0.14 \pm 0.03$$

$$M_F = (1.46 \pm 0.48)10^{-3}$$

$$= (0.29 \pm 0.09)10^{-3}$$

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

1. PAC Studies on the 80 KeV 3^- State of ^{144}Pr - B.K. Sinha and R. Bhattacharyya - The rotation of the angular correlation pattern of the (53-80) keV cascade of ^{144}Pr has been detected under an applied magnetic field of 21 K gauss. The amount of rotation is $\omega\tau = 0.08 \pm 0.05$ radian. Further studies are in progress.

2. Complex Angular Momentum Methods For Composite Particle-Nucleus Elastic Scattering - B.K. Satpathy, Sambalpur University, Sambalpur, D.K. Mishra, Ravenshaw College, Cuttack and S.K. Samaddar - Regge-Type representations for the scattering amplitude, developed earlier are used for the study of elastic scattering of ^3He and triton from nuclei. The pole parameters are determined taking optical potential parameters as input. Calculated cross sections are in agreement with experiment. The spin and parity of a few levels of the compound nuclei are predicted.

3. An Exact Description of (p,p) Reaction - S.K. Samaddar and Suprokash Mukherjee - The distorted wave Born approximation may be considered as the only practical method for the analysis of direct reactions till to-day. Unfortunately, though it is widely applied, clear understanding of the theory has not yet been possible. Dodd and Greider attempted at formulating an

integral equation with the DWBA amplitude as the inhomogeneous term and pointed at certain formal difficulties for its convergence. We have found that their equation is erroneous. Using the projection operator technique of Feshbach, we have written the exact (d,p) reaction amplitude which has certain interesting features about (i) the distortion of the outgoing proton and (ii) the contribution from inside the nucleus. The equation also helps in understanding the DWBA.

4. <u>Interpretation of $^{206}Pb(t,p)^{208}Pb$ Reactions in Terms of Particle-Core States in ^{208}Pb</u> - K. V. Chalapati Rao -Igo et al. have recently studied energy levels in ^{208}Pb up to an excitation energy of 8.5 MeV though $^{206}Pb(t,p)$ reactions. The (t,p) reaction is known to be sensitive to the two-neutron particle correlations in a nuclear state,so most of the levels excited are expected to have 2p-2h structure. We have attempted to understand these levels by coupling the two neutrons outside ^{208}Pb to the vibrations of ^{206}Pb core. This is an extension of our previous calculations on ^{207}Pb where we studied the positive parity states excited in $^{206}Pb(d,p)^{207}Pb$ reaction by coupling a neutron in the 126-184 shell to the ^{206}Pb core. The two neutrons are assumed to interact through a surface-delta interaction whose strength is fixed by fitting the energy levels of ^{210}Pb. The strength of the particle-core interaction is chosen to be the same as

the one used in our calculations on ^{207}Pb. The results of the calculations are in fairly good agreement with experiment.

5. <u>A Study of the Properties of Ion Beam From Duoplasmatron</u> - D.K. Bose, S.N. Sengupta and B.D. Nagchaudhuri - Extraction of ion beam from a duoplasmatron ion source has been carried out using a modified extraction system. The properties of the extraction system and the results of beam emittance measurements are studied.

6. <u>Nanosecond Pulsing For Electrostatic Accelerator</u> - B. Sethi, V.K. Tikku, H. Singh, S.C. Mukherjee and S. K. Mukherjee - A nanosecond pulsing system for the terminal of a Cockroft Walton accelerator is described. The system consists of an r.f. ion source followed by a gap Einzel lens. Two pairs of deflection plates are mounted in quadrature inside the lens assembly and a phase related r.f. voltage at a frequency of 6.5 Mc/s is applied to the two pairs of plates. The beam spot moves in an elliptic path and crosses a chopping aperture once in each cycle. In a bench test the beam bursts of a few nsec are received in a wide-band Faraday cup matched to a 50 Ω coaxial cable, and observed on a sampling oscilloscope. The burst duration at the collector is also calculated using simplifying assumptions, and the performance characteristics of the system are studied.

7. <u>L/K Electron Capture Ratio From Gamma-Ray - X-Ray Sum Peak In Ge(Li) Spectra</u> - B.K. Das Mahapatra - A new method has been developed for the determination of L/K electron capture ratio from the spectrum obtained with a Ge(Li) detector. In this method P_K , the probability for a K-electron capture to take place is evaluated from a quantitative analysis of the gamma-ray - X-ray sum peak observed with the detector. With the PK thus evaluated and the known corrections for captures from higher shells, L/K capture ratio is readily determined. The observed L/K capture ratio in the decay of ^{133}Ba is found to be in good agreement with the recently reported work. Also the total L/K capture ratio in the decay of 12.4 y. ^{152}Eu is measured.

8. <u>Half-Life of the 208.1 keV Level in ^{199}Hg and the Internal Conversion Coefficients of the Transitions in ^{199}Hg</u> - H. Singh, B. Sethi and V.K. Tikku - The half-life of the 208.1 keV level in ^{199}Hg has been measured by the delayed coincidence set up. A value of 70 $\pm$ 15 psec is obtained. The γ -transition rates deduced from our experiments, on comparison with Weisskopf s.p. estimate reveal that the M1 part of the 208.1 keV transition is more retarded (retardation factor, FW = 60) than the 49.9 keV transition (F_W=16). These results, the B(E2) values, and also the comparison of the experimental and model dependent values of magnetic moment for the first excited level in ^{199}Hg, are seen as an evidence

for the core particle model description for the excited levels in this nucleus.

9. Decay of ^{48}Sc - H. Singh, V.K. Tikku and B. Sethi - The disintegration characteristics of the 44 h ^{48}Sc activity have been studied by use of high resolution Ge(Li) detector. Irradiation of specpur vanadium metal powder(^{51}V, 99.75%) 14.7 MeV neutrons gives, in addition to the 44 h ^{48}Sc activity, a 3 h activity also. The 44 h ^{48}Sc activity decays with the emission of 174.9, 985.3, 1038.6, 1212.7 and 1313.3 keV γ-rays. The 1212.7 keV γ-ray represents the crossover transition between the 3518 and 2295 keV levels in ^{48}Ti. The 3 h activity appears to belong to an isomer of ^{48}Sc. The measurements are also carried out by producing ^{48}Sc activity from the irradiation of specpure titanium metal powder with fast neutrons. Based on the singles and coincidence measurements, a decay scheme of ^{48}Sc is proposed.

10. A New Level in ^{67}Zn - D. Basu and P. Sen - The decay of 78 h Gallium 67 to Zinc 67 was studied with a high resolution Ge(Li) detector and a 4096 channel analyzer. Besides the gamma rays at (91 + 93), 184, 209, 300, 393, 394,704,795, 888 keV energies, a new gamma ray at more gamma rays at 700 and 791 keV are present. A new level has been proposed in the decay scheme.

11. Decay of ^{97}Zr and ^{97}Nb - V.K. Tikku, H. Singh and B. Sethi - The decays of the 17 h ^{97}Zr and 72 min ^{97}Nb have been studied using high resolution Ge(Li) detector and 4096 channel analyzer. The ^{97}Zr source was produced by the irradiation of enriched ^{96}Zr(85.25%) at Cirus reactor at a neutron flux of 5 x 10^{12} n/sq. cm. sec. for 2 days. In addition to the previously reported γ-rays of ^{97}Nb and ^{97}Mo, new γ-rays at 805.6, 1018.1, 1026.7 and 1361.0 keV energies are observed, and found to decay with the 17 h half-life of ^{97}Zr. Based on these measurements a combined decay scheme of ^{97}Zr and ^{97}Nb is proposed.

12. Decay of ^{126}I - B.P. Pathak and M.L. Chatterjee - The decay characteristics of 13 d ^{126}I have been reinvestigated using Ge(Li) and scin-tillation spectrometers. A previously unreported γ-ray of 56 keV has been observed. The existence of low intensity γ-rays of 1377 and 2044 keV has been confirmed by using a 20 cm^3 coaxial Ge(Li) detector. An improved decay scheme of 1261 is proposed on the basis of the present study.

D. ALIGARH MUSLIM UNIVERSITY, ALIGARH

1. On The Shell Effects in (n,2n) Reaction Cross Sections at 14.8 MeV - J.P. Gupta, Raj Kumar and R. Prasdad - Presence of shell effects in (n,2n) reactions at 14.8 MeV have been indicated by various workers. Hille and Dilg et al., however, have recently shown the lack of evidence of shell effects by plotting literature values of (n, 2n) reaction cross sections against the asymmetry parameter (n-z)/A. In a programme of cross section measurements, (n,2n) reaction cross sections for some forty four cases have been measured, Measured cross sections are compared with the cross sections calculated from the emperical formula given by Barr et al. The ratio $\sigma_{exp}/\sigma_{cal}$, when plotted against the proton number 'Z', indicates the presence of shell effect.

2. Some Calculations on Nuclear Level Spacings - A.K. Chaubey and M.L. Sehgal - We have done some calculations on nuclear level spacings. Lang and Lecoteur have given an expression for spin independent level spacing:- D_0 X const $= (4AW/11)^2 \exp-(4AW/11)^{\frac{1}{2}}$. Using our earlier values of D_0 we have calculated the value of 'constant' in several nuclei. It was observed that this constant has got some structure and varies with number of neutrons in the target nucleus, in very interesting way.

3. <u>A Calculation of the Real Part of the Nucleon Optical-Model Potential</u> - Q.N. Usmani and I. Ahmad - Hartree -Fock density distribution has been used to calculate the real part of the nucleon optical-model potential under the formalism of Greenlees et al. Radial distribution of the calculated potential is compared with the phenomenological one, with a view to highlight some interesting points.

4. <u>On Inelastic Scattering of Neutrons by Deuterons</u> - V.K. Sharma, D.S. College - The distorted wave approximation is applied to the problem of neutron-deuteron inelastic scattering. It is assumed that the two body interaction is of central type with Yukawa radial dependence, and the Wheeler's resonating group method is used to derive coupled integro-differential equations.

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

1. Gamma-Gamma Angular Correlation Measurements in ^{186}Os - M.L. Narasimha Raju, P. Jagam, B. Verma Reddy and D.L. Sastry - The (631-137) keV gamma-gamma directional correlation in ^{186}Os is measured with a sum peak coincidence scintillation spectrometer using both liquid and solid sources. The present correlation function in liquid source is in good agreement with that reported by King et al. The present measurements indicate that there is no attenuation of the correlation in solid source due to time dependent perturbations.

2. Angular Correlation Studies in Mercury -198 - K.Venkata Ramana Rao and V. Lakshminarayana - The angular correlation of the cascade (676-412) keV. in the decay of Gold-198 is studied, using high efficiency sum-peak coincidence arrangement. The resultant correlation pattern is

$$W(\theta) = 1 - (0.272 \pm 0.01)\, P_2 (\cos\theta) \; (0.143 \pm 0.006) P_4 (\cos\theta)$$

Assuming a $2^+ \rightarrow 2 \rightarrow 0$ spin sequence connecting the cascade, the present correlation coefficients are used to obtain the mixing ratio of the 676 keV transition to be (0.85 ± 0.06). The results indicate monopols contribution and an admixture of particle and collective excitations in the 676 keV transition in Hg-198. Vibration-like wavefunctions furnished by Covello & Sartoris and Ialongo & Alaga for the 2^+ states are

used and the mixing ratios are estimated to be 5.03 and 0.143 respectively. It is concluded that the vibration-like wavefunctions based on microscopic models are not adequate for describing the second 2^+ state in Mercury-198.

3. <u>Experimental P-Wave Neutron Strength Functions and the Optical Model</u> - J Rama Rao, M. Sriramachandra Murty, K. Siddappa and A. Lakshmana Rao - Experimental p-wave neutron strength functions in about 40 nuclei in the mass region $60 < A < 200$ are extracted from average neutron capture cross sections determined at 25 keV. The s-wave capture contributions in these cross sections are evaluated and subtracted out using the s-wave resonance parameters relevant to the keV region recently reported by Musgrove. The p-wave strength functions, so derived, together with those of others, are compared with the optical model predictions of Buck & Perey and Fiedeldey & Frahn. In the 3p resonance region, $80 < A < 120$, there is good agreement with Fiedeldey and Frahn's calculations where as in the deformed region, $150 < A < 190$, better agreement is noticed with Buck and Perey's predictions. Possible indication of shell effects are also observed around $A \sim 140$ and 200.

4. <u>Modification of the Siegbrain-Slatis Beta Ray Spectrometer for Data Gamma Coincidence Studies</u> - M. Ravindranath, C. Narasimha Rao and K. Venkata Reddy - An Intermediate image

beta ray spectrometer of the Seigbalm-Slatis type for measuring beta gamma coincidence is developed. The gammas are detected by a sodium-iodide crystal-6810A photomultiplier assembly fixed in the fron pole-piece behind the source. The Geiger counter on the beta side has been replaced by a plastic scintilator-6810A photomultiplier detector. The effect of the magnetic field on the gamma photomultiplier is eliminated using a compensating coil arrangement. The shape of the 960 keV beta transition in the decay of Au-198 has been measured in coincidence with the 412 keV gamma ray.

5. Internal Conversion Measurements of Transitions in ^{59}Co- C. Narasimha Rao, K. Venkata Ramaniah and K. Venkata Reddy - The conversion lines in the decay of ^{59}Fe have been studied by means of an intermediate image beta ray spectrometer of the Sieghahn-Slatis type and relative conversion electron intensities of the conversion lines of 141, 191, 334, 1099 and 1299 keV transitions have been determined with a view to, determine the conversion coefficients of the above transitions. The relative photon intensities have been obtained from the gamma spectrum using Ge(Li) detector. The conversion coefficients are calculated relative to the conversion coefficient of the 191 keV transition.

6. Determination of Conversion Coefficients in ^{75}As - B. Mallikarjuna Rao, K. Venkata Ramaniah and K. Venkata Reddy - The conversion electron spectrum of ^{75}As has been

reinvestigated by means of an intermediate image beta ray spectrometer. The relative intensities and conversion coefficients for the 121, 136, 198, 264, 279 and 400 keV transitions have been determined. The relative conversion line intensities are normalised with the gamma intensities through the 264 keV transition.

7. Conversion Coefficient Measurements in ^{160}Dy - K. Venkata Ramaniah, P. Mallikarjuna Rao and K. Venkata Reddy - The internal conversion coefficients for the 299, 337, 682, 879, 960, 1060 and 1103 keV transitions in ^{160}Dy have been measured by recording the conversion electron spectrum using a Siegbahn-Slatis beta ray spectrometer. The relative photon intensities of M.A. Ludington et.al. have been employed. The conversion coefficients are calculated relative to the conversion coefficient of 879 keV transition

8. Radioactive Decay of ^{76}As - K.L. Narasimham, M.N. Seetaramanath and V. Lakshminarayana - The decay of the radioactive isotope ^{76}As, produced by the (p,n) reaction on enriched ^{76}Ge, is studied using a 2.5 c.c. Ge(Li) detector system 41 gamma rays are identified and their energies and relative intensities are determined. The results are in general agreement with those of Tizawa et al. Some gamma rays observed by them are also seen in the present work but did not follow the half-life. Four new gammas of energies 733, 955, 1051 and 1883 keV are observed in the present work.

F. BANARAS HINDU UNIVERSITY, VARANASI-5.

1. Ground State Spin Parity of Odd-Odd Rare-Earth Nuclei - D.K. Gupta and P.C. Sood - Nordheim's rules (1950) for assigning spin-parity to the ground states of odd-odd spherical nuclei were extended to the deformed region by Gellagher and Moszkowski (1958). Later detailed empirical studies brought out frequent violations of weak rule of Nordheim, and modification of the same was suggested by Brennan and Bernastein (1960). During recent years substantial new data have become available on odd-odd deformed nuclei. Accordingly we have undertaken a critical examination of the validity of the Gallagher-Moszkowski rules. The study has to be based on the respective odd-mass nuclides.. The results of these investigations for nuclei of the rare earth region has been completed.

2. A-Dependence of the Optical Model Potential - D. C. Agrawal and P.C. Sood - The optical model analysis of 11 MeV proton scattering from 20 isotopes in the region ^{48}Ti to ^{76}Ge by Perey and Perey (Phys. Lett. 26B, 123, 1968) was said to have 'revealed a very smooth variation of real well depth as a function of mass number while not following the expected isospin dependence of the potential'. Several contradicting views have since been expressed on the subject. An extensive systematic examination of the optical model potentials defined by analyses of both proton and neutron scattering at various

energies and over wider mass range falls to substantiate this A-dependence of the real well depth, whereas the isospin dependence of the potential is still evident with strong local fluctuations, which in piecemeal examination may yield erroreneous conclusions.

3. Decay of Ir^{192} - Rajendra Prasad, S.P. Ram, L. Chaturvedi, S.N. Chaturvedi and A.K. Nigam - Experimental studies on the decay of Ir^{192} are being made using the Ge(Li) gamma ray detector and the sum coincidence technique. The relative intensities of most of the gamma transitions have been determined and compared with the other available results.

4. Higher Order Matrix Elements in Beta Decays - R.P. Singhal - The higher order matrix elements have been deduced for some hindered-allowed beta decays by utilizing all the available experimental data. Exact electron radial functions (with finite size corrections) have been used. It is found that the anomalous shape factor and the non-zero directional correlation can be explained by assuming small values of the matrix elements within the frame work of (V-A) theory. The empirical values of the matrix elements are also compared with other theories. The present work encompasses areas of nuclear models, weak interaction theory, and also the charge independence of nuclear forces.

G. INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

1. Investigation of Nuclear Levels in ^{28}Si by Means of $^{27}Al(p,\gamma)^{28}Si$ Reaction - C. Rangacharyulu, V.C. Jadhao, G.K. Mehta and R.N. Singru - Energy levels of the nucleus ^{28}Si have been investigated by studying the $^{27}Al(p,\gamma)^{28}Si$ reaction with the 2-MeV Van de Graaff accelerator. In particular, the resonance at the proton energy E_p = 0.992 MeV leading to the 12.542 MeV level in ^{28}Si was studied in detail. The gamma decay of this level, when studied with a Ge(Li) detector and coincidence spectrometer, indicates that a level at 10.27 MeV in ^{28}Si is populated in the decay process. The existence of this level at 10.27 MeV, which was in doubt earlier, seems to be justified by our data.

2. Nuclear Studies of ^{99}Rh - D.K. Gupta, C. Rangacharyulu, R.Singh and G.N. Rao - The radioactive decay of 16.1 day ^{99}Rh has been studied using Ge(Li)-Ge(Li) coincidence spectrometer and Na(Tl)-Na(Tl) Sum-coincidence spectrometer. Evidence for the existence of a new gamma ray of energy 910.8 keV is obtained. A level scheme for ^{99}Rh is established. Four new cascade transitions from the energy levels at 850.3, 1000.2, 1295.2 and 1382.9 KeV are reported. The relative intensities and energies of all the gamma transitions are determined. The halflife of the 89.4 KeV level is measured using the delayed coincidence method. The value obtained is 20.5 $\pm$ 0.1) nsec.

3. <u>Nuclear Lifetime Measurements of Some Excited States in 75-As, 131-Cs, 133-Cs, 170-Yb, 187-Re and 197-Au</u> - D.K. Gupta and G.N. Rao - The halflives of some short lived nuclear excited states in 75-As, 131-Cs, 133-Cs, 170-Yb, 187-Re and 197-Au are measured using the delayed coincidence techniques. The present values are compared with the previous measurements.

4. <u>Lifetime And Magnetic Moment of 68 KeV State In 44-Sc</u> - D.K. Gupta, D.N. Sanwal And G.N. Rao - The halflife of the 68 KeV state in 44-Sc is measured using delayed coincidence techniques. The value obtained for the halflife $T_{\frac{1}{2}}$ = 155.8 nsec. The magnetic moment of the 68 KeV state in 44-Sc is also measured using time differential perturbed angular correlation technique in an external magnetic field of 7 KOe. The magnetic moment μ = + 0.351 n.m. The hyperfine field measurement at 44-Sc nuclei in iron matrix is in progress.

5. <u>Search For Super Heavy Elements in Natural Materials</u> - Brij M. Trivedi - Predictions have been made that the elements around Z = 114 should have long lives ($> 10^8$ yrs) against spontaneous fission and alpha decay and that they should have survived in earthly materials. Based on these predictions a number of laboratories around the world have tried to look for these elements in rocks, ocean sediments and the old lead samples. Workers in these labs. have looked for high energy

spontaneous and induced fission fragments and high energy neutrons in these samples. So far no clear evidence exists for these elements.

Since the elements around 114 should resemble in their chemical properties with elements around lead (Z = 82) (114 is eka lead), we have tried to separate them from rocks, making use of their volatile property. The samples thus obtained were analysed by alpha particle spectroscopy. So far no anomalous alhha activity has been found in these samples.

6. <u>Ge(Li) - Ge(Li) Coincidence Studies in ^{131}Cs</u> - R.Singh and G.K. Mehta - The level scheme of ^{131}Cs has been studied by Ge(Li) - Ge(Li) fast - slow coincidence spectrometer. The existence of 30 gamma rays and the levels at 78.8, 123.5, 133.4, 215.7, 373.0, 585.0, 620.0, 696.3 and 1048.4 keV have been confirmed. No evidences are found for 215.7 - 78.8, 696.3-373.0 and 696.3 - 133.4 transitions reported by earlier workers. The relative intensities of various transitions have been found to agree very well with the results of other authors.

H. INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR-2

1. Equivalence of Two Internucleon Potentials in σ_{int} Calculations - B.K. Srivastava and S.S. Raghavan - It has been shown that, for nuclei in the $1p$ shell, the photodisintegration integrated cross section ($\sigma_{int} = \int_0^\infty \sigma(W)\, dW$), whose sum rule expression involves the two-body potential directly, fails to distinguish between any two potentials. We explain this inability of σ_{int} calculations to distinguish between two potentials in terms of the well known range-depth relationship for the nuclear two-body potentials.

2. Effect of Tensor Forces on (γ, p) Photodisintegration of He^4 - H.L. Yadav, D.Mahanti and B.K. Srivastava - Different radial shape wave functions containing a mixture of ^1S state and the principal $^5D_1$ state, obtained by the variational calculation of the binding energy of the alpha particle using the tensor velocity-dependent potential of Nestor et al., are employed to calculate the photodisintegration cross section of the process $He^4(\gamma,P)H^3$.

It is seen that the results are in better agreement with the experimental results of Gorbunov et al. as compared to the earlier calculations with central velocity-dependent potentials or tensor potentials without hard core or velocity-dependent components.

I. INDIAN INSTITUTE OF TECHNOLOGY, NEW DELHI-29

1. On the Transport of One Speed Neutrons - A.K. Ghatak and Shashi Bala - The decay of a monoenergetic burst of neutrons in slabs of various thicknesses has been analytically studied, assuming isotropic as well as highly anisotropic scattering. The calculations corresponding to the fundamental mode have been compared with exact numerical calculations. This comparison shows that if we use Marshak's boundary conditions the results are more accurate than what are obtained by using Mark's boundary conditions. The calculations have been applied to the study of the monoenergetic burst of neutrons in heavy non-moderating assemblies and also to the transport of neutrons of energy corresponding to the first Bragg peak in polycrystalline moderators like beryllium and graphite.

J. PUNJAB UNIVERSITY, CHANDIGARH-14.

1. Magnetic Moment of the 3^-, 1374 keV Level of ^{182}W - A.K. Dhar, Bhupender Singh, Vikram Singh and H.S.Hans - The angular correlation of the 179-152 keV γ - γ cascade in ^{182}W has been measured. The magnetic moment of the 3^-, 1374 KeV levels has been determined by observing the rotation of the 179-152 keV γ - γ angular correlation in an external magnetic field of 15 kilogauss.

2. The Internal Hyperfine Fields on Arsenic in Cobalt And Nickel Hosts - A.K. Dhar, Bhupender Singh, Vikram Singh and H.S. Hans - The hyperfine internal magnetic fields on arsenic nuclei in cobalt and nickel hosts have been measured by the integral reversed field method of perturbed angular correlation technique. The $5^+/2$ (121.1-keV) $5^-/2$ (279.6-keV) $3^-/2$ cascade in ^{75}As was used for the directional correlation and rotation measurements. Using $g = 0.36 \pm 0.04$ and lifetime $\tau = (4.67 \pm 0.43)10^{-10}$ sec for the 279.6-keV level of ^{75}As, the hyperfine fields on arsenic in cobalt and nickel at room temperature have been found to be

$$H_{Co}^{As} = -265 \pm 50 \text{kilogauss},$$

$$H_{Ni}^{As} = -145 \pm 25 \text{ kilogauss}$$

respectively. The hyperfine fields on arsenic in iron, cobalt and nickel have been found to be proportional to the effective host moments.

3. <u>Directional Correlation And Multipole Mixing of The Gamma Transition in ^{99}Tc</u> - S.S. Bhati, A.K. Bharddwaj, Nirmal Singh, P.C. Mangal and P.N. Trehan - Directional correlations have been measured for 740-181, 740-(41)-140, 140-41 and 740-41 keV gamma cascades in ^{99}T. on the basis of these measurements, a spin assignment of $3/2^+$ for 921 keV level has been confirmed. The multipole mixtures of 740,140 and 41 keV gamma rays are found to be E2 + $<$ 1%M1, 95% M1 + (5$\pm$1%) E2 and predominantly M1 + (0.7$\pm^{0.5}_{0.4}$)% E2 respectively. The reduced transition probabilities of 41 and 140 keV transitions are deduced. These results when compared with the single particle estimates indicate that 181 ($5/2^+$) and 140 ($7/2^+$) keV states are predominently single particle intrinsic states.

4. <u>Gamma-Gamma Directional Correlations in ^{147}Pm</u> - A.K. Bhardwaj, S.S. Bhati, Nirmal Singh, P.C. Mangal and P.N. Trehan - Gamma-gamma directional correlations of 599-91, 280-412 and 280-322 keV cascades in ^{147}Pm observed in the decay of ^{147}Nd have been studied by the slow-fast coincidence method. The measured directional correlation functions for these cascades are:

1. $W(\theta,599\text{-}91) = 1+(0.022\pm0.19)P_2(\cos\theta)-(0.012\pm0.033)P_4(\cos\theta)$
2. $W(\theta,280\text{-}412)= 1+(0.021\pm0.007)P_2(\cos\theta)+(0.0013\pm0.005)P_4(\cos\theta)$
3. $W(\theta,280\text{-}322)= 1+(0.022\pm0.009)P_2(\cos\theta)-(0.009\pm0.0\ 6)P_4(\cos\theta)$

The study supports the spin assignments of $5/2^+$,$3/2^+$

and $5/2^+$ for 91, 412 and 685 KeV levels respectively. The graphical analysis of these functions yields mixing ratios of 599 and 412 keV gamma rays as M1+(19^{+6}_{-4})% E2 and E2+3.8% M3 respectively. The character of 322 keV gamma ray is found to be predominently M1 with $<$ 0.5% E2 admixutre. It is in disagreement with the results of the previous workers. In the light of this study a discussion of the level structure of ^{147}Pm is attempted.

K. PUNJABI UNIVERSITY, PATIALA, INDIA

1. Neutron Proton Mass Deformation of the First 2^+ Excited State of ^{122}Te - H.S. Sahota - Although vibrational models of the nucleus predict vanishingly small quadrupole moments for the spherical nuclei yet sizable quadrupole moments have been found to exist[1] for the first excited 2^+ states of such nuclei in the region $104 < A < 130$. Following the treatment of Greiner[2] we have searched for any difference in the deformations due to the neutron and proton mass distributions for the 564 keV first 2^+ excited state of ^{122}Te. It has been found that a neutron deformation of nearly 6 per cent in excess of the proton deformation is consistent with the mixing ratio of the $2^+ - 2^+$ transition. This is in agreement with the findings of Taylor and Singh[3] for the first excited 2^+ states in ^{124}Te and ^{126}Te.

1. J.de Boer and J. Eichler, Advances in Nuclear Physics (Plenum Press, New York) 1968.
2. W. Greiner, Nucl. Phys. 80, 417 (1966).
3. H.W. Taylor and B. Singh, Gand.J. Phys. 49,881(1971).

L. UNIVERSITY OF DELHI, DELHI - 7

1. Half-Life Measurement of the 1291.6 keV Level in ^{59}Co - S.D. Chauhan, R.K. Garg, S.C. Pancholi, S.L. Gupta and N.K. Saha - Half-life of the 1291.6 keV level in ^{59}Co has been measured using experimental techniques based on leading-edge timing spectrometry. The decay curve analysed with the moments, slope and Laplace transform methods gave a weighted average value of $T_{\frac{1}{2}} = 0.516 \pm 0.006$ ns. Partial half-lives have been calculated for the 192.3 keV and 1291.6 keV gamma transitions depopulating the 1291.6 keV level and the results are analysed in terms of the core-particle coupling models.

2. Alpha-Gamma Directional Correlation in a Polycrystalline ^{241}Am Source - R.K. Garg, S.D. Chauhan, S. L. Gupta and N.K. Saha - Measurements of the $\alpha - \gamma$ directional correlation for the $\alpha_{5486} - \gamma_{59.4}$ $(5/2^- \xrightarrow{\alpha} 5/2^- \xrightarrow{\gamma} 5/2^+)$ cascade have been carried out in a polycrystalline ^{241}Am sample using time - differential PAC technique. The value of the attenuation parameter λ_2 and the unperturbed value of the $A_2(0)$ - coefficient, obtained after accounting for finite time resolution and isotropic contribution from the $5/2^- \xrightarrow{\alpha} 7/2^- \xrightarrow{\gamma} 5/2 \xrightarrow{\gamma} 5/2^+$ triple cascade are:

$A_2(0) = -0.37 \pm 0.02$; $\lambda_2 = (1.81 \pm 0.17) \times 10^9 \text{ sec}^{-1}$.

Using the $A_2(0)$-value, an estimate of the mixing ratio of

L = 0 and L = 2 partial alpha waves in the main α-group is made and the result compared with α-decay-theories. From the exponential trend of the $A_2(t)$ vs. t curve, time-dependent behaviour of the interaction phenomena, as predicted by the theory of Abragam and Pound for polycrystalline sources, is confirmed.

3. <u>Directional Correlation Studies in ^{59}Co</u> - M.M. Bajaj, Ashok Kumar, S.K. Soni, S.C. Pancholi, S.L. Gupta and N. K. Saha - Gamma-gamma directional correlation studies have been made on all the measurable cascades in the decay of ^{59}Fe to ^{59}Co using Ge(Li) and NaI(Tl) detectors and a multichannel analyser system. The expansion coefficients for various cascades are:

Cascades (keV)	A_2	A4
142.25-1291.58	- 0.070 ± 0.005	0.014 ± 0.015
192.81-1099.27	0.008 ± 0.004	0.004 ± 0.008
334.81-1099.27	- 0.099 ± 0.012	- 0.008 ± 0.025

The expansion coefficients for the 142.25-(192.23)-1099.27 keV triple cascade have been deduced from the measured data to be A_2 = - 0.0115 ± 0.0009 and A4 = 0.A 6.7% correction was applied to the 142.25 - 1291.58 keV cascade on account of the contribution from the 142.25-(192.23)-1099.27 keV triple cascade. The mixing ratio analysis of the correlation functions yields the following values of the mixing parameter for

the 142.25, 192.23, and 334.81 keV radiations: $-0.026 \leqslant \delta_{142} \leqslant 0.027$; $\delta_{192} = 0.22 \pm 0.02$ and $\delta_{335} = 0.13 \pm 0.06$, respectively. The results are analysed in terms of the weak-coupling models.

4. <u>A New Variational Method For Pulsed Neutron Problem</u>

- Feroz Ahmed and Subhash Saini - A new variational method has been developed to study the pulsed neutron problem in crystalline moderators, which permits one to take account explicitely of discontinuities in the values of transport cross section of crystalline moderators at Bragg Energies. For reasons of simplicity, the trial function was taken as a linear combination of maxwellian and an exact solution of an eigenvalue equation for some choosen value of buckling, say β^2. This gives asymptotic decay constant Λ_0 within 2% of the corresponding value obtained by numerically solving the diffusion equation. However, when trial function is a linear combination of maxwellian and exact solutions of the eigenvalue equation for two properly choosen values of buckling, say β_1^2 and β_2^2, then for any given value of β^2, the asymptotic decay constant λ_0 and associated neutron flux ϕ_0 are found very accurately.

This variational method has been extended further by assuming the trial function to be a linear combination of maxwellian and two other functions dependent upon the energy variation of the transport cross sections.

M. UNIVERSITY OF POONA, POONA-7.

1. A Study of the Magnetic Flux of the 5 MeV Betatron to Increase Its Energy to About 10 MeV - M. R. Bhiday, V.N. Bhoraskar - The 5 MeV betatron has the facility to accelerate the electrons in one quarter of the a.c. cycle, as usually the case of a conventional betatron. The increase of current causes the saturation of the central core and hence limits the maximum energy of the electrons to be accelerated.

In order to increase the energy of the electrons from 5 MeV to about 10 MeV, biasing technique is used, which indeed needs the study of the variation of the flux in the median plane with the radius at any particular instant of time.

The median plane of the betatron is divided in concentric planes, and a relative study of the magnetic flux of each concentric plane is done with the central flux. From this, the variation of the flux with the radius is studied, which is used for calculation in the biasing of the betatron for its increase in energy.

