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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

Consolidated Progress Report for 1971 on Nuclear Data Activities in the NDS Service Area

Argentina
Australia
Brazil
Bulgaria
Hungary
India
Iran
Republic of Korea
Poland
Romania
Republic of South Africa
Uruguay
Yugoslavia

August, 1971

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

Foreword

This consolidated progress report in 1971 has been prepared for the first time in response to suggestions received from 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 It is intended to encourage a closer relationship between Member States and provide for a wider circulation of unpublished progress reports from countries within the Nuclear Data Section service area.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, preceeded 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
Nuclear Data Activities in Argentina

Argentine Atomic Energy Commission

March, 1971

PROGRESS ON THE STUDY OF THE THERMAL NEUTRON RADIATION CAPTURE REACTION

(M.A.J. Mariscotti, C. Pomar, M. Simon; Cyclotron Lab.)

One of the irradiation tubes at the RA-3 Reactor, has been used to extract a 5mm collimated neutron beam for studies of the (n, γ) reaction.

Gamma rays are detected with a Ge(Li) detector and NaI scintillator both in singles and coincidences, a target of Cr has been exposed to the beam and the γ-spectra analyzed with the purpose of determining the Ge(Li) detector efficiency in the high energy range.

Several target elements have been studied; Nd, Y, Ti and As, and branching ratios have been measured. In the particular case of Ti the experiment was carried out in an attempt to establish the existence of low lying excited states due to core excitations. The results of this investigation are being analyzed and will be published in the near future.

REACTOR PHYSICS DIVISION

1.- Activation resonance integral of Nd^{146}, Nd^{148}, Nd^{150}

The measurement of Nd^{146}, Nd^{148} and Nd^{150} activation resonance integral has been almost completed. Samples were prepared with natural neodymium and gold as a standard, activities were obtained by irradiating bare and cadmium covered samples for two hours in the internal reflector of the RA-1. The measurements were made in a Ge(Li) coaxial detector. Gamma rays of Pm^{149} (285 keV), Nd^{147} (532 keV), Pm^{151} (275 and 342 keV) and Au^{198}(412 keV) were measured.

Preliminary results agree with that of Alstad et al (J. Inorgánic Nuclear Chem. 29 2155 (1967) and disagree with the resonance integral calculated from resonance parameters (JINR P3-3564 (1967)).

2.- Self-shielding of Zr^{96}

Due to the anomalous characteristics of Zr^{96} (Canadian Journal of Physics, 48, 2362 (1970) a careful determination of epithermal self-shielding of Zr^{96} was undertaken. Experimental determination has been completed and preliminary calculations show a good agreement, indirectly confirming resonance parameters of the 301 eV

3.- The activation resonance integral of Ge^{74} and Ge^{76}

The final analysis of the results for Ge^{74} and Ge^{76} has been completed and a paper has been prepared for publication. Self-shielding and infinite diluted resonance integral are consistently discrepant with the values calculated from resonance parameters (Maletzki et al. Atomn. Energ., French Translation, 24 (1968) 173).

4.- Instrumentation

A Hewlet-Packard computer (2116B) has been put "on line" with a Ge-Li spectrometer. A soft-ware has been developed to calculate on line the data reduction needed for our experimental work. An automatic sample changer is being built and will be added to our system.

G. Ricabarra, D. B. de Ricabarra, R. F. de Turjansky,
D. Waisman.- Reactor Physics Division, Reactor Department.

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

Progress Report 1970

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

Nuclear Spectroscopy Division
Comisión Nacional de Energía Atómica
Buenos Aires - Argentina

A set-up for nuclear spectroscopy studies of short-lived, fission-produced radioisotopes became operative at the Argentine AEC, in Buenos Aires, around the beginnig of 1969. The system is of the ISOL type, consisting in a continuous production and mass separation of the nuclei, followed by detection of the emitted radiation by means of solid-state detectors coupled to appropriate analysing devices.

A sample of uranyl stearate containing up to 20 g of 90% enriched uranium is exposed to a thermal neutron flux density of about 10^8 $n.cm^{-2}.s^{-1}$, produced by the (d,n) reaction on ^7Li through the use of a Cockcroft-Walton accelerator. The fission products are swept into the ion source of a double-focussing, Scandinavian-type, 90° mass separator of 1.5 m radius. Xe-I mixtures are used as sweeping gas. The activities are collected on fixed or moving collectors, according to the particular problem being studed. Two Ge(Li) detectors of nearly 35 cm^3, having about 2.2 and 3.0 keV resolution, and a Si(Li) electron detector with a resolution

+ Member of the Scientific Research Career of the Argentine Scientific and Technical Research Council.

of 7.5 keV, have been used up to now. To a lesser extent NaI(Tl) detectors are also used for half-life determinations. Recently, a high resolution Si(Li) X-ray detector has been included as an additional facility. The pulses from the detectors are fed through conventional commercial electronics to a 2116B Hewlett-Packard computer provided with two ADC's and a 16K memory, operable as a 4096 channel pulse height analyser. A 512 -and a 1600- channel PHA are also in use.

From the very beginning, our aim was to install a transport line as short as possible between the uranium sample and the ion source of the mass separator in order to enhance the shorter half-lives, as well as to favour the collection of halogens. The overall performance of the set-up was satisfactorily tested by reproducing the gamma-ray spectra of $^{137 \text{ to } 142}Xe$ previously reported by TRISTAN[1]. The neutron-reach Kr isotopes were also collected efficiently, including ^{93}Kr, which has a half-life as short as 1.2 s. Finally, the system proved capable of handling reasonable quantities of bromine and iodine activities.

The research programme started at the beginning of 1970 with an investigation of the decay of $^{134m,g}I$ to ^{134}Xe [2]. A 3.56 min isomeric state was definitely placed in ^{134}I (it had previously been proposed[9] from less decisive evidence). Conversion electron measurements established the E3 multipolarity of the 272.2 keV isomeric transition. The amount of β^--branching from the isomeric level was determined. Measurement of the internal conversion coefficients of 11 transitions belonging to the decay of ^{134g}I allowed the determination of the corresponding multipolarities and a subsequent reduction of the number of possible spins and parities proposed [3,4] for the ^{134}Xe level scheme.

A determination of conversion coefficients in several nuclei of the "heavy" ^{235}U-fission peak followed [5]. Altogether, about 35 of them were measured for transitions which proceed in $^{133, 135, 136}Xe$, $^{135, 137, 139}Cs$ and ^{138}Ba. Based upon the published information regarding the corresponding level schemes, as well as on additional information we obtained, the multipolarities determined were used to assign parities and spins for the excited levels.

A study [5] was performed on the dynamics of the emanation in, and following removal of the gaseous fission products from, the uranium container. It included a discussion of the transport times along the tubing connecting the uranium container to the mass separator ion source and of the efficiency of the latter. The laws established were confirmed experimentally. They need to be taken into account when determining fission yields with ISOL-type systems.

Under progress is an investigation concerning the decay of 14 min ^{138}Xe. Nagahara et al. [6] proposed a level scheme for ^{138}Cs which includes a postulated-up to now undetected- 15.4 keV transition. We aim at clarifying the level scheme by thoroughly investigating the low-energy gamma-ray spectrum. Single gamma and conversion electron measurements have been performed. X-ray and coincidence measurements are planned for early 1971.

Two contradicting papers [7,8] have been published on the decay of 55 s ^{86}Br to ^{86}Kr. The discrepancies might be resolved by using a mass separator, which would avoid the perturbing prescence of ^{87}Br, which has almost the same half-life. Some exploratory runs have been performed and it is intended to begin more detailed measurements early in 1971.

As in earlier years, the programme enjoyed the continuous support of the efficient work of technitians A.Barroetaveña, J.Cava, R.D'Agostino, F.di Giacomo, A.Gorgoshidse, E.S.Menéndez, J.A.Purificato and A.Tersigni.

1) W.L.Talbert; private communication.

2) Submitted for publication in Phys.Rev.C.

3) W.G.Winn and D.G.Sarantites; Phys.Rev. 184 (1969) 1188.

4) E.Takekoshi et al.; Nucl.Phys. A133 (1969) 493.

5) Communicated at the 54th meeting of the Argentine Physical Society, 1970.

6) T.Nagahara et al.; J.Phys.Soc. Japan 26 (1969) 232.

7) E.T.Williams and C.D.Coryell; Phys.Rev. 144 (1966) 945.

8) A.Lundán; Z.Physik 236 (1970) 403.