2. A Variable Energy Quadrupole Lens Pair Combined With 60° Spectrometer For a Broad Range Spectrometer - M.R. Bhiday, V.N. Bhoraskar - A quadrupole lens pair is designed to accept the particles between 1 MeV to 6 MeV. A complete

double focusing can be achieved for any energy of the electrons in the above range. A 60° Magnetic Spectrometer is combined with this doublet and the positions of the quadrupole lenses with respect to the spectrometer are calculated to get the maximum focusing and acceptance of the electrons.

N. UNIVERSITY COLLEGE OF SCIENCE, CALCUTTA-9

1. Internal Bremsstrahlung From ^{204}Tl - S. Mitra, M. Nath, A.K. De, P.C. Bhattacharya and A.K. Das - The spectral distribution of internal bremsstrahlung (IB) emitted in the β-decay of ^{204}Tl has been measured from 80-600 keV with a NaI(Tl) scintillation spectometer. A modified geometrical arrangement used in the experiment reduces the contribution due to external bremsstrahlung relative to IB to a minimum. The experimental results have been compared with the theoretical calculations from KUB - Lewis & Ford - Nilsson theory. A comparative study of the present results in relation to two other single counter experiments[1,2] reported so far who found a substantial excess number of photons at low energy, has been done.

References:

1. R.A. Ricci, Physica 24, 297 (1958)
2. K. Narasimhamurty and S. Jnanananda, Proc. Phys. Soc. 90, 109 (1966)

O. UNIVERSITY OF ROORKEE, ROORKEE

1. Triple Gamma Angular Correlation Studies of the Radiations from the Decay of Ir^{192} - U.S. Pande and B. P. Singh - Three NaI(Tl) detecotrs (Spectrometers) mounted in the plane of the table (two detectors are fixed perpendicular to each other and third detector is movable in opposite quadrant of the two fixed detectors) are used for the coincidence and angular correlation studies for the triple gamma cascade 589 keV - 296 keV - 316 keV in Pt^{192} from the decay of Ir^{192}. Angular correlation function W(θ) obtained by the method of least square fit and without applying solid angle correction is

$$W(\theta) = 1-(0.110 \pm 0.021)\, P_2\,(\cos\theta) + (0.052 \pm 0.030)\, P_4\,(\cos\theta)$$

The multipolarity of 296 keV transition was obtained for the spin sequence of $4+ \xrightarrow[\text{Pure } E_2]{589\text{keV}} 2+ \xrightarrow[(M_1 + E_2)]{296\text{ keV}} 2+ \xrightarrow[E_2]{316\text{ keV}} 0+$.

The 'δ' (the amplitude mixing ratio) of 296 keV gamma-transition thus obtained is (-) 10^{+3}. The sign δ is independent of phase convention in this measurement.

2. A Separable Potential Model For $^1S_0$ Neutron Proton Interaction - A.P.S. Sirohi and M.K. Srivastava - A number of separable potential models have been proposed for the NN interaction. The off-shell behaviour of these separable

potentials is quite different from that of a local potential except in the low energy region. For example, the half-off-shell reaction matrix elements $K(p,k:k^2)$ show an oscillatory behaviour for a local potential while in the case of separable ones they have a smooth monotonic behaviour for $p \geqslant 4\ fm^{-1}$. Around $p \sim 3\ fm^{-1}$, the local potentials give rise to a repulsive hump reflecting the repulsive core at r of order 0.5 fm. Such a hump is absent in the case of the separable potentials used hitherto.

It is shown, that these differences in the off-shell behaviour are not an inherent feature of separable potential models. Even with them it is possible to generate the characteristic oscillatory behaviour of the half-shell reaction matrix elements of local potentials and thereby to make their off-shell behaviour closer to that of the local potentials.

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-VIII	1971

Progress Report on

Nuclear Data Activities in Iraq

May 1972

The (n,γ) group activities within the physics Department of Nuclear Research Institute - Iraqi Atomic Energy Commission for the years 1970 - 1971

This group utilizes one of the reactor channels as a source of neutron and its work is mainly in the (n,γ) field. However, a new setup is being completed to study neutron inelastic scattering on various isotopes. The group is equipped with a 4096 channel analyzer & two Ge(Li) detector of 30 and 15cc. Also an 8"x12" NaI(TI) detector for anticoincidence measurements and anticompton experiments.

The group had been completed and are going to complete the following researches and works during 1970 and 1971.

1. Measurement of the Reaction $^{35}Cl(n,\gamma)$ ^{36}Cl using a Three-Crystal Pair & Anti-Compton Spectrometer.

J.D.Jafar, A.A.Abdulla, N.H.Al-Quraishi, M.S.Alwash, J.Kaifosz, M.A.Khalil, M.H.Al-Kaissy & Z.Kosina.

The Cl(n,γ) reaction was investigated and the energies and intensities of 190 resolved γ-rays are reported.

A three-crystal NaI-Ge pair and anti-compton spectrometer was used. A computer programme useful in the automatic analysis of γ-ray spectra is briefly described.

A boot-strap technique generated a self-consistent energy calibration and the binding energy of ^{36}Cl was determined to be 8580.7 ± 1 KeV.

The appearance of single and double escape peaks in addition to photopeaks above pair production threshold will complicate the γ-ray spectrum even further and may cause ambiguities in its interpretation. It is essential to use pair spectrometers for accurate high energy measurements of γ-transitions.

In this present work a high efficiency three crystal NaI-GeNaI pair spectrometer has been used in an investigation of the (n,γ) spectrum from natural chlorine.

The intensity of the 25mm extracted neutron beam from the thermal column of the IRT-2000 was 1.5×10^8 n/sec at the target position. The three crystal pair spectrometer consits of a splitting annular Na(TI) crystal 12" long x 8" in diameter with 2" central through-hole. The two halves are optically isolated and each is viewed by six 2" EMI 9656 phtomultiplier tubes of high quantum efficiency 28%. The central detector is a 10CC coaxial Ge(Li) crystal mounted at the end of a long right-angle arm extending from a chicken-feed type LN_2 dewar vessel. The measured energy resolution (fwhm) of one crystal half was 10.6% for Cs^{137} and 8% and 7.5 for the Co^{60}. lines. The resolution of the Ge(Li) detector was 3 KeV for Co^{60} (1.33 MeV).

The coincidence efficiencies with energy restriction on the annihilation pair can be high, from 20-25% of the double escape peak area in the single spectrum may be collected in the coincidence mode. The high-energy data (above 2047.1 KeV) were taken with the pair spectrometer in a single run of 22 hours. The electronic arrangement permits simultaneous accumulation of data in the two operating modes when two multichannel analyzers are available.

The results were analyzed by an IBM 1130 computing system. A special programme was written for the automatic analysis of γ-ray spectra where the whole spectrum is plotted, smoothed and peaks located. Then the whole spectrum was divided into intervals for fitting and normalized discrete gaussian shape weighting function was used. After this the energies and intensities of γ-rays were determined.

The results were found to be in satisfactory agreement with those of Groshev et al. for the commonly observed lines. The results are listed in Table (1).

Table 1

Gives the energies and their intensities from ^{35}Cl (n,γ) ^{36}Cl

No.	Energy	Intensity	No.	Energy	Intensity
1	8580.7	3.91	51	4752.2	0.13*
2	7792.1	10.38	52	4730.2	0.76
3	7415.4	11.52	53	4684.5	0.05
4	6979.2	2.46	54	4617.6	0.31
5	6953.3	0.16*	55	4588.1	0.29
6	6894.6	0.08*	56	4549.1	0.66
7	6870.2	0.08*	57	4526.1	0.48*
8	6646.0	0.01*	58	4519.1	0.18*
9	6628.9	4.55	59	4459.2	0.10
10	6620.9	8.97	60	4441.3	1.20
11	6544.9	0.16	61	4416.0	0.34
12	6487.4	0.19	62	4355.8	0.17
13	6423.3	0.33	63	4299.0	0.46
14	6380.4	0.27	64	4282.2	0.05
15	6341.9	0.16	65	4207.0	0.19
16	6268.6	0.44	66	4191.6	0.10
17	6112.0	23.82	67	4165.4	0.08
18	6087.8	1.25	68	4139.4	0.38
19	6051.0	0.05	69	4128.5	0.14
20	5957.5	0.29	70	4112.8	0.06
21	5904.0	1.38	71	4083.4	0.86
22	5778.9	0.15	72	4019.3	0.07*
23	5756.6	0.10*	73	4055.5	0.63
24	5734.8	0.48	74	4042.2	0.07
25	5716.2	6.15	75	4029.0	0.17
26	5704.4	0.50*	76	3999.9	0.14
27	5634.7	0.07	77	3981.7	(1.40)
28	5604.9	0.48	78	3963.6	0.40
29	5585.7	0.58	79	3917.0	0.11
30	5518.5	1.98	80	3862.4	0.06*
31	5474.7	0.10	81	3823.8	1.97
32	5372.4	0.06	82	3775.1	0.19
33	5262.8	0.13	83	3750.5	0.36
34	5247.8	0.64	84	3737.3	0.20
35	5205.8	0.26	85	3708.0	0.18*
36	5151.9	0.18*	86	3697.4	0.14*
37	5143.8	0.09*	87	3661.4	0.22
38	5125.0	0.04	88	3665.5	0.28
39	5110.7	0.09	89	3625.8	0.15*
40	5079.1	0.17	90	3613.6	0.08*
41	5018.8	0.51	91	3604.7	0.36*
42	4991.0	0.20*	92	3600.6	0.43*
43	4980.8	4.09	93	3588.8	(0.74)
44	4954.5	0.10*	94	3518.9	0.12*
45	4945.5	1.22	95	3567.2	0.30*
46	4886.4	0.08	96	3561.9	0.90*
47	4846.3	0.04	97	3549.3	0.09*
48	4830.4	0.23	98	3514.4	0.06*
49	4816.1	0.19	99	3502.2	0.49
50	4758.7	0.14*	100	3470.0	0.15

Table 1 (Cont.)

No.	Energy	Intensity	No.	Energy	Intensity
101	3460.7	0.07*	153	2296.0	0.28
102	3429.3	0.84	154	2263.1	0.16*
103	3415.1	0.08*	155	2247.4	0.13*
104	3375.0	0.65	156	2241.1	0.16*
105	3367.1	0.08*	157	2234.1	0.32'
106	3350.6	0.17	158	2210.9	0.32
107	3333.2	0.84	159	2191.7	0.24
108	3316.5	0.25	160	2169.3	0.62
109	3294.3	0.07	161	2124.6	0.32
110	3273.5	0.04*	162	2110.2	0.26
111	3267.7	0.09	163	2094.8	0.81
112	3250.8	0.21	164	2063.7	0.45*
113	3245.0	0.11*	165	2058.0	0.82*
114	3212.5	0.07*	166	2047.1	0.50
115	3201.5	0.11	167	1959.9	10.03
116	3161.8	0.09*	168	1951.7	16.25
117	3152.2	0.06*	169	1625.9	0.19
118	3135.3	0.11	170	1610.1	3.16
119	3116.5	0.92	171	1513.7	0.27
120	3106.6	0.11*	172	1394.7	0.15
121	3095.2	0.07*	173	1327.6	0.92
122	3087.1	0.08*	174	1204.3	0.30
123	3062.1	3.97	175	1165.0	24.40
124	3027.7	0.07*	176	1131.6	1.61
125	3016.3	1.02*	177	788.0	23.35
126	3002.1	0.76	178	633.0	0.33
127	2994.9	0.93	179	609.5	0.23
128	2975.3	1.44	180	596.0	0.90
129	2953.7	0.18*	181	517.1	27.20
130	2896.3	0.48	182	436.2	0.90
131	2877.5	0.29*	183	357.6	0.07
132	2864.4	0.73	184	337.8	0.09
133	2845.9	0.88	185	325.3	0.17
134	2811.4	0.45	186	291.9	0.31
135	2801.1	1.01	187	252.2	0.13
136	2754.4	(0.96)	188	197.0	0.41
137	2740.0	0.14*	189	173.8	0.37
138	2711.9	0.09	190	138.1	0.37
139	2677.0	1.56			
140	2648.8	0.28			
141	2623.7	0.58			
142	2593.2	0.11			
143	2538.7	0.33			
144	2529.1	0.27			
145	2492.7	0.79			
164	2470.7	0.90			
147	2432.2	0.21			
148	2420.4	0.63			
149	2397.2	0.17			
150	2385.8	0.12			
151	2330.8	0.22			
152	2316.9	0.87			

1) Asterisks indicate poor estimate for the intensity due to complex line shapes.
2) Intensities in parentheses have a slight contamination from known 24Na lines.

2. Cascade De-excitation of p-levels in Even-Odd Nuclei with $21 \leq A \leq 41$ after Thermal Neutron Capture.

J.D.Jafar, M.A.Khalil, Fawzia A.H. & A.M.Demidov.

It is observed that the majority of p-levels with a large neutron width $\theta^2(2J + 1)$ also have the largest reduced transition probability (I/E^3) when decaying into the single-particle level 2s1/2 neutron state. However, for 2p1/2 levels and other p-levels higher than $2P_{3/2}$ the largest reduced transition probabilities are observed for de-excitation into the $2p_{3/2}$ state. This enhanced M1 strenght in comparison with E1 transitions, in the decay of p-levels, results from the predeminantly single-particle character of p-states and the relatively simple nature of the M1 transitions involved where only the spin-orbit coupling is affected while the nuclear core undergoes slight re-arrangement. For example, in ^{29}Si the matrix elements of M1 transitions from the 2p1/2 level nearly equals the single-particle estimate, whereas the E1 transition into the 2s1/2 state is only 5.5×10^{-3} of the single-particle value. Table (2) gives the radiation width of p-levels.

Table 2 Radiation Widths of p-levels

Nucleus	Level Energy MeV	Transition Energy MeV	Type of Transition	Experiment		Theory
				eV	W.U	eV
^{29}Si	4.93	4.93	E1	0.52	$6.9.10^{-3}$	75
^{29}Si	6.33	6.33	E1	0.91	$5.5.10^{-3}$	166
^{29}Si	6.33	1.41	M1	0.051	0.9	0.057
^{41}Ca	2.47	0.52	M1	9.10^{-4}	0.35	$2.7.10^{-3}$
^{41}Ca	2.47	2.47	E2	9.10^{-6}	$1.2.10^{-2}$	$7.5.10^{-4}$
^{41}Ca	2.47	0.46	E1	10^{-7}	10^{-3}	$7.5.10^{-2}$

Gamma Rays From Thermal Neutron Capture in Si^{30} & S^{34}

J.D.Jafar, A.A.Abdulla, N.H.Al-Quraishi, M.S.Alwash,
M.A.Khalil & A.M.Demidov.

Gamma radiation from the reactions $Si^{30}(n,\gamma)\ Si^{31}$ and $S^{34}(n,\gamma)\ S^{35}$ was measured with a Ge(Li) spectrometer. All the observed γ-transitions can be placed in the decay schemes of Si^{31} and S^{35} except the 4093 KeV in Si^{31}.

The neutron binding energy is 6588.4 ± and 6986.4 ± 0.3 KeV for Si^{31} and S^{35} respectively.

The γ-ray spectra from thermal-neutron capture in enriched S^{34} reported here, had not been previously measured. And only about two or three of the strongest γ-transitions in Si^{31} and S^{35} have been identified in previous studies of thermal neutron capture in natural targets.

In this work the energies and intensities of γ-transitions in Si^{31} and S^{35} are listed. The decay scheme for S^{35} was constructed, on the basis of energy levels identified in the (d,p) reaction. Primary transitions to the ground or first excited states were not observed.

In table (3), Report Ph-9, 1970, the absolute intensities I_γ and the reduced transition probabilities, I_γ/E^3 are listed for primary M1 transitions feeding 2S1/2 and 1d3/2 one-particle and one-hole states for eight nuclei with odd neutrons in the mass range A=21-41.

Given the ratio of the reduced primary transition Probabilities $\frac{B(M1)}{B(E1)}$. The WeissKof single-particle estimate for this ratio is≈ 0.028 for nuclei with A≈30. This reduction in the transition probability suggests that "Channel capture" is important in these reactions. The partial radiative width should then be proportional to E^2 and not to E^3 as this was predicted by Lane and Lynn, due to the dependance of the transition matrix elements on the level depth relative to the capture state in channel capture. For this reason the partial radiative width was calculated for two cases :

When width is assumed to be proportional to E^3 and to E^2 respectively. Table 4, Report Ph-9, 1970, gives the ratio of reduced transition probabilities feeding $2P_{3/2}$ and $2P_{1/2}$ levels.

It may be concluded that this data lends further support to the importance of the channel capture mechanism in the processes under consideration.

Tables (5,6) gives the energies and their intensities for both reactions.

Table 3

INTENSITY & RELATIVE PROBABILITY OF M1 TRANSITION FROM THE CAPTURE STATE TO $1d_{3/2}$ & $2S_{1/2}$ LEVELS

Primary transition to $1d_{3/2}$ or $1d^{-1}_{3/2}$ state				Primary transition to $2S_{1/2}$ or $2s^{-1}_{1/2}$ state			
Nucleus	E_x (MeV)	I_γ %	$\frac{B(M1;\ 1/2^+ \to 3/2^+)}{B(E1;\ 1/2^+ \to 3/2^+)}$ %	E_x (MeV)	I_γ %	$\frac{B(M1;\ 1/2^+ \to 1/2^+)}{B(E1;\ 1/2^+ \to 3/2^-)}$ %	B_n (MeV)
^{21}Ne				2.79	3.1	0.33	
^{25}Mg	0.976	0.4	0.6	0.584	1.8	0.12	7.33
^{29}Si	1.273	8	1.3	0	2.4	0.25	8.48
^{31}Si	0	1	0.14	0.752	<0.4	<0.08	6.59
^{33}S	0	2.3	1.1	0.842	3.8	2.25	8.64
^{35}S	0	<0.1	<0.05	1.572	<1.6	<1.8	6.99
^{37}Ar	0	10.1	1.4	1.410			8.79
^{41}Ca	2.01	1.0	2.7	2.371	2.2	10	8.36

Average = 1.0

Average = 2.1

Average without ^{41}Ca = 0.8

Table 4

RATIOS OF REDUCED TRANSITION

PROBABILITIES FEEDING $2P_{3/2}$ AND $2P_{1/2}$ LEVELS

Nucleus	$\frac{(I_\gamma / E_\gamma^3)\ 2P_{1/2}}{(I_\gamma / E_\gamma^3)\ 2P_{3/2}}$	$\frac{(I_\gamma / E_\gamma^2)\ 2P_{1/2}}{(I_\gamma / E_\gamma^2)\ 2P_{3/2}}$
^{29}Si	1.5	0.86
^{31}Si	3.0	1.26
^{33}S	1.7	0.9
^{35}S	3.1	1.3
^{37}Ar	1.8	1.05
^{41}Ca	2.0	1.2

TABLE 5

GAMMA RAYS FROM THE ^{30}Si (n,γ) ^{31}Si REACTION

This work			Beard et al.[1]	
E_γ [a]) (KeV)	E_R [b]) (KeV)	Intensity [c])	E (KeV)	Intensity
752.44 ± 0.15	0.01	100	753.0 ± 1.0	1.1
1306.1 ± 0.3	0.03	18	1307 ± 2	0.081
1695.6 ± 0.5	0.05	2.3	1694.8 ± 1.0	0.032
1837.3 ± 0.8	0.07	2.6		
2204.6 ± 0.8	0.08	12	2206.9 ± 0.6	0.11
2316.7 ± 1.0	0.09	2.8		
2781.1 ± 0.15	0.13	66	2781.0 ± 0.2	0.77
3054.76 ± 0.16	0.16	71	3055.0 ± 0.4	0.73
3534 ± 1.0	0.22	≈5	3534.0 ± 1.0	0.022
3630.7 ± 0.4	0.23	6.3	3630.2 ± 0.3	0.076
4382 ± 2	0.33	1.7	4381.5 ± 0.4	0.018
4529.3 ± 0.3	0.36	14	4528.3 ± 0.2	0.13
4903 ± 1	0.42	<1.0	(4902)	<0.007
6587.6 ± 0.8	0.8	1.1	6588.7 ± 0.4	0.018

a) Except for the 4903 KeV, all the γ-rays listed have been included in the level scheme for ^{31}Si.

b) E_R is the recoil-energy correction.

c) Number of γ-rays per 100 neutron captures in ^{30}Si.

TABLE 6

GAMMA RAYS FROM THE ^{34}S (n,γ) ^{35}S REACTION

E_γ [a] (KeV)	E_R [b] (KeV)	Intensity [c]
646.9 ± 0.5	0.00	0.7
775.5 ± 0.15	0.00	19.5
908.1 ± 0.3	0.01	0.5
1572.15± 0.1	0.03	39
1839 ± 1	0.05	3.6
2022.8 ± 0.2	0.06	12
2082.65± 0.1	0.06	18
2347.5 ± 0.1	0.08	54
2555.9 ± 0.4	0.09	3.4
2614.3 ± 0.3	0.10	1.3
2796.6 ± 0.5	0.11	6.1
3184.3 ± 0.2	0.15	7
3331.08± 0.15	0.16	7.8
3390.86± 0.2	0.17	5.5
3802 ± 0.3	0.21	3.6
4189.6 ± 0.3	0.26	1.9
4268.4 ± 0.7	0.27	0.4
4638.4 ± 0.2	0.32	56
4903.4 ± 0.3	0.36	3.2
4963.2 ± 0.5	0.37	2.6
6078.2 ± 1.0	0.50	0.3

a) All the γ-rays listed have been included in the level scheme for ^{35}S .

b) E_R is the recoil-energy correction.

c) Number of γ-rays per 100 neutron capture in ^{34}S.

Gamma Rays from Thermal Neutron Capture in Se^{75}, Se^{78}, Se^{81}, Mo^{97}, Mo^{99} and Mo^{101}.

M.A.Khalil, M.R.Ahmed, S.A.Al-Najar,
A.M.Demidov, F.A.Hussian & Kh.I.Shakarchi.

The study of Se^{75}, Se^{78}, Se^{81}, Mo^{97}, Mo^{99} and Mo^{101} decay schemes by the thermal neutron capture method carried out by utilizing Ge(Li) detector and 4096 channel analyzer and the channel No: 1 on the (IRT-2000). The isotopes of Se^{78}, Se^{81}, Mo^{97}, Mo^{99} were studied before by other groups, but not accurately. Their intent was to study the low and high energy portions of the spectra, i.e. below 3MeV and above 6MeV. That portion of the spectrum lying between 3 and 6 MeV was not studied before because of the difficulties that usually arise in analysing the spectrum associated with the overlapping of photopeaks with single and double escape peaks. The great complexity of the spectrum in the medium energy range above the pair production threshold causes many ambiguities in identifying the "pure" photopeaks and furthermore misinterpretation of the experimental results. More than 50 new γ-lines were found from the results of our experiments & we introduction about 20 new levels in the decay scheme. Also we determined the binding energy values and the intensity of all γ-transitions observed. The decay scheme for each of Se^{75}, Se^{78}, Se^{81}, Mo^{97}, Mo^{99} & Mo^{101} isotopes were constructed. The spectrum calibration utilizing Cl, Si for calibration the standard sources ^{36}Cl, ^{29}Si, ^{203}Hg, ^{137}Cs, ^{60}Co, ^{57}Co & ^{22}Na were used . Gain and Zero stabilization techniques were employed and the overall spectral resolution (FWHM) over 24 hours was approximately 3.5 KeV for E=1MeV and 8KeV at E=7 MeV. The IBM-1130 computer at the Engineering College was utilized for sorting out the decay schemes and calculating the energy levels for each isotope.

To simplify the techniques of sloving the problems of mixing between the peaks in the spectrum of Se and Mo isotopes pair spectrometer can be employed. This technique attenuate the contribution of γ-energies which are not created by pair production. This method was not employed because of the lack of material and the very small cross sections of Se and Mo isotopes.

Fast Neutron Inelastic Scattering Facility at the IRT-2000.

A.A.Abdulla, M.R.Ahmed, S.A.Al-Najar, M.A.Al-Amily
Kh.I.Shakarchi.

Inelastic Scattering of Fast Neutrons :-

The nuclear physics group planned to study the feasibility of the inelastic scattering of fast neutrons using neutron filters for the reduction of capture reactions. Using an extracted beam and Ge(Li) detector we expect that gamma-ray de-excitation, following neutron inelastic scattering, can be readily identified, and that such type of nuclear reactions provided by pile neutrons will involve a large amount of separated isotopes, available at this time.

Introduction :-

In this field of research only two experiments were done: The first by Donahue in 1961 who used an extracted beam and NaI(Tl) detector in angular correlation measurements. The second by Nichole and Kennet (1971), who used Ge(Li) detectors for studying in-core inelastic scattering experiments. They also used neutron filters.

It was decided here to provide such experiments using 30cc coaxial Ge(Li) detector and 4096 channel analyzer, and the channel number (8) was chosen for this purpose.

Filters :

0.5mm Cd, 40mm Pb and 10mm B_4C filters, Pb stainless steel collimators were installed into the channel gate and the extracted beam was of the same dimension of the last collimator (about 25mm). The beam was allowed to pass through series of filters outside the channel gate to achieve further exclusion of the thermal & resonance components. These filters were made of B_4C and Cd plates of different thicknesses, taking into consideration that other materials such as paraffine and lead may also be used as filters. The filter-box and collimator 20mm in diameter which was used to collimate the filtered beam, were enclosed together inside a "Shielding block" made in the form of an iron container filled with paraffine and heavily loaded with iron and adjacently placed to the reactor wall. The filter-box together with the steel box plugged in, which was filled with paraffin and iron as a continuation of the shielding block, was equipped with a pulley to make possible the process of changing the different filters under investigation.

Set-up of the facility :

The detector shielding assembly was made of three layers 5cm Fe, 8cm paraffin with B_4C and 10cm Pb. A cylinder of LiH 20mm in diameter and 10cm in lenght was plugged into the hole made in the detector shield to project additionally the detector crystal against the scattered fast neutrons.

Calculations :

Calculations were carried out to determine the expected distribution of the neutron spectrum after transmission through different filters of different thicknesses. Also the rise of the temperature in the first filter exposed to neutrons and gamma-rays was calculated.

Primary Results :

More than 30 γ-rays due to $Nb^{93}(n,n'\gamma)Nb^{93}$ reaction were detected and related to the excitation of the energy levels : (743.9), (808.5), (978.8), (1082.5), (1296.7), (1485), (1501), (1684.6), (1911.5), (1968.4) (KeV).

The Solid State Group activities within the Physics Department of Nuclear Research Institute - Iraqi Atomic Energy Commission for The years 1970 - 1971

The solid State Group is equipped with a 4-circle Neutron diffractometer and a 4-circle X-Ray diffractometer.

The main work which has been done and carried out so far could be summarised as :

1. After finishing the commissioning and bringing the Neutron diffractometer into working condition. The immediate work carried out was testing of all systems of the N.D. (Monochromator, detection system, and programming control system). The work include measuring of the :-

   a- Rocking curves of the monochromator at different Bragg angles.

   b- Stability and plateau of the two detection systems (monitor and main channels).

   c- Automatic operation and reproducibility.

2. The evaluation of the various diffractometer parameters for the powder diffractometry. A Nickle powder has been used as a standard sample. The whole pattern of Nickle is registered for different collimation conditions in order to determine the resolution and intensity by using different soller slits collimators. Effects of fuel elements arrangements on flux in horizental channel No. 6 were determined.

3. Three powder samples of MgO isotopes ($Mg^{24}O$, $Mg^{25}O$, $Mg^{26}O$) has been investigated in order to evaluate the scattering cross section of each isotopes seperately. In addition to these three isotopes, MgO natural has been investigated also. This study has been shown that the diffraction maximum intensities with odd Millers's indices are significantly less than these with even indices. This indicates that the sign of the coherent scattering amplitudes are positive. The values at the wavelength $\lambda=1.02$ Å are : $b^{24}Mg=0.547 \pm 0.018$, $b^{25}Mg=0.362 \pm 0.014$, $b^{26}Mg=0.489 \pm 0.015$. And thus the values for the natural mixture of magnesium isotopes will be equal to 0.523 ± 0.017, which is in good agreement with formerly measured values.

At present the Solid State group is engaged in determining the thermal neutron spectrum of the horizental channel (no.6) using the Lead Siggle Crystal which is mounted in the Neutron diffractometer as monochromator.

Expansion of this unit will be in the direction of the Magnetic structure studies which will be materialised by the installation of a cryostat and magnet and therefore extending the work to a temperature at or even below the temperature of liquid helium (4.2°K).

X-Ray Diffraction :

Since the commissioning of the Hilger and Watts single crystal diffractometer, the intention has been to carry our work complementary to the Neutron diffraction. This was materialised in determining the percentage of $Mg(OH)_2$ in the three isotopes of MgO, $Mg^{24}O$, $Mg^{25}O$, $Mg^{26}O$ by quantitative X-Ray diffraction phase analysis. The direct method suggested by Alexander and Klug with some modification which were later used to study their coherent amplitude scattering by neutron diffraction.

Amongst the work that was carried out by this group is the evalution of the various diffractometer parameters and also the application of quantitative phase analysis to metallic and Inorganic materials.

At present, preliminary studies are being made to make use of the diffractometer in the calculation of absorption coefficients from metallic spherical and cylenderical single crystals. Future plans include the extension of quantitive phase analysis to ternary and quaternary systems and also the application of X-rays in particle size determination of powders and colloidal solutions.

Expansion of this unit will be materialised by the installation of a second X-Ray generator with vertical tube stand, this generator will provide stable X-Ray to many cameras that are available both in the chemistry and physics department.

The Activation Analysis Group activities within the Physics Department of Nuclear Research Institue - Iraqi Atomic Energy Commission for the years 1970 - 1971

The activation analysis laboratory is well-equipped to handle both roution analysis & research work. The equipment presently includes 30cc Ge(Li) detector, 2048-channel analyser, fast pneumatic transport system, and a number of NaI detectors and counting systems.

Research continues to occupy the major portion of the available operation time of the measuring facilities in this group. A variety of research projects were undertaken in the last year, and some of them have been brought to a sussessful conclusion while others are at the developmental stages. Abstracts of the published papers are included in Section B.

A. Services

The group also performs a number of service analyses for the other departments of the Institute and for outside agencies. During the last year the group analysed over 1,300 service samples for the following :

1- Dept. of Geology,
Dept. of Chemistry,
Dept. of Isotope Production
of the Nuclear Research Institute.

2- National Minerals Company,
Dora Oil Refineries,
Dept. of Geological Survey,
University of Baghdad,
and the Army Chemical Laboratories.

B. Research

Below is a list of the research projects completed during the last year or in progress :

Completed :

1- " The activation analysis of uranium and thorium and their mixtures by delayed neutron detection method. " by E.T.George, G.I.Barisov, G.Y.Al-Shahery and M.Al-Abbasi.

The analysis of fissile isotopes of ^{235}U, and ^{232}Th were carried out in the IRT-2000 reactor using delayed neutron detection technique. An automatic vaccum pneumatic transporter was used with two channels of irradiation: bare and cadmium covered. Pressurized ^{3}He detector was used for neutron counting.

The results of the quantitative determination of uranium in several reference samples (IAEA standards) and the limit of sensitivity of the method are presented.

Two methods of the quantitative determination of fissile elements in two component mixtures (with known and unknown total mass of fissile elements) are described. For a mixture of ^{235}U and ^{238}U the range of the determined weight ratios of ^{235}U and ^{238}U under both methods is found. For a mixture of U_{nat} and Th the range of the weight ratios of U_{nat} and Th under their unknown total mass is found, as well as the limit of sensitivity of the method for thorium under the zero content of uranium.

2- "Determination of trace elements in Iraqi crude oils via NAA". by Hussain Al-Shahristani and M.Al-Atyia.

The trace elemental composition of crude oil from the various Iraqi oil fields has been studied. The instrumental neutron activation analysis technique was used. The method neither requires chemical separation nor pre-or post-concentration of trace elements by ashing. High resolution Ge(Li) detector permitted the simultaneous multi-elemental determination of V, Al, Mn, and Na.

The vanadium concentrations remained quite constant within the same reservoir but varied remarkably among reservoirs of different geological ages. The vanadium concentration ranged from 1.6-109 ppm. Manganese generally followed the same trend as vanadium with its concentration varying from

less than 0.15 to 1.6 ppm. Sodium and aluminum concentrations varied from one sample to another even within the same reservoir. Concentrations ranged from 5-55 ppm and from less than 25-1050 ppm for aluminum and sodium respectively.

3- "Determination of some elements in the sediments of Iraqi rivers by NAA" by E.T.George and M.J.Al-Atyia.

In this work many sediment samples from the Iraqi rivers were analyzed for geological purposes, using INAA. The γ-rays were detected and analyzed using a high-resolution 30 cm^3 Ge(Li) detector and ND-2048 channel analyzer. The elements determined are: Na, Mg, Al, Ca, Ti, V, Mn, Sc & Hf.

Using 3 sec. irradiation, 20 sec. delay and 10 sec. counting Sc and Hf were successfully determined by their isotopes ^{46m}Sc ($T_{1/2}$=20 sec.) & ^{179m}Hf ($T_{1/2}$=19 sec.)

The method used in this analysis was simple, non-destructive, fast and quite sensitive.

4- "Vertical Migration of oil in the Northern Iraqi oil fields: vanadium concentration evidence".

by Hussain Al-Shahristani and M. J. Al-Atyia.

A study was made to determine the vanadium concentration in oil samples representing the various pay horizons of all the Iraqi Oil fields. Variations of vanadium content of oils from different pays were measured to establish the history of migration and accumulation of these oils. The vanadium content of oil from different fields varies drastically from 1.6 to 109 ppm whereas the vanadium content of oils drawn from different wells in the same pay is remarkably constant. In the Kirkuk field, oil from Lower/Middle Cretaceous reservoirs contains 45 ppm V compared to

26 ppm V for oil from the overlying Oligocene/Lower Miocene reservoirs. In the Zubair field, oils from the second, third and fourth pays contain 57, 15 and 2 ppm V respectively.

The path of migration of oil in the northern Iraq oil fields is clearly reflected by the vanadium concentration variation. The results indicate that oil in Northern Iraq originated during the Lower/Middle Cretaceous, and has migrated vertically to the Tertiary reservoirs where it is found now.

5- "Determination of Uranium Content in Geological Samples by Neutron Activation". by M.R.Ahmed, A.A.Abdulla and G.Y.Al-Shahery.

Samples were irradiated in the IRT-2000 research reactor at the Nuclear Research Centre. The decay rate of $^{239}Np \rightarrow ^{239}Pu$ was measured and compared with a standard of known uranium content. Two techniques were applied; in the first method a Ge(Li) γ-ray spectrometer of high resolution was used to measure the γ-ray spectrum from this decay. In the second scintillation counters were placed in coincidence for detecting two-step cascade γ-rays from the same decay. The results from both techniques were in satisfactory agreement.

6- "Measurement of Neutron and Gamma field Parameters on Irradiation Position of Vacuum Pneumatic Transporter System".
by E.T.George, G.I.Borisov, G.Y.Al-Shahery, M.A.Al-Abbasi, O.K.Zhuravlev.

A system of vacuum pneumatic transporters was assembled and the tubes inserted into the IRT-2000 reactor through a horizontal channel. The system is described in short, listing basic technical characteristics. Given are the data of the measurements of neutron and gamma field parameters on the irradiation positions of the pneumatic transporters.

In Progress :

7- "Determination of Arsenic in Iraq tobacco via NAA",

by H.Al-Shahristani and A. Romaya.

Two methods are under development to measure exceedingly small quantities of arsenic in tobacco samples.

The first involves chemical separation and the second is instrumental using coincidence technique.

8- "Investigation of some problems of spectral interferences when analyzing geological samples",

by E.T.George and M.Al-Atyia

During the measurement of activated geological samples, a number of compound peaks are observed. This study has been undertaken to resolve these peaks and particularly the 511 KeV.

9- "Determination of cadmium in foods",

by H.Al-Shahristani and S.Is'hac

A technique is being developed to determine cadmium concentrations in local foods. Cadmium is initially absorbed on anion exchange resins and its radioactive indium daughter-product is washed away and counted.

10- "Determination of elements with very short half lives produced by (n,γ) and (n,n') reactions",

by H.Al-Shahristani, E.T.George, M.Al-Atyia and K.Abbas.

Radioactive elements with half-lives ranging from sub-second to few seconds are being investigated using a fast pneumatic transport system and synchronised counting facility.

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,
Physics Division, Atomic Energy Research Institute, Korea

(1) FAST NEUTRON INDUCES (n, α) AND (n,p) REACTIONS IN GERMANIUM.

M. Cho, M. K. Chung, H. D. Kang and S. W. Cho,
Atomic Energy Research Institute

-- A He^3 detector by utilizing a pair of Si surface barrier detector is under construction for fast neutron spectroscopy. However as the (n, α) and (n,p) cross section of silicon is much higher than in germanium, background counting rate is thought to be high. To overcome this difficulty in Si detector and to testify the applicability of lithium drifted germanium counter as a fast neutron spectrometer, lithium drifted germanium counters of the volumes of 3 cc and 0.6 cc cooled to liquid nitrogen temperature were bombarded with 14 MeV neutrons and the pulse height distributions from the neutron-induced reactions such as (n, α) and (n,p) reactions inside the germanium counters were measured and compared with the data obtained by silicon detector. The characteristics deteriolation of the detector due to lattice defect introduced by fast neutron.

(2) RREVIEW OF THE CURRENT STATUS OF THE U-238, Np-237 AND Th-232 FISSION CROSS SECTIONS

H. I. Bak* end A. Lorenz**
* Seoul National University
**IAEA Nuclear Data Section Vienna, Austria

-- The experimental fission cross-section data of U-238, Np-237 and Th-232, published up to the end of 1970, are reviewed and analyzed

between their respective thresholds and 20.0 MeV. The results of a statistical analysis of the available data performed with a weighted Least-squares Orthogonal Polynomial Fitting computer programme are presented in the form of point-wise cross-section values together with their uncertainties, and in the form of graphs of the fitted curves with an indication of a region of 95% statistical confidence level. An estimate of the fission spectrum weighted average cross-sections and their respective uncertainties is also given.

(3) N-P SCATTERING AT LOW ENERGY.

Seung Tae Kim and Yoon Suk Koh,
Seoul National University

-- The fact that neutron-proton interaction is partially noncentral is well known. Although the tensor potential $V_T(r)S_{12}$ has been introduced, solving the scattering problem with this potential is much complicated. In order to avoid the complexity, we introduce the deformed potential.

$$\left.\begin{aligned} V &= \tfrac{1}{2}\mu w^2(r^2 - a^2) + \tfrac{1}{2}\varepsilon\omega\, w^2(r^2 - a^2)\cos^2\theta\,, & r \leq a \\ &= 0 & , \; r \geq a \end{aligned}\right\} \quad (1)$$

where and W are to be determind from the experimental data.
In formulating $\sigma(\theta)$, we have followed Goldberger and Watson, assuming $|\varepsilon|<1$ The T-matrix is given by

$$\begin{aligned} \langle\beta|T|\alpha\rangle &= \langle\beta|T_1|\alpha\rangle + (X^{T-}_{1\beta}\,,\, V_2\, X^{+}_{\alpha}) \\ &\cong \langle\beta|T_1|\alpha\rangle + (X^{T-}_{1\beta}\,,\, V_2\, X^{+}_{1\alpha}) \qquad \ldots\ldots\ldots\ldots \quad (2) \end{aligned}$$

The right hand side of (2) can be easily calculated. Using the formula $\sigma(\theta) = A\,|\langle\beta|T|\alpha\rangle|^2$, we can determine the two parameters ε and W from the experimental results at two angles, namely $\theta_1 = 60^\circ$ $\theta_2 = 90^\circ$, when the neutron energy is 14.1 Mev. And we check the theoretical values of cross-section at other angles as well as at other neighboring

energy E = 13.7 Mev with experimental data.

(4) ENERGY DISTRIBUTION OF PHOTOPROTONS FROM $^{93}_{41}Nb(\gamma,p)$ REACTION IRRADIATED WITH 19.0 Mev γ- rays.

B. N. Seong
Seoul National University

— The energy distribution of photoprotons from Nb irradiated with 19.0 Mev bremsstrahlung produced by betatron have been detected in Ilford C2 nuclear emulsions. The thickness of emulsions were 200 microns. In the energy distribution are appeared many structures which were analogues to those observed in the case of light nuclei. This result indicates that perhaps it will enable to be explained by shell model rather than statistical theory.

(5) PRECISE DETERMINATION OF RELATIVE GAMMA-RAY INTENSITIES IN THE DECAY OF Ag^{110m} AND In^{116m} FOR TOTAL ABSORPTION PEAK DETECTION EFFICIENCY OF Ge(Li) IN THE ENERGY RANGE 80 - 3000 KEV.

M. K. Chung, S. W. Cho,
Atomic Energy Research Institute

— After the determination of intrinsic volume of Ge(Li) detector (3 cc) by gamma-ray scanning method, the relative detection effciency of gamma-ray total absorption peak was obtained in the energy range 80 - 3000 kev by pairpoint method. Semi-empirical approach to the determination of detection efficiencies was also tried and the results were discussed. The relative intensities of the gamma-rays in the decay of Ag^{110m} and In^{116m} were re-determined according to the efficiency curve which we obtained. Of great usefulness in efficiency calibration would be a radioactive source with many lines with known relative intensities distributed over a wide range.

Ag^{110m} and In^{116m} soon to fullfil these requirements.

(6) THEORY OF SUPERHEAVY NUCLEI IN THE OSCILLATOR MODEL.

Kiuck Lee,
Marquette University

— Recently Marinov and his co-workers[1] reported the discovery of element 112, and subsequent reports by others[2] indicate that the discovery of element 112 as well as the existence of other stable superheavy nuclei may be doubtful. On the other hand, Sobiczewski and his co-workers[3] extended their theorotical study in search for stable superheavy nuclei for mass numbers up to 600. Thus, the search for superheavy nuclei will undoubtedly continue. In view of these developments, theorotical feasibility of stable superheavy nuclei will be discussed with the aid of the harmonic oscillator model, in close analogy with its roles in the development of the theory of nucleus with ordinary mass numbers. For rigorous treatment the three dimensional harmonic oscillator with spheroidal deformation will be employed in estimating the magic numbers beyond Z = 82 and N = 126. Since the coulomb's energy is known to play an important role in nuclei with large Z the effect of the coulomb's energy of deformed nuclei as well as the spin-orbit coupling will be discussed.

* Work supported in part by Marquette University Committee on Research.

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[2] For example, W. Grimm, G. Hermann, and H. D. Schuessler, Phys. Rev. Lett. 26, 1040 (1971).

[3] A. Sobiczewski, T. Kroqulski, J. Blocki, and Z. Szymanski, Nucl. Phys. A168, 519 (1971).

(7) SINGLE PLAT CRYSTAL GAMMA-RAY SPECTROMETER IN COMBINATION WITH Ge (Li) DETECTOR FOR RADIATIVE CAPTURE STUDIES.

M. K. Chung, S. W. Cho and K. C. Tripathi,
Atomic Energy Research Institute

— To suppress Compton background, a single flat crystal spectrometer in combination with a Ge(Li) detector was constructed and applied to the thermal neutron capture gamma spectroscopy. In this report the operational principle of the spectrometer system and the results of preliminary experiments will be given in detail.

(8) SEMICONDUCTOR DETECTORS AND ITS APPLICATIONS TO NEUTRON MEASUREMENT.

D. H. Suh, E. K. Kim,
Atomic Energy Research Institute

-- The performance of a Si(Li) surface-barrier semiconductor detector and its applications for neutron measurements are described in this report. The detector is constructed from 75 - 120 ohm-cm p type Si with a vacuum evaporated gold film electrode, which showed an energy resolusion about 3% for 5.4 MeV alpha rays. We have measured the spatial distribution of neutrons at the thermal column of TRIGA-II reactor and linearity between counting rates and reactor power, using Li^6 (n, α)T reactions.

(9) STUDY ON THE PERFORMANCE OF THE PLASTIC SCINTILLATORS

Young-Ho Kang, Sahng-Yun Lee,
Dept. of Physics, Kyungpook National University

We have studied the performance of the Plastic Scintillators. In this report, by polymerization of various monomer, the Pastic Scintillators were made, and their characteristics are described.

As the monomer, the n-butylmetacrylate, vinyltoluene, and styrene were used. Pterphenyl and 2, 5-diphenyloxazole were used as the primary phosphor, 1, 4-di-(2-5-phenyloxazolyl)-benzene as the secondary phosphor to monomer. Comparing with inorganic scintillator, the Plastic Scintillator, has great difficulty in analyzation of the energy of nuclides, and its background counting rate is nearly proportional to the thickness of the plastic scintillator. The minimum detectable amount for ^{90}Sr of this scintillator was 0.12--0.15 mμCi.

Furthermore, the probe of scintillation dector was also made, and we found that the possiblity of production of plastic scintillation detectors in our Laboratory.

(10) NEUTRON FLUENCE MEASUREMENT WITH URANIUM- OR THORIUM-DOPED FISSION TRACK DETECTOR

Young Soo Yoo,
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-- The fission fragment track detector (FTD) of U- or Th-doped phosphate glass adopting an etching thechnique has been known to be suitable for neutron dosimetry. In this paper, a neutron detector which consists of a phosphate glass doped with a fissile material such as natural uranium (UO_2) or thorium (ThO_2) is described Fission fragment tracks registered in the glass were etched by sodium hydroxide and counted under an optical microscope with a magnification of about 420. The detector was exposed to Pu-Be standard neutron sources and thermal neutrons in graphite pile for the calibration purpose.

The registration efficiency as a function of etching concentration, temperature of etching solution, and etching time was also studied. For each parameter, an optimum time for etching in NaOH of 20 per cent concentration by weight was found to be 20 minutes at 60°C

for U-doped FTD and 10 minutes at the same condition for Th-doped FTD. Let these parameters be the "normal condition."

The sensitivities of U-doped FTD for fast and thermal neutron were found to be respectively, 0.48×10^{-6} ($\pm$ 1.9%) and 2.35×10^{-6} ($\pm$ 1.4%) fission fragment tracks/neutron, and that of Th-doped FTD for fast neutron was 0.32×10^{-6} ($\pm$ 3.2%) tracks/neutron.

(11) THE VARIATIONAL METHOD APPLIED TO THE NEUTRON TRANSPORT EQUATION

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Noether's theorem is applied to the one dimensional neutron transport equation. It is obtained the transformation rendering the functional of the one dimensional Boltzmann equation invariant. It is derived the law conserving the product of the directional flux and its adjoint flux. The possible types of the solution of the Boltzmann equation are discussed. The results are compared with the wellknown solution.

(12) MODAL NODAL TRANSPORT ANALYSIS

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A unified modal-nodal expansion of the angular distribution of neutron flux in one spatial dimension is considered, following the proposal of Harms. Several standard nodal and/or modal methods of analysis are shown to be specializations of this technique. The modal-nodal moment from of the mono-energetic transport equation with isotropic sources and scattering is derived and the infinite medium eigenvalue problem solved.

The technique is shown to yield results which approximate the exact value of the inverse diffusion length in non-multiplying media more accurately than standard methods of equal or somewhat greater computational complexity.

(13) AN ANALYSIS OF SHIELDING DESIGN OF TRIGA MARK - II REACTOR --After Power Upgrading by 2.5 Folds--

Chang Kun Lee,
Atomic Energy Research Institute

Korea's TRIGA Mark-II reactor was primarily designed in 1950's and was constructed in 1962 for 100 kw thermal output, but it was upgraded to 250 kw in July 1969. Nevertheless, the shield remains unchanged, although the radiation level has increased. The result of computation in this paper shows that, with the existing shield, it is safe for the fast neutrons even after the power upgrading by 2.5 times. It is, however, somewhat dangerous for the gamma rays which are comprised of primary and secondary. For the analysis of the reactor shielding design, an attempt is made for the computation toward the horizontal direction. From theoretical point of view, it can be concluded that some layer of additional shield must be reinforced to the existing concrete in order to be radiologically safe in the reactor hall.

(14) SHIELDING EFFECTIVENESS OF MAGNETITE HEAVY CONCRETE ON COBALT-60 GAMMA-RAYS

Yong Kyu Lim
Atomic Energy Research Institute

The gamma-ray shielding effects of magnetite concretes have been

measured using a broad beam Co-60 gamma-ray source. Mathematical formulae for a transmission ratio-to-shield thickness relation were derived from the attenuation curve obtained experimentally and are

$$I_{(x)} = I_{(o)} \exp(-\mu X) \exp(1.03 \times 10^{-1}X - 3.38 \times 10^{-3}X^2 + 5.29 \times 10^{-5}X^3)$$

when $X < 20$ cm,

$$I_{(x)} = I_{(o)} \exp(-\mu X) \exp(4.66 \times 10^{-2}X + 2.12 \times 10^{-1})$$

when $X > 20$ cm.

Here $I_{(x)}$ is radiation intensity after passing through a thickness X of absorber, $I_{(o)}$ is the initial radiation intensity, μ is the linear attenuation coefficient of magnetite concrete and is given by $(0.0532\,\rho + 0.0083)$[4] cm^{-1} in accordance with an earlier study, and X is the thickness of absorber. In addition, a model shield which is a rectangular magnetite concrete box with walls of 8 cm thickness walls and internal demensions of 40 x 40 x 40 cm was constructed and its shielding effect has been measured. The emergent radiation flux appears to be greater with this configuration than with a slab shield of equal thickness.

(15) PREPARATION OF HIGH SPECIFIC ACTIVITY ^{51}Cr

Taeyoung Kim, Young Kuk Kim
Atomic Energy Research Institute

High specific activity ^{51}Cr is mainly prepared by Szilard-Chalmers process from K_2CrO_4 target. Usually the recoil atom, Cr*(III), is coprecipitated with Fe(III) as a scavenger to be separated from K_2CrO_4. A new preparation method has been developed, by adding 0.1N NaOH and C_2H_5OH to the irradiated target solution, to precipitate Cr*(III) without any scavenger such as Fe(III). The new method gives the product of higher specific activity and

better yield than that of other methods, in the shorter processing time.

This method is compared with the conventional method and the French method, and following results are obtained: the new method gives specific activity more than twice that of the conventional method and better yield than the conventional method; the French method and the new method give similar specific activity, but yield of the new method is almost twice that of the French method.

(16) STRONTIUM-90 LEVELS IN MILK

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The levels of strontium-90 in milk produced in Korea were determined during the past six years. Milk samples were collected from dairies and market shops in seoul area. Strontium-90 in milk was separated from calcium using fuming nitric acid and purified radiochemically. After seculear equilibrium was completed, the ratioactivity of yttrium-90 was counted in a low background beta counting system. The determination of stable calcium in milk was also made by volumetric method using 0.1 N potassium permanganate solution. The highest value of 34.9 pCi ^{90}Sr/g-Ca was determined in August, 1966 and the lowest value was 7.5 pCi ^{90}Sr/g-Ca in August, 1967. From the result we can say that levels of strontium-90 are decreasing year after year and are far bellow the maximum permissible level recommended by International Committe on Radiation Protection.

(17) STUDY ON IODINE LABELLING (I) INFLUENCES OF REDUCING AGENT AND IODATE--^{131}I IN SODIUM IODIDE--^{131}I SOLUTION ON LABELLING

Jaerok Kim,

Atomic Energy Research Institute

In Iodine-131 labelling of iodocompounds such as tetrachloro-P-tetraiodo R-fluorescein, sodium orthoiodohippurate and a non-iodocompound, human serum albumin (HSA), the labelling rates and yields are accurately compared with each other. The reaction systems conducted for each compounds were different conditions; sodium iodide^{-131}I containing reducing agent, sodium iodide^{-131}I free from reducing agent, and sodium iodide^{-131}I free from reducing agent but containing considerable amount of iodate^{-131}I etc.

The labelling yields were generally poor; 10% in the case of using sodium iodide^{-131}I containing reduing agent, and 50 ~60% in the case of using sodium iodide^{-131}I free from reducing agent but containing considerable amount of iodate^{-131}I. However, fair yields were obtained in the case of using sodium iodide^{-131}I free from reducing agent and mostly in the form of iodide^{-131}I. The reaction entities involved in these reactions are also briefly discussed.

(18) KINETIC STUDIES ON THE HALIDE EXCHANGE REACTIONS OF SOME SUBSTITUTED BENZYL CHLORIDES

Ikchoon Lee, Bon-Su Lee and Jae Eui Yie

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Kinetic studies on the halide exchange reactions of some substituted benzyl chlorides have been carried out using radioisotope tracer halide ions.

Results are consistent with our previous conclusion that the rates of halide exchange reactions in acetone with arylmethy halides are dictated by the polarizabilities of both substrate and nucleophile.

Progress Report on Nuclear Data Research in Poland

(May 1971 - April 1972)

Compiled by A. Marcinkowski

May 1972

"Cross-Sections for the $^{85}Rb(n,2n)^{84g,m}Rb$, $^{87}Rb(n,2n)^{86g,m}Rb$ and $^{117}Sn(n,np)^{116}In$ Reactions in the Neutron Energy Range 13-17 MeV".

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The absolute cross-sections for $^{85}Rb(n,2n)^{84g,m}Rb$, $^{87}Rb(n,2n)^{86g,m}Rb$ and $^{117}Sn(n,np)^{116}In$ reactions were evaluated from the γ-activity measurements with the use of a scintillation spectrometer. The reaction final products were identified by their characteristic γ-ray transitions and the least square analysis of the decay curves. The neutrons were obtained in the Van de Graaff accelerator from the $T(d,n)^4He$ reaction. The measurements were refered to the well known cross-sections of the $^{56}Fe(n,p)^{56}Mn$ and $^{64}Zn(n,2n)^{63}Zn$ reactions [1,2]. The results are shown in tables 1-3. The errors are the statistical errors only.

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Table 1

Cross Sections for the $^{85}Rb(n,2n)^{84g,m}Rb$ Reaction

	σ_g (mb)	σ_m (mb)
13.0 ± 0.2	398 ± 64	370 ± 11
13.3 ± 0.1	439 ± 26	405 ± 13
13.8 ± 0.1	639 ± 28	468 ± 8
14.5 ± 0.1	759 ± 40	491 ± 11
15.1 ± 0.2	648 ± 46	530 ± 23
15.4 ± 0.2	483 ± 28	525 ± 12
16.0 ± 0.2	700 ± 83	603 ± 53
16.6 ± 0.1	867 ± 116	600 ± 16
17.8 ± 0.1		671 ± 20

Table 2

Cross Sections for the $^{117}Sn(n,np)^{116}In$ Reaction

	σ(mb)
13.9 ± 0.1	1.17 ± 0.11
14.1 ± 0.2	1.23 ± 0.07
14.5 ± 0.1	1.26 ± 0.17
15.1 ± 0.2	2.03 ± 0.26
15.4 ± 0.2	1.80 ± 0.21
16.6 ± 0.1	6.4 ± 2.6

Table 3

Cross Sections for the $^{87}Rb(n,2n)^{87g,m}Rb$ Reaction

	σ_g (mb)	σ_m (mb)
13.0 ± 0.2		295 ± 39
13.3 ± 0.1	589 ± 71	501 ± 48
13.8 ± 0.1	636 ± 83	491 ± 40
14.5 ± 0.1	789 ± 67	518 ± 40
15.1 ± 0.2	525 ± 110	601 ± 20
15.4 ± 0.2	546 ± 100	630 ± 20
16.0 ± 0.2		522 ± 64
16.6 ± 0.1		567 ± 56

Excitation of isomeric activities in $^{131,133,135}Ba$ using 14.8 MeV neutrons

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Introduction

It is of interest to investigate the cross sections for excitation of isomeric activities in Ba in order to obtain more reliable information on the possible trend of the isomeric cross section against the neutron number of the residual nucleus performed under the same experimental conditions. The ^{129m}Ba and ^{137m}Ba fall near the opposite ends of this chain. The decay scheme of ^{129m}Ba is not well known. The cross section for excitation of ^{137m}Ba was determined in our earlier work [1].

Table 1

Cross sections for /n,2n/ and /nn'γ/ reactions with 14.8 MeV neutrons from the present work

Target, reactions and isomeric nucleus	Half life	E_γ keV	Conversion coefficient	Measured cross section /mb/
^{132}Ba/n,2n/^{131m}Ba	14.6 min	107	0.9 ± 0.15	696 ± 120
^{134}Ba/n,2n/^{133m}Ba	38.9 h	276	3.45 ± 0.20	827 ± 80
^{136}Ba/n,2n/^{135m}Ba ^{135}Ba/nn'γ/^{135m}Ba	28.7 h	268	3.82 ± 0.20	1294 ± 120

Experimental procedure

The cross section measurements were carried out by the activation method. Natural "specpure" barium was irradiated by 14.8 MeV neutrons from the neutron generator. The neutron flux was monitored by counting the alpha particles from T/d,n/^{4}He reaction with the help of solid state detector. The activities of the irradiated samples were measured using 8 cm^{3} Ge/Li/ and 1.5" x 1" NaI/Tl/ gamma-ray detectors.

Results

Table 1 summarizes the cross-sections obtained in the present work together with the values of half-lives, gamma-ray energies and conversion coefficient used in the calculations. The estimated error in our measurements is of the order of $\pm$10% for ^{133,135}Ba and $\pm$20% for ^{131}Ba.

Discussion

In this work only the metastable state cross sections σ_m was measured. The experimental total

cross sections σ_{tot} /$\sigma_{tot} = \sigma_m + \sigma_g$, σ_g - ground state cross section/ is known only for ^{132}Ba/n,2n/ ^{131}Ba / $T_{1/2}$ = 11 d / [2] and cannot be determined by activation method for ^{134}Ba/n,2n/^{133}Ba /very long half-life equal 7.7 y / and ^{136}Ba/n,2n/^{135}Ba /stable/. Recently Pearlstein [3] computed total cross sections at neutron energies 13.1, 14.1 and 15.1 MeV for large number of isotopes which agree excellently with the available experimental data. The errors of these semiempirical predictions have been assumed to be as large as ±15%. Using our results for σ_m and Pearlstein's predictions for σ_{tot} we can estimate the "experimental" isomeric cross ratios $\frac{\sigma_m}{\sigma_{tot}}$. The theoretical isomeric cross section ratios were calculated on the basis of the statistical theory of nuclear reactions using the method described by Huizenga and Vandenbosch [4] /Table 2/. This method is restricted to compound type reactions only. The compound nucleus mechanism for /n,2n/ reaction is well established. The values of penetrability factors for neutrons were taken from ref. [5] .

Table 2

Isomeric cross section ratios for $^{131,133,135,137}Ba$

Reaction	I_m	I_g	σ_m exp. /mb/	σ_{tot} estim. from [3] /mb/	$\left(\frac{\sigma_m}{\sigma_{tot}}\right)_{exp}$	$\left(\frac{\sigma_m}{\sigma_{tot}}\right)_{calc.}$
$^{132}Ba/n,2n/^{131}Ba$	$11/2^-$	$1/2^+$	696	1690±15%	0.41±0.09	0.51
$^{134}Ba/n,2n/^{133}Ba$	$11/2^-$	$1/2^+$	827	1720±15%	0.48±0.08	0.62
$^{136}Ba/n,2n/^{135}Ba$	$11/2^-$	$3/2^+$	1294	1725±15%	0.75±0.13	0.62
$^{138}Ba/n,2n/^{137}Ba$	$11/2^-$	$3/2^+$	1048	1900±15%	0.55±0.1	0.63

The composite model for nuclear level densities proposed by Gilbert and Cameron [6] was used in computations.

Fig. 1a shows the metastable state cross sections measured in this work /together with the cross sections for excitation of ^{137m}Ba in /n,2n/ reaction taken from our earlier work [1] /plotted as a function of neutron number for constant spin value of isomeric level. It can be seen from this figure that the measured metastable cross section for ^{135m}Ba deviate considerably from other values. On the other hand the calculated isomeric cross section ratios follow a smooth curve /fig. 1b/ when plotted as a function of neutron number. Calculated and experimental isomeric ratios are in agreement within the experimental errors. A possible explanation for the deviation of cross section for excitation of ^{135m}Ba lies in the strong contribution of ^{135}Ba/nn'γ/^{135m}Ba process to /n,2n/ reaction. Although the separated isotope of ^{135}Ba was not available in the present work an attempt to estimate the /nn'γ/ cross section for ^{135}Ba was made. From Fig. 1a is seen that the

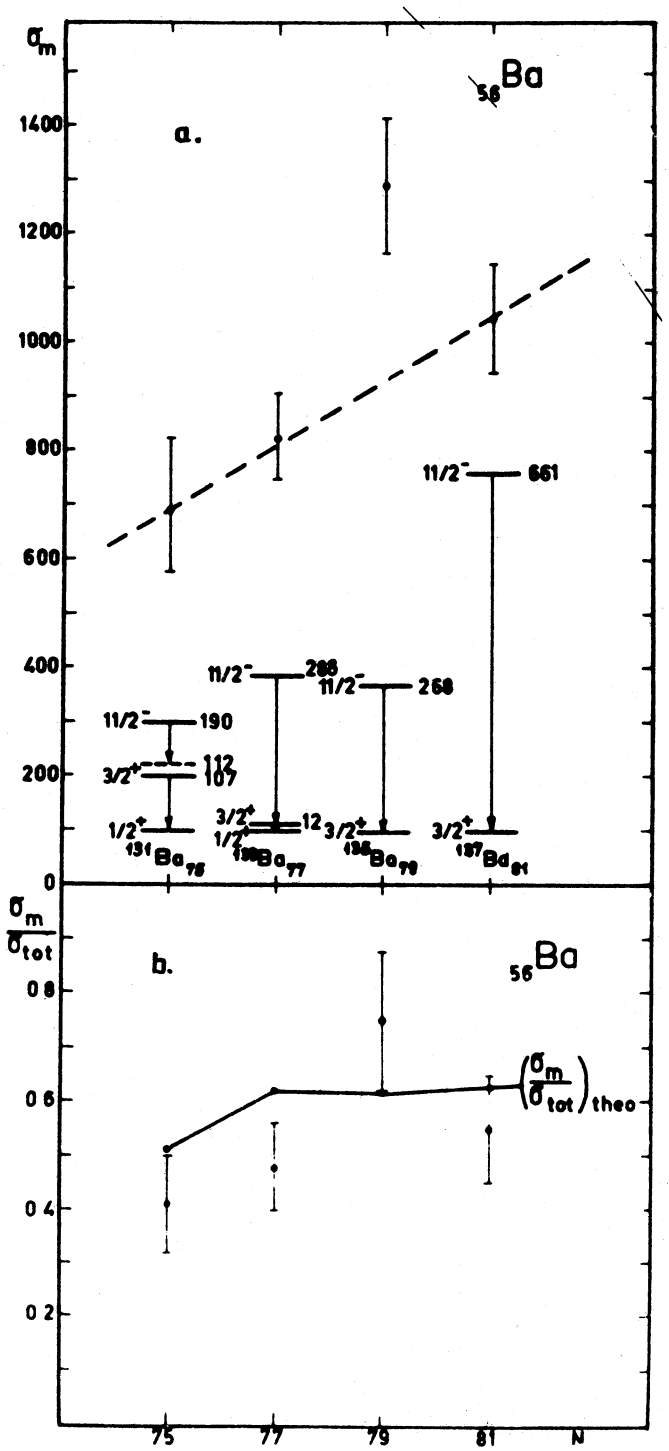

Fig.1.a/The cross sections for excitation of / $11/2^-$ / isomeric levels in odd-A isotopes of Ba by 14.8 MeV neutrons in /n,2n/ reaction as a function of neutron number. b/ The calculated and experimental values of isomeric ratios for these same isotopes as a function of neutron number.

value of metastable cross section for $^{136}Ba/n,2n/^{135m}Ba$ reaction is about 950 mb. The constancy of theoretical isomeric cross section ratio /fig. 1b/ for neighbouring nuclei of ^{135}Ba suggests a similar value for this nucleus. Using the theoretical isomeric cross section ratio and Pearlsteins total cross section for $^{136}Ba/n,2n/^{135}Ba$ reaction at 14.8 MeV neutron energy it is possible to estimate σ_m cross section as not higher than 1080 mb. The experimental value for $^{136}Ba/n,2n/^{135m}Ba+^{135}Ba$ $/nn'\gamma/^{135m}Ba$ reaction is 1294 mb. Comparison of these two values and errors yields the upper limit for contribution of the $^{135}Ba/nn'\gamma/$ reaction as <500 mb. To establish a trend in the σ_m cross section for the /n,2n/ reaction as a function of the neutron number N, one has to disregard the experimental point corresponding to the ^{135}Ba. since in this case exist an essential contribution from the $/nn'\gamma/$ process. Through the remaining three points one may draw a streight line, as shown in fig. 1a, which corresponds to the systematic increase of σ_m with N.

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"Differential cross sections for the (n, α) reactions in ^{160}Dy, ^{162}Dy and ^{164}Dy at 14 and 18 MeV".