9) H.Erten and C.D.Coryell; Chemistry Progress Report MIT-905-133, p.14 (1968).

Progress Report on

Nuclear Data Activities in Australia

(May 1970 - May 1971)

June 1971

1. FISSION PRODUCT EVALUATION

Re-evaluation of capture and total cross sections for all elements in the A.A.E.C. library is now complete. This data has been transmitted to the I.A.E.A. Nuclear Data Section and to the N.N.C.S.C. at Brookhaven, U.S.A.

Reactivity liftime studies have indicated that adequate accuracy can be achieved in thermal reactor system calculations with 41 nuclides represented explicitly and with the remainder lumped together as a pseudo fission product.

Studies of fast reactor systems are now in progress with the aim of reducing still further the number of fission products which require explicit representation in burn up calculations.

2. MULTILEVEL ANALYSIS OF CROSS SECTIONS

Cook (AAEC) is developing a new multilevel theory in which the cross section parameters, as proposed by Adler and Adler, are exact. The theory distinguishes between the contributions to the reaction matrix from the resonant compound nucleus processes and the essentially constant direct processes. Programmes have been written which fit cross sections to the Adler-Adler scheme and calculate reaction matrix parameters from Adler-Adler constants.

Cook's theory shows that the same equations and constants for the fission and capture cross sections are obtained regardless of the spin assignment. It has proved impossible to make spin assignments without accurate scattering cross section information. The main advantage of Cook's work lies in the ease with which analysis of fission and capture cross sections can be made.

3. FISSION PHYSICS

3.1 Musgrove has made trajectory calculations for the light particles emitted in spontaneous fission of ^{252}Cf. Initial dynamic variables were found which reproduced the measured energy spectra for ^{1}H, ^{2}H, ^{3}H and ^{6}He particles. It was also noted that the heavy fragment separation at scission increased as the mass of the third particle decreased. A naive interpretation might be that increased stretching of the neck progressively breaks down the structure of the third particle.

3.2 Boldeman has spent much time and effort in preparing his equipment for re-measurements of $\nu_p(E)$ for ^{235}U with energy resolution of better than ± 10 keV. This work should commence soon.

3.3 Measurements of the average total kinetic energy ($\bar{E}_k$) of ^{233}U with incident energy have been complimentary to his $\bar{\nu}_p(En)$ data for ^{233}U.

4. CROSS SECTION DATA DISPLAY INFORMATION

A display programme for A.A.E.C.'s IBM360-50 computer and Calcomp 565 plotter enables data libraries and multigroup cross sections to be displayed. It is flexible and one such feature enables a super-imposition of cross sections from different sources to be compared.

It is proposed to expand this work into a full interactive video display.

5. NEUTRON CAPTURE STUDIES

5.1 Resonance keV Neutron Capture

Resolved resonance spectra have been obtained from thin samples of Ti, Ni and Fe at a 1 metre flight path using a 20 x 15 cm shielded NaI detector. Partial capture yields for ^{48}Ti, ^{58}Ni and ^{56}Fe have been analysed to give $\sigma_0 \Gamma_{\gamma i}$ and sometimes $\Gamma_{\gamma i}$. This information has enabled partial capture cross sections to be established.

For Ti multiple scattering corrections were obtained by using two target thicknesses of 0.5 and 1.0 mm Ti. The yield for the fifth excited state of ^{49}Ti was analysed using a multi-level interference cross section. The ground state transition in ^{49}Ti confirms the presence of a d-wave resonance at 39 keV.

5.2 Average keV Capture in Zinc

Gamma ray transition strengths in ^{65}Zn and ^{67}Zn following neutron capture were analysed and the results compared with calculations based on resonance parameters and a statistical neutron capture mechanism. Estimates of p- and d-wave strength functions were obtained. Substantial deviations from the statistical behaviour of averaged transition strengths led to the conclusion that configuration effects are important in partial neutron capture cross sections.

5.3 Interpolations for Nuclear Level Spacings and Radiation Widths

Nuclear level densities obtained from the free gas model were used to interpolate unknown level spacings. The model's level density parameter was fitted semi empirically to give a good fit to measured level spacings. A formula was obtained for the total radiation width as a function of mass number, average level spacing and excitation energy. No correlation between radiation width and neutron strength function was observed. These parameters have been used to calculate the 30 keV capture cross sections which have been compared with measurements of Allen (1970) and calculations of Benzi and Reffo (1969).

Progress Report on

Nuclear Data Activities in Brazil

Compiled by Silvio B.Hardade

June 1971

PROGRESS REPORT ON NUCLEAR DATA IN BRAZIL

May, 1971

1. INTRODUCTION

Nuclear physics research in Brazil is concentrated mainly in the following research centers (main experimental facilities are indicate):

Institute of Physics, University of São Paulo (3.5 Mev Van de Graaff, 75 Mev electron LINAC, "Pelletron" tandem accelerator in construction): charged particle reactions, electron induced reactions, nuclear spectroscopy.

Instituto de Energia Atômica, São Paulo (5 Mw pool reactor) : neutron cross-sections, photonuclear reactions, neutron capture gamma-ray studies, nuclear metrology.

Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro (28 Mev electron LINAC): nuclear spectroscopy, neutron physics.

Catholic University, Department of Physics, Rio de Janeiro(4 Mev Van de Graaff in construction): nuclear spectroscopy.

Instituto de Engenharia Nuclear, Rio de Janeiro (Argonaut type reactor): nuclear spectroscopy, neutron spectroscopy.

Institute of Physics, University of Rio Grande do Sul,Pôrto Alegre (angular correlation equipment): nuclear spectroscopy.

2. DEVELOPMENTS IN THE ACQUISITION AND BUILDING OF FACILITIES FOR NUCLEAR PHYSICS MEASUREMENTS

2.1. "Pelletron" accelerator, Institute of Physics, University of São Paulo

This machine formed by a 4 Mv injector coupled to a 9 Mv Tandem, will provide continuous and pulsed charged particle beams of 22 Mev protons, 27 Mev alpha particles, and 200 Mev heavy ions. The building is finished and the accelerator is being assembled. The facility includes a IBM/360/44 computer, on-line data processing, scattering chambers, and instrumentation for gamma, neutron, and charged particle spectrometry. The initial operation is programmed for the second semester of 1971. Research will include mechanisms of nuclear reactions, nuclear spectroscopy, charged particle radioactive capture reactions, angular correlation, Coulomb excitation, neutron time-of-flight.

2.2. Electron Linear Accelerator, Institute of Physics, University of São Paulo

Variable energy up to 75 Mev; 1 μA unanalysed mean current; resolution of analysed beam 0.5%. This accelerator has been installed during 1969-70 and is already in operation. Research program includes electrodisintegration experiments, electrofission, photofission and delayed neutron studies; nuclear spectroscopy of radionuclides deficient in neutrons; electron scattering.

2.3. Electron Linear Accelerator, Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro

Energy: 28 Mev; 60 μA mean current; pulsed beam with pulses from 500 nsec 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, and 20 meters are in use for neutron time-of-flight spectrometry. Resonant neutron capture studies are in progress.

2.4. Van de Graaff Accelerator, Catholic University, Department of Physics, Rio de Janeiro

This is a 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 building for housing the accelerator is already finished and the accelerator is being assembled. Computer facilities, including IBM-1130 and IBM-7044 computers, are available. Future research will include ^{3}He induced reactions, (d,n) reactions, and Coulomb excitation.

2.5. Other Nuclear Instrumentation

2.5.1. Instituto de Energia Atômica, São Paulo

In operation at the IEA-R1 research reactor: neutron capture gamma-ray collimated beams for photonuclear studies including photofission, magnetic beta spectrometer for convertion electrons, neutron crystal spectrometer, neutron diffractometer, Be-filter/slow chopper/time-of-flight spectrometer.

400 Kv Van de Graaff, pulsed neutron source being used for fast and thermal neutron pulse propagation studies.

2.5.2. Instituto de Engenharia Nuclear, Rio de Janeiro, GB

A neutron crystal spectrometer has been built and is in operation at the J-9 beam port of the Argonaut type reactor. Four LiF (111) crystals assembled together are used as monochromator. The thermal neutron spectrum and the effective neutron temperature in this beam port has been measured.

2.5.3. Instituto de Pesquisas Radioativas, Belo Horizonte

A vertical neutron beam tube was installed in the IPR-R1 TRIGA reactor. At 100 Kw, the thermal neutron flux at the top terminal of the tube is 7.9×10^{5} n/cm^{2}.sec.