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The absolute differential cross sections for the ^{160}Dy(n, α)^{157}Gd, ^{162}Dy(n,α)^{159}Gd and ^{164}Dy(n, α)^{161}Gd reactions have been measured at two neutron energies $14.12\ ^{+0.12}_{-0.08}$ and 18.15 ± 0.12 MeV by direct registration of the alpha particles. The alphas were detected by n-type surface barrier detectors. The experimental arrangement used in the measurements is described in our earlier work [1]. The neutrons were obtained from ^{3}H(d,n)^{4}He reaction with deuterons accelerated in the Van de Graaff accelerator. The neutron flux measured by counting the recoil protons from a thin polyethylene foil. The absolute calibration of the monitor was performed by measuring of the 847 keV γ-transition in

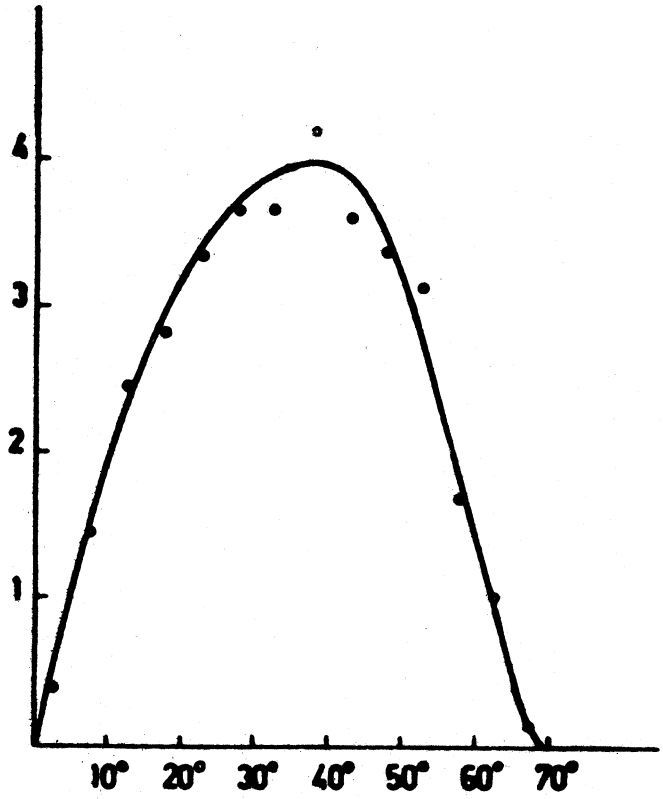
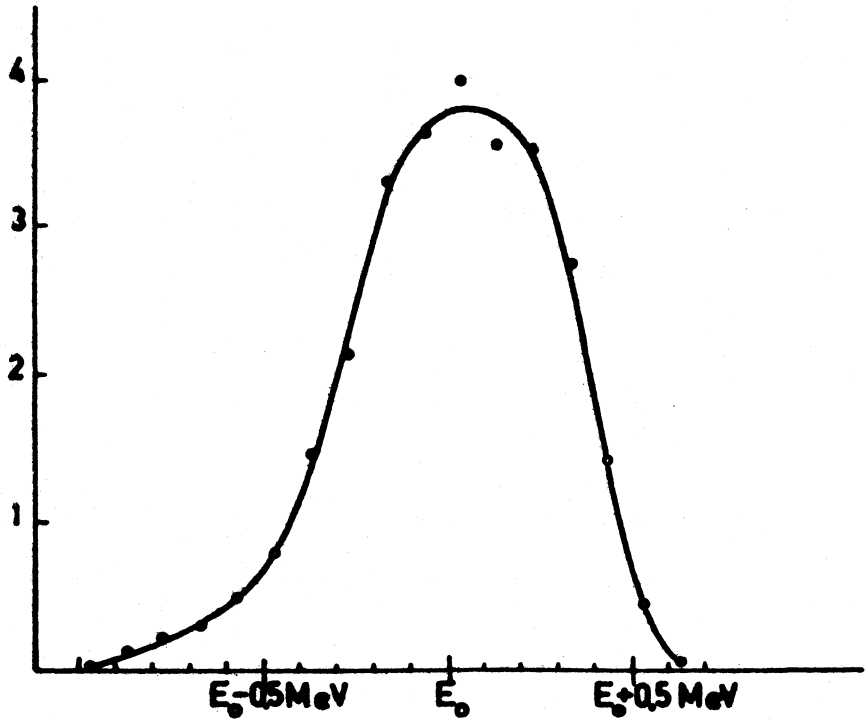


fig.1



^{56}Fe produced in $^{56}Fe(n,p)^{56}Mn$ reaction with succesive β-decay of ^{56}Mn. The cross section for $^{56}Fe(n,p)^{56}Mn$ reaction was taken as 110 mb and 57 mb for neutron energies equal to 14.12 and 18.15 respectively [2].

The results of differential cross section measurements are shown in tables 1-6. Cross sections were measured with the angular spread shown in fig.1 and the total experimental energy spread of alpha particles shown in fig.2. The errors indicated in the tables are statistical. In tables 1-6 the cross sections integrated over whole alpha particle spectrum are also shown.

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Table 1

Differential Cross Sections for the $^{160}Dy(n,\alpha)^{157}Gd$ Reaction at 14.12 MeV.

E_α(MeV)	$\mu b \cdot sr^{-1} MeV^{-1}$	E_α(MeV)	$\mu b \cdot sr^{-1} MeV^{-1}$
16.36	78 ± 34	19.40	123 ± 46
16.57	58 ± 30	19.61	103 ± 40
16.78	27 ± 22	19.84	133 ± 50
16.99	69 ± 30	20.05	159 ± 59
17.21	59 ± 28	20.26	156 ± 57
17.44	100 ± 41	20.47	159 ± 58
17.68	94 ± 38	20.68	133 ± 50
17.88	85 ± 34	20.89	136 ± 50
18.10	77 ± 32	21.01	112 ± 42
18.31	77 ± 32	21.13	89 ± 35
18.51	107 ± 41	21.25	63 ± 27
18.74	99 ± 38	21.37	34 ± 14
18.96	115 ± 44	21.58	15 ± 8
19.18	81 ± 32	21.79	1 ± 5

Integrated cross section = 0.51 ± 0.20 $mb.sr^{-1}$

Table 2

Differential Cross Sections for the $^{162}Dy(n,\alpha)^{159}Gd$ Reaction at 14.12 MeV.

E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$	E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$
15.37	26 ± 24	18.37	93 ± 36
15.57	23 ± 23	18.57	90 ± 35
15.77	9 ± 22	18.77	103 ± 40
15.97	25 ± 21	18.97	111 ± 43
16.17	46 ± 27	19.17	96 ± 37
16.37	26 ± 20	19.37	97 ± 37
16.57	34 ± 21	19.57	93 ± 35
16.77	43 ± 22	19.77	84 ± 32
16.97	36 ± 20	19.97	39 ± 16
17.17	42 ± 22	20.17	37 ± 16
17.37	36 ± 19	20.37	19 ± 10
17.57	56 ± 24	20.57	9 ± 6
17.77	63 ± 27	20.77	6 ± 5
17.97	77 ± 32	20.97	4 ± 4
18.17	73 ± 29		

Integrated cross section = 0.30 ± 0.11 $mb.sr^{-1}$

Table 3

Differential Cross Sections for the $^{164}Dy(n,\alpha)^{161}Gd$ Reaction at 14.12 MeV.

E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$	E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$
16.02	11 ± 13	18.32	46 ± 19
16.20	34 ± 17	18.51	43 ± 19
16.40	10 ± 11	18.70	45 ± 19
16.59	15 ± 11	18.88	41 ± 17
16.79	39 ± 17	19.07	50 ± 21
16.98	10 ± 6	19.26	48 ± 20
17.17	17 ± 10	19.44	40 ± 17
17.36	31 ± 15	19.64	29 ± 13
17.55	30 ± 14	19.83	32 ± 14
17.74	27 ± 14	20.01	24 ± 10
17.93	42 ± 18	20.21	12 ± 7
18.12	32 ± 15	20.39	2 ± 4

Integrated cross section = 0.13 ± 0.07 $mb.sr^{-1}$

Table 4

Differential Cross Sections for the $^{160}Dy(n,\alpha)^{157}Gd$ Reaction at 18.15 MeV

E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$	E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$
18.80	79 ± 33	22.40	80 ± 18
19.00	63 ± 23	22.60	66 ± 16
19.20	88 ± 24	22.80	116 ± 23
19.40	70 ± 21	23.00	85 ± 18
19.60	83 ± 23	23.20	91 ± 19
19.80	129 ± 28	23.40	94 ± 19
20.00	91 ± 23	23.60	86 ± 18
20.20	66 ± 20	23.80	91 ± 18
20.40	94 ± 22	24.00	91 ± 18
20.60	81 ± 20	24.20	98 ± 19
20.80	77 ± 19	24.40	76 ± 15
21.00	99 ± 22	24.60	58 ± 12
21.20	96 ± 21	24.80	42 ± 10
21.40	95 ± 21	25.00	16 ± 6
21.60	77 ± 18	25.20	9 ± 5
21.80	89 ± 20	25.40	3 ± 4
22.00	82 ± 19	25.60	5 ± 3
22.20	66 ± 16		

Integrated cross section = 0.53 ± 0.08 $mb.sr^{-1}$

Table 5

Differential Cross Sections for the $^{162}Dy(n,\alpha)^{159}Gd$ Reaction at 18.15 MeV.

E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$	E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$
19.10	50 ± 24	21.90	65 ± 18
19.30	56 ± 24	22.10	64 ± 17
19.50	52 ± 23	22.30	62 ± 17
19.70	74 ± 24	22.50	81 ± 19
19.90	74 ± 23	22.70	57 ± 16
21.10	68 ± 22	22.90	75 ± 17
20.30	73 ± 22	23.10	70 ± 17
20.50	72 ± 21	23.30	65 ± 16
20.70	51 ± 20	23.50	67 ± 16
20.90	69 ± 21	23.70	79 ± 17
21.10	81 ± 21	23.90	39 ± 11
21.30	58 ± 18	24.10	19 ± 9
21.50	55 ± 18	24.30	29 ± 9
21.70	64 ± 18	24.50	17 ± 7

Integrated cross section = 0.34 ± 0.06 $mb.sr^{-1}$

Table 6

Differential Cross Sections for the $^{164}Dy(n,\alpha)^{161}Gd$ Reaction at 18.15 MeV.

E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$	E_α(MeV)	$\mu b.sr^{-1}MeV^{-1}$
18.85	51 ± 37	21.45	14 ± 15
19.05	46 ± 27	21.65	49 ± 18
19.25	50 ± 26	21.85	54 ± 18
19.45	13 ± 23	22.05	53 ± 17
19.65	55 ± 24	22.25	48 ± 16
19.85	55 ± 23	22.45	67 ± 18
20.05	36 ± 21	22.65	56 ± 17
20.25	40 ± 20	22.85	54 ± 15
20.45	63 ± 22	23.05	26 ± 12
20.65	31 ± 19	23.25	32 ± 12
20.85	47 ± 20	23.45	17 ± 10
21.05	48 ± 19	23.65	7 ± 8
21.25	35 ± 18	23.85	6 ± 3

Integrated cross section = 0.21 ± 0.04 $mb.sr^{-1}$

"Energy distributions of alpha particles from $^{160}Dy(n,\alpha)^{157}Gd$, $^{162}Dy(n,\alpha)^{159}Gd$ and $^{164}Dy(n,\alpha)^{161}Gd$ reactions at 18 MeV".

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Using semiconductor α-particle spectrometer [1] the energy distributions of alpha particles from $^{160}Dy(n,\alpha)^{157}Gd$, $^{162}Dy(n,\alpha)^{159}Gd$ and $^{164}Dy(n,\alpha)^{161}Gd$ reactions at 18.15 ± 0.12 MeV have been measured. The neutrons were obtained from $^{3}H(d,n)^{4}He$ reaction with deuterons accelerated in the Van de Graaff accelerator. The flux of neutrons was monitored by counting the recoil protons knocked from a thin polyethylene foil. Recoil protons were registered by a CsI(Tl) scintillator followed by photomultiplier and standard electronics. The accuracy of neutron monitoring was better than 2%.

Samples of ^{160}Dy, ^{162}Dy and ^{164}Dy were made of oxides and deposited on thick carbon backings by means

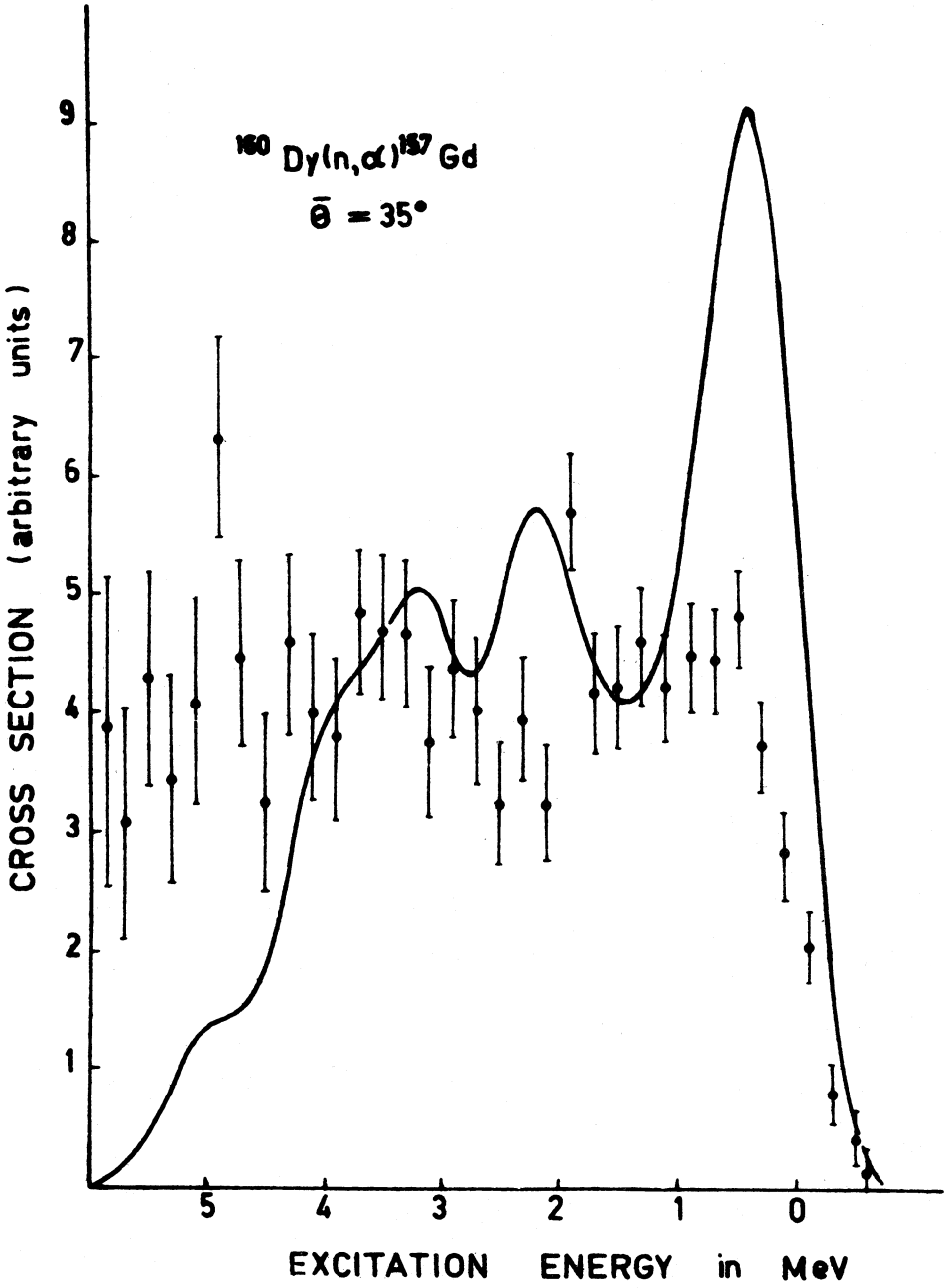
^{160}Dy(n,α)^{157}Gd
$\bar{\theta}$ = 35°
CROSS SECTION (arbitrary units)
9
8
7
6
5
4
3
2
1
5
4
3
2
1
0
EXCITATION ENERGY in MeV

fig. 1

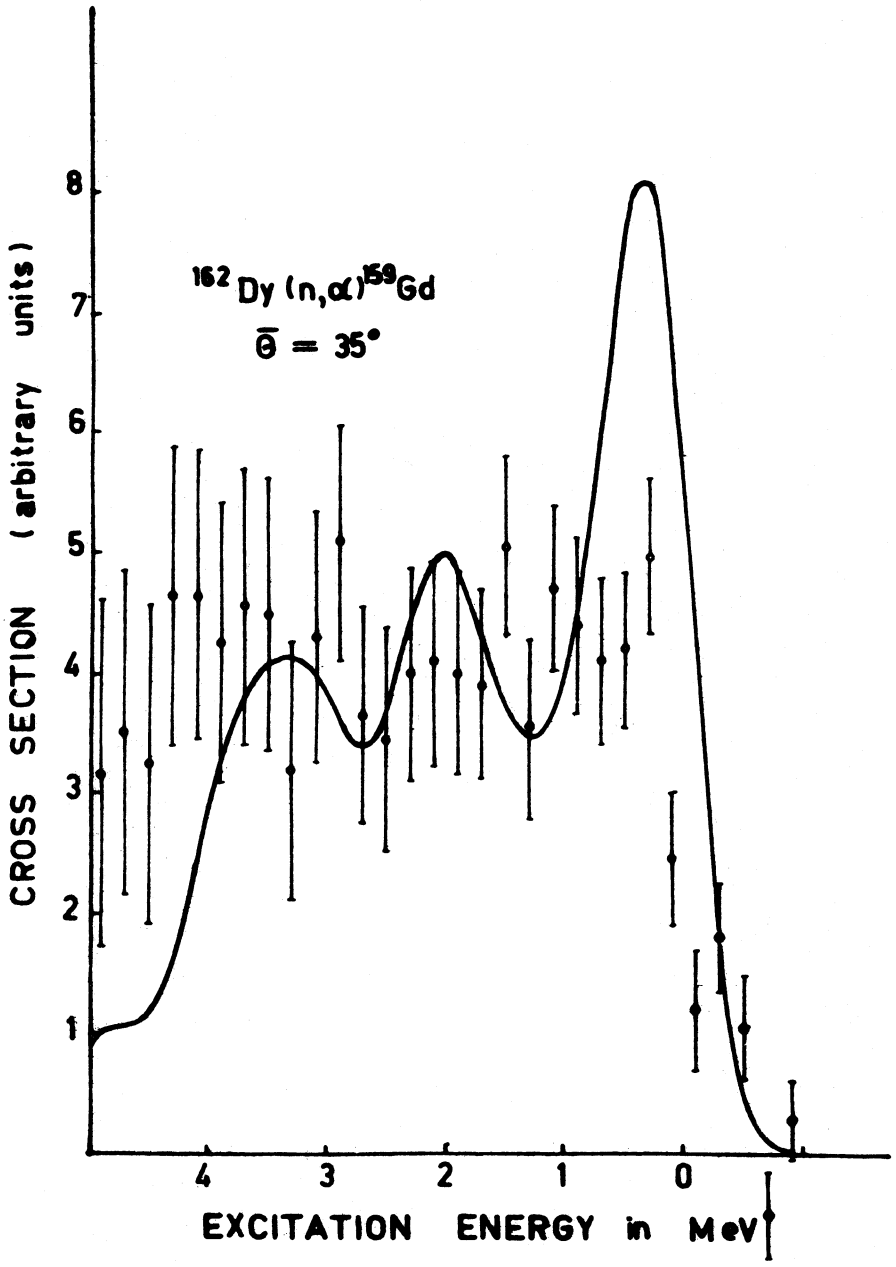
^{162}Dy (n,α)^{159}Gd
$\bar{\theta}$ = 35°
CROSS SECTION (arbitrary units)
8
7
6
5
4
3
2
1
4
3
2
1
0
EXCITATION ENERGY in MeV

fig.2

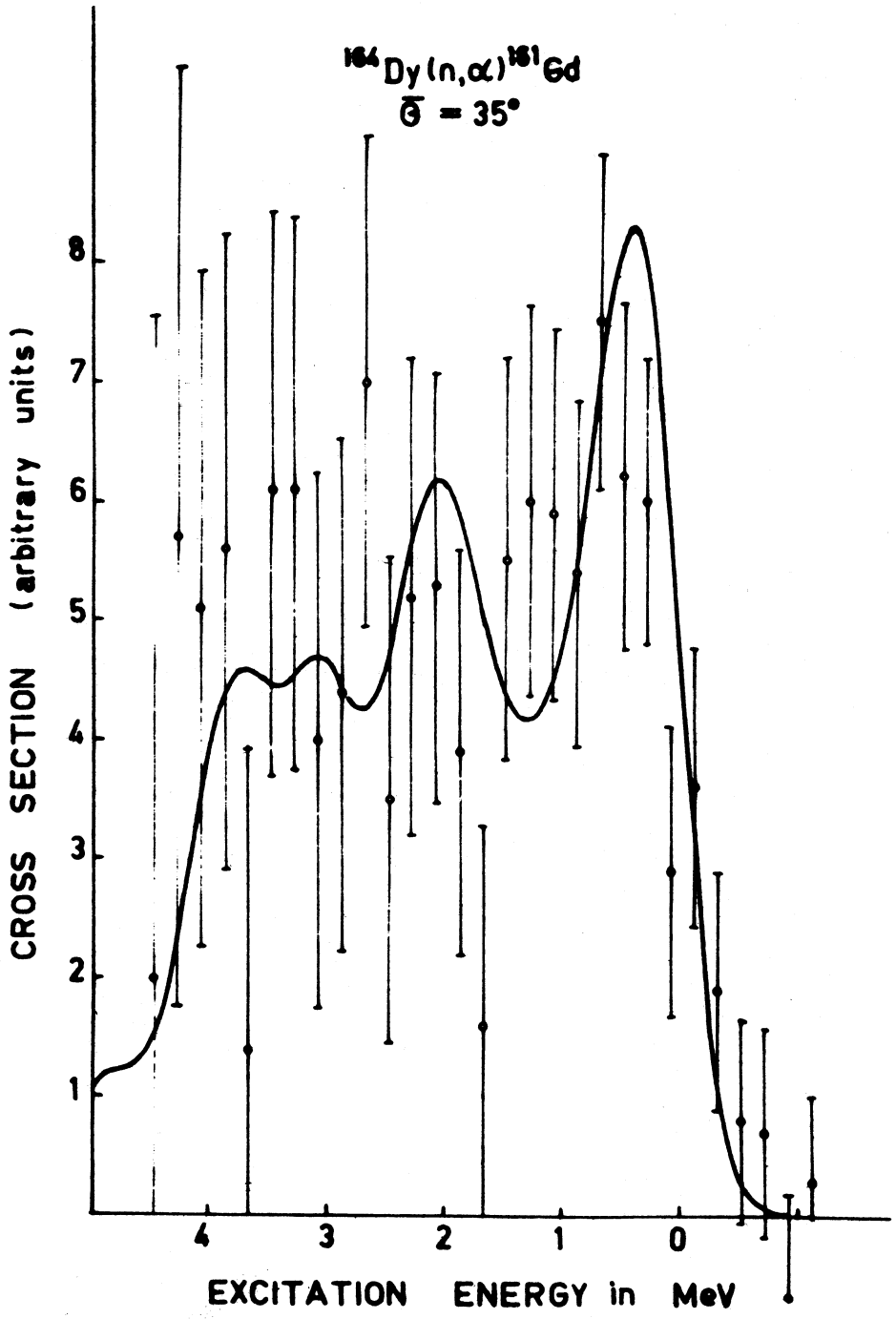
$^{164}Dy(n,\alpha)^{161}Gd$
$\bar{\theta} = 35°$
CROSS SECTION (arbitrary units)
1
2
3
4
5
6
7
8
4
3
2
1
0
EXCITATION ENERGY in MeV

fig. 3

of sedimentation from suspensions in isopropyl alcohol.

The results of measurements are shown in figs.1-3. All spectra were measured for forward angles with average angle equal to 35°. The error bars in figures refer to statistical errors only.

In the figs. 1-3 the results of the calculations based on direct reaction mechanism [2] are also shown. In these calculations the knock-on mechanism was assumed.

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"Calculation of the energy spectra of alpha particles emitted during (n,α) reactions induced by 14 MeV neutrons in rare earth nuclei".

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It is now well established that the emission of α-particles under fast neutron bombardment in heavy nuclei ($A \geq 120$) cannot be explained by means of the compound nucleus mechanism. In the last progress report [1] we have described a method of the energy spectra calculations based on direct reaction mechanism. In this model incident neutron knocks the alpha particle from the target nucleus and occupies the one-particle state in final nucleus. To describe this type of reaction the corresponding triangular graph of the disperssion theory [2] have to be calculated. We have shown that the experimental energy spectrum of α -particles from the $^{162}Dy(n,\alpha)^{159}Gd$ reaction at 14 MeV is in a good agree-

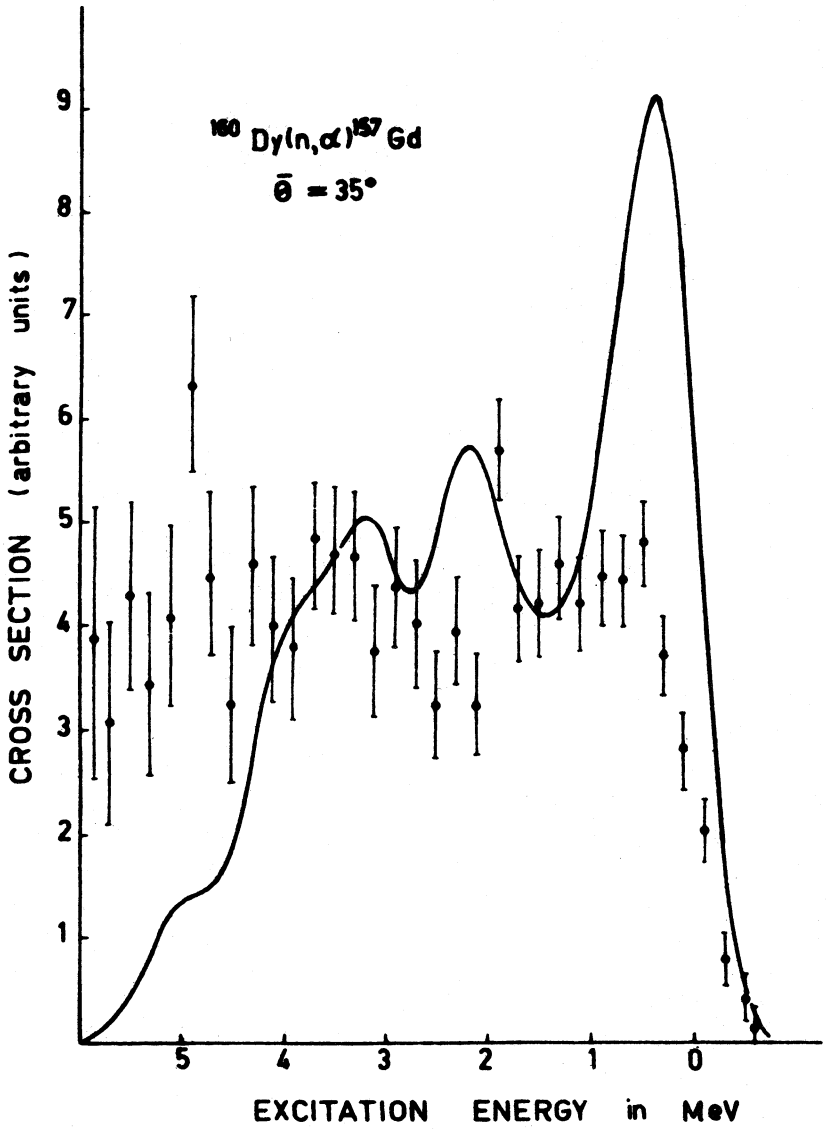

Fig.1 Comparison of the calculated relative cross section (full line) with experimental data for the $^{160}Dy(n,\alpha)^{157}Gd$ reaction. The experimental resolution a is equal to 400 keV. The positions and the heights of the lines denote the energies and knock-on cross sections of single-neutron in the final nucleus. The asymptotic quantum numbers of Nilsson states are indicated above.

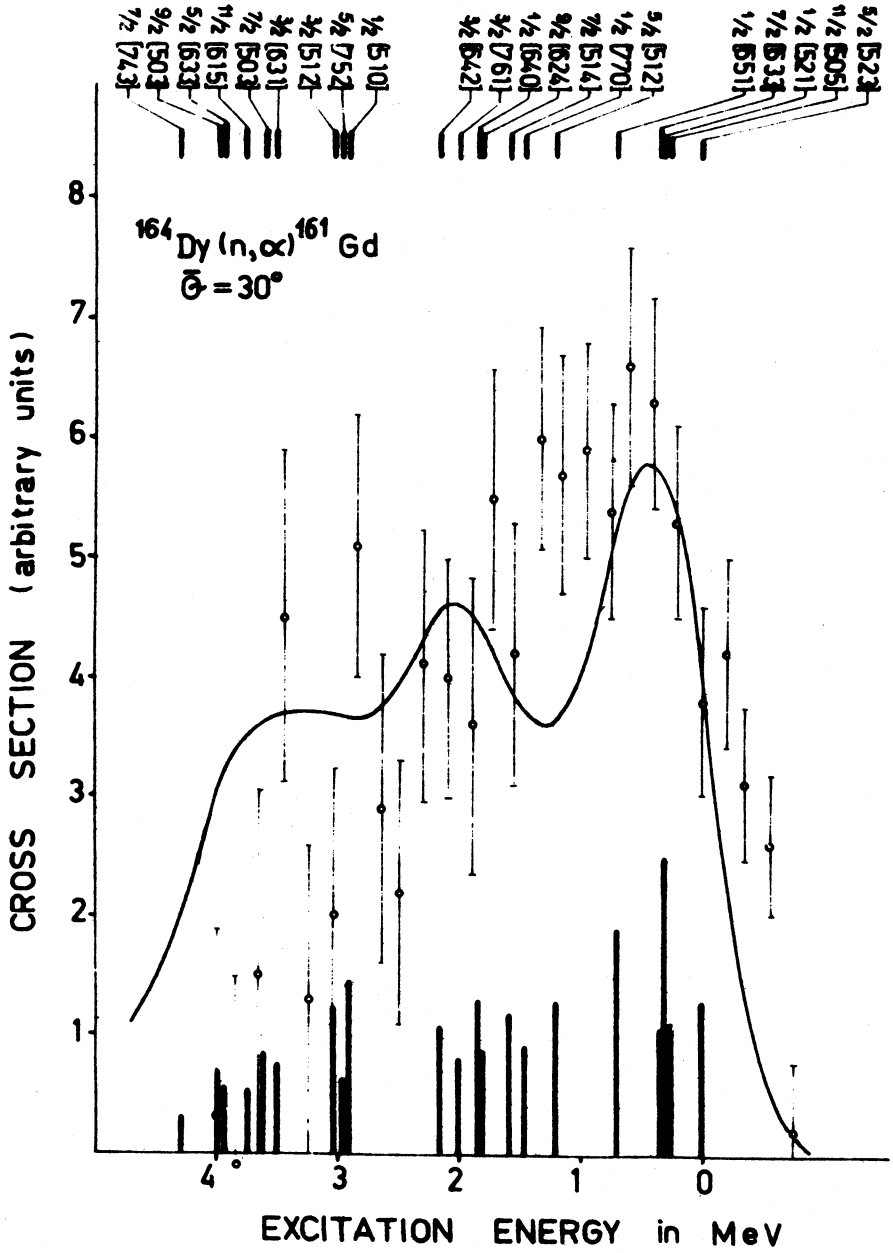

Fig.2 The $^{164}Dy(n,\alpha)^{161}Gd$ reaction. The experimental resolution a is equal to 380 keV. For other explanations see fig.1.

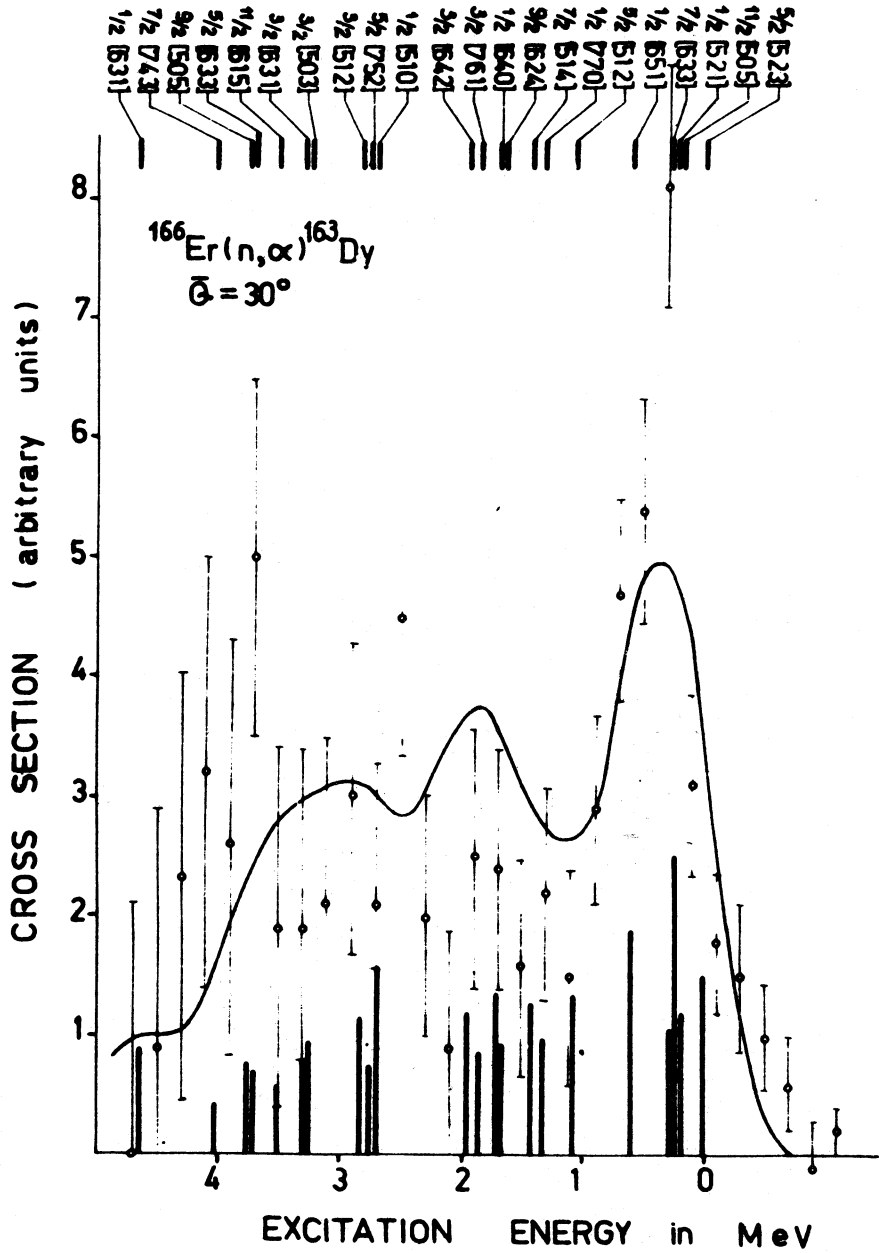

Fig.3 The $^{166}Er(n,\alpha)^{163}Dy$ reaction. The experimental resolution a is equal to 300 keV. For other explanations see fig.1.

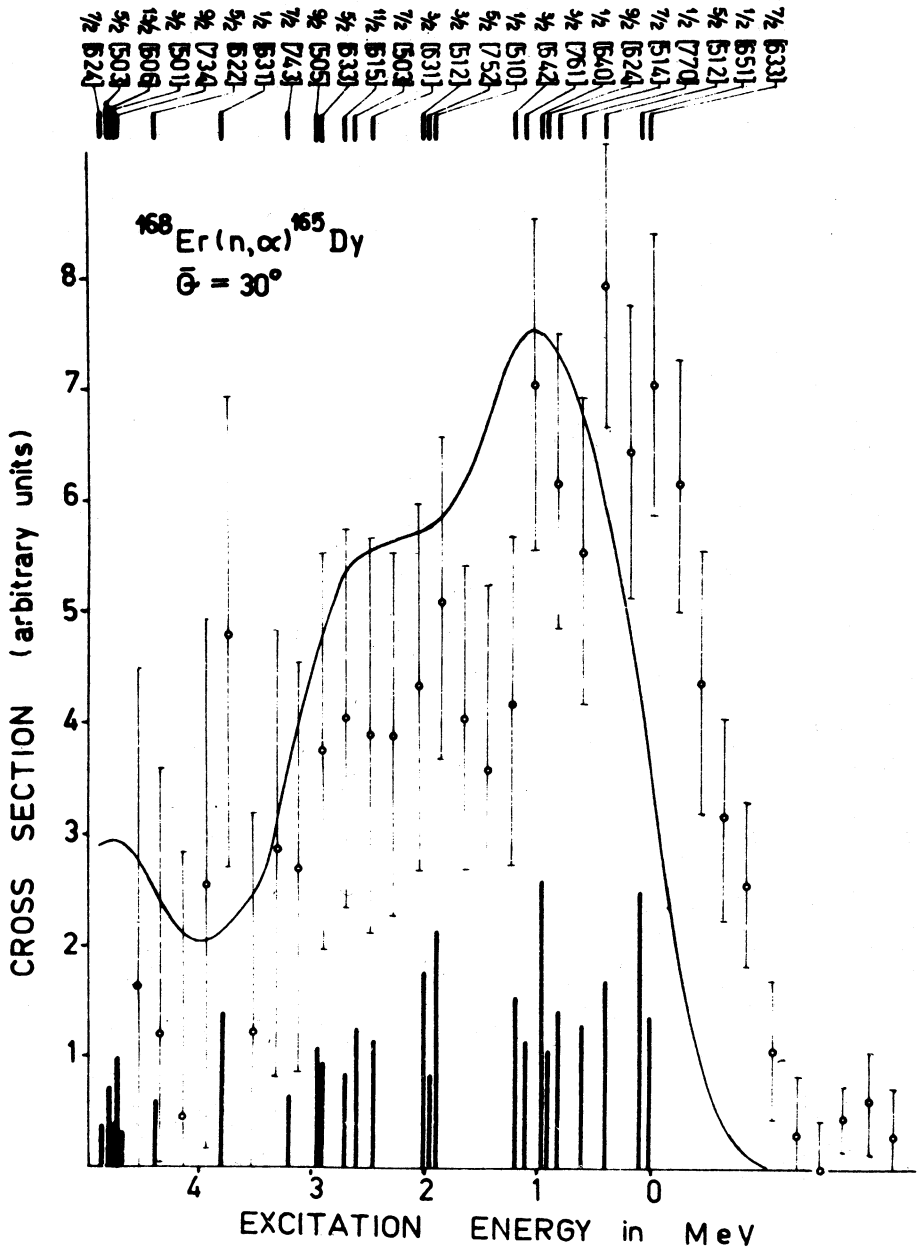

Fig.4 The $^{168}Er(n,\alpha)^{165}Dy$ reaction. The experimental resolution a is equal to 400 keV. For other explanations see fig.1.

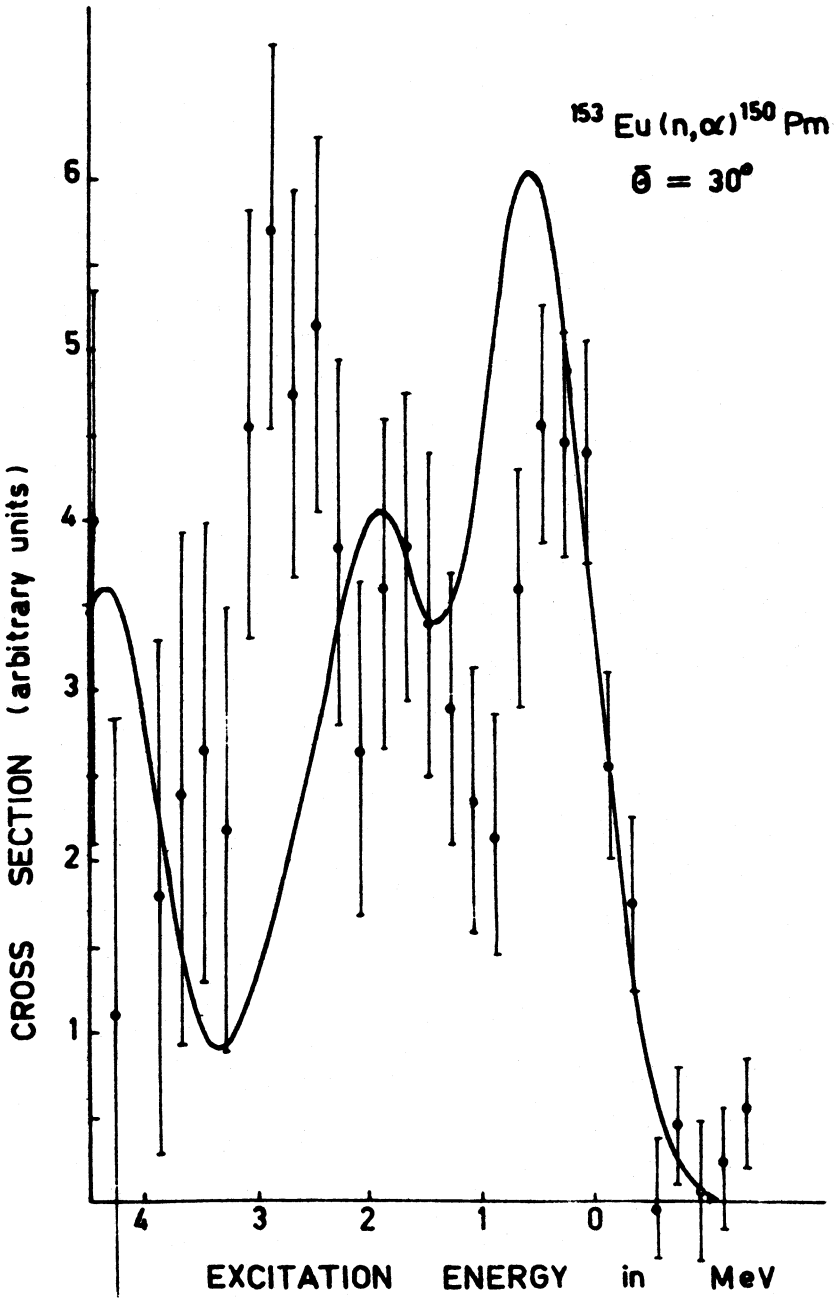

Fig.5. The $^{153}Eu(n,\alpha)^{150}Pm$ reaction. The experimental resolution a is equal to 400 keV.

ment with the predictions of the model.

In this report we present the results of further calculations performed for $^{153}Eu(n,\alpha)^{150}Pm$, $^{160}Dy(n,\alpha)^{157}Gd$, $^{164}Dy(n,\alpha)^{161}Gd$, $^{166}Er(n,\alpha)^{163}Dy$ and $^{168}Er(n,\alpha)^{165}Dy$ at neutron energy equal 14 MeV. The calculated spectra are compared with the experimental data obtained in our laboratory [3] .

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The nature of "polar emission"

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Surprisingly high rate of α-particles going along the fission line [1/] has been observed. According to our hypothesis this phenomenonis a manifestation of existence of others than the neutron and γ-ray deexcitation channels of the excited fission-fragments. The performed calculations show, that the experimental spectrum and intensity of alphas emitted along the heavy fragments-flight direction can be explained assuming the in-flight evaporation from these fragments if using the known from other sources data on excitation energy distribution, spin distribution, density of levels parameter, binding and pairing energies, mass and charge distributions in fission, moment of inertia optical model parameters etc. As concerns the alphas emitted in the same direction as the light fragments, their spectrum can be explained also , when taking into account the deformation of these fragments. However, for the interpretation of the intensity and of the angular distribution, rather unreasonable low value of the moment of inertia / $\sim$ 0.3 of $\mathcal{J}_{rigid}$/ should be assumed. The calculations for "polar" particles other then alphas were performed as well and, in particular

an anticipated value of the ratio of $^{6}He/^{4}He$ intensities is by about 2 orders of magnitude smaller than in the tripartition of ^{236}U.

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Phys. Lett. 33B /1970/ 568.

"Investigation of the energy threshold of neutron registration in dielectric track detectors".

Krystyna Józefowicz

Reactor Physics Dept., Institute of Nuclear Research

In the Reactor Physics Department the dielectric track detectors are investigated, especially for the neutron fluence measurements. It is possible, among others, to detect neutrons by recording in polymer foil the tracks of recoil atoms, produced in elastic collisions of neutrons with the constituent atoms of detector. In order to establish the energy threshold and detection efficiency of neutron registration by recoil atom tracks the examined detectors (Makrofol E polycarbonate foils) have been irradiated with known fluences of monoenergetic neutrons.

The Van de Graaff accelerator "LECH" was used to obtain monoenergetic neutrons of 0.6 to 2.2 MeV energy from $T(p,n)^3He$ reaction. Thin tritium target was used. The neutron fluence was monitored with BF_3 "long" counter in all irradiations and moreover with fission track detectors for higher energy neutrons.

The irradiated foils were etched with 6.25 N NaCH

or KOH water solutions at 60°C. The number and size of tracks is now examined under the microscope for particular neutron energy, etching solution and etching time. The results (series of curves) will enable to determine the energy threshold and efficiency of neutron registration as well as to optimize the etching conditions.

"Calibration of proportional counters used in neutron spectrometry ".

Lesław Adamski

Reactor Physics Dept., Institute of Nuclear Research

A fast-neutron spectrometer has been developed in the Reactor Department for the investigation of reactor neutron spectra in fast multiplying media. The spectrometer consists of a spherical hydrogen-filled proportional counter 1 and an appropriate electronic system/ fast amplifier, n-gamma discriminating unit, two-dimensional analyzer etc./.

A series of spherical counters of various size and various hydrogen pressure has been constructed in the Nuclear Electronics Department of the INR. For each counter some instrumental spectra must be found for various energies of incident neutrons.

For this aim the Van de Graaff accelerator was used. Monoenergetic neutrons of 0.35 to 0.60 MeV energy range were obtained in a thin tritium target, using the $T(p,n)^3He$ reaction. The results of these calibrations were used after numerical processing in the unfolding of proton-recoil spectra, which are obtained in the

counters placed in the neutron multiplying media.

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Energy levels of ^{228}Th excited in the decay of ^{228}Pa

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Joint Institute of Nuclear Research, Dubna, USSR

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x/ Institute of Nuclear Physics, Cracow, Poland

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xxx/ Institute of Physics, Jagiellonian University, Cracow, Poland.

Abstract: The decay of ^{228}Pa has been studied by various techniques. Singles spectra of γ- and K X-rays have been measured with Si/Li/ and Ge/Li/ detectors. A set of two Ge/Li/ detectors has been used to study γ-γ and γ- K X-ray coincidences. Measurements of γ spectra in coincidence with selected internal -conversion lines have been carried out with a Ge/Li/ detector and a six-gap magnetic β spectrometer .

Finally, spectra of internal-conversion electrons have been studied in a β spectrometer which uses a Si/Li/ detector placed together with a system of diaphragms in a homogeneous magnetic field. The ^{228}Pa decay scheme has been constructed including 39 levels of ^{228}Th. It accounts for 111 of 160 transitions ascribed to the ^{228}Pa activity. The electron-capture decay energy has been determined to be $2103 \begin{smallmatrix} +16 \\ -12 \end{smallmatrix}$ keV. The strength distribution of the electron-capture feeding of the ^{228}Th levels is analysed in terms of current nuclear models.

The ^{228}Th levels below 1500 keV are grouped into 8 rotational bands. Four of these bands are believed to be related to the K = 0, 1, 2 and 3 octupole vibrations. Relative positions of the levels ascribed to the octupole bands can be reproduced rather well, provided that the theory takes into account the effect of Coriolis coupling. From the best-fit condition, the coupling matrix elements are found to be: A_{01} = 31.5 keV, A_{12} = 21.5 keV and A_{23} = 35.5 keV, while the unperturbed moment-of-inertia parameter, assumed the same for all octupole bands, is A_{-} = 8.34 keV. The values of coupling matrix elements are compared to the predictions of microscopic calculations. The paper is under preparation.

Progress Report on Nuclear Data Activities in Romania 1971

Compiled by S. Râpeanu and N. Mateescu

1972

PRINCIPLES CONCERNING THE ORGANIZATION OF THE NUCLEAR DATA LABORATORY

N.Mateescu, S.Râpeanu, A.Bădescu-Singureanu,
D.Gheorghe, S.Mateescu

I. INTRODUCTION

The limited preocupations of various laboratories in the field of nuclear data became unsufficient compared with the development of nuclear applications especially in energetics on industrial scale. This represented the decisive element for the setting up of some national and then international laboratories specialized in collecting, treating and dissiminating of nuclear data.

In order to increase the capability of exchanging the huge amount of compiled and evaluated nuclear data it was necessary to create the Nuclear Data Section of the I.A.E.A. (and other international centers).

Although the N.D.S. center offers the access to many types of data, those countries which have a nuclear power programme and want to develop their own library must take into account the experience of the most developed ones as U.S.A. U.S.S.R. and England, beyound the N.D.S. recommendation.

II. THE LABORATORY OF EVALUATED NUCLEAR DATA

The purpose of this laboratory, from the general point of view, is to offer the evaluated nuclear data to the user in an appropriate form.

The role of the laboratory is of an intermediate between the producer and the user of nuclear data. By this role we understand the achievement of :

a) a concrete and coherent research programme, able to answer to the present and long-term necessities,

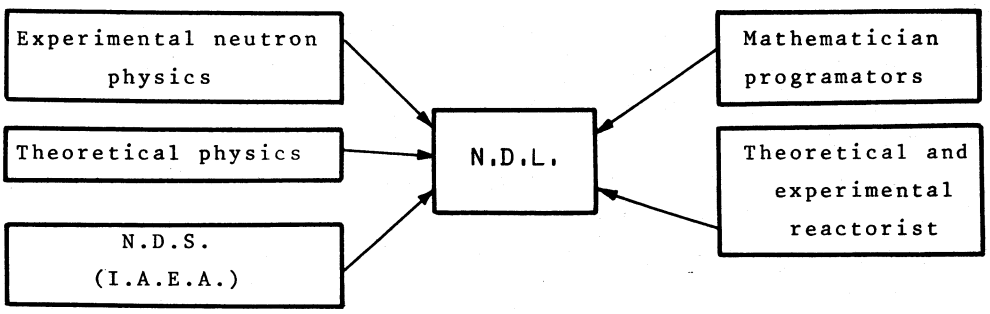
b) an effective control of the whole source of information and exchange of information concerning the nuclear data (including the exchange with the I.A.E.A. center).

c) the elimination of the discordance between the way in which the compiled data are offered and the way in which the respective data are necessary (especially the adequate data for computing the group constants),

d) as much as possible to provide the user with those data which cannot be obtained by the help of the I.A.E.A. center.

The main and immediate task of the laboratory as a result of the above mentioned consideration is to set-up a *library of microscopic evaluated nuclear data* in which these data should be accessible in the specific forms.

The connections of the nuclear data laboratory with other laboratories or centers are schematically established as it follows.



Organization

The laboratory will be divided into working team as follows :

a) The team specialized in the organization of the data format, the procedure to be used for storing, changing and retrieving of the data. First, this group must adapt one of the existing formats to our requirements and possibilities and to the interna-

tional panel recommendation [1]. In addition they will adapt the associated computer programmes.

This team must include minimum three specialists among which a mathematician.

b) The evaluators team which has the tasks to establish isotopes, elements or mixture for which the data are to be evaluated and to make the proper evaluation. They will depend on the documentation offered especially by the I.A.E.A.. After the evaluation has been accomplished they introduce them into the library and check them.

This group must be composed at least of physicists specialized in thermal, resonance and fast neutron physics. The consultant physicists and the collaborators in the field of theoretical physics, nuclear reactions and nuclear reactor design are to join them.

The formats for the library will follow the main line of the most developed national library as ENDF/B (U.S.A.),U.K.N.D.L. (U.K.) and KFK (F.R.G.). The adaptation of one of these national library formats to our computer possibilities and to our necessities will maintain the flexibility, the accuracy in the cross - section description, methods of checking the evaluated data,method of interpolation as far as the possibility of a quick up-dating of the stored data.

All stored data will be accompanied by an adequate documentation and justification about the evaluation procedure. The library output must be able to provide data in various forms as required by uses.

Evaluation activities

As is well known, that the evaluation work, roughly speaking, consists in a critical comparison of the compilated data in order to select them by specific averaging procedures.The evaluator is obliged to take into account the experimental techniques and the aspects connected to the fundamental physics.

Thus we should have a detailed documentation on the way in which the data have been obtained and to have a multilateral know-

ledge specific to an experimental physicist and theoretician.

The evaluating *objectives*, systematically presented by Schmidt [2], are :

a) To complete the gaps in the nuclear data within the field in which measurements have not been yet accomplished. This can be made by interpolation or extrapolation using the existing experimental points. The procedure can be done graphically,by theoretical models or by nuclear systematics. The last can be applied with great care and especially for interpolation between the neighbouring nuclei.

b) To make a consistent set of data.

The achievement of this requirement can be done by :

- reducing the available data to the same physical conditions ;
- trying to obtain all the cross-sections for the same energy ;
- checking the correctness of this data (for example whether the total cross-section is identical to the sum of the partial cross-section).

c) To remark systematic experimental errors. This is the most difficult task because the evaluators have to do a very careful study about the experimental conditions. Usually, because of the limitations of time and manpower this requirement can be fulfilled only for the most important cross-sections.

The main stages which are to be carried out by the evaluator are the following :

a) The bibliographical information using as source the CINDA system and N.D.S. required information.

b) The collected data should be stored temporary using an available format so as to allow various kinds of analyses as for exemple data selection, reduction to the same condition, renormalization, average procedures, comparison with theoretical models.

Regarding the comparison of experimental results with various theoretical models it is to be emphasized that at the beginning there will be applied only a few programmes :

- a parametrized programme for scattering low generation ;
- one level Breit-Wigner for resolved resonance ;
- a simplified optical and statistical model for fast neutrons.

We hope that in the next future, the international panel should be able to recommend a more or less standard model.

c) The treatment of experimental data, as was mentioned above, to obtain the recommended value. The consistency of this value are checked taking into account, as much as possible,all information concerning the corresponding element or isotope so that finally to obtain the consistent set of evaluated data.

d) The data should be stored in the library and then printed again to avoid some possible errors.

FINAL CONSIDERATIONS

From the above related situation, it results that the problem of the group constants has not been included in the laboratory of nuclear data. In order to avoid some comentaries and to make some precissions at the same time concerning the way of using the evaluated nuclear data, the following schema gives the key to the answer.

The A laboratory - Basic nuclear data laboratory for reactors ;
The B laboratory - Group constants
The C laboratory - Reactor calculations.

In fact this schema is practical the same for all nuclear research centres. In other words the principal user of nuclear data is the B laboratory which in his turn is strongly dependent of reactorist designers.

CONCLUSIONS

1. The existence of the evaluated microscopic nuclear data library is closely connected and organically integrated in the complex activities of the energetic nuclear programme.

2. The reactorist must handle very quickly a lot of data. Because the necessary systems of codes to handling the data within the various library in the world are not accessible, is necessary a proper system of codes.

3. There are certain difficulties in obtaining evaluated data from other countries.

4. The activity of evaluating nuclear data must be specialized in a certain field. The existence of some specific sets of evaluated data allows a exchange of other sets of data from other library centres in the world.

5. A direct collaboration with I.A.E.A. or other centres in some very well delimited field of evaluation activity should be recommended.

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NUCLEAR DATA ACTIVITIES AT THE INSTITUTE FOR NUCLEAR TECHNOLOGY

S.Râpeanu, I.Iftode and H.Stefan

Our institute was founded in July 1971 and involved especially in problems of reactor engineering. The institute is supplied with the necessary microscopic nuclear data from the Institute of Atomic Physics, mainly from the laboratory of nuclear data for reactors, which is charged with the preparation of a computerized library of the ENDF/B type. However, at INT there is a team of physicists charged with the production of group constants for reactor physics and shielding calculations.

The following facilities are available :

- access at the research reactor VVR-S ;
- access at the computers IBM 370/135, ICL 1905, IBM 360/40 ;
- a PDP 15 on-line computer, ordered from the company ;
- a spectrometer with recoil protons of own design and construction, now in stage of routine operation ;
- experimental device with adjustable fast spectrum in construction ; the spectrum can be computed with high accuracy,due to the geometrical simplicity, by means of a SN code ;
- auxiliary equipment.

The nuclear data activities go towards two main directions:

A <u>Group constants</u>.

A_1 a code for generation of resonance cross-section and shielding factors in the σ_o- concept is under testing.

A_2 another code under testing is a THERMOS-like code to produce thermal group constants for reactor cells with slightly enriched uranium. The code averages the spectrum over the mains re-

gions of the cell (fuel, cladding moderator), the running times being thus with an order of magnitude smaller than of the usual THERMOS codes ; that makes it suitable for reactor optimization studies. The number of groups is optional.

A_3 - several other codes under testing are meant to produce, among others, reactor group constants for light and heavy water power plants.

A_4 - in an early stage it is a B_1 code for calculation of within group fluxes and currents to be used as weighting functions in the cross-section collapsing calculations. This is made for several reactor block compositions and has a large variety of edits.

A_5 - it is intended to assimilate a MC^2 - like code for production of group constants directly from the nuclear data files.

B <u>Nuclear data measurements</u>

B_1 - experiments to measure the scattering cross-section of several reactor materials in the fast range are proceeding.

B_2 - it is performed a program of "dirty" nuclear data measurements, such as spectral indexes with activation detectors, resonance integrals, etc.

THE STRUCTURE IN THE $F^{19}(\gamma,xn)$ REACTION CROSS SECTION

D.Catană, G.Baciu, C.Iliescu, V.I.Opriş, M.Orbeşteanu

The cross section of the photoneutron and photoproton reactions as well as the photoabsorption on fluorine have been treated in many papers [1-3].

The main purpose of this work is to investigate the F^{19} (γ,xn) reaction cross section, in the energy interval 11-26 MeV, with a bin of loo keV in measuring of the yield curve. The cross section was obtained by the help of Penfold and Leiss method.

The experimental results are compared with the photo - absorption cross section computed using the single-particle wave functions of an anisotropic harmonic oscillator.

Experimental procedure

The $F^{19}(\gamma,xn)$ reaction yield was measured with the I.F.A. betatron in the energy range from 11.2 MeV up to 26 MeV the maximal betatron energy. The yield curve have been measured with a bin of loo keV, and the statistical errors on the whole were less than 1%.

The experimental procedure was extensively described in a paper [4] and here we give only those data which relevant for this reaction.

The fluorine sample was a disc from chemically pure teflon the effective thickness was o.824 g/cm^2. The contribution of the C^{12} (γ,n) reaction was substracted (the yield curve of this reaction was measured in the same conditions).

The stability of the energy control system was checked by reference to the 17.28 MeV - break in the $O^{16}(\gamma,n)$ yield curve and was constant during the experiment within + 15 keV.

The dose dependence vs. maximal energy point of bremsstrahlung has indicated an effective thickness of the Pt betatron target of o.15 mm (o.312 g/cm^2).

Results

The cross section of the reaction has been computed using Penfold and Leiss method with the B numbers for a thick Pt target (o.312/g/cm^2) in forward direction for bremsstrahlung spectrum.

In fig.1 is given the cross section of $F^{19}(\gamma,xn)$ reaction and the total photoabsorption cross section reported by Dolbikin [5].

If we suppose that the cross section of $F^{19}(\gamma,p)$ reaction has the same order of magnitude as the cross section of $F^{19}(\gamma,n)$ reaction, the using of the thick-target bremsstrahlung spectrum should be more realistic.

For the calculation of the total photoabsorption cross section we have started from the model proposed by Spicer [6]. A computation of possible E_1 transition energies in F^{19} was made, using the Nilsson level schema and treating F^{19} as a deformed nucleus in which single-particle excitation can occur alone or together with a collective rotational excitation. In the calculation of transition energies the pairing energy was included. The main assumption is that the nuclear deformation is the same both in the ground state and in excited states. The ground state deformation parameter was taken o.43.

The integrated computed cross section from 9 MeV to 3o MeV is of 381 mb.MeV, while the dipole sum rule gives for an exchange parameter K = o.5 a value of 398 mb.MeV.

The electric dipole photoabsorption cross section is shown also in fig.1

A comparison between the cross sections indicated a satisfactory agreement both in position of the peaks and in their amplitudes.

In conclusions, the use of thick target bremsstrahlung spectrum in the forward direction, when the γ beam is very well collimated should be more realistic than Schiff spectrum.

On the other hand, this measurement shown the ability to resolve resonances of the order of o.5 $\pm$ 1 MeV width in (γ,xn) cross sections in the high energy region and narrower in the low energy one, when bremsstrahlung is used as a photon source.

A computation of the E_1 photoabsorption cross section based on the single particle and rotational excitation using Nilsson levels has shown itself to be capable of explaining the kind of resonance structure which is observed in experimental photonuclear cross sections of fluorine.

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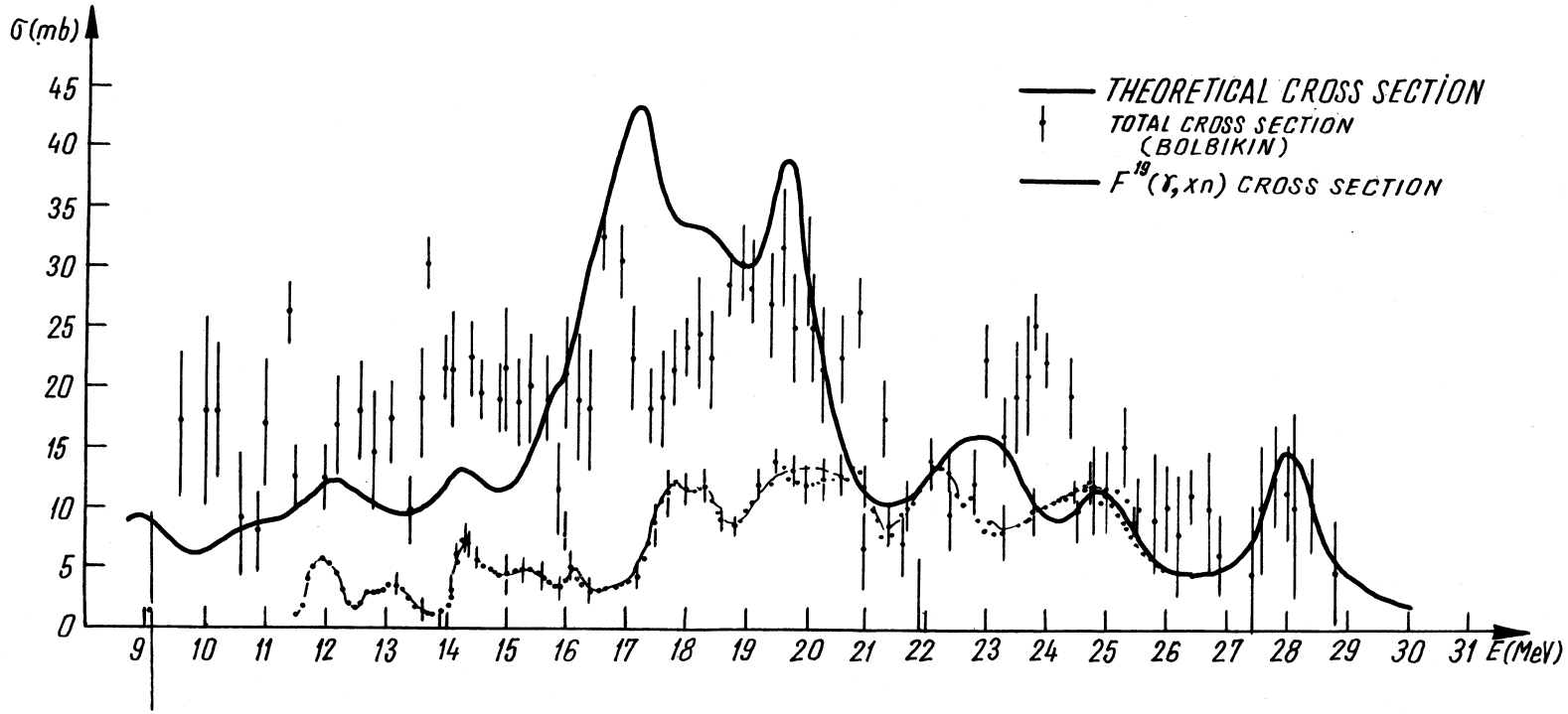
σ(mb)
45
40
35
30
25
20
15
10
5
0
9
10
11
12
13
14
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16
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18
19
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22
23
24
25
26
27
28
29
30
31
E(MeV)
THEORETICAL CROSS SECTION
TOTAL CROSS SECTION (BOLBIKIN)
F19(γ,xn) CROSS SECTION

Fig.1.

MAGNETIC SCATTERING OF NEUTRONS IN $MnPt_3$

D.Bally, Z.Gheorghiu, M.Toţia

S.J.Pickart*

The temperature dependence of the small-angle magnetic scattering of neutrons in $MnPt_3$ (ordered phase) in a large domain of wave-vector values was investigated. The scattered neutrons were detected by BF_3 counters. The experimental data were corrected both for angular resolution and for inelasticity. The sample was introduced in a 4 kOe magnetic field parallel to the scattering plane. The experimental data show that for $T \lesssim T_c$ and $\varkappa \leqslant 0.08\ A^{-1}$ the scattering is mainly determined by the interaction of the neutrons with the collective modes. Significant scattering due to the spin waves observed up to sufficiently large $\varkappa$ values is in a good agreement with the recent results of the magnetic structure studies on $MnPt_3$ (to be published). An anomalous behaviour of the magnetic diffuse scattering was noticed near T_c. This result is strongly correlated with the temperature dependence of the individual scattering properties of the atoms in the magnetic lattice in the neighbourhood of the Curie point.

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THERMAL NEUTRON SCATTERING IN LIQUID BISMUTH

D.Bally, D.Gelberg, V.Tarină

Thermal neutron elastic scattering experiments on molten Bismuth have been carried out. The structure factor of the liquid was measured in a range of the wave-vector transfer value within 0.5 - 9.5 $Å^{-1}$. The measurements were made using neutrons of wavelength 1.15 Å and BF_3 counters. The resolution of the used diffractometer was about 2%. The sample was kept at a temperature of 300°C. The radial distribution function was obtained and interpreted on the basis of existing theories.

ABSOLUE DETERMINATION OF ^{235}U FISSION CROSS-SECTION FOR 2200 m/s NEUTRONS

C.Borcea, A.Borza, A.Buţă, F.Cîrstoiu, L.Marinescu, I.Mihai
I.M.Mihăilescu, M.Petraşcu, V.Savu, V.Simion, T.Năşcuţiu

An absolute ^{235}U fission cross-section measurement was performed applying a method elaborated in our institute [1,2]. In this method is avoided the knowledge of an intermediate cross - section for the neutron determination.

For the absolute cross-section measurement the determination of the following quantities is necessary : the neutron flux, the detection efficiency of fission events and the density of nuclei in the target.