3. MEASUREMENT, ANALYSIS AND EVALUATION OF NEUTRON AND NUCLEAR CROSS-SECTIONS

3.1. Neutron Cross-Sections

Instituto de Energia Atômica, São Paulo

The total cross-section and effective absorption coefficient of a germanium single crystal has been measured in the direction (111) using a crystal spectrometer in the energy range 0.01 ev - 1.0 ev. (R. Fulfaro)

The total neutron cross-section of polyethylene has been measured using a slow-chopper time-of-flight spectrometer and a crystal spectrometer in the energy range 0.0008 ev - 0.13 ev; the experimental data are compared with published calculated cross-sections and emphasis is given in the analysis of the results in the very low energy region. (S.B.Herdade, C.Rodrigues, L.Q.Amaral and L.A.Vinhas)

Neutron scattering cross-sections per hydrogen atom of methanol, ethanol, n-propanol, iso-propanol, n-butanol, ethanediol, and propanetriol have been determined at room temperature, in the range 0.0008 ev - 0.13 ev, by means of a slow-chopper T-O-F spectrometer. (C.Rodrigues, L.A. Vinhas, L.Q.Amaral and S.B.Herdade)

Cold neutron differential scattering data were obtained for methanol at room temperature. Experimental studies of the quasi-elastic and inelastic scattering of cold neutrons in n-propanol, iso-propanol, and t-butanol are in progress at the Be-filter/chopper/T-O-F facility. (L.Q.Amaral, C.Rodrigues, L.A.Vinhas and S.B.Herdade)

Measurement of neutron scattering cross-section per H atom of t-butanol above and below the melting point are in progress . (L.Q.Amaral, C. Rodrigues, L.A.Vinhas, S.B.Herdade and R.Fulfaro)

Institute of Physics, University of São Paulo

The ratio of the neutron capture cross-section of Sm, Eu, Gd, Tb, Dy, Ho, Er, Lu, and Ta, to that of In (assumed as standard) has been measured at the energies 30, 65, and 300 Kev. The reaction $^{7}Li(p,n)$ has been used as the neutron source, and a Moxon-Rae detector has been utilized to detect the gamma-rays. (Jacques Lépine)

3.2. Photonuclear Reaction Data and Electron Induced Reactions

Instituto de Energia Atômica, São Paulo .(IEA-R1 research reactor)

The ratio $\Gamma n/\Gamma f$ has been determined for ^{238}U and ^{232}Th near threshold, using monochromatic neutron capture gamma-rays in the energy range 6 to 9 Mev. (O.Y.Mafra, S.Kuniyoshi, and J.Goldemberg).

The (γ,n) reaction cross-sections for Li, ^{6}Li, and ^{209}Bi has been measured using neutron capture gamma-rays in the energy range 5.43 Mev to 10.83 Mev. (M.F.Cesar, O.Y.Mafra, and J.Goldemberg)

The cross-section for the reaction $^{2}H(\gamma,n)$ reactior has been measured using gamma lines of different multipole character /^{72}Ga(2.504 Mev), and ^{24}Na(2.758 Mev)/. (M.F.Cesar, O.Y.Mafra and J.Goldemberg)

Angular distribution studies of fission fragments from $^{238}U(\gamma,f)$ reaction are in progress; solid state track detectors such as glass plates and "makrofol" are used. (S.Kuniyoshi, O.Y.Mafra, C.Renner, M.F.Cesar, and J.Goldemberg)

Institute of Physics, University of São Paulo.(Electron LINAC)

The ratio $\sigma(e,f)/\sigma(\gamma,f)$ of the electrofission to the photofission cross-section of ^{238}U and ^{232}Th is being determined in the energy range 20 Mev to 50 Mev. Studies of delayed neutrons emitted in the photofission of ^{238}U and ^{232}Th are in progress. (I.C. Nascimento, G.Moscati, J.Goldemberg)

3.3. Charged Particle Reactions

Institute of Physics, University of São Paulo

The values of Q_o for the following reactions have been determined: $^{20}Ne(d,\alpha)^{18}F$ (Q_o = 2790 ± 10 Kev), and ^{24}Mg (d,n)^{25}Al . (L.C.S. Bouères, H.A.Maia, L.C.Campello, O.Dietzsch)

The excitation curve in the range E_p = 1.0 - 2.0 Mev, and the spectrometry of ^{41}K are being studied for the reaction $^{40}A(p,\gamma)^{41}K$. (M. Melnikoff, J.P.de Souza and O.Sala)

Using nuclear emulsion techniques the following reactions in tin isotopes are under study: $^{112}Sn(d,p)^{113}Sn$, $^{122}Sn(d,p)^{123}Sn$, $^{124}Sn(d,t)^{123}Sn$. (T.Borello, O. Dietzsch, E.W. Hamburger, C.Q.Orsini)

4. NUCLEAR LEVEL SCHEMES AND RADIOACTIVE DECAY DATA

Instituto de Energia Atômica, São Paulo

Energy levels of ^{28}Al have been studied by the reaction $^{27}Al(n,\gamma)^{28}Al$ using a Ge(Li) detector. Twelve new lines have been identified and suggest the existence of 2 levels near the ground state: $0^+(790 \pm 20)$ Kev and $1^+(830 \pm 15)$ Kev. (M.A.N. de Abreu)

The total internal conversion coefficient of ^{203}Tl 279 Kev transition was measured to be 0.233 ± 0.003, with systematic error less than 0.5%, using the $4\pi\beta(PC)-\gamma$ coincidence system and the variation of the efficiency parameter technique. (L.P.Moura)

The half-life of the 514 Kev level of ^{85}Rb has been determined by measuring the delayed coincidence between the X-rays and the 514 Kev γ-rays in the decay of ^{85}Sr, with the result: 1018 ± 80 nanosecond. (L.P.Moura)

The fission track method was used to determine the decay constant λ_F for spontaneous fission of ^{238}U. Samples of natural uranium in contact with mica remained sealed for 4.216 years. The decay constant was found to be $\lambda_F = (7.30 \pm 0.16) \times 10^{-17}$ year^{-1}. (M.P.T.Leme, C.Renner and M.Cattani)

Institute of Physics, University of Rio Grande do Sul, Pôrto Alegre

The mean life of the 50 Kev level of ^{233}Ra has been measured by means of γ-γ coincidences between the 236 kev and the 50 Kev transitions with the result $\tau_{1/2}$ (50 kev) = 580 ± 50 psec. (R.Livi, F.C. Zawislak)

The γ-γ angular correlations for 12 cascades in ^{131}Cs have been measured; the values 1/2 and 5/2 have been confirmed for the spins of the levels 620 Kev and 133 Kev, respectively, and the spin 3/2 has been atributed to the 124 Kev level. (A.Maciel, A.Vasquez, M.H.P. Correa, and J.D.Rogers).

Institute of Physics, University of São Paulo

The energy levels of negative parity of the odd isotopes of copper have been studied. (J.A.Guillaumon Filho, I.D.Goldman)

Also concluded:

Time dependent angular correlation measurements for the first 2^+ state of ^{150}Sm recoilling into vacuum. (T.Polga, W.M.Roney, H.W.Kugel, R.R. Borchers)

The magnetic hyperfine interaction of the first (2^+) state of ^{142}Ce in Iron. (H.W.Kugel, T.Polga, R.Kalish and R.R.Borchers)

Department of Physics, Catholic University, Rio de Janeiro

The energy level scheme of ^{142}Nd has been studied from the β disintegration of ^{142}Pr, and β^+ disintegration of the chain ^{142}Sm - ^{142}Pm. (F. Smolka, A.G.de Pinho, and J.M.F.Jeronymo)

Other recent work:

The 1/2 ground states of ^{127}Cs and ^{129}Cs.

Enhanced low-energy E2 transitions in the odd. A isotopes of Sb, I, Cs and Pr.

Levels of the odd mass isotopes of Sb and I and the unified model.

Progress Report on

Nuclear Data Activities in Bulgaria

Compiled by E.Nadjakov

May, 1971

PROGRESS REPORT

Bulgaria I970

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

I. A group /N.Kashukeev, N.Kalinkova et al./ is developing a programme of photo-fission studies at the IRT-I000 reactor in Sofia /see Progress Report, Bulgaria I969/. Test results on correlation measurements of energy, mass and angular fission fragment distributions after neutron irradiation have been obtained. A double pulse ionization chamber with grids and electronic collimation has been applied. Minsk-2 electronic computer data processing has been used.