The neutron flux was determined by using a thick ^{10}B target, the neutron being detected through the 477.4 keV gamma rays of ^{7}Li counted with a NaI spectrometer. The gamma ray detection efficiency was determined in the following way : at the same place where the boron target would be placed a gold foil of the same area and shape was irradiated with neutrons. After irradiation, the gold 412 keV line was recorded in the same geometry as the 477.4 keV line. Subsequently the activity of the irradiated gold foil was measured absolutely with a $4\pi\beta$-γ counter.

The efficiency of fission fragments detection was determined using two ^{235}U targets (a thick and a thin one) in two ionization chambers, counting the number of events corresponding to the thick and thin targets, and knowing the ratio between the target densities, and the efficiency of one ionization chamber (100% for the thin target).

The density of ^{235}U nuclei in the targets was determined from alpha activity, measured in a 2π geometry, using a gas flow pro-

portional counter. The isotopic composition was determined with a mass-spectrometer. An accuracy of 0.52% concerning ^{234}U was obtained.

The measurements were carried out at an horizontal channel of the VVR-S reactor in Bucharest, the 2200 m/sec. neutrons being selected by the time of flight technique. The determined value for fission cross-section is 581.7 $\pm$ 7.8 barns.

This work was performed under a research contract supported by CSEN - Bucharest.

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[2] C.Borcea, A.Borza, A.Buţă, A.Isbăşescu, L.Marinescu, I.Mihai, T.Năşcuţiu, M.Petraşcu, V.Savu, V.Simion, Rep.I.F.A. NR-33 (197o)

FAST NEUTRON CROSS-SECTION OF ^{24m}Na

D.Ploştinaru, E.A.Ivanov, A.Iordăchescu, S.Vajda,
Gh.Pascovici

In the literature there was given the cross-section of ^{24m}Na, excited by $^{23}Na(n,\gamma)$ reaction, only for thermal neutrons [1,2]. We have measured this isomeric cross-section at several neutron energy between 1 MeV and 4 MeV. The pulsed beam technique we have used. A ^{7}Li target has been irradiated with proton beam (width lo ms, repetition time 1 s) and so obtaining bursts of fast neutrons. In the pauses between the bursts it were recorded spectra at some different time intervals, the spectra containing the 4472 keV γ-ray from decay of ^{24m}Na.

Two methods of bombarding and recording have used :1)with an external probe and with Ge(Li) and NaI(Tl) detectors, the last shielded for the direct neutron flux, 2) internal irradiation, when the NaI(Tl) detector crystal was also as target. The final results was obtained by the second method, which has a higher efficacity than the first one. In this case an absorber was used against the 472 keV γ-ray.from the decay of ^{7}Be, excited by ^{7}Li (p,n) reaction.

The experimental results obtained at three different fast neutron energies are the following : σ_m = o.1 $\pm$ o.o4 ; o.1 $\pm$ o.o4 and o.12 $\pm$ o.o4 mb. at the neutron energies of o.92; 2.28 and 3.95 MeV, respectively. The great errors are due to the correction imposed by the experiment, the principal correction being from the background which is produced by the difused neutrons, and from the imprecisely known of the detector efficacity for an internal source uniformly distributed in the crystal. The experimental errors can be decreased by rearanging the cyclotron experiments room, increasing the detector - difusing pieces, distance.

REFERENCES

[1] K.F.Alexander and H.F.Brinckmann, Annalen der Physik 12, 225 (1963)

[2] L.V.Groşev et all, First Geneva Conference, 2, 39 (1955)

CALCULATION OF ELASTIC AND INELASTIC CROSS SECTION ON ^{60}Ni AND ^{32}S

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Differential cross sections for elastic and inelastic ($Q = -1.33$ MeV) scattering on ^{60}Ni for E_n = 2,3,4,5,6.44, 7.54 and 8.56 MeV were calculated with optical model, Hauser-Feshbach statistical and DWBA method. Comparison are made to the experimental data of ref. [1]. Some details of calculations and model parameters were previously presented [2]. Good fits were obtained to the experimental angular distributions ($Q = o$, and $Q = -1.33$ MeV) at E_n = 6.44, 7.54 and 8.56 MeV.

The excitation functions for the integrated elastic and inelastic scattering cross sections are compared with the available experimental data in fig.1. The quality of the fit give some confidence for the predicted cross sections at lower energies, where the experimental data are lacking.

Similar results were obtained for ^{32}S at E_n = 2.45, 2.85, 4.o, 4.48 and 4.9 MeV.

This work is pertinent to request 373 of RENDA [3].

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[1] F.G.Perey, C.O.Rigoleur and W.E.Kinney, ORNL-4523 (197o)

[2] Annual Report on Nuclear Data Research in Romania, Comitetul de Stat pentru Energia Nucleară and Institutul de Fizică Atomică, Bucharest 1971

[3] RENDA, Compilation of EANDC Requests for Neutron Data Measurements EANDC 85 "U" (April 197o)

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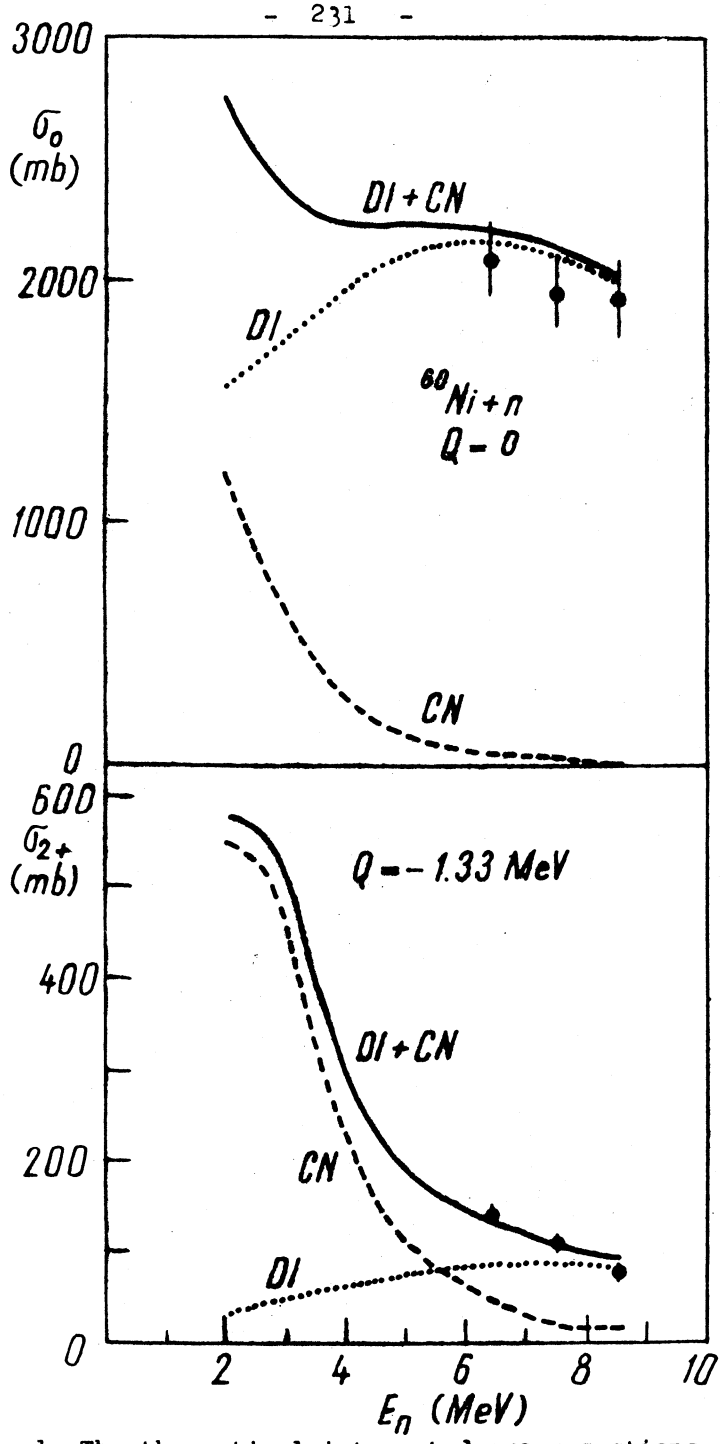

Fig.1. The theoretical integrated cross sections (full line) represent the sum of the direct interaction (dotted curves) computed by using the optical model (elastic) and DWBA (inelastic) and the compound nucleus contribution, computed with the Hauser-Feshbach theory (dashed curves).

OPTICAL MODEL CALCULATIONS FOR SCATTERING OF FAST NEUTRONS (8-15 MeV) BY Cr AND Fe

D.Bucurescu, M.Ivaşcu, D.Popescu, G.Semenescu, M.Titirici

Optical model calculations for neutrons of 8 to 15 MeV, with 1 MeV step were performed for the Cr and Fe nuclei, using both the average parameters of Wilmore and Hodgson [1], and those of Rosen et al [2]. The calculated angular distributions were compared to the existing experimental ones, at 8 MeV [3] and at 14 MeV (see [1]). Small differences between the two theoretical predictions are found at forward angles, while at backward angles the fit given by the potential of Rosen et al. (which containes also the spin -orbit interaction) is much better (fig.1). Thus, it appears that these optical model parameters should be preferred for calculations in this energy range, at least for medium weight nuclei.

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[1] D.Wilmore, P.E.Hodgson, Nucl.Phys. 55, 673 (1964)

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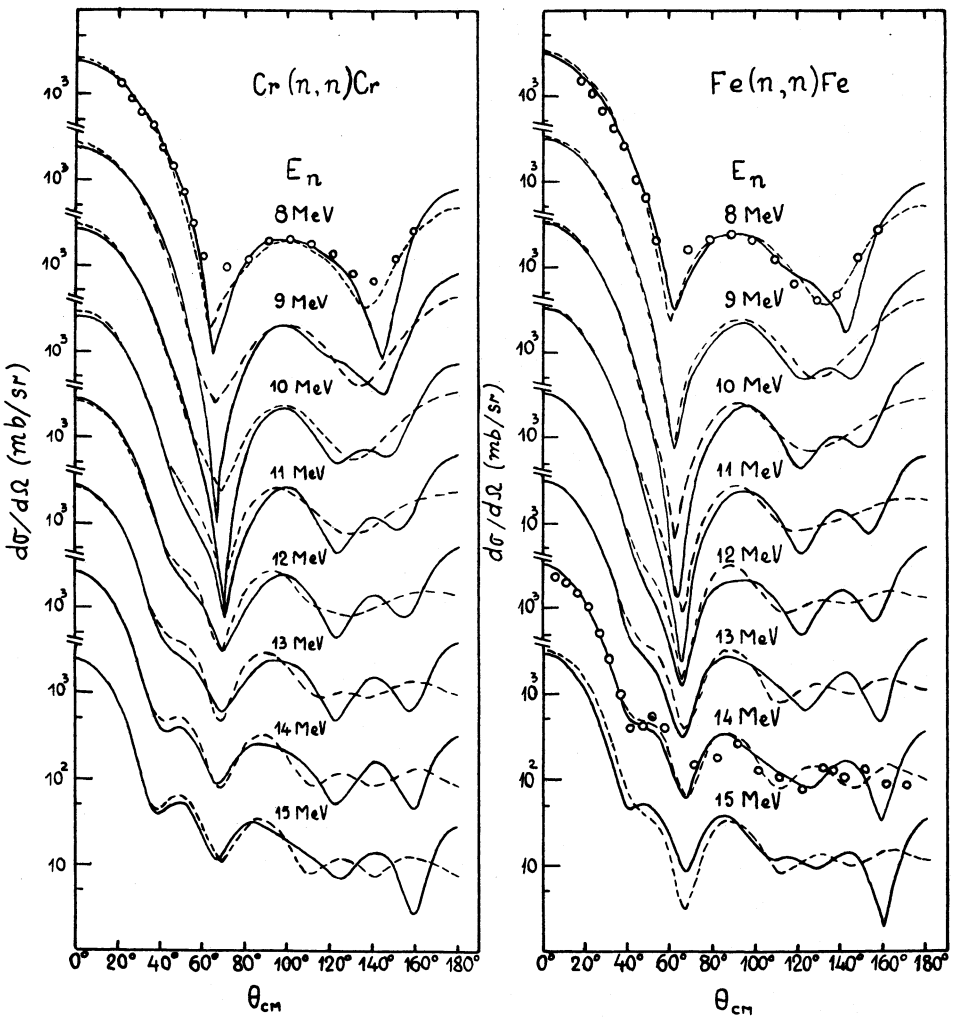

Figure 1. Optical model calculations. The full lines and the dashed lines represent the predictions of Wilmore - Hogson [1] and Rosen et al [2] potential, respectively. Experimental data are shown by circles.

Progress Report on Nuclear Data Activites in the Republic of South Africa 1971

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PROGRESS REPORT TO THE INDC

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Compiled by D. Reitmann

1. Southern Universities Nuclear Institute, Faure, Cape Province

A 5,5 MeV van de Graaff accelerator, equipped with terminal pulsing and klystron bunching, is used in a wide variety of nuclear physics experiments, including the following which are relevant to the field of neutron data:

1.1 Study of the level structures of ^{232}Th and ^{238}U using the (n,n'γ) reaction

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

Level structure information on these important nuclei is still surprisingly inadequate even at excitations below 1 MeV. The main source of information had been the Coulomb excitation studies of Stephens et al.[1] supplemented in the case of uranium by neutron scattering by Barnard et al.[2] The (n,n'γ) reaction has since been used to provide more detailed information than hitherto available.[3] Further measurements have been undertaken

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1) F.S. Stephens et al., Proc. third Conf. on Reactions between Complex Nuclei (University of California Press, 1963) p.303

2) E. Barnard et al., Nuclear Physics 80 (1966)46

3) W.R. McMurray et al., Int. Conf. on Nuclear Structures, Montreal (1969)

to provide the data reported here. Many of the new levels observed have also been deduced from recent studies of the decay of ^{239}Pa by Herrmann et al.[1] and from a study of the (n,n'γ) reaction undertaken by Poenitz[2].

The present work is based on γ-ray spectra obtained over several years using a time gated Ge(Li) detector to discriminate against neutron induced backgrounds with incident neutron energies between 700 and 1900 keV. New levels are assigned on the basis of the observed γ-ray energy, energy threshold, shape of the excitation curve and the associated γ-ray decays. Branching ratios have been corrected for the relative γ-ray detection efficiency and for the γ-ray attenuated in the sample. The uncertainty on the branching ratios is less than $\pm$ 10% except for the very weakest transitions.

Altogether 43 γ-rays were observed in the spectra from a ^{232}Th sample of which 35 have been assigned to levels in ^{232}Th. The other 8 gammas had low yields and poorly defined thresholds and only three of these appeared in spectra obtained below the effective fission threshold at about 1250 keV.

The γ-ray energy uncertainties are derived from the reproducibility of measurements alternated with careful calibrations. The precision of the measurements is also indicated by the level energies determined by different branches of the decay. The results for ^{232}Th are tabulated in Table I. The energy values for the first and second excited states, given as 49,5 $\pm$0,2 and 162,5 $\pm$0,2 keV respectively, were obtained from the decay branching. The position of the level at 1073,28 keV was established from complementary data provided by neutron time-of-flight measurements reported in Item 1.2 of this report. The observation here of new levels and of decay schemes which in significant aspects are different to those reported by Stephens et al, places doubt on their spin assignments and characterisation of collective bands in the level scheme at excitations greater than 700 keV.

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1) G. Herrmann et al., Proc. Int. Conf. on the Properties of Nuclei far from the region of β-stability (Cern, 1970) Vol. II p. 985

2) W.P. Poenitz, Argonne Applied Physics Annual Report 1969/70,p.24

TABLE I

Levels of ^{232}Th and their decay γ-rays deduced from (n,n'γ) measurements

Level Energy (keV)	γ-ray Energies (keV) (% branching in brackets)	Level Energy (keV)	γ- ray Energies (keV) (% branching in brackets)
0		1073,28 ±0,2	1023,78(100)
		1077,7 ±0,2	1077,7 (100)
49,5 ±0,2		1078,56 ±0,2	1029,06(100)
162,5 ±0,2		1094,7 ±0,2	1045,13(54) 932,25(46)
(333)		1105,75 ±0,2	1056,06(89) 943,45(11)
(555)		1122,04 ±0,2	1072,43(71) 959,55(29)
714,6 ±0,2	714,51(15) 665,25(85)	1143,44 ±0,2	980,94(100)
730,65±0,2	681,15(100)	1182,57 ±0,2	1133,07(100)
774,5 ±0,2	774,22(24) 725,08(14,5)	1352,2 ±0,5	1302,7 (100)
	612,34(61,5)	1387,55 ±0,3	1387,5 (17) 1338,2(33)
785,5 ±0,2	785,4 (34) 736,07(66)		1125,0(50)
829,85±0,2	780,35(100)	1479,9 ±0,7	1430,4(100)
873,17±0,2	823,67(100)	1484,4 ±0,5	1321,9(100)
890,8 ±0,2	728,3 (100)	1489,0 ±0,5	1489,0(54) 1439,4(46)
960,4 ±0,3	798,0(68) 627,2(32)	1554,4 ±1,0	1504,9(100)
1053,7 ±0,2	1053,5(34) 1004,3(66)		

In the study of ^{238}U, 36 γ-rays were observed and 31 assigned to 20 levels in ^{238}U. The thresholds to three weakly excited gammas were inadequately determined and the level energies are therefore tentative. Three of the unassigned γ-rays are only observed at incident neutron energies exceeding 1400 keV where the fission cross section increases sharply.

The levels of ^{238}U and the branching ratios are tabulated in Table II. There is generally close agreement between the results from the present study and the work reported by Herrmann et al., and Poenitz

though some discrepancies remain. We obtain close lying doublets at 927,2 and 930,9 keV and at 1059,7 and 1060,7 keV and a single level at 1167,7 keV. Herrmann et al. find levels at 1167,5 and 1168,9 keV. It is possible that this last doublet was missed by us as the doublet decay schemes are similar.

TABLE II

Levels of ^{238}U and their decay γ-rays deduced from (n,n'γ) measurements

Level Energy (keV)	γ-ray Energies (keV) (% branching in brackets)		Level Energy (keV)	γ-ray Energies (keV) (% branching in brackets)	
0			(1045,9 ±1,0)	1001(100)	
44,9 ±0,2			1059,7 ±0,2	1015,0(69)	911,3(31)
148,3 ±0,2			1060,7 ±0,2	1060,7(100)	
(307,1)			1105,6 ±0,2	957,3(100)	
(520)			1128,5 ±0,3	1083,7(53)	448,0(47)
680,1 ±0,2	680,0(40)	635,3(60)	(1167,7 ±0,3)	1122,8(100)	
731,9 ±0,2	687,0(56)	583,5(44)	1179,0 ±0,3	1179,0(100)	
826,6 ±0,5	519,5(100)		(1202,0 ±1,0)	1202,0(100)	
927,2 ±0,3	882,3(100)				
930,9 ±0,2	931,1(2)	885,8(98)	(1215,6 ±3,0)	1215,6(100)	
950,3 ±0,3	905,4(100)		(1223,5 ±0,4)	1223,5(-)	1179,0(-)
966,3 ±0,2	966,3(9)	921,4(31)	1278,5 ±0,3	1278,6(30)	1233,4(44)
	818,0(60)			1130,0(26)	
997,35 ±0,2	952,3(53)	849,2(47)			
1037,3 ±0,2	1037,2(55)	992,5(45)			

There are again significant discrepancies between the decay schemes obtained here and those of Stephens et al. Herrmann et al. have found similar differences and have deduced different collective bands and spin values for levels in the excitation energy region from 900 to 1200 keV.

Further work on both ^{232}Th and ^{238}U will therefore be undertaken to combine the data from the direct measurement of inelastic neutrons with the data from the measurement of the decay γ-rays. It is hoped that a comparison of Hauser Feshbach theory with the measured (n,n') cross sections will enable realistic spin assignments (and therefore also of collective bands) to be made for the level schemes which have been determined in the present work.

1.2 Inelastic scattering of neutrons from ^{232}Th

W.R. McMurray and I.J. van Heerden (SUNI)

with

E. Barnard and P. van der Merwe (AEB, Pelindaba)

Neutrons scattered from ^{232}Th have been detected in a time-of-flight system to obtain absolute inelastic cross sections from the levels in ^{232}Th at excitations greater than 700 keV. The measurements will complement the work on the level scheme and decay gammas using the (n,n'γ) reaction. Previous measurements of inelastic cross sections[1] did not distinguish the separate levels in the excitation region above 700 keV.

Neutron time-of-flight spectra have been obtained at a series of neutron energies using the 3 MeV van de Graaff accelerator at the Atomic Energy Board. The neutron detector incorporated a 2,54 cm thick plastic scintillator on a very low noise photomultiplier tube. With constant fraction timing discrimination, the detector was capable of better than 2nsec timing resolution and bias levels down to about 50 keV neutrons. The observation of inelastic scattering from the levels with excitation greater than 1 MeV is made increasingly difficult by the relative smallness of their cross sections and the growing background particularly from fission neutrons at incident neutron energies exceeding 1200 keV. It has, however, been possible to provide information concerning the

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1) A.B. Smith, Phys. Rev. 126 (1962)718

existence of a level at 1023,78 keV where the corresponding gamma threshold in the (n,n'γ) measurements was not adequately defined. As no neutron peak is observed at the energy corresponding to such a level, the 1023,78 keV γ-ray has been assigned to the decay of a level at 1073,3 keV. The excitation of the group of levels at about this energy is already observable in spectra obtained at En = 1270 keV.

The analysis of the results is continuing.

1.3 Study of the ^{75}As levels using the (n,n'γ) reaction

P.J. Celliers and W.R. McMurray

Knowledge of the level structures of ^{75}As was mainly limited to the levels below 800 keV[1] except for less reliable information from energetic photoexcitation[2] and the observation of resonant scattering at E_γ = 822; 865 and 1074 keV.[3] Much more information on the levels and their decay properties was required to assist in the interpretation of the level structure in terms of nuclear models. ^{75}As can be considered as a $2p3/_2$ proton coupled to a ^{74}Ge core in its ground or excited states and this provides an explanation for at least some of the negative parity states.

The present work has used the (n,n'γ) reaction to determine a detailed level scheme up to an excitation of about 1800 keV, branching ratios and neutron inelastic scattering cross sections. Incident neutrons of energy between 300 and 2200 keV were used. The final results for the levels up to 1975 keV excitation are listed in Table III. The level structure deduced here is also confirmed by (n,n') measurements undertaken for this purpose (see Item 1.4 of this report).

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1) Robinson et al., Nuclear Physics A104 (1967)104
Anne et al., Phys. Rev. 176 (1968)1329
Raeside et al., Nuclear Physics A130 (1969)677
D.L. Smith, Argonne Applied Physics Annual Report 1969/70

2) Moreh and Shahel, Israel AEC Annual Report (1969)

3) Celliers et al., International Conf. on Properties of Nuclear States, Montreal (1969)

TABLE III

Levels of ^{75}As and their decay γ-rays deduced from (n,n'γ) measurements

Level Energy (keV)	Spin	γ-ray Energies (keV), % branching in brackets		
0	$^3/2^-$			
198,8	$^1/2^-$	198,8(100)		
264,8	$^3/2^-$	264,8(100)		
279,8	$^5/2^-$	279,8(100)		
304,0	$^9/2^+$	(304,0(100))		
400,7	$^5/2^+$	400,7(6)	136,0(64)	120,8(30)
468,6	$^1/2^-$	468,6(100)		
572,2	$^5/2^-$	572,2(100)		
618,4	$^3/2^-$	618,4(20)	419,0(70)	353,5(10)
821,9	$^7/2^-$	821,9(86)	542,9(14)	
861,2		861,2(51)	661,8(14)	459,7(35)
865,1	$^5/2$	865,1(96)	293,5(4)	
886,2		621,2(19)	606,5(56)	314,4(25)
1043,9		740,1(35)	643,1(65)	
1064,3		1064,3	799,5	785,0
1075,5	$^1/2$	1075,5(100)		

The observed γ-ray yields have been determined using the programme SAMPO. Absolute normalisation of gamma yields to (n,n') cross sections was accomplished by comparison with the γ-ray yield from the excitation of the first excited state in ^{56}Fe for which the scattering cross section is accurately known.

The deduced inelastic neutron scattering cross sections as a function of energy have been compared with Hauser Feshbach calculations using the ABACUS programme. In this case the optical model parameters could not be determined from elastic cross section data. The parameters were therefore obtained from a best fit to the measured cross sections for the levels with known J^π at 468 keV ($^1/2^-$); 572 keV ($^5/2^-$) and 618 keV ($^3/2^-$). Starting with reasonable values of the parameters only Vo and Wo had to be adjusted to give a satisfactory fit in shape and magnitude to the experimental data. The values used were

Vo	=	44 MeV	(Wood-Saxon form)
Wo	=	14 MeV	(Surface-Gaussian form)
Vso	=	7 MeV	(Differentiated Wood-Saxon)
a	=	0,62 fm	
b	=	0,50	
c	=	0,50	

H-F fits to the measured cross sections for the levels at 822; 865 and 1075 keV indicate spins of $^7/2$; ($^5/2$; $^7/2$) and $^1/2$ respectively. Evidence from the relative excitation of the 822 and 865 keV levels by Coulomb excitation and by resonant scattering favours the $J = {}^5/2$ assignment for the level at 865 keV.

Angular distribution measurements of the γ-rays from the (n,n'γ) reaction are in this case not very sensitive to spin value. Measurements at angles of 30; 45; 60; 75 and 90° to the incident neutrons have been compared with theoretical calculations using the programme MANDY. The comparison confirms the spin assignments derived from H-F fits to the excitation cross sections.

1.4 Inelastic scattering of neutrons from ^{75}As

W.R. McMurray and I.J. van Heerden (SUNI)

with

E. Barnard and P. van der Merwe (AEB, Pelindaba)

Measurements of the inelastically scattered neutrons from ^{75}As were undertaken in order to confirm aspects of the level structure of ^{75}As deduced from a study of the gamma decays following inelastic scattering (Item 1.3 of this report).

Neutron spectra were observed using the 3 MeV van de Graaff accelerator at the Atomic Energy Board.

The results obtained at incident neutron energies between 1050 and 1350 keV give direct confirmation of all the low lying levels up to 618,4 keV which were previously found in other investigations. The new levels now deduced in the (n,n'γ) study in the range from 821,9 to 1128,5 are also clearly observed.

These results will be used to obtain absolute cross sections to check on those derived from the measurement of the decay γ-rays.

1.5 A small sample method for investigation of the (n,n'γ) reaction

S.A. El Bakr+, I.J. van Heerden, W.K. Dawson+
W.J. McDonald+ and G.C. Neilson+

A technique has been developed to study (n,n'γ) reactions using very small scattering samples, in which the scatterer is placed in close proximity to the neutron source. In this arrangement, the neutron beam through the scatterer is neither monoenergetic nor of constant flux, and there is also no possibility of shielding the γ-detector from the neutron beam. To show that reliable yield curves can be obtained with this technique, the excitation for the 847 keV γ-ray in ^{56}Fe has been measured, using a 3,147 gm natural Fe scatterer.

To correct for geometric effects, an unfolding technique was developed to account for the angular distribution and energy distribution of the neutrons through the scatterer, and for the γ-ray attenuation in the scatterer. Time-of-flight gating was used to discriminate against neutron induced events in the Ge(Li) detector. The resulting yield curve that was obtained for the 847 keV γ-ray in ^{56}Fe is in good agreement with previous data.[1)]

A publication describing this method has been published in Nuclear Instruments and Methods, 97(1971)283.

1.6 Energy levels and transitions in ^{114}Cd from the (n,n'γ) reaction

S.A. El Bakr+, I.J. van Heerden, W.J. McDonald+ and G.C. Neilson+

The ^{114}Cd nucleus has been the object of a great number of experimental and theoretical investigations. Through (n,γ), (d,p), (p,p'), (d,d') and coulomb excitation, levels have been well established at 557 keV (2^+), 1135 keV (0^+), 1210 keV (2^+), 1283 keV (4^+)

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1) R.W. Benjamin, P.S. Buchanan and I.L. Morgan
Nucl. Phys. 79 (1966)241

1305 keV (0^+) and 1363 keV (2^+). The strongly enhanced B(E2) transition strengths observed in coulomb excitation work[1,2] are evidence for a collective nature of the low-lying levels in ^{114}Cd. The four lowest excited states fit well in the picture of one phonon and two phonon quadrupole vibrational excitations. However, levels above 1,4 MeV are not very well known and furthermore, different results have been obtained regarding the mode of decay of the 1210; 1305 and 1363 keV levels.

The small sample method[3] in conjunction with a high-resolution timing Ge(Li) spectrometer have been used to observe γ-rays following neutron inelastic scattering from ^{114}Cd. Gamma-ray excitation curves have been measured in the neutron energy range of 1,1 to 2,1 MeV. The present experiment confirms the existence of levels at 1730; 1840; 1862; 1956 and 2047 keV. The 1210 keV transition is observed at E_n = 1,2 MeV and 1363 keV at E_n = 1,4 MeV. This rules out Smither's suggestion[4] that the 1210 and 1363 keV transitions depopulate a level at 2573 keV (=1209 + 1363 keV). Analysis is in progress to determine spins of levels above 1,4 MeV excitation.

1.7 Levels of ^{154}Sm from the (n,n'γ) reaction

S.A. El Bakr+, I.J. van Heerden, B.C. Robertson+, W.J. McDonald+ and G.C. Neilson+

The ^{154}Sm(n,n'γ)^{154}Sm reaction has been used to study the properties of ^{154}Sm excited states up to 2 MeV excitation. Gamma-ray decay modes and excitation functions have been ueasured using a Ge(Li) detector. The energy resolution of the Ge(Li) detector was sufficient to resolve gamma-rays from the levels at 1178 and 1182 keV excitation. The existence of levels at 1120; 1204; 1338; 1515; 1540 and 1550 keV has been confirmed. Additional new levels have been proposed at 1707; 1756; 1891; 1923 and 2070 keV excitation. Level

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+ Nuclear Research Centre, University of Alberta, Edmonton Canada.

1) P.H. Stelson and F.K. McGowan, Phys. Rev. 121(1961)209

2) F.K. McGowan, R.L. Robinson, P.H. Stelson and J.L.C. Ford, Jr., Nucl. Phys. 66(1965)97

3) S.A. El Bakr, I.J. van Heerden, W.J. McDonald and G.C. Neilson, Nucl. Inst. and Method, 97(1971)283

4) R.K. Smither, Phys. Rev. 124(1961)183

spins have been inferred by comparing the branching ratios to the predictions of the collective model, and by comparing the production cross sections to the predictions of the Hauser-Feshbach statistical model. Spin assignments have been made of 2^+, 5^- and 3^+ to the levels at 1178; 1182 and 1540 keV respectively. The latter has been identified at the 3^+ member of the γ-vibrational band.

The following comments on the decay scheme of ^{154}Sm have to be made:

(a) The 1120 and 1204 γ-rays have two different thresholds and therefore do not belong to the same level. These two levels have been observed at 1120 and 1209 keV by (p,p'). (Phys. Rev. 135 (1964) 3939).

(b) The two γ-rays 1255,9 and 1070,9 keV show a threshold of 1,4 MeV, and therefore they originate from a level at 1338 keV. This level has been observed by (p,p') at 1344 $\pm$10 keV.

(c) At E_p = 4,0 MeV, E_n^{eff} = 2,1 MeV, the following weak γ-rays are observed:

E	Possible origin
743	1756 → 921
839	1756 → 1012
1503	1584 → 82
1540	1540 → 0
1550	1550 → 0
1584	1584 → 0
1660	1660 → 0
1657	1923 → 267
1809	1891 → 82
1842	1923 → 82
1892	1892 → 0
2070	2070 → 0

1.8 The level structure of ^{93}Nb and ^{115}In from (n,n'γ) measurements

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

The decay schemes of ^{93}Nb and ^{115}In mentioned in the previous report were based on γ-ray spectra obtained from inelastic neutron scattering. These spectra have been re-analysed using the SAMPO programme. The γ-ray yields have been corrected for neutron flux, γ-ray attenuation in the scatterer, γ-ray efficiency of the Ge(Li) detector and the effect of the time-gate used to discriminate against neutron induced events in the detector. Absolute γ-ray production cross sections were obtained by comparison to the γ-ray yield of the 847 keV line from $^{56}Fe(n,n'\gamma)$ at a few selected neutron energies. Yield curves for neutron inelastic scattering cross sections have been determined from the observed branching ratios and these are now being compared with Hauser-Feshbach predictions.

1.9 The level structure of ^{55}Mn from (n,n'γ) measurements

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

In order to obtain more information about the energies and spins of levels of ^{55}Mn, the γ-ray transitions following inelastic scattering of neutrons have been studied.

A number of γ-ray spectra were obtained for incident neutron energies between 1000 and 2875 keV in 125 keV steps. From the relative excitation cross sections and threshold energies of the observed gammas a level scheme with levels at 125,77; 984,75; 1292,39; 1528,72; 1884,27; 2197,97; 2252,03; 2266,1; 2278 and 2365,16 keV has been deduced. Further work is being planned to resolve the uncertainties which still exist especially with regard to the group of levels above 2198 keV.