The energy distribution results are the following ones:

	Time-of-flight method	Present experiment
Light fragment energy	99.4 ± I.0 MeV	I00.I4 MeV
Heavy fragment energy	68.2 ± 0.7 MeV	69.64 MeV
Width at I/2h, L	I3.8 MeV	I2 MeV
Width at I/2h, H	20 MeV	I9 MeV
Ratio of most probable energies	I.46	I.46

The total kinetic energy distributions of fission fragments for all fragment masses and fixed mass ratios m_I/m_2 have been obtained. The average total kinetic energy for all m_I/m_2 is I68.5 MeV, distribution width - 26 MeV. The total kinetic energy decrease in the symmetric fission region is estimated to 2I.5 MeV.

The most probable mass ratio is m_I/m_2 = I.48. The min/max ratio in the mass distribution has an order of magnitude I/400.

The fragment ranges for Ar + 4% CO_2 and Ar + 4% CH_4 have been studied. The angular distribution has been found to be isotropic, which is a check for angular distribution measurement possibilities.

2. A group /V.Hristov, A.Stanolov, L.Alexandrov/ continues its investigations on neutron diffusion and thermalization in heterogeneous water lattices by pulse methods, using a fast chopper at the IRT-I000 reactor in Sofia.

Several series of experiments on thermal neutron heterogeneous absorption by non-stationary diffusion /parameters D and C/ have been performed, and the data are under processing. The purpose is to verify recent theoretical results by Kazarnovsky, Ilieva /Institute of Physics, USSR Academy of Sciences, Moscow, to be published/. Cubic light water lattices with a geometric parameter $B^2 = 0.0695 - 0.3965$ cm^{-2} have been used, containing cylindrical aluminium tubes /lattice spacing I.8 cm, tube radius 0.5 cm/ with water solution of H_3BO_3, $\Sigma_a \approx 0.2$ cm^{-I}.

Experiments on the dependence of neutron temperature on B^2, and experiments on M_2 /thermalization parameter/ by the moderator poisoning method with a non- I/V absorber are under preparation.

3. A group /N.Antonov, D.Damianov, V.Hristov, T.Troshev/ has performed experiments on two-group fast neutron diffusion parameters for a heterogeneous water medium with empty cylindrical tubes /lattice spacing I.8 cm, tube radius = 0.5 cm and ratio of tube to water volumes p = 0.3I98/ at the IRT-I000 reactor in Sofia.

The first group relaxation lengths $\lambda_{\parallel}, \lambda_{\perp}$ have been determined by the removal cross-section method. The second group coefficients $L_{\parallel}^2/L_0^2$, $L_{\perp}^2/L_0^2$ and the coefficient of anisotropy $L_{\parallel}^2/L_{\perp}^2$ have been obtained by the exponential method.

The results are as follows:

		Experiment	Theory /Behrens/
	$\lambda_{\parallel}$	I6.75 cm	-
3 MeV < E	$\lambda_{\perp}$	I6.75 cm	-
	$\bar{\lambda}$	I6.75 cm	I4.I8 cm
	$L_{\parallel}^{2}/L_{0}^{2}$	2.I6	I.95
I.44 eV < E < 3 MeV	$L_{\perp}^{2}/L_{0}^{2}$	I.79	I.79
	$L_{\parallel}^{2}/L_{\perp}^{2}$	I.20	I.09

compared with the theory by Behrens D.I. /Proc.Phys.Soc.A62,607,I949/.

One observes that the $\lambda_{\parallel} \approx \lambda_{\perp}$ measured values are slightly higher than the calculated homogeneous value $\bar{\lambda}$. This could be explained as a diffusion prolongation according to the theory of Behrens. One also observes that the $L_{\parallel}^{2}/L_{0}^{2}$ value/ and accordingly $L_{\parallel}^{2}/L_{\perp}^{2}$ / is slightly higher than the calculated one. The measured and calculated $L_{\perp}^{2}/L_{0}^{2}$ values coincide.

4. A group /Z.Zhelev et al./ is working on decay properties and level schemes of neutron defficient isotopes obtained on a 660-MeV proton accelerator /in Dubna/.

5. A group /E.Nadjakov et al./ is working on decay properties and level schemes of neutron defficient isotopes obtained on heavy ion accelerators /U-300 and U-200 in Dubna/.

Liaison Officer to the INDC for Bulgaria:
Emil Nadjakov
Institute of Physics with Nuclear Research Centre
Bulgarian Academy of Sciences
Sofia I3, Bulgaria

Progress Report on
Nuclear Data Activities in Hungary

Hungarian Academy of Sciences,
Central Research Institute for Physics, Budapest,

Department of Atomic Physics,
Roland Eötvös University, Budapest,

Institute of Experimental Physics,
Kossuth University, Debrecen.

April, 1971

THE γ-DECAY OF $g_{9/2}$ ANALOGUE RESONANCES IN THE $^{59,61,63,65}Cu$ NUCLEI

I. Szentpétery and Judith Szücs
Central Research Institute for Physics, Budapest

The excitation function of $^{58,60,62,64}Ni\ (p, \gamma\ )^{59,61,63,65}Cu$ reactions was measured in the $E_p = 3.2 - 4.2$ MeV energy region with the 5 MeV Van de Graaff generator of the Central Research Institute for Physics. The excitation functions were measured with a 7.5 x 7.5 cm NaI crystal; the γ-spectra of the investigated resonances were taken with a 30 cm^3 Ge(Li) detector.

In the case of $^{58,60,62}Ni$ the $g_{9/2}$ analogue resonances were found near to the predicted bombarding energy on investigation of the γ decay of these resonances, strong M1 transitions were found to the anti-analogue states. This phenomenon has already been observed with s-d shell muclei, but it has not been found previously in the case of f - p nuclei. Measurements of the angular distributions for the primary γ- transitions were carried out as well. The Γ_γ and A_2 values are given for these transitions. From the position of the analogue and anti-analogue states an estimate can be given for the avarage strength of the $V_1(r)$ symmetry potential.

GAMMA-GAMMA ANGULAR CORRELATION MEASUREMENTS IN THE $^{59}Co/n,\gamma/^{60}Co$ REACTION

by
B. Kardon, D. Kiss, Z. Seres
Central Research Institute for Physics, Budapest, Hungary

Published in the Proceedings of the International Conference on Angular Correlation in Nuclear Disintegration. Delft, 1970.

Angular correlation measurements of gamma radiation following thermal neutron capture in ^{59}Co have been performed with a combination of a 10 ccm Ge/Li/ diode and a ϕ 12.7 x 12.7 cm NaI/Tl/ detector. In the decay of ^{60}Co cascades of 6876.6 - 555.7 keV and 6984.6 - - 447.2 keV were observed. The spins and parities of the 505 keV and 613 keV levels were found to be 3^+.

SMALL-ANGLE SCATTERING OF NEUTRONS BY DEFORMED NUCLEI

G. Pálla

Central Research Institute for Physics, Budapest.
To be published

It has recently been suggested that long-range interactions may be responsible for the "anomalous" small-angle elastic scattering on ^{232}Th and ^{238}U. It is shown that the existence of an anomaly must be considered as a misinterpretation of the effect of deformation of the nuclei on the values of the differential cross-section.

PHENOMENOLOGICAL FORMULA FOR /n,2n/, /p,2n/ AND /p,3n/ REACTION CROSS-SECTIONS

L. Jéki

Central Research Institute for Physics, Budapest

Report KFKI-71-8 /1971/

A phenomenological formula is suggested to calculate /n,2n/, /p,2n/ and /p,3n/ reaction cross-sections which gives good agreement between the calculated and measured values.

^{252}Cf FISSION NEUTRON SPECTRUM FROM 0,01 TO 1,0 MeV

P.P. Dyachenko, B.D. Kuzminov
Institute of Physics and Power Engineering, Obninsk, USSR

L. Jéki, Gy. Kluge, Gy. Kozma, A. Lajtai
Central Research Institute for Physics, Budapest

To be published

The results of measuremets by time-of-flight technique on fission neutron spectrum of ^{252}Cf from 0,01 to 1,0 MeV are reported.

A ^{6}Li loaded glass scintillator and a gas scintillation detector (80 % Ar + 20 % Ni) are used for the detection of fission neutrons and fragments, respectively.

The results are discussed in terms of the evaporation model.

SURVEY OF MEASUREMENTS OF THE FISSION NEUTRON SPECTRUM OF ^{252}Cf.

L. Jéki, Gy. Kluge, A. Lajtai
Central Research Institute for Physics, Budapest

Report KFKI-71-9 /1971/

The background sources arising in different techniques for measuring fission neutron energies were studied in detail and the background due to the detection of delayed gamma rays was calculated. The proposed value of the Maxwellian temperature for the energy distribution of neutrons from the spontaneous fission of ^{252}Cf is about T=1.57 MeV.

PRODUCTION OF SPONTANEOUSLY FISSIONING ISOMERS OF URANIUM, PLUTONIUM AND AMERICIUM IN THE NEUTRON REACTIONS

Yu.P. Gangrsky
Joint Institute for Nuclear Research, Dubna, USSR

T. Nagy., I. Vinnay., I. Kovacs
Central Research Institute for Physics, Budapest

The cross-sections of production of spontaneously fissioning isomers ^{238}U , ^{242}Pu , ^{243}Am in the reaction (n , n') and ^{242}Am in the reaction (n,2n) were measured. The upper limits of the production of fissioning isomers ^{231}Th , ^{234}U , ^{237}U , ^{238}Pu in the reaction (n, 2n) were obtained. The time-of-flight method and neutrons from the reactions $^{3}H + d$ and $^{9}Be + d$ were used.

UNFOLDING NEUTRON SPECTRA FROM ACTIVATION DATA BY CODES RFOL AND RF07

L. Turi., A. Fischer.
Central Research Institute for Physics, Budapest

Two methods for unfolding neutron spectrum from activation data described. Program RF01 can be used only for the case of threshold detectors, while program RF07 has no such restrictions and by using proper foils can determine simultaneously the spectrum in the whole energy range of reactors. The algorithm of the methods and input/output specifications of the codes are given.

UNFOLDING NEUTRON SPECTRA FROM ACTIVATION DATA BY CODE RFSP

A. Fischer., L. Turi.
Central Reseach Institute for Physics, Budapest

A method for unfolding neutron spectra from activation data is described. The code RFSP is an advanced version of the well-known SPECTRA code /1/. The program determine the spectrum which satisfies the activation equations and minimizes quantity characterizing the deviation from the reference spectrum. A typical run by RFSP requires much less time than one by SPECTRA. The algorithm of the method and input/output specifications of the code are given.

/1/. Greer et al. SC-RR-67-746

PRODGROUP – A PROGRAM FOR THE PRODUCTION OF MULTIGROUP REACTOR CONSTANTS FROM THE EVALUATED NUCLEAR DATA AVAILABLE AT IAEA

P. Vértes
Central Research Institute for Physics, Budapest

The evaluated data files available at IAEA are used for generating multigroup constant sets for P_1 equations. The method of data handling and calculation and the corresonding computer program have been elaborated and 26-group constant sets for 15 elements from KEDAK data have been obtained.

A MUFT-TYPE FORTY GROUP CONSTANT LIBRARY

P. Vértes
Central Research Institute for Physics, Budapest

A MUFT type library making use of the evaluated nuclear data files distributed by IAEA has been produced by means of a computer program. Sets for 15 elements from KEDAK data and for 3 elements from UKAEA data have been obtained.

SPECTRUM CALCULATION OF NEUTRONS TRANSMITTED THROUGH AND REFLECTED FROM SLABS OF DIFFERENT MATERIAL AND THICKNESS

S. Makra, P. Vértes, L. Koblinger
Central Research Institute for Physics, Budapest
To be published.
Partly supported by IAEA Agreement No. 889/CF

An albedo code is used for the calculation of neutron spectra. Discrete energy, fission or reactor input spectra are used, and the spectra of the neutrons reflected from, or transmitted through, slabs of 5 - 200 cm thickness are calculated. Neutrons from thermal energies up to 10.5 MeV are considered. Calculations were performed for the following materials: H_2O, $/CH_2/_n$, C, Al, Be, Fe, Pb, concrete, concrete + Fe, concrete + B, $/CH_2/_n$ + B, and some selected sandwiches of H_2O, Al, and Be up to a maximum number of six layers.

CALCULATIONS OF DOSE FRACTIONS OF SLOW, INTERMEDIATE, AND FAST NEUTRONS BEHIND SHIELDS OF DIFFERENT COMPOSITION AND THICKNESS AS WELL AS READINGS OF SELECTED DOSIMETERS

S. Makra and E. Békés
Central Research Institute for Physics Budapest, Hungary

New Developments in Physical and Biological Radiation Detectors Symposium, IAEA, Vienna 1970.

The percentage doses of slow, intermediate, and fast neutrons were determined for a fission source shielded by materials of different composition and thicknesses. Water, polythene, iron, concrete, concrete+iron, and concrete+boron materials, and thicknesses ranging from 5 cm to 200 cm were considered.

Making use of these results one can estimate the percentage dose measured by different dosimeters and hence the correction factors to be applied.

A more sophisticated method of evaluating the reading is to multiply the response function by the spectra values and to integrate over the energy range in question. On the basis of these calculations, readings are presented for several dosimeters and the results compared. The results show the great importance of intermediate energy neutrons.

NEUTRON AVERAGE ENERGIES: CALCULATIONS AND THEORY OF MEASUREMENTS

S. Makra
Central Research Institute for Physics, Budapest
Report KFKI-70-6-HP (1970)

Basic features of neutron average energy $/\tilde{E}/$ measuring techniques are dealt with and calculated $\tilde{E}$ values are presented.

An average energy measuring device determines the following quantity:

$$\tilde{E}_{eff} = \frac{\int_{E_1}^{E_2} E\, k(E)\, \Phi(E)\, dE}{\int_{E_1}^{E_2} k(E)\, \Phi(E)\, dE}$$

where Φ /E/ is the neutron spectrum, and k/E/ is a weight factor. Generally k/E/ $\neq$ 1, resulting in a difference between $\tilde{E}$ /when k/E/ $\equiv$ 1/ and $\tilde{E}_{eff}$.

In this paper the Block & Shon technique /based on the energy dependence of the spatial distribution of thermalized neutrons in a moderator/, as well the double sphere method based on the energy dependence of the counting ratio of two Bonner spheres of different diameters are investigated. The energy dependence of the sensitivity, the k/E/ factors, the accuracy, and the optimum sphere diameters are calculated. The values of $\tilde{E}$ and $\tilde{E}_{eff}$ after the neutrons have penetrated different shields /water, polyethilene, iron, concrete and some of their mixtures/ are determined for some reactor sources using the spectra calculated by albedo method, and is some cases are comparted with values measured at different reactors.
The $\tilde{E}$ values for reactor spectra which have penetrated through different shields vary by a factor of 25, while the ratio $\tilde{E}_{eff}/\tilde{E}$ is 1,0 $\pm$ 0,3 for both techniques, if $\tilde{E} > 0,5$ MeV, but may reach 2- 3 if $\tilde{E}$ is low.

SPIN CUT-OFF FACTORS FROM /n,2n/ REACTIONS FOR N $<$ 50 NUCLEI

D. Horváth and A. Kiss
Department of Atomic Physics
Roland Eötvös University, Budapest
To be published in Act.Phys.Hung.

The experimental data on isomeric ratios measured in /n,2n/ reactions are re-evaluated using a method based on the Huizenga-Vandenbosch assumptions. So far only the experimental values of isomeric /n,2n/ cross-section ratios reported for N<50 nuclei at 14 MeV have been re-analysed. The dependence of the extracted spin cut-off factors on the parameters used is discussed, and their values are compared with those predicted by the Fermi gas model; their ratios are found to be about 0,5.

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

The general activities and experimental facilities are the same as described in our previous report sent to NDS on 27 March 1970.

Results in the past year and plans for the future.

Measurements on the angular distributions of fission fragments from ^{232}Th and ^{238}U at 14 MeV have been completed, and the results that were sent to NDS are being published.

The /n,2n/ cross-section for ^{238}U was determined. The analysis of gamma spectra from fission fragments is in progress for the determination of independent and cumulative yield for some fragments.

By detailed investigation of the fine structure in the mass distributions of fission fragments from ^{235}U and ^{238}U at 14 MeV, the enrichment of these isotopes in fuel elements can be determined. This method would be suitable for the determination of the enrichment of ^{235}U in unused canned fuel elements in a safeguard system.

Measurements on prompt gamma-ray spectra from inelastic scattering of 14 MeV neutrons for U and Fe have been performed.

In the near future we shall begin systematic investigation of /n,t/ cross-sections for d+t and d+d neutrons using a low background proportional counter.