1.10 The reaction $^{45}Sc(p,p'\gamma)^{45}Sc$

N.J.A. Rust, W.J. Naudé, J.W. Koen and W.L. Mouton

The investigation of the properties of low-lying energy levels of ^{45}Sc was continued with the intention of describing these in terms

of the excited core model. According to this model the coupling of a $^{7}/_{2}^{-}$ proton to the first excited (2^{+}) state of ^{44}Ca gives rise to the splitting of a multiplet of states with spins $^{3}/_{2}^{-}$; $^{5}/_{2}^{-}$; $^{7}/_{2}^{-}$; $^{9}/_{2}^{-}$; and $^{11}/_{2}^{-}$ in ^{45}Sc. Energies and branching ratios of states up to 1,8005 MeV were accurately determined with the reaction $^{45}Sc(p,p'\gamma)^{45}Sc$. The yield of inelastically scattered protons was measured at the laboratory angles 90°; 130° and 150° for incident proton energies from 5,2 to 5,48 MeV. Average cross sections were compared with predictions on the basis of Hauser-Feshbach theory in an attempt to eliminate spin uncertainties. Preliminary results combined with existing knowledge indicate that the levels at 0,3762; 0,7204; 1,2373; 1,4092 and 1,6620 MeV are the members of the above-mentioned multiplet.

1.11 Polarization in n-p and n-d Scattering

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

The polarization in n-p scattering has been studied at 16 MeV and 22 MeV using an anthracene scintillation crystal as a polarization analyser. The directional dependence of the pulse shape discrimination properties of the crystal enable one to determine directions of recoil protons within the crystal and thus to determine the left-right asymmetry in the scattering of polarized incident neutrons. Preliminary results obtained at 22 MeV were published in the Proceedings of the Third International Symposium on "Polarization Phenomena in Nuclear Reactions" (ed. H.H. Barschall and W. Haeberli, University of Wisconsin Press, 1971, p.430). Further measurements made at these energies will shortly be submitted for publication. This work has now been extended to other energies in the range 8 to 22 MeV and the polarization in n-d scattering is also being studied by the same technique using a deuterated anthracene crystal.

1.12 Cross sections for the D(n,n) and D(n,2n) reactions

G. Pauletta and F.D. Brooks

The D(n,n) and D(n,2n) reactions have been studied in the neutron energy range 5 to 22 MeV by bombarding a deuterated liquid

scintillator with monoenergetic neutrons and using pulse shape discrimination techniques to identify the respective charged particle products, namely recoil deuterons and breakup protons. The two reactions may be separated very clearly in this manner and the ratio of their respective cross sections may thus be obtained directly. The cross sections for the two reactions are then obtained by combining the ratio values with total cross section data taken from the literature. The results obtained in the 12 to 22 MeV region are now being prepared for publication.

1.13 Fission Isomer in Uranium-236

J.V. Pilcher, F.D. Brooks and W.R. McMurray

A search was made for fission isomers produced by bombarding natural and enriched (35% U-236) uranium metal samples with pulsed 30 ± 15 keV neutrons and detecting high energy fission neutrons between accelerator bursts. The samples were 2,5 cm diam discs of mass ~ 15 gm and the fission neutron detector was a liquid scintillator (NE213, volume ~ 1,2 litre) fitted with a pulse shape discriminator. Data were also taken with an indium sample, with pulse shape discrimination off (indium has a relatively high capture cross section), to determine the time distribution of incident neutrons at the sample position.

A least squares analysis of the time distribution of detected fissions indicated a fission isomer in ^{236}U of half life 92 ± 15 nanoseconds. An isomer ratio (ratio of isomeric to prompt fissions) of 0,008 ± 0,004 was also deduced from the data. This half life is in agreement with the values reported by Elwyn and Ferguson (Nucl. Phys. A148(1970)337) and by Boca et al. (Rev. Roum.Phys.Tome 16 No. 4(1971)473). However the present isomer ratio is about a factor of 5 lower than expected on the basis of the results of Boca et al.

1.14 Search for superheavy elements

C. Rudolph, F.D. Brooks and R.D. Cherry

A 4π-six-detector neutron multiplicity counter has been constructed and is now in use on a routine basis to screen natural

samples for possible superheavy element content. The six detectors are liquid scintillation counters fitted with pulse shape discriminators to reject gamma-rays. The associated electronic logic includes effective means for vetoing spurious events initiated by energetic charged cosmic ray particles. The sample material is placed at the centre of the system and the search is based on the detection of neutron coincidences from spontaneous fissions within it. Superheavy fissions are expected to show a high fission neutron multiplicity, which should thus render them recognizable.

The samples investigated to date include manganese nodules dredged from the seabed, lead of unknown origin and osmium and iridium ore concentrates. None have so far shown significant evidence of a superyheavy presence.

1.15 The direct excitation of analogue dipole states via (n,p) reactions

B.T. Chait, S.M. Perez and F.D. Brooks

The direct excitation of analogue dipole states in the product nuclei of the $^{28}Si(n,p)^{28}Al$ and $^{40}Ca(n,p)^{40}K$ reactions is being studied using neutrons in the 20-30 MeV energy range. The cross-sections and angular distributions for such transitions are being investigated and compared with predictions based on the theory developed by Clement and Perez (Nucl. Phys. A165(1971)569). At present there is little experimental data available for making such comparisons.

The reaction on ^{28}Si is studied using a pair of silicon surface barrier detectors placed 10-20 cm apart; and that on ^{40}Ca using a CaF_2 scintillation crystal paired with a single surface barrier detector. In each case protons from (n,p) reactions in the first detector, which travel to the second detector are selected. At 22 MeV the discrimination is performed using the time-of-flight technique and at 30 MeV using a ΔE-E telescope.

2. Nuclear Physics Research Unit, University of the Witwatersrand, Johannesburg

Relevant research facilities include a 2 MeV pressurized Cockcroft-Walton accelerator which was modified for positive ion operation during 1971, a small neutron generator and an EN-tandem, installation of which started at the end of 1971. Major research projects include charged particle reactions, ion channeling and neutron activation studies.

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

Neutron physics research is carried out at a 3 MeV pulsed van de Graaff accelerator, equipped with terminal pulsing and klystron bunching, as well as at the 20 MW research reactor, Safari I. A CDC-1700 computer is used for on-line data collection and processing at the accelerator.

3.1 Nuclear spectroscopy from (n,γ)-reactions with slow neutrons

M.A. Meyer, C. Hofmeyr and B.C. Winkler

The tangential thermal beam tube in the reactor, which is used as a neutron source for capture studies, was modified in order to reduce the gamma-ray background. Additional results were obtained on the capture gamma-ray spectra from samples of ^{70}Ge and ^{58}Ni. The behaviour of a neutron wave guide was investigated in some detail.

3.2 Nuclear spectroscopy from (n,n'γ)-reactions

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

Energy levels in stable nuclei at excitation energies up to about 1,5 MeV were studied by means of (n,n'γ)-reactions, employing the van de Graaff accelerator and the ^{7}Li(p,n)-reaction as neutron

source and Ge(Li)-diodes with fast timing as gamma detectors. Results on level schemes of ^{127}I, ^{197}Au, Sb and Br have been published[1-4]. Similar studies on Cs, Rb and Ho are in an advanced stage of preparation for publication.

3.3 Fast neutron scattering

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

The results of a detailed study of total-, elastic- and inelastic scattering cross sections for fast neutrons on ^{45}Sc have been published[5]. Inelastic scattering cross sections for Ti, combined with elastic scattering and total cross section measurements done at Argonne, are still being analysed at ANL. Detailed local measurements on Cs and Rb (totals, elastic and inelastic scattering) are being analysed at Pelindaba. Elastic scattering and high resolution differential inelastic scattering measurements on the 126 keV level in Mn have been completed. Some (n,n')-measurements on Ho, to complement the (n,n'γ)-studies mentioned in the previous section, have also been carried out.

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Progress Report on Neutron Physics Research and Dosimetry in Yugoslavia

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NEUTRON PHYSICS RESEARCH

Prompt γ-ray spectra from the radiative capture of 14,4 MeV neutrons in Cu, Se, Br, In, and I

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J. Stefan Institute and Faculty for Natural Sciences and Technology, University of Ljubljana, Ljubljana, Yugoslavia

The γ-ray spectra and corresponding integrated cross sections due to the radiative capture of 14,1 MeV neutrons in monoisotopic In and I, and polyisotopic Cu, Se and Br are presented.

The experimental technique has been previously described[1-3].

Unfolded γ-ray spectra from the radiative capture of 14,1 MeV neutrons in Cu, Se, Br, In, and I are shown in figs. 1-5. Corrections due to the absorption of γ-rays and the scattering of neutrons in samples were taken into account. The error bars include the statistical fluctuation of counts, the uncertainties due to the background corrections, and the error introduced by the unfolding procedure.

Integrated cross section data presented in the table are obtained by the integration of γ-ray spectra over all γ-ray energies higher than E_n, the relative energy in the C.M. system. The errors of the integrated cross section values include besides the errors of the spectral intensity, also the uncertainty of the spectrometer efficiency and the uncertainty of the flux determination.

Spectra reported here have not been previously measured, except the spectrum of iodine[4]. In this experiment the γ-ray spectrum was measured with a NaI(Tl) crystal at 90° to the neuutron beam and is therefore not directly comparable with our spectrum which is integrated

over a solid angle of 4π . However, both data are presented in fig.5 without any correction. The average agreement is better than the experimental error. This can be seen from the comparison of Dinter's value of 1090 ± 170 μb. It would therefore appear that the angular distribution is rather isotropic.

Integrated cross section values are presented in table 1. Their values lie around 1 mb and agree with the expected smooth mass dependence[5].

Comparison of integrated cross section values with the data obtained by the activation technique (σ_{act}) shows that the two cross sections agree only for Se, for other elements the σ_{act} are higher than σ_{int}. Such a behaviour was qualitatively discussed in refs[5,6] with the conclusion that the two cross sections agree only for nuclei in the vicinity of closed neutron shells.

Cross sections for the radiative capture of 14.1 MeV neutrons and parameters of the samples.

Sample	Density of the sample (g/cm^3)	Diameter (cm)	Integrated cross section (μb)	Isotopes	Activation cross section (μb)
Cu	8.92	2.0	770±110	^{63}Cu (69.1%)	2560± 380[a)]
				^{65}Cu (30.9%)	6300±1900[a)]
Se	1.42	3.0	860±130	^{80}Se (50.0%)	
				^{78}Se (23.6%)	
				^{76}Se (9.1%)	
				^{82}Se (8.8%)	650± 200[a)]
				^{77}Se (7.5%)	
				^{74}Se (1.0%)	
Br	3.09	3.0	1100±160	^{79}Br (50.6%)	
				^{81}Br (49.4%)	3500± 850[b)]
In	7.28	2.0	1200±200	^{115}In (95.8%)	5970± 810[a)]
				^{113}In (4.2%)	
I	3.10	3.0	1100±160	^{127}I (100 %)	2500± 500[a)]

a) Data taken from ref.[7)]
b) Data taken from ref.[8)]

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Figure captions

Fig.1. Corrected γ-ray spectrum from the radiative capture of 14.1 MeV neutrons in natural copper, containing 69% of ^{63}Cu and 31% of ^{65}Cu

Fig.2. Corrected γ-ray spectrum from the radiative capture of 14.1 MeV neutrons in natural selenium, containing mainly ^{78}Se (23,6%) and ^{80}Se (50%)

Fig.3. Corrected γ-ray spectrum from the radiative capture of 14.1 MeV neutrons in natural bromium, containing 50.6% of ^{79}Br and 49.4% of ^{81}Br.

Fig.4. Corrected γ-ray spectrum from the radiative capture of 14.1 MeV neutrons in natural indium, containing mainly ^{115}In (95,8%)

Fig.5. Corrected γ-ray spectrum from the radiative capture of 14.1 MeV neutrons in ^{127}I.

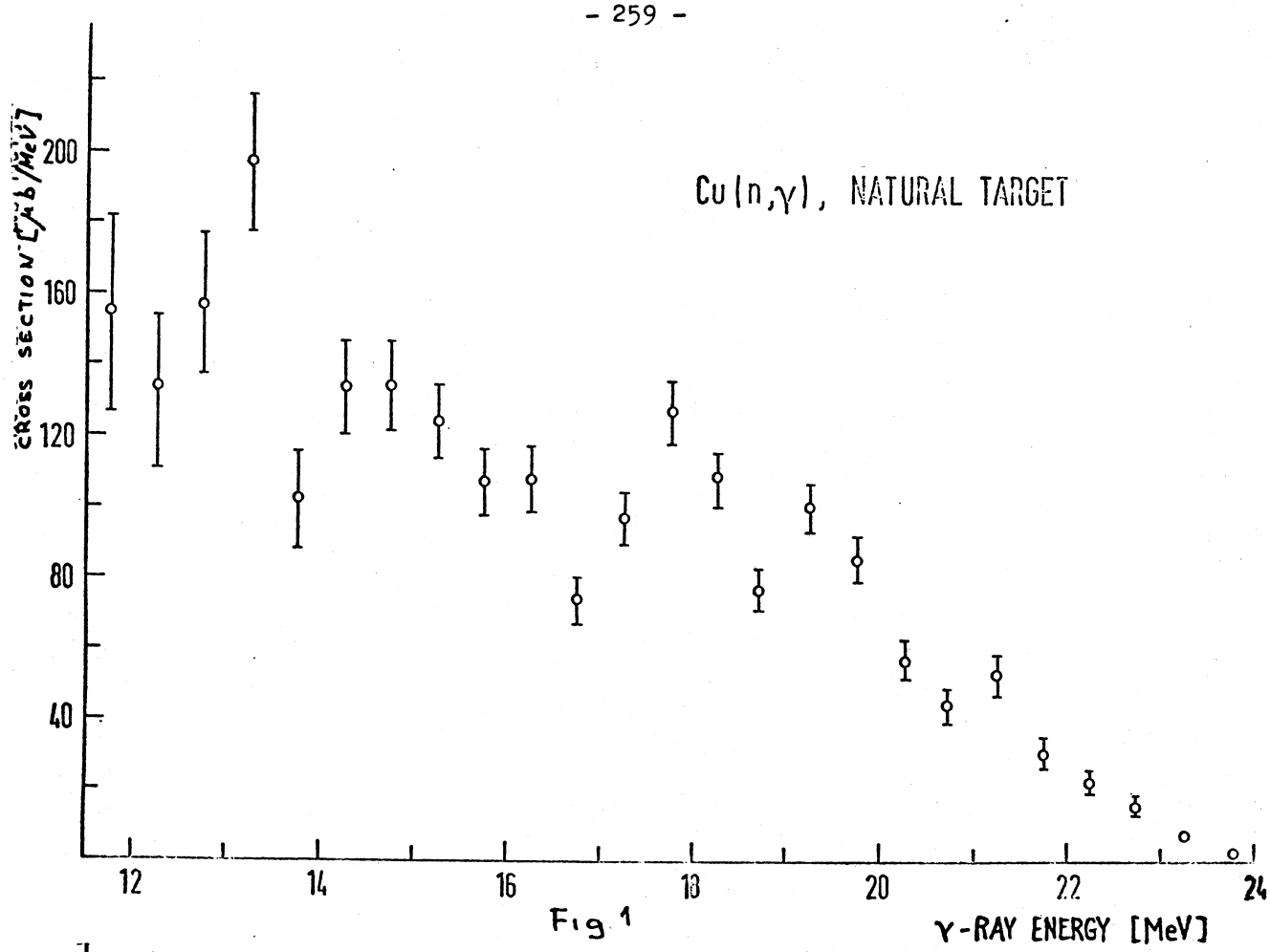
Cu(n,γ), NATURAL TARGET
CROSS SECTION [μb/MeV]
200
160
120
80
40
12
14
16
18
20
22
24
γ-RAY ENERGY [MeV]

Fig. 1

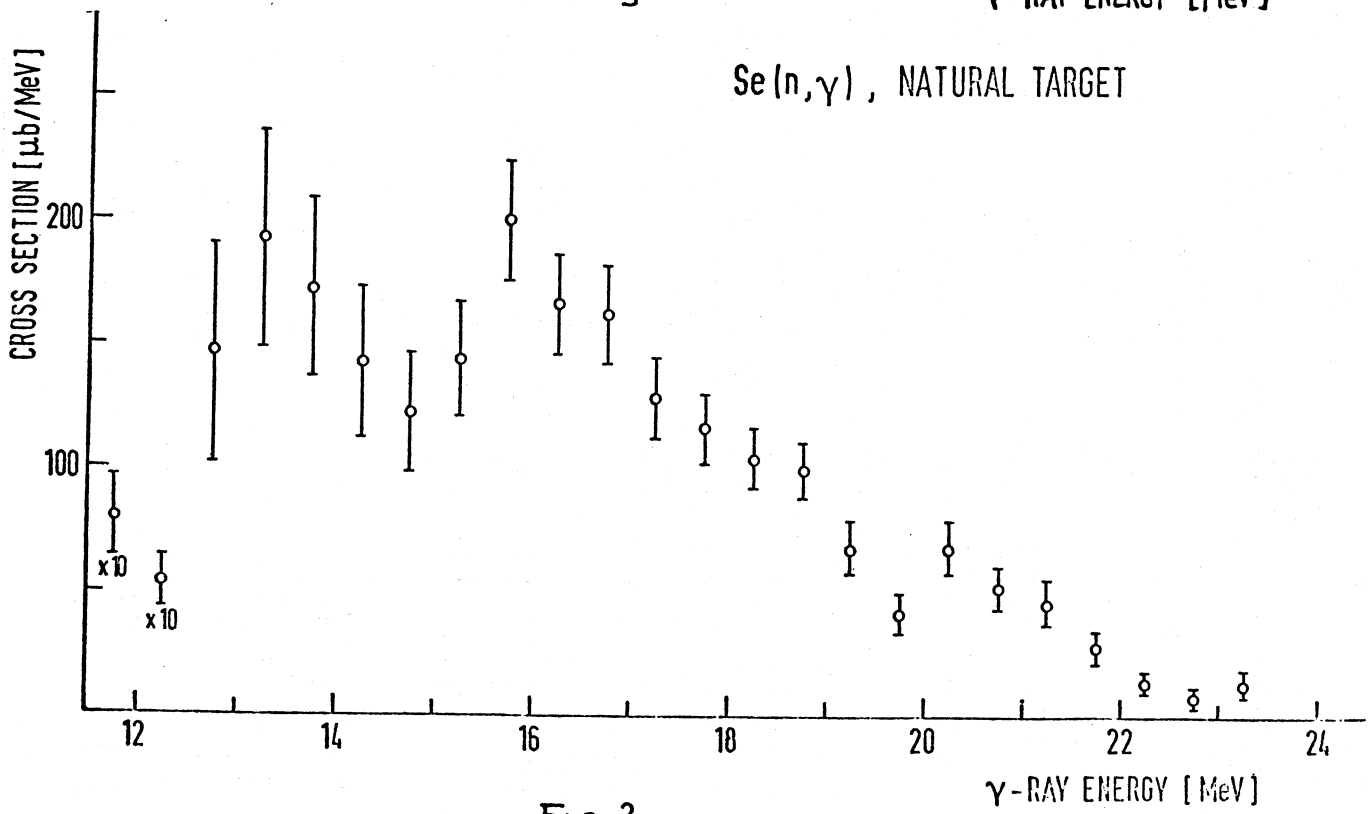
Se(n,γ), NATURAL TARGET
CROSS SECTION [μb/MeV]
200
100
x10
x10
12
14
16
18
20
22
24
γ-RAY ENERGY [MeV]

Fig. 2

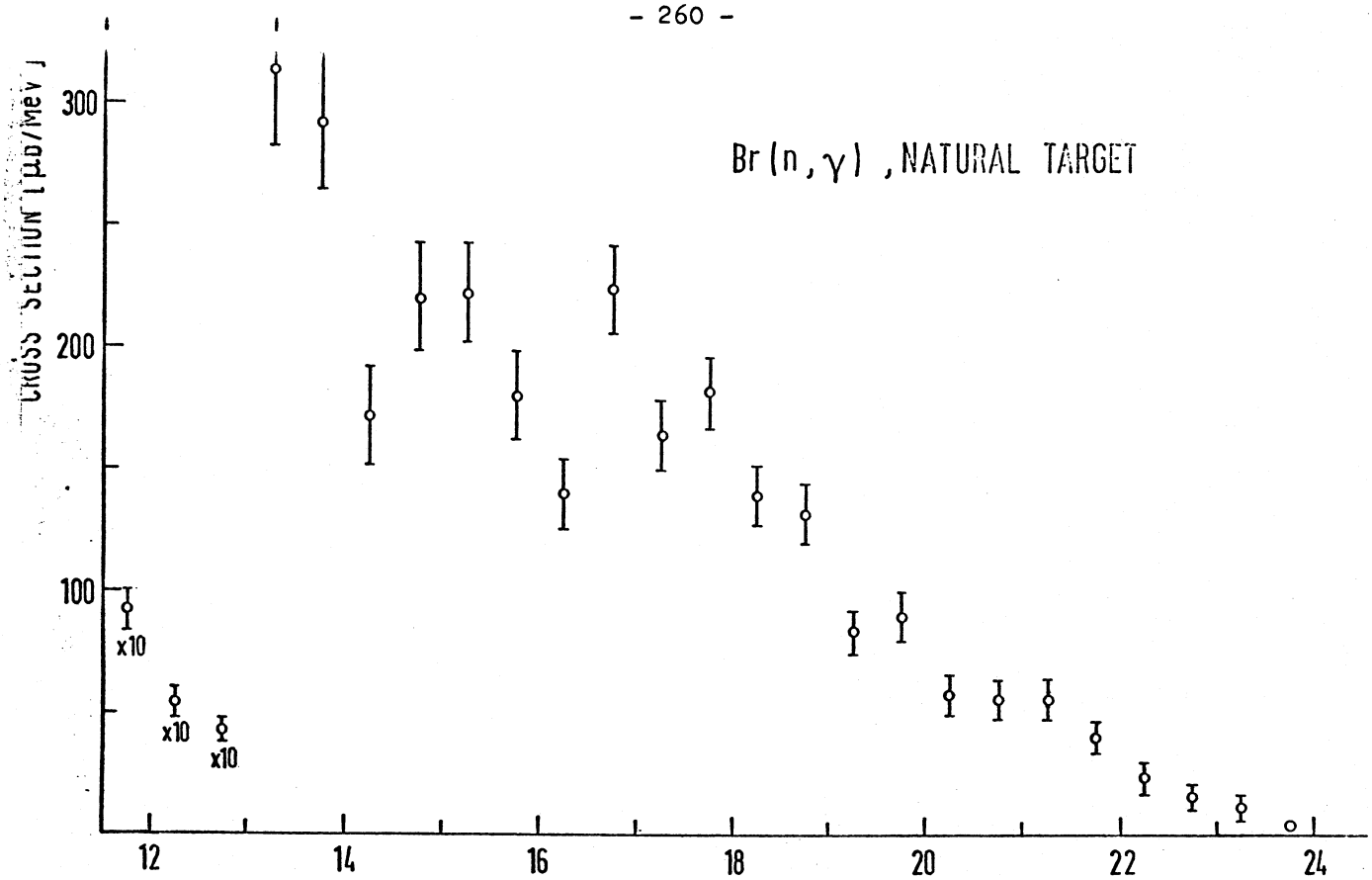
CROSS SECTION [μb/MeV]
300
200
100
x10
x10
x10
Br(n,γ) ,NATURAL TARGET
12
14
16
18
20
22
24
γ-RAY ENERGY [MeV]

Fig. 3.

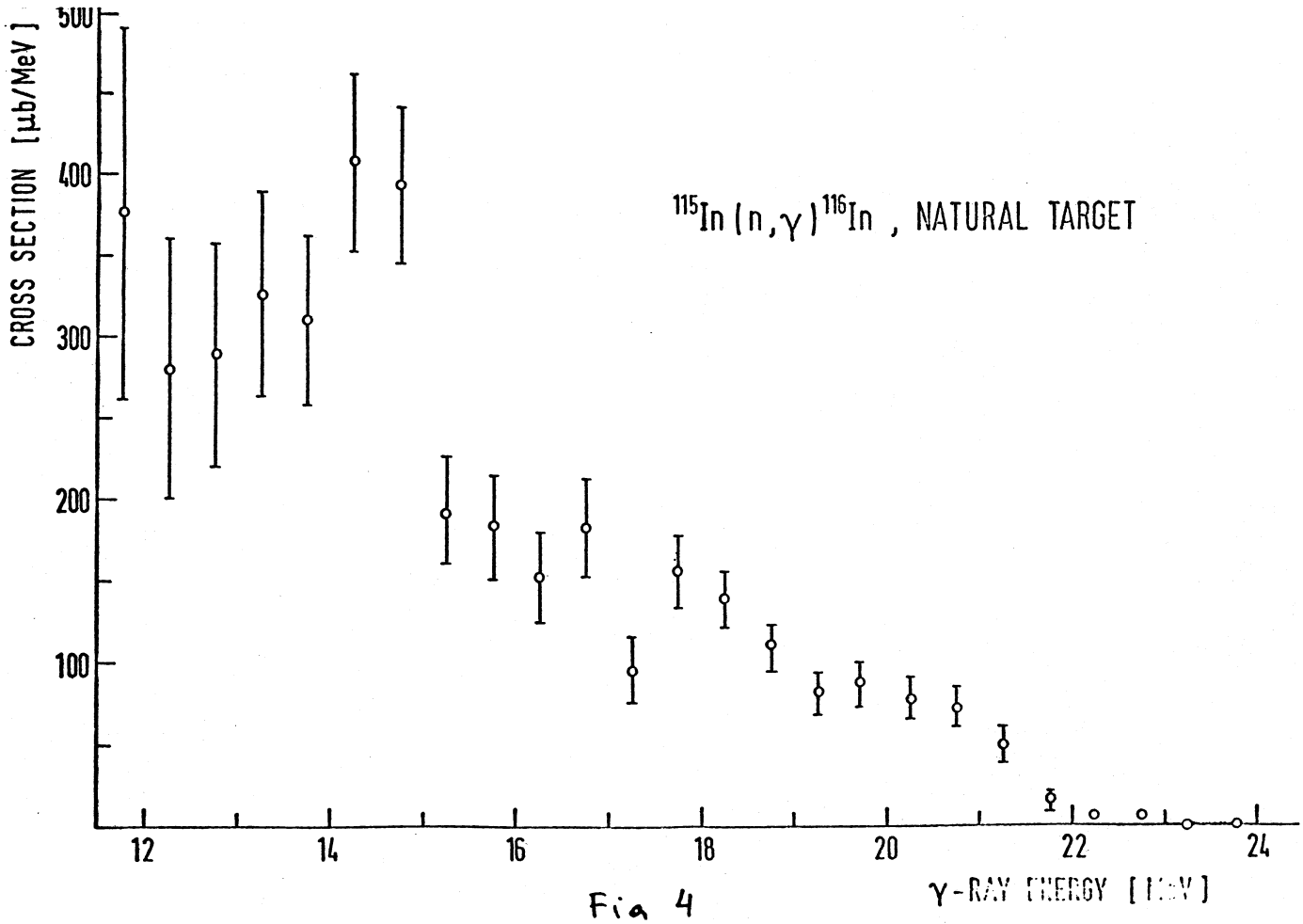
CROSS SECTION [μb/MeV]
500
400
300
200
100
115In(n,γ)116In , NATURAL TARGET
12
14
16
18
20
22
24
γ-RAY ENERGY [MeV]

Fig 4

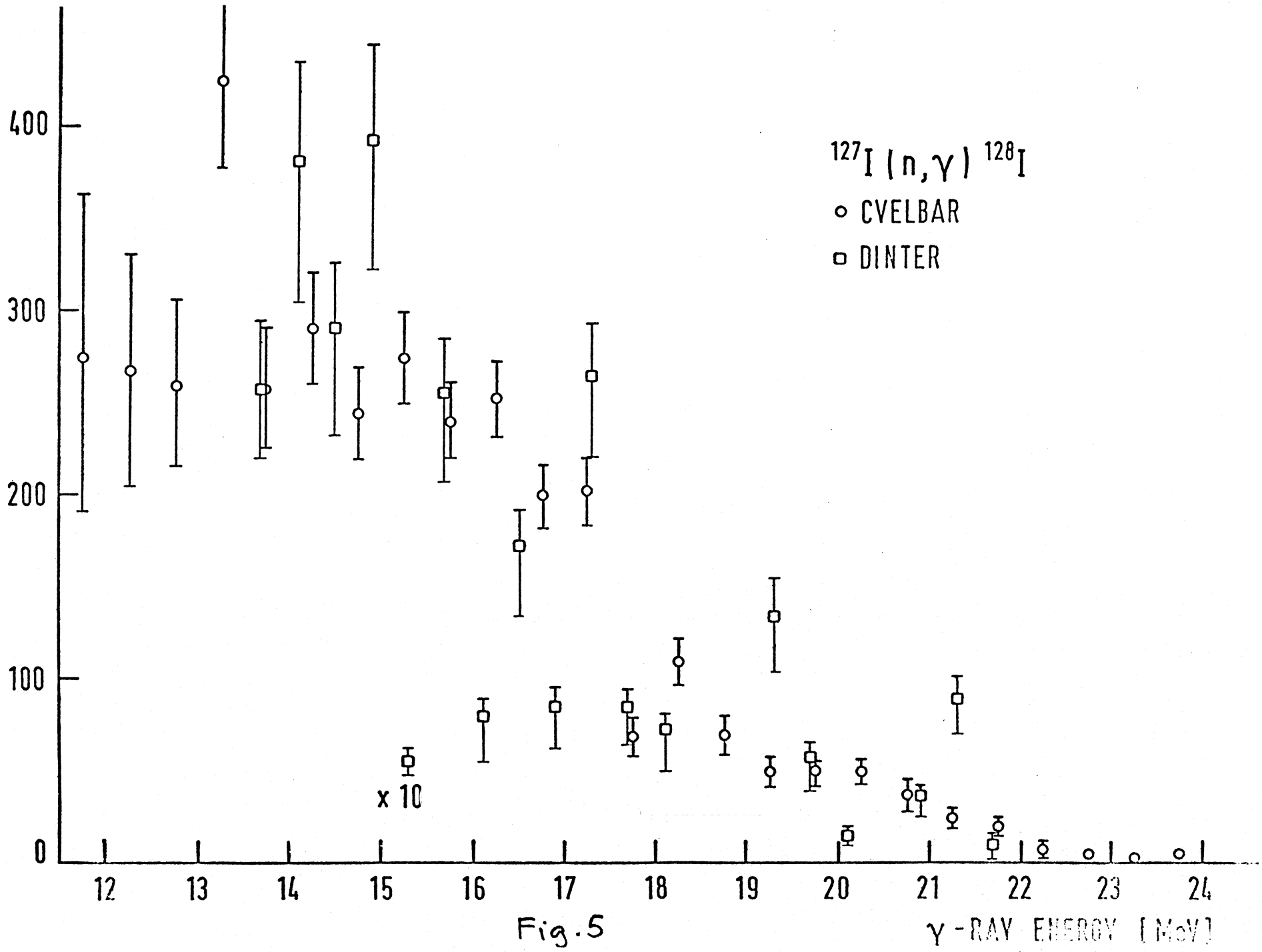
$^{127}I(n,\gamma)^{128}I$
○ CVELBAR
□ DINTER
400
300
200
100
0
x 10
12
13
14
15
16
17
18
19
20
21
22
23
24
γ-RAY ENERGY [MeV]

Fig.5

Mass dependence of the cross section for the radiative capture of 14 MeV neutrons

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To be presented at "Nuclear Structure Study with Neutrons", Budapest

There are two methods in the study of the cross sections for the radiative capture of fast neutrons: activation technique and measurements of prompt γ-ray spectra. In contrary to the activation cross section values (σ_{act}) which include all radiative transitions into bound states, the integrals of the prompt γ-ray spectra (σ_{int}), due to the experimental reasons, cover only the (one step) transitions to the bound states of final nuclei. Therefore $\sigma_{act} \geqslant \sigma_{int}$. The difference between the two cross sections was expected to be of the order of few tens of percent. Experimentally the σ_{act} values were found to be up to 20 times higher than σ_{int}. As a function of mass number the σ_{act} data are scattered in the region between 0,5 mb and 20 mb. The σ_{int} data on the other hand show a rather smooth mass dependence [1].

The difference between the two cross section data is not yet well understood but it seems, that the new precise measurement of σ_{act} have to be preformed before

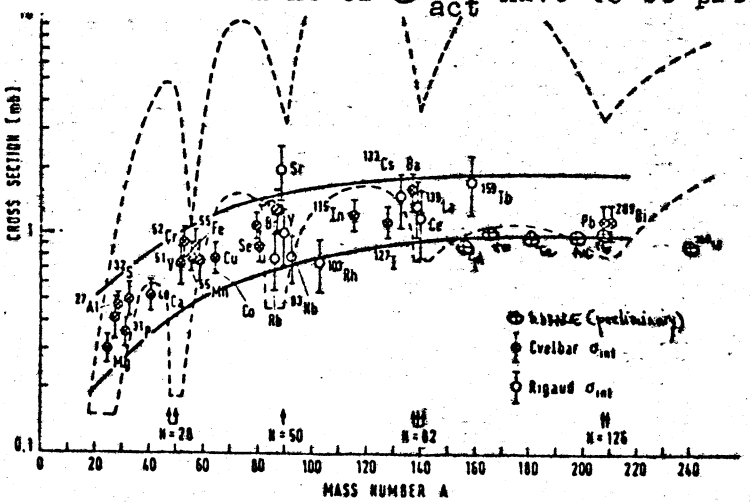

Fig.1 Mass dependence of cross sections for the radiative capture of 14 MeV neutrons. The dashed line limites the region of σ_{act} data.

the theoretical study of the transitions via unbound states which should be responsible for the real difference between the σ_{act} and σ_{int} will be done.