Present data are rather scanty, though they are important from the pure scientific-point of view, but also in connection with tritium regeneration as regard controlled thermonuclear devices . It is planned to make measurements of /n,α/ and /n,γ/ cross-sections below 1 MeV using photoneutron sources.

Progress Report on

Nuclear Data Activities in India

(for the year 1970)

Compiled by M.Balakrishnan

May, 1971

INDIAN NUCLEAR DATA GROUP

Members

1.	M. Balakrishnan (Secretary)		Nuclear Physics Division, BARC
2.	V.C. Deniz		Reactor Engineering Division, BARC
3.	A.S. Divatia (Convener)		Nuclear Physics Division, BARC
4.	S.S. Kapoor		Nuclear Physics Division, BARC
5.	D.N. Kundu		Saha Institute of Nuclear Physics
6.	B.P. Rastogi		Reactor Engineering Division, BARC
7.	N.S. Satyamurthy		Nuclear Physics Division, BARC
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	(")	Electronics Division, BARC

PREFACE

The seventh progress report on Nuclear Data Activities in India covers the work done during the year 1970. A part of the work outlined in this report has been presented at the Nuclear Physics & Solid State Physics Symposium held at Madurai during December 1970.

The total number of CINDA entries sent to the International Atomic Energy Agency during the period of the report is 20. A progress report on Nuclear Data activities has been compiled and submitted to the International Nuclear Data Committee.

Studies with KEDAK evaluated cross section library and unevaluated point cross section data obtained from IAEA have been carried out. A 26 group cross section set was generated from the basic energy point data to study the large power reactors. This set consists of 20 materials and covers the energy range 0.025 eV - 10.0 MeV.

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

a) Work on the various systems of the 224 cm Variable Energy Cyclotron to be installed at Calcutta is under way. The casting of steel for the 250 tonne magnet at the Heavy Engineering Corporation, Ranchi is nearing completion, and machining is in progress. The process technology for the coils has been finalized at the Heavy Electricals of India Ltd., Bhopal. Work on other systems and further design studies are in progress at the Bhabha Atomic Research Centre. The foundation and the basement of the building at Calcutta are complete and the superstructure work is in progress. A User's Committee for Physics has been set up and meetings have been held to work out plans for utilisation.

b) A repetitively pulsed fast reactor facility is to be installed at the Reactor Research Centre at Kalpakkam to serve as an intense neutron source for basic and applied research in the fields of solid state and nuclear physics, nuclear and radiation chemistry, radiation biology, etc. The proposed pulsed reactor is basically similar to the IBR reactor in operation at Dubna in the USSR since 1960. It is to be plutonium fuelled, air cooled with an average power dissipation of 30 kW and provide 50 pulses per second, each of which delivers over $2x10^{13}$ neutrons.

A zero energy fast critical facility to help optimise the reflection pulsing mechanism design and other reactor parameters is under construction at Trombay and is expected to go critical by the end of 1971. Based on these studies the pulsed fast reactor design would be carried out. It is expected that the pulsed facility would be available for use by 1974.

c) The 2 MeV Van de Graaff accelerator at the Indian Institute of Technology, Kanpur is in operation and an unanalysed proton beam of 60 microamperes at 2.2 MeV is available. Studies on proton - capture reactions have started.

d) At the Panjab University, Chandigarh, the sub-systems of the 6 MeV Variable Energy Cyclotron have been assembled and tested. The building to house the cyclotron is nearing completion.

AS Divatia

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

A. BHABHA ATOMIC RESEARCH CENTRE, TROMBAY, BOMBAY 85

1. Lowest T=3/2 State in ^{33}Cl Observed as a Resonance in $^{32}S(p,\gamma)^{33}Cl$ Reaction - M.A. Eswaran, M. Ismail and N.L. Ragoowansi - Nuclear Physics Division - The yield of the reaction $^{32}S(p,\gamma)^{33}Cl$ near the lowest T=3/2 state has been measured by counting the residual activity between bursts of a mechanically chopped beam. A natural target of Sb_2S_3 was employed and a Ge(Li) detector was used for counting the positron annihilation radiation from the decay of ^{33}Cl. The resonance was found to be at $E_p=3.371\pm0.006$ MeV in agreement with the elastic scattering experiments. By comparison of the thick target yield of this resonance with that of the resonance at $E_p=2.547$ MeV the radiation width Γ_γ has been determined to be 0.56 ± 0.18 ev for this lowest T=3/2 state. The branching of this state, is found to be $\sim$ 90% to the $1/2^+$ first excited state in ^{33}Cl. This transition is likely to be from the analogue to the anti-analogue state and its radiation width corresponds to 0.22 Weisskopf unit.

2. A Doorway State Observed as a resonance in the $^{35}Cl(p,p_0)$ Reaction - S.K. Gupta, S.S. Kerekatte, S.Swami*, M.R. Dwarakanath, K.K. Sekharan** and A.S. Divatia - Nuclear Physics Division - In the $^{35}Cl(p,p_0)$ reaction a resonance of 15 KeV width has been observed with its shape consistent with $l_p=0$ assignment, which corresponds to a level at 10.901 ± 005 MeV in ^{36}Ar. This resonance

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* Member of I.I.T. Powai, Bombay
** Now at the University of Kentucky, U.S.A.

does not appear in the $^{32}S+\alpha$ channel and therefore, it has been interpreted as an isolated bound doorway state. The observed level is in accordance with the predictions of Payne[1] after taking into account the difference in the penetration factors for protons and neutrons. Our observations also agree with the shell model calculations of Glaudemans et al[2] who predict a level at 10.5 MeV with $J = 2^+, T = 0$ in ^{36}Ar which has a 67% doorway state configuration of $(s_{1/2})^3(d_{3/2})^5$.

1. G.L. Payne, Phys. Rev.174,1227(1968)
2. P.W.M. Glaudemans et al,Nucl.Phys.56,529 and 548(1964).

3. A Study of $^{64}Ni(p,n)^{64}Cu$ Reaction - S.S. Kerekatte,S. K. Gupta and A.S. Divatia - Nuclear Physics Division - The total yield of the $^{64}Ni(p,n)^{64}Cu$ reaction has been measured using the 4π geometry neutron counter, for incident proton energies from 2.475 to 5.500 MeV, in 5 KeV steps. The excitation function exhibits the Ericson fluctuations, with an average level width of $\sim$ 7 KeV. Over the fluctuations strong resonances have been observed at E_p=3.895 and 4.620 MeV. These resonances are isobaric analogs of the 3rd and the 6th excited states of ^{65}Ni,in the compound nucleus ^{65}Cu.

4. Evidence for Doorway States in $^{29}Si(\alpha,n)^{32}S$ Reaction - M. Balakrishnan, M.K. Mehta and A.S. Divatia - Nuclear Physics Division - Many evidences are known to exist for doorway states in nuclear reactions interpreted as states of two particle one hole, 2 particles two holes etc. and they are observed prominently

in elastic and inelastic scattering of protons or alphas. In this work evidence for doorway state for a more complicated case like the $^{29}Si(\alpha,n)^{32}S$ reaction is indicated for incident alpha energy from 3.00 to 5.40 MeV, as seen by the averaging of compound nuclear resonances. The widths of structures observed are around 275 keV. Possible significance are discussed. The strength function $\langle\Gamma\rangle/\langle D\rangle$ for the compound resonances in the region of excitation covered is found to be ~ 0.3.

5. Isobaric Analogue States in ^{67}Ga - M.G. Betigeri, C.M. Lamba, N.Sarma, D.K. Sood and N.S. Thampi - Nuclear Physics Division - The isobaric analogue states of ^{67}Zn have been observed in the compound nucleus ^{67}Ga through the study of elastic scattering of protons on ^{66}Zn. This study covers the first six levels analogous to ^{67}Zn. Two of these being high ℓ transitions could not be observed. The energy, ℓ -value, total width and proton partial width of the other four resonances are determined by a shape fitting procedure and the results are compared with available evidence from $^{66}Zn(d,p)$ reaction.

6. Fragment Angular Distributions in the 14 MeV Neutron-Induced Fission of The^{232}, U^{233}, U^{238}, Np^{237}, Pu^{239} and Am^{241} using Solid-State Track Detectors - R.H. Iyer and M.L. Sagu - Radio-Chemistry Division - An efficient and novel experimental set up which allows simultaneous measurement of the angular distribution of fragments from five independently fissioning nuclei at a time has been developed. Laxan polycarbonate plastic was used as the

solid-state track detector. The data have been analysed in terms of a polynomial of the form $A+B\cos^2\theta+C\cos^4\theta$. From a least square fit of the experimental data with the above relation, the fragment anisotropies, $\sigma_f(0^\circ)/\ \sigma_f(90^\circ)$, for Th^{232}, U^{233}, U^{235}, U^{238}, Np^{237}, Pu^{239} and Am^{241} were calculated to be 1.82 ± 0.12, 1.34 ± 0.12, 1.67 ± 0.14, 1.66 ± 0.13, 1.28 ± 0.13, ~~1.28±0.08~~, 1.18 ± 0.08 and 1.35 ± 0.10 respectively. Fragment angular distributions in the fission of Pu^{239} and U^{235} induced by thermal neutrons were found to be isotropic within the statistical errors ($\angle$ 5%) of counting the tracks.

7. <u>Excitation functions for the Neutron Induced Fission of Heavy Nuclei</u> - K.N. Iyengar*, R.H. Iyer**, S.S. Kapoor, D.M. Nadkarni and M.L. Sagu** - Nuclear Physics Division - This work is a part of the data of our experiments to measure fission cross-sections of several nuclei namely, ^{232}Th. ^{233}U, ^{237}Np, ^{239}Pu and ^{241}Am relative to that of ^{235}U in the neutron energy region of 0.32 to 2.1 MeV at energy intervals of about 100 keV. Fission events were recorded using Lexan Solid State Track detectors in a 2 geometry. Mono-energetic fast neutrons were generated with $T(p,n)^3He$ reaction using the 5.5 MeV Van de Graaff Accelerator.

8. <u>Emission of long Range Charged Particles in the Fission of ^{235}U by Thermal to 4 MeV Neutrons</u> - D.M. Nadkarni and S.S. Kapoor, - Nuclear Physics Division - The rate of emission of long range charged particles in fission has been determined in the case of fission of ^{235}U induced by thermal, 2 MeV and 4 MeV neutrons.

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* Tata Institute of Fundamental Research, Bombay-5.
** Radio Chemistry Division.

The method used consisted in recording the energy spectrum of these charged particles, using a semiconductor detector, in coincidence with fission fragments detected in a 2π geometry with a parallel plate ionization counter. Together with our earlier measurements of emission probability of long range alpha particle in 3 MeV neutron induced fission of ^{235}U, the present results indicate a rather weak dependence of emission probability of charged particles in fission on the excitation energy of the fissioning nucleus. These results, obtained for the case of a single fissioning nucleus, are compared with those obtained by other workers at much higher excitation energies where multiple chance fissions contribute.

9. Kinetic Energy Distribution in Reactor Neutron Induced Fission of ^{241}Am - M.V. Ramaniah, Satya Prakash, S.B. Manohar, S.P. Dange, A. Ramaswami, A.G.C. Nair and R.J. Singh - Radiochemistry Division - Recoil ranges in aluminium of fission products from reactor neutron induced fission of ^{241}Am have been determined using two different techniques, namely, direct counting of the fission product gammas using a Ge(Li) detector and by radiochemical techniques. Kinetic energy distribution was obtained from recoil range data using semi-empirical range-energy relations. The observed kinetic energy deficit was found to fit well in the correlation of kinetic energy deficit with shells published earlier from this laboratory.*

* J. Inorg. Nucl. Chem., 1969,Vol.31,pp.1217 to 1224.

10. Elastic and Inelastic Scattering Cross-sections of Chromium, Iron and Nickel - S.B. Garg and B.P. Rastogi - Reactor Engineering Division - Chromium, iron and nickel act as moderators in fast power reactors as the neutrons suffer elastic and ineleastic collisions. The elastic and inelastic scattering cross-sections have been calculated for the neutron incident energies ranging from 1.0 MeV to 10.0 MeV using the spherical local optical model. The best values of optical model parameters have been obtained by fitting the measured elastic angular distributions. Woods-Saxon form for the imaginary part and the Thomas form for the spin-orbit coupling term.

11. Triton Knockout From ^{7}Li Nucleus - A.K. Jain and N. Sarma - Nuclear Physics Division - The reaction $^{7}Li(p,pt)^{4}He$ at 55 MeV incident energy has been studied in the distorted wave impulse approximation (DWIA) using the properly antisymmetrized α - t cluster model wave function for ^{7}Li nucleus. It is observed that the inclusion of the distortion of the incoming and the outgoing waves affects the results significantly. From the study of the localization of the reaction it is found that the exchange terms appearing in the antisymmetrization of the cluster model wave function affect the angular correlation appreciably. Calculated results are compared with the available experimental data.

12. Further Studies of K X-Rays Emission from ^{252}Cf Fragments - S.S. Kapoor, D.M. Nadkarni, S.R.S. Murthy, V.S. Ramamurthy and P.N. Rama Rao - Nuclear Physics Division - It is known that the K X-rays emitted in fission result from the internal conversion

process during the γ-deexcitation of fission fragments, and therefore the average yield of the K X-rays from specified fragments is related to the average number of transitions which are internally converted. In this work K X-rays emission from ^{252}Cf fission fragments has been studied to determine (a) average K X-ray yields from different fragments upto 110 nsec and 1000 nsec after fission,(b) the average multiplicity of K X-ray emission from fragments of specified nuclear charges and (c) whether the X-ray emission probability from the pair fragments (Z_H, Z_L) is independent or correlated. Fission fragments from the ^{252}Cf source were detected in a 2π geometry by a mini ion-chamber, and the X-rays were detected by two independent cooled Si(Li) detectors, placed on either side of the chamber and the double and triple coincidence K X-ray spectra were recorded. Information has been obtained on the first moment ($\langle n \rangle$) second moment ($\langle n^2 \rangle$) of to the X-ray emission distribution function, and the correlation coefficient $R(Z_H, Z_L)$ and on the intensity of relatively long half life components in the X-ray emission from different fragment nuclei.

13.. An Unified Theory on the Structure of Atoms and Nuclei - R. Ramanna and S. Jyothi - Nuclear Physics Division - Recent developments in Mathematics concerning differentiable manifolds, the theory of differential forms and the geometric theory of partial differential equations have been employed to present an unified theory on the structure of atoms and nuclei. The procedure consists in defining a Schrodinger equation over an Euclidean patch which overlaps with other Euclidean patches in a specified way to form a manifold. The invariance of the Schrodinger equations in the overlapping region leads to a second order non-linear partial differential equation whose solutions are doubly periodic functions. There are only two single-valued solutions to this differential equation giving rise to lattices in the complex space. Of these lattices one consists of corners of an array of equilateral triangles and the other consists of corners of an array of isosceles right-angled triangles. The first solution corresponding to the equilateral triangle lattice was used[1] to derive the shell structure, Coulomb energies and binding energies of spin-less stable systems. In this study it is shown that the second solution corresponding to the isosceles right-angled triangle lattice is used to calculate the binding energies of atoms and these come out to be in agreement of about 3% for the few available experimental values and also in good agreement with those obtained by the perturbation theory. It is also shown that this lattice under certain approximations is equivalent to a pure Coulomb law and the Bohr orbits of the hydrogen atom are correctly predicted.

1. R. Ramanna and S. Jyothi, International Journal of Theoretical Physics, Vol.2, No.4 (1969) pp.381-403.

14. Shell Effects on Nuclear Level Densities - V.S. Ramamurthy, S.K. Kataria and S.S. Kapoor - Nuclear Physics Division - On the basis of our microscopic calculation of the nuclear level density versus excitation energy carried out using a realistic shell-model single particle level scheme and BCS formalism to include pairing effects, a simplified prescription for taking into account

shell effects on nuclear level densities has resulted. It has been shown earlier by us that contrary to general belief even at moderate excitation energy of 30-40 MeV the shell effects on the level density disappear. In present work we have shown that the conclusions of Kahn and Rosenwig and Gilbert showing persistence of shell effects at high excitation energies are based on a misinterpreation of the ground state shell corrections in the nuclear masses.