The aim of this contribution is i) to show that also the σ_{int} value of Pb for which only preliminary data exist 2) and that of Bi for which prompt γ-ray spectrum was not presented before, fit into the extrapolated band of the data measured for lighter nuclei, and ii) to present the new preliminary result of the measurement of γ-ray spectrum and corresponding σ_{int} for ^{88}Sr.

From Fig.1 one can see that σ_{int} value of Sr 1970 μb $\pm$ 580 μb does not fit into already mentioned band of other experimental values. As the corresponding spectrum was measured at about 90° relative to the neutron direction [3], it was expected that this outstanding value might be due to the anisotropy in angular distribution of capture γ-rays. We repeated the measurements with the technique in which the spectrum is averaged over half sphere (2π geometry). The result is presented in Fig.2 together with the original results [3]. On the difference in low energy part of the spectra not much conclusion could be done, but the difference around the $S_{1/2}$ level might be due to the anisotropy in angular distribution of γ-rays. This expectation is supported also by the shape of the calculated spectrum (integrated over 4π) which reproduces our experimental data. The details of the calculation will be published. The σ'_{int} value of the experimental spectrum presented in Fig.2 is 1260 $\pm$ 260 μb.

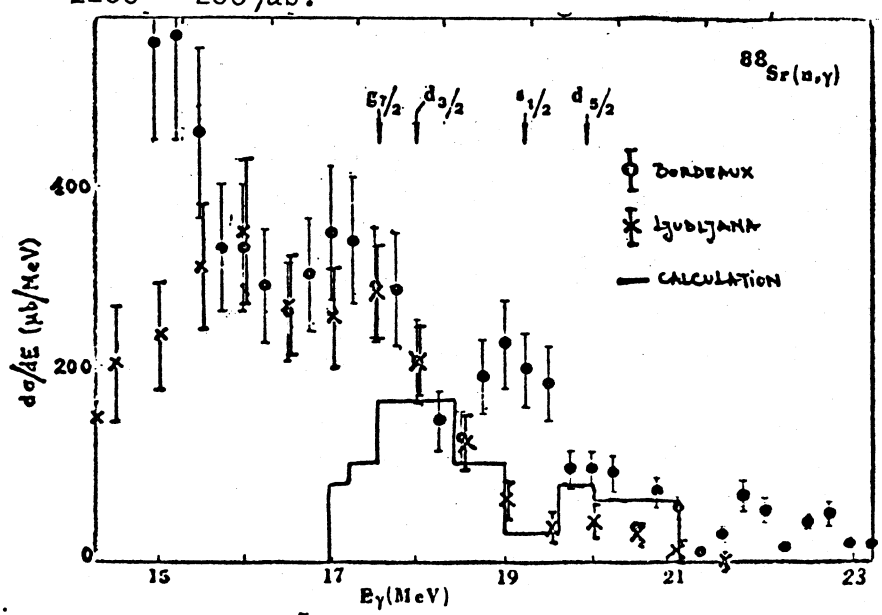

Fig.2 Spectrum of γ-rays from the radiative capture of 14 MeV neutrons in ^{88}Sr.

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Mass dependence of direct-semi-direct theory calculations for the 14 MeV neutron radiative capture

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To be presented at "Nuclear Structure Study with Neutrons", Budapest

The experimental spectra of prompt γ-rays following the radiative capture of 14,1 MeV neutrons in ^{28}Si, ^{40}Ca, ^{88}Sr, ^{138}Ba, and ^{208}Pb are compared with the spectra calculated according to three current approaches of the direct--semi-direct (DSD) theory and by the modified approach developed by the author. As an example the spectra of ^{40}Ca and ^{208}Pb are presented.

The spectra of prompt γ-rays following the radiative capture of 14,1 MeV neutrons have been recognized as an effective tool for testing the DSD theory for the dynamics of fast nucleon capture reaction. In order to examine systematically how approapriate are different current formulations of this theory (1,2,3) the spectra of ^{28}Si, ^{40}Ca, ^{88}Sr, ^{138}Ba and ^{208}Pb are calculated. All experimental quantities which enter into calculations (i.e. single particle energies, spectroscopic factors, depth of the isospin potential V_1 (4,5), and position, width and dipole sume of the giant dipole resonance) are the most recent experimental data.

It is found that the approach due to Lushnikov and Zaretsky (LZ), while reproducing very well the spectra of light nuclei, does not explain the experimental results for the heavier nuclei. The calculated cross sections being typically too low by a factor of 4.

The calculation according to Clement, Lane, and Rook (2) (CLR) give good agreement with the experiment for ^{28}Si

and ^{40}Ca, but the agreement becomes steadily worth with encreasing A. In the case of ^{208}Pb there is on average a factor of 2 between the calculated and experimental spectral intensities.

In the case of the calculation by Zimanyi, Halpern, and Madsen (3) (ZHM), the coupling constant is vague, because it depends on the number of neutrons and protons that are active in the semi-direct process. In most cases this number is not well defined. For ^{40}Ca and ^{208}Pb, where it is well defined, the cross sections are too high for a factor of 2 and 1,5, respectively.

A different coupling interaction (6), developed by the authors following the CLR approach but calculating the nuclear matrix element more exactly, has been tried. The spectra calculated by this approach are in good agreement with the experimental ones over the whole mass region.

The calculated spectra for ^{40}Ca and ^{208}Pb shown as an example on fig.1 and fig.2 in comparison with the experimental spectra.

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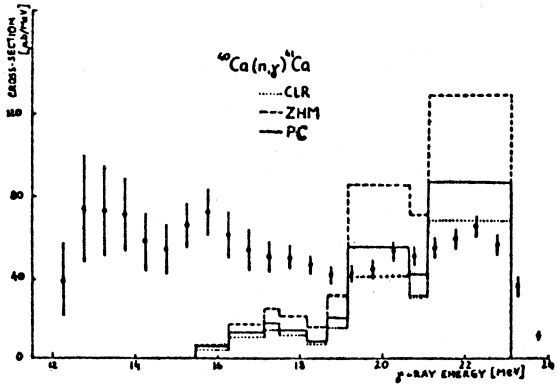

Fig.1. Experimental spectrum of γ-rays from the radiative capture of 14,1 MeV neutrons in Calcium, compared with spectra calculated according to CLR approach of DSD theory (dotted line), ZMH approach (dashed line), and the modified approach by the authors (PC) (solid line).

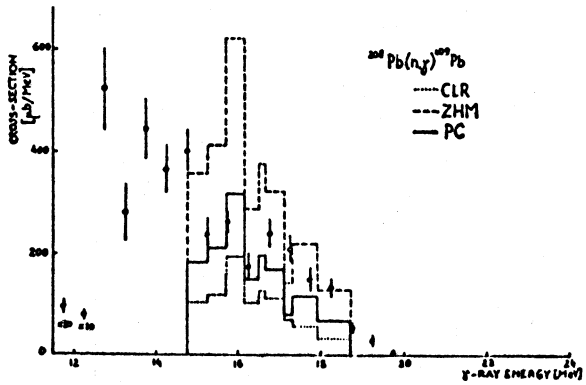

Fig.2. Experimental spectrum of γ-rays from the radiative capture of 14,1 MeV neutrons in lead compared with spectra, calculated according to CLR approach (dotted line), ZHM approach (dashed line) and PC approach (solid line).

Search for systematics in fast neutron radiative capture*

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and
J. Vuletin
Faculty of Electrical Engineering, Split, Yugoslavia

The existing differences in fast neutron capture cross sections obtained by the activation (σ_{act}) and integration methods (σ_{int}) are presently the subject of considerable interest. In principle, σ_{int} could be smaller than σ_{act}, since the former quantity measures only the decay to the bound states of the final nucleus, while the latter includes the decays to the bound and unbound states. This difference, however, should not be too large, since the decay to the unbound states leads mainly to particle emission; gamma rays compete favourably with particle emission only in the narrow region just around the binding energy.

The present experimental evidence shows that σ_{int} follow a smooth path in the whole region from A=23 to A=238 /1,2/ (dotted region), On the other hand, activation cross sections vary considerably as a function of A, but also σ_{act} measured by different authors yield results differing by more than a factor of two.

We started a systematic survey of 14 MeV (n,γ) reactions by the activation method.

Table 1

Target	σ_{act}(mb)	Target	σ_{act}(mb)
^{23}Na	0.25±0.04	^{55}Mn	1.4±0.2
^{27}Al	0.33±0.1	^{41}K	2.0±0.3
^{37}Cl	1.8 ±0.2	^{127}I	7.0±0.5
^{51}V	1.4 ±0.2		

* To be presented at "Nuclear Structure Study with Neutrons" Budapest

The obtained results (Fig.1 and Tab.1) show that σ_{act} are generally larger than σ_{int}. This difference appears to be small near the closed neutron shells, but for from them it may reach an order of magnitude.

References

1) F. Cvelbar, A. Hudoklin and M. Potokar, Nucl. Phys. A138 (1969) 412; A158 (1970) 251

2) D. Drake, I. Bergquist and D.K. McDaniels, Phys.Lett. 36B (1971) 557.

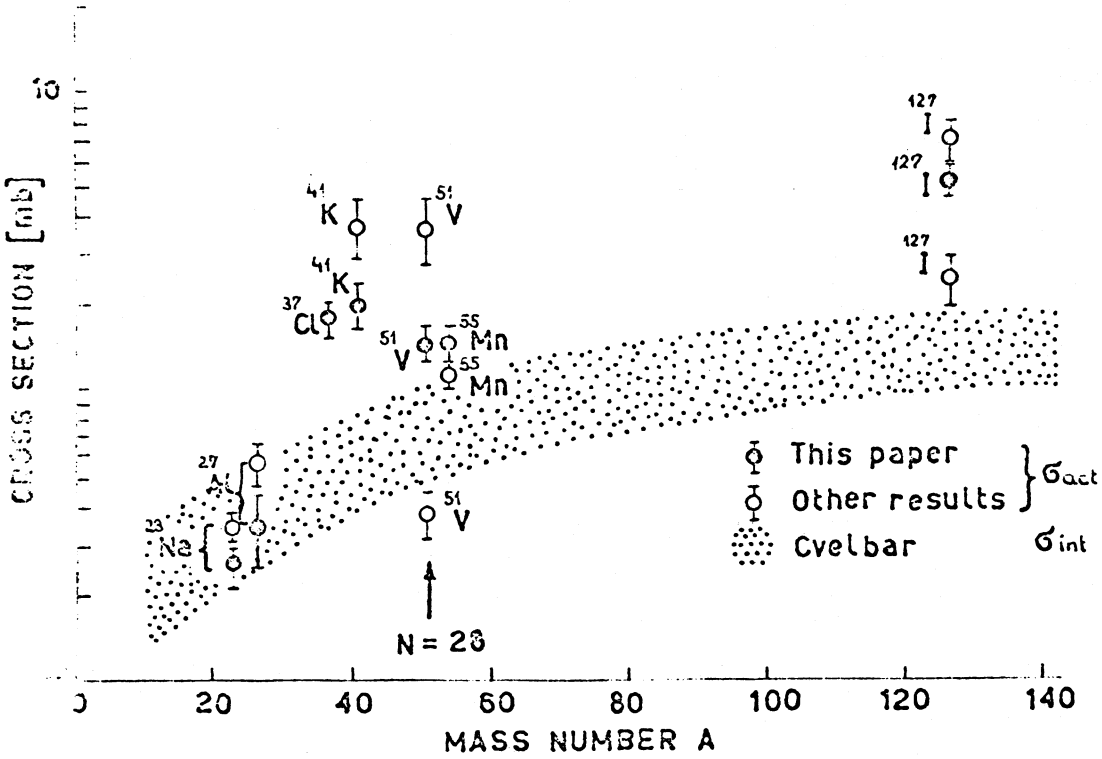

Fig. 1. Interpretation and some activation (n,γ) cross sections

Correlation measurements of neutron-induced multiparticle reactions in nuclear emulsions

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Nucl.Instr. and Meth. 100 (1972) 211-216

The complete measurement of three and more particle breakups has become feasible by the use of nuclear emulsions loaded with the element on which the reaction is to be studied. In fact, such an arrangement offers an almost 4π detection geometry with a twofold advantage over the standard two-counter experiments. The yield of the reaction is considerably increased in comparison with that obtained with the two-counter setup. Moreover, measurements performed by this technique are extended to almost the whole solid angle. Thus the condition of exploring the large momentum space, so important in the study of multiparticle breakup reactions, is also fulfilled.

A procedure of using nuclear emulsions in complete measurements of three-body breakup reactions is described.

Study of the $^{12}C(n,n)3$ alpha reaction in a kinematically complete experiment

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The breakup of the ^{12}C into three alpha particles was studied via the inelastic $^{12}C(n,n')^{12}C(3\alpha)$ process and the excited states involved are 9.6, 11.8 and 12.7 MeV.

The reaction $n+^{12}C \longrightarrow n+\alpha+\alpha+\alpha$ was investigated using nuclear emulsions. The emulsions contain a large amount of ^{12}C(17.6% per atoms) and can therefore be used simultaneously both as a target and a detector. The three alpha prong events were measured and selected from the other three prong processes by the energy and momentum balance with the aid of an off-line CAE 90-40 code.

The neutron and alpha particle spectra in the ^{13}C centre-of-mass system as well as the spectrum of the ^{5}He relative energies were analyzed in order to define the contributions of different sequential processes:

1. $n+^{12}C \longrightarrow n+^{12}C(\alpha)^{8}Be(2\alpha)$
2. $n+^{12}C \longrightarrow \alpha+ {}^{9}Be(n)^{8}Be(2\alpha)$
   $\hookrightarrow {}^{9}Be(\alpha)^{5}He(n,\alpha)$
3. $n+^{12}C \longrightarrow {}^{8}Be(2\alpha)+{}^{5}He(n,\alpha)$

It was found that the $^{12}C(n,\alpha)^{9}Be(n)2\alpha$ reaction contributes only in the intermediate 2.43 MeV state of ^{9}Be. The presence of this reaction manifests as a distinct peak on the continuum of the three alpha energies generated in process 1. The intensity of the sequential process via ^{9}Be is 9.8%, but due to the kinematical conditions it coincides only with the events of process 1 involving ^{12}C

excitations higher than 11.5 MeV. In this region of ^{12}C excitations, therefore, the mixing of processes 1 and 2 becomes considerable and one has to be cautious in the interpretation of the respective ^{12}C-3α data. Fortunately, the $^{9}Be_{2.43}(n)^{8}Be(2\alpha)$ sequence involves only the formation of ^{8}Be in its ground state, which is not of primary interest in this study.

No evidence was found for the process proceeding via ^{5}He in the ground state.

The three alpha correlation spectra for ^{12}C resonances at 9.6, 11.83 and 12.71 MeV are presented in triangular Dalitz diagrams. Only those data were analyzed for which the ^{12}C excitation falls between the narrow strip of $\pm$0.3 MeV around the resonance.

The three alpha breakup of the ^{12}C nucleus in the 9.63 MeV excited state ($I^{\pi} = 3^{-}$) is shown in fig.1. The density distribution of the data is typical of a sequential decay through the $^{8}Be_{g.s.}$ with the strong intensity peaks near the maximum energies of the three alphas. There is no trace of evidence for the simultaneous breakup to be present.

The data on the three alpha breakup of the 11.83 MeV state of the ^{12}C nucleus are presented in fig.2. The scheme of the loci of relative energies corresponding to the ground and first excited state of ^{8}Be is also given. The main features of the reaction resulting from the Dalitz diagram are as follows: 1) high density of events along the line corresponding to the transition via the ground state of ^{8}Be; 2) clustering of experimental points along the lines corresponding to the transition to the first excited state of ^{8}Be, although the points are more scattered due to the large width of the 2.9 MeV ^{8}Be state; 3) very weak intensity at the intersections of the two bands of the same relative energies (2.9 MeV of ^{8}Be).

The spin and parity of the 11.83 MeV state were not established with certainty[1]. The tentative spin - parity assignment is 2^-, but 1^- was not ruled out. The present results show that a large part (25%) of the ^{12}C(11.83 MeV) - 3 alpha decay proceeds via the $^{8}Be_{g.s.}(0^+)$. Hence, due to spin and parity conservation laws, the 1^- assignment for the 11.83 MeV state is the only possible one.

Figure 3 shows the Dalitz plot of the breakup of the 12.71 MeV ($I^{\pi} = 1^+$) ^{12}C excited state into 3 alpha. The spin and parity considerations exclude the transition to the ^{8}Be ground state. The population of points along the lines corresponding to the ground state transition is due to the contribution of the $^{12}C(n,\alpha)^{9}Be(n)^{8}Be(2\alpha)$ chain. In this diagram the intersections of the lines corresponding to the 2.9 MeV relative energies of ^{8}Be come close together around the centre. As expected, the experimental points cluster in the centre.

Reference

1) F. Ajzenberg-Selove, T. Lauritsen, Nucl.Phys. A114 (1968) 1.

Figure caption

Fig. 1. Dalitz diagram of the three alpha breakup of the ^{12}C nucleus in the 9.63 MeV state. The loci of relative energies corresponding to the ground state of ^{8}Be are given in the lower scheme.

Fig. 2. Dalitz diagram of the three alpha breakup of the ^{12}C nucleus in the 11.83 MeV state. The loci of relative energies corresponding to the ground and first excited state of ^{8}Be are given in the lower scheme.

Fig. 3. Dalitz diagram of the three alpha breakup of the ^{12}C nucleus in the 12.71 MeV state. The loci of relative energies corresponding to the ground and first excited state of ^{8}Be are given in the lower scheme.

$^{12}C \longrightarrow 3\alpha$

$E^{*}_{^{12}C} = (9.64 \pm 0.3)$ MeV

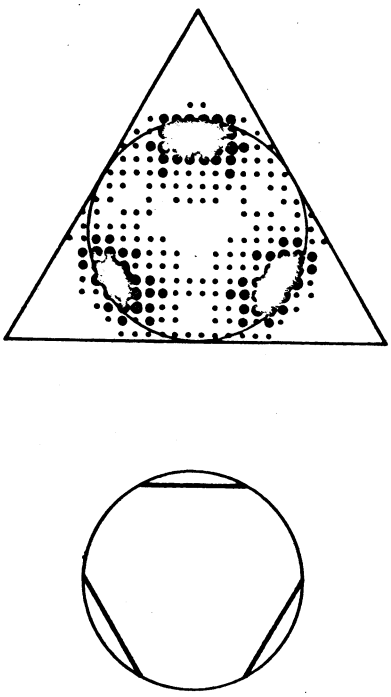


Fig. 1.

$^{12}C \longrightarrow 3\alpha$

$E^{*}_{^{12}C} = (11.83 \pm 0.3)$ MeV

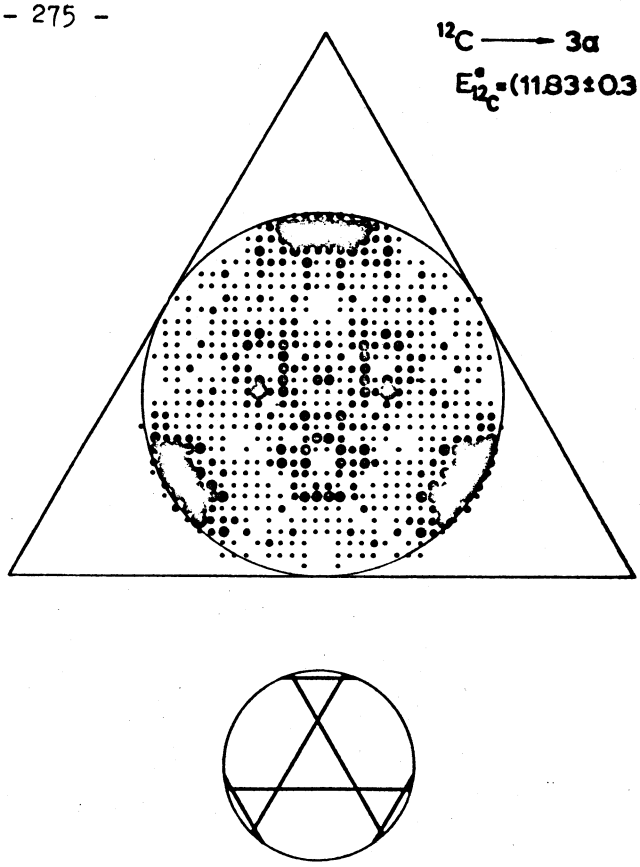
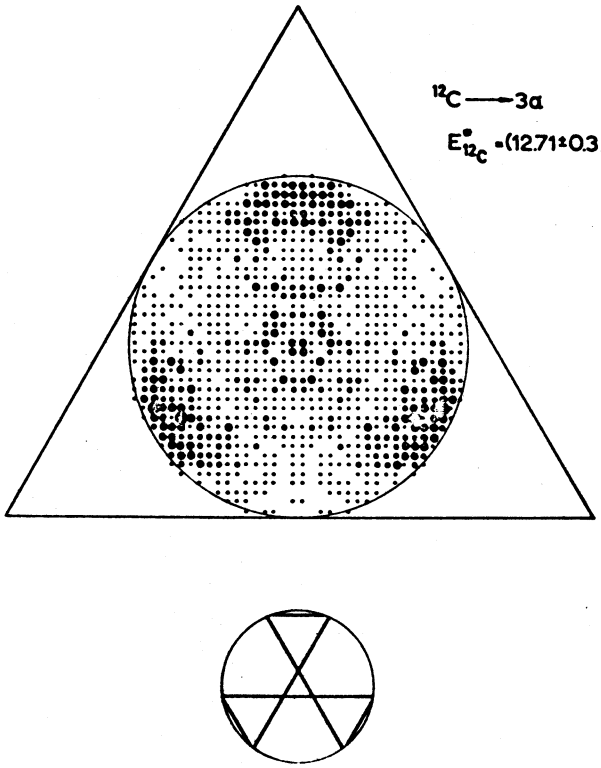


Fig. 2.

$^{12}C \longrightarrow 3\alpha$

$E^{*}_{^{12}C} = (12.71 \pm 0.3)$ MeV



Isomeric cross section ratios for (n,p) reactions induced by 14.6 MeV neutrons in Te isotopes

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Although the isomerism in isotopes of tellurium is well established, the available data on the yield ratio for the isomeric pair formation of tellurium isotopes are scarce for 14-15 MeV neutrons. In this work we have measured the (n,p) cross sections for the metastable and ground states of all unstable tellurium isotopes.

Irradiations were performed at 14.6 ± 0.2 MeV with neutrons obtained from the $^{2}H+^{3}H$ reaction using 200 keV Cockcroft-Walton generator of the Institute "Ruđer Bošković". The neutron flux was about 2×10^{9} n/sec, and the total neutron yield was monitored by the associated α-particles. Gamma-ray spectra were measured using 25 cm^{3} Ge(Li) detector coupled to the 400-channel analyser.

In Table 1 the experimental and theoretical results isomeric ratios for (n,p) reactions are shown. Calculations of the isomeric ratio were performed for several values of (ν = 1,2,3,4,5) and for several values of the cut-off parameter σ (σ = 3,4,7) included in the known formula for spin-dependent level density[1].

Reference

1) C. Bloch, Phys.Rev. 93 (1954) 1094.

Table 1

Target	Product	Exp.val. (mb)	σ_m/σ_g	Theoretical values									
				σ = 3 or 4					σ = 7				
				ν					ν				
				1	2	3	4	5	1	2	3	4	5
^{120}Te	^{120m}Sb	64±10	0.78	.241	.243	.247	.251	.273	.505	.584	.588	.669	.722
	^{120g}Sb	82±13											
^{122}Te	^{122m}Sb	21±6	0.81	.120	.130	.138	.144	.148	.302	.364	.422	.473	.519
	^{122g}Sb	17±3											
^{124}Te	$^{124m1}Sb$	5±0.8	0.38	.830	.870	.882	.923	.949	.644	.648	.638	.637	.632
	$^{124m2}Sb$	2±0.3											
	^{124g}Sb	13±2	0.15	.272	.337	.386	.434	.475	.159	.172	.179	.183	.185
^{126}Te	^{126m}Sb	1.5±0.1	0.50	.177	.212	.240	.268	.286	.262	.328	.376	.423	.466
	^{126g}Sb	3±0.9											
^{128}Te	^{128m}Sb	1±0.1	0.67										
	^{128g}Sb	1.5±0.3											
^{130}Te	^{130m}Sb	0.9±0.2	0.64										
	^{130g}Sb	1.4±0.3											

for ^{126}Te $\sigma = 3$

FAST NEUTRON DOSIMETRY

An effort has been recently made on developing methods of fast neutron dosimetry. The following two contributions are representative of the work done so far.

New chemical systems for low-level fast neutron dosimetry

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The response of two dosimetric systems, (1) 0.20 m$\underline{M}$ ferrous sulphate, 5.0 m$\underline{M}$ benzoic acid and 0.20 m$\underline{M}$ xylenol orange in 0.05$\underline{N}$ sulphuric acid, and (2) 2,2,4-trimethylpentane + 10% (by volume) ethanol + 10% chlorobenzene + $2 \times 10^{-6}\underline{M}$ K-thymolsulphonphthalein + upto 0.1% water + HCl, to 14.7 MeV neutrons was studied. The average neutron flux in the irradiation cell was measured by filling the cell with magnesium acetate solution. The neutron flux incident on the surface of the cell was measured by aluminium activation. Efforts have been made to use the best available cross section data and to achieve the highest possible experimental accuracy. The G-values and other details for the use of these systems in fast neutron dosimetry are given.

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Neutron dosimetry experiments using a tissue equivalent proportional counter

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Presented at International Symposium on Neutron Dosimetry in Biology and Medicine, Neuherberg/Minich

An experimental method for measurement of dose equivalent in mixed radiation field is presented. The method is based on the measurement of energy deposition in a very small tissue-equivalent volume. The experimental arrangement consists of a small, sealed off, tissue-equivalent counter and the associated electronics.

A thin wall polyethylene plastic sphere 30 cm in diameter is filled with tissue equivalent liquid. The shape and the diameter of the tissue-equivalent phantom are chosen according to the ICRU Report 19. The tissue-equivalent proportional counter is located within the plastic phantom and can be easily positioned at any place within the sphere. The pulse height spectra obtained from the proportional counter were processed by a standard electronic analyzing system. The pulse height distributions thus obtained contain valuable information on the dose per event distribution which is used for evaluation of quality factor of the radiation in question.

Progress Report on Nuclear Data Activities in Australia

(May 1971 - May 1972)

June 1972

DATA PROJECTS

(a) Fission Products (J. L. Cook, E. Clayton, H. Ferguson, E. Rose)

To date a number of minor revisions have been made to the original 1970 fission product poi nt cross section file to remove obvious anamolies arising from attempts to obtain the correct resonance integrals. A visual display facility would have been extremely useful in detecting such pecularities as arose in the original file. Our next major update is planned to commence in 1974 in which we will produce a rather more extensive file than is required for thermal and fast reactor burnup studies. This is because requests are continaully arising for data on nuclides not in our present file that are being used in projects other than burnup studies.

The initial phase of the evaluation will be a compilation of some 800 nuclide energy level schemes and gamma decay intensities. Attempts will be made shortly to improve further the prediction of level densities, radiation widths and strength functions. In particular, the accuracy of predictions of (n,γ) cross sections above 1 MeV will be checked.

A basic alteration is being made to the GUNYA code as the 1970 evaluations showed rather too often effects attributable to strong bound levels. Instead, a 1/v contribution, which is what one expects from a spectrum of bound levels, will be used to remove thermal cross section discrepancies. Provisions are also being made to obtain measure resonance integrals from the predicted data. The final file will consist of a 128 group cross section set for each nuclide and each reaction.

(b) Multi-Level Fitting of Fission Cross Sections (J. L. Cook, W. Bertram, A. R. Musgrove)

An intensive study is being made of the Adler-Adler resonance parameter formalism in an effort to extract the maximum amount of information from a given set of fitted parameters. We have prepared

our own fitting program and translated several overseas codes which do similar fits to provide checks. The major problem is to find the parameters of the level matrix. The special solution given by Adler and Adler at the 1970 Helsinki Conference is, they admit, not unique. We are searching for solutions different to theirs which would allow one to keep the number of fission channels fixed and where the radiation width is constant from resonance to resonance. We have proved that such a solution exists and are investigating it numerically to see if one can also find conditions which could be used to spcify the number of fission channels.

(c) $\bar{\nu}_p$ Measurements (J. W. Boldeman, R. L. Walsh)

The absolute number of prompt neutrons emitted in the spontaneous fission of ^{252}Cf is being measured using a large liquid scintillator tank. Major effort has been given to measurement of the neutron detection efficiency of the scintillator with calibrations using the np scattering process. A careful investigation of sources of experimental error has been made including corrections for delayed fission gamma rays (-0.198 $\pm$ 0.051%) and French Effect (-0.09 $\pm$ 0.10%). Work continues on the dead time corrections. An experiment has been designed to test that the axial hole through the scintillator can be satisfactorily taken into account. A final result cannot yet be presented. However, it is obvious that the result will be much lower than previous scintillator measurements and in approximate agreement with results from $MnSO_4$ baths and the Boron Pile. The final accuracy is expected to be 0.4 per cent.

Measurements are in progress of fission fragment angular distributions for neutron fission.

(d) Neutron Capture Cross Section (B. J. Allen, J. W. Boldeman R. J. Cawley, M. J. Kenny, R. L. Walsh, A. R. Musgrove, and D. M. Chan and D. B. Stroud (Melbourne University))

An active collaboration program is underway between ORNL and AAEC on the high resolution measurement and analysis of capture cross sections of separated isotopes. Measurements have been made at the 140 MeV Oak Ridge Electron Linear Accelerator in the energy range 3-1000 keV. At Lucas Heights analysis is underway on Si^{NAT}, the isotopes of Ca, Cr, Ti, Zr and Ba.

The pulsed Van de Graaff at Lucas Heights has also been used by D. Stroud to measure the 30 keV capture cross sections of Co, Er, Mo, Ag, Ta and the isotopes of ^{84}Mo and ^{96}Mo.

(e) IAEA Compilation (B. J. Allen)

The IAEA Working Group on the compilation, evaluation and dissemination of nuclear data met in Vienna on March 13-17, 1972. The group reviewed the various data fields and user requirements, and made a number of recommendations intended to facilitate the supply of updated, evaluated nuclear data to the applied users. Among the recommendations were the establishment of a compilation and evaluation newsletter, active participation by IAEA member states to assist the major data centres, a survey of user needs in the area of activation analysis, and designated responsibilities for A-chain evaluations.

(f) Neutron Reactions

1. Neutron Capture Spectra (M. J. Kenny, J. R. Bird and D. M. Chan (Melbourne University), Hla Pe (University of N.S.W.), L. E. Carlson (ANU)

Klystron bunched proton beams (2 nsec width, 1 MHz repetition rate) are used to provide pulsed keV neutron beams (10-90 keV) from the $^{7}Li(p,n)$ reaction. Time of flight and γ-ray pulse height spectra are simultaneously accumulated to obtain decay schemes for a number of

resonances. The present work is concentrated on looking for p-wave capture in 2s-1d shell nuclei. In many cases, strong transitions are seen to positive parity final states. These are generally weak or unobserved in thermal (s-wave) capture and are most probably E1 transitions following p-wave capture. Sample sizes of up to 2 kg of F, Al, Si, S, Cl and Ar have been used. Silicon results are being compared with total capture cross section data obtained at OREAL. A system is being developed to measure γ-ray spectra at 90° and 135° to enable the resonance spin to be derived.

2. Fission Processes (R. L. Walsh, J. W. Boldeman and J. Caruana and J. Mathur (Wollongong University College)

Measurements are in progress of neutron emission from fission fragments of specific mass and charge in the spontaneous fission of ^{252}Cf. The mass resolution on the fission fragments is 4 amn and 540 eV on the X-rays used to identify the fragment charge. Even-odd effects have been noted in the X-ray yields.

(g) Prompt Nuclear Analysis (M. D. Scott, L. H. Russell, J. R. Bird)

Gamma rays from the reaction $^{19}F(p,\alpha\gamma)^{16}O$ have been used to detect traces of fluorine in etched zirconium metal down to concentrations less than 0.01 $\mu g/cm^2$. By using proton energies above the 0.875 MeV resonances a distribution of fluorine in depth in oxide films is also obtained. Tests are proceeding on the use of gamma rays from (p,γ) and $(p,p'\gamma)$ reactions in oxygen isotopes to obtain a simultaneous measurement of the concentration of the three stable oxygen isotopes.

Collaboration with James Cook University of Townsville is aimed at determining the performance of (n,γ) reactions with prompt gamma-ray detection for analytical work.