14. On the Production Possibility of Superheavy Nuclei - V.S. Ramamurthy and S.S. Kapoor - Nuclear Physics Division - The inclusion of the shell effects in the liquid drop model deformation energy of nuclei has led to the now well known prediction of an island of stability in the doubly magic superheavy region around Z = 114 and N = 192. In the attempts currently being made to produce superheayy nuclei in the laboratory, in particular by heavy ion bombardment, the nucleus is unavoidably formed with an excitation energy of a few tens of MeV, and the nucleus must therefore undergo a cascade of neutron emission for the end product to be a stable superheavy nucleus. On the basis of our level density calculations we have computed Γ_f/Γ_n at different excitation energies for nuclei in the superheavy region. It is shown that if the fissioning nucleus is "hot" ($E_x \simeq$ 30-40 MeV), the existence of a shell fission barrier in the ground state does not decrease the otherwise very large Γ_f/Γ_n expected for the case of zero liquid drop barrier. Consequently the fraction of compound nuclei surviving fission and reaching the ground state after a cascade of neutron emission is expected to be very small, thereby posing a problem for the laboratory production of these superheavy nuclei.

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

1. The Level Structure of ^{75}Se - Baldev Sahai, B. Lal - The level structure of ^{75}Se has been investigated upto an excitation energy of 1500 keV by studying the gamma-gamma coincidence spectra in a reaction ^{75}As(p,nγ) ^{75}Se at incident proton energies 3.0 and 3.5 MeV and also by observing the direct gamma-ray spectra using a 30 c c Ge(Li) detector with incident protons in the energy range 1.5 to 4.0 MeV. A detailed decay sheme for ^{75}Se levels with branching ratios for some of the levels has been worked out.

2. Study of Low Lying Levels in ^{51}Cr and ^{59}Ni - B. Lal, Baldev Sahai - The low lying levels in ^{51}Cr and ^{59}Ni have been reached by (p,nγ) reaction on ^{51}V and ^{59}Co targets. The angular distributions of some of the ground state transitions have been compared with the statistical model calculations based on Satchler and Sheldon's formalism to extract the information on the spin of the levels and the multipole mixing ratios of the transitions. The spins of the levels of ^{51}Cr at 749, 1165 and 1479 KeV have been confirmed to be 3/2, 9/2 and 11/2 respectively. The spin of 879 KeV level of ^{59}Ni is found to be 3/2.

3. Coulomb Excitation of Selenium Isotopes(^{74,76,77,78,80,82}Se) - A.P. Agnihotry, K.P. Gopinathan, M.C. Joshi and K.G. Prasad - A thick target of Selenium natural material was exposed to alpha particles from a 5.5 MeV. Van de Graaff accelerator at Trombay

The γ-rays emitted from the target were detected by a high resolution (Ge(Li) detector (20 cc). The gamma-rays corresponding to Coulombe excitation of different isotopes $^{74-82}Se$ were identified. From measurements of thick target yields corrected for their natural isotopic abundances, the relative $B(E_2)\uparrow$ values were determined. Using a well known $B(E_2)\uparrow$ value of 2^+ level of ^{78}Se, absolute values of $B(E_2)$ in units of $(10^{-50}.e^2.cm^4)$ for all the other gamma-rays were determined. ^{77}Se:(23±2),(18+6±2.0), (1.0±0.2) for 440-,240 and 250 keV levels respectively. ^{74}Se : (48.0±15) for 635 keV (2^+) level, ^{76}Se : (45±4) for 560 keV (2^+) level, ^{78}Se: (38.4±.8 for 612 keV(2^+)level, ^{80}Se:(27.6±2.5) for 665 keV(2^+) level and ^{82}Se: '20±4) for 654 keV(2^+) level. The $B(E_2)\uparrow$ value for ^{74}Se is new. The $B(E_2)\uparrow$ value for 250 keV level in ^{77}Se is more accurate compared to the earlier value obtained from unresolved gamma-rays 240 and 250 keV using NaI(Tl) scintillation detector. Our improved value is in good agreement with the value obtained from the half life measurements of this level. From the observed $B(E_2)$ values the r.m.s. quadrupole distortion $\beta_{r.m.s.}$ are deduced for the Selenium Isotopes.

4. <u>g-Factor of the 603 keV Level in ^{124}Te By Beta-Gamma Perturbed Angular Correlations</u> - A.P. Agnihotry, M.C. Joshi and K.G. Prasad - We have attempted to extend the $\beta-\gamma$ perturned angular correlations to the measurement of nuclear g-factor in the case of 124Sb ⟶ 124Te. The active ^{124}Sb was diffused into a thin (10 mg/cm^2) iron foil which was polarized by a small electromagnet. The internal field acting at the site of Te was

used for perturbing the beta-gamma angular correlations. Our result for 2^+ level at 603 keV ($\tau_{1/2}$ = 4 PS) in ^{124}Te indicate that g-factor extracted (g = 0.45 ± 0.1) by this method is in good agreement with that obtained by conventional gamma-gamma perturbed angulaar correlation technique.

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

1. Deexcitation Phenomena in Prompt Fission Fragments - Ratna Sarkar and Aparesh Chatterjee - Improvements on our RGM-PES approach to the fission phenomena are made to study (a) the partition of the excitation energy of the fissioning nucleus into the prompt fragments and (b) the prompt gamma deexcitation processes in the fragments. While studying (a), a simple RGM saturation condition is used to partition the excess excitation energy of the fissioning nucleus into the conjugate fragments; the predictions are compared with the experimental work on fission of ^{232}Th by 25.7 and 29.5 MeV ^{4}He-ions and of ^{226}Ra by 13.0 MeV protons. In studying (b), the prompt fragment gamma ray deexcitation energies and yields are compared with the experimental information on the thermal neutron fission of ^{235}U and spontaneous fission of ^{252}Cf. The predictions agree fairly well with observations.

2. Study of (p,p') and (p,n) Reactions in Be^9 - J. Mahalanabis - We have calculated the cross-sections for (p,p') and (p,n) reactions in ^{9}Be at medium energies, leading to excitation of the 2.43 MeV state (5/2) in Be^9 and ground state of ^{9}B (isobaric analouge state), respectively. The results are compared with the available experimental data. It is seen that better fit is obtained with Wilkinson's wavefunction rather than the oscillator wave-function.

3. <u>Optical Potential for Deuteron</u> - S.K. Samaddar and Suprokash Mukherjee - An analytic expression for the deuteron optical potential given by one of us (Mukherjee) is used to calculate the differential cross-section for the elastic scattering of the deuteron in the energy range 11.8 MeV to 27 MeV from various targets. The nuclear optical potential parameters used are those of Engelbrecht and Fiedeldey for neutron. The results are in fair agreement with experiment.

4. <u>Magnetic Moment of the 280 KeV $5/2^-$ State of As^{75}</u> - B.K. Sinha and R. Bhattacharyya - The magnetic moment of the 280 keV $5/2^-$ level of As^{75}As has been measured using a modified IRF method. This has resulted in a better accuracy of the measured value 10% compared to an accuracy of 20-30% as found in the published literatures.

5. <u>L/K Capture Ratio From Ge(Li) Spectrum</u> - B.K. Dasmahapatra - A new and simple method has been developed for the measurement of the L/K electron capture ratio for the nuclei whose decay schemes are known. A careful calibration of the Ge(Li) detector in the K-X ray region, together with the accurate determination of the intensity of the cascade gamma-ray, yield the capture ratio in a straight forward way. Using this technique the L/K capture ratio for the ^{133}Ba decay has been measured.

6. The Decay of ^{126}I - K.S.N. Murty, B.P. Pathak and M. L. Chatterjee - The decay characteristics of 13d ^{126}I, produced by the (n,2n) reaction on analytically pure ammonium iodide have been studied. The gamma rays of energies (relative intensities) 388.4 (100), 491.3 (8.1), 511.0 (5.6), 666.6 (98), 753.9 (12.3), 879.9 (2.2), 1420.1 (0.82) and 2050 (weak) keV have been observed. The results of beta and gamma measurements have been incorporated into a decay scheme. The results were found to be consistent with a recent work.

7. Decay of ^{68}Cu(30 sec.) And ^{68m}Cu(3.75 min) - V.K. Tikku, H. Singh and B. Sethi - The existence of an isomer of ^{68}Cu is confirmed and its half life measured as 3.75±0.05 min. The radioactive sources of $^{68g\&m}Cu$ were produced by the fast neutron irradiation of enriched samples of ^{68}Zn and ^{71}Ga and spec pure ZnO. A new group of energy (intensity) 4.6 MeV (13%) corresponding to the transition ^{68g}Cu- ^{68}Zn is obtained. From the experimental data the isomeric cross-section ratio (σ_m / σ_γ) for the production of the metastable and ground state is calculated to be 0.9±0.2. The γ-spectra were recorded using 2.00.cc Ge(Li) detector. The $\gamma - \gamma$ and $\beta - \gamma$ coincidences are performed. Based on the results a decay scheme is proposed for ^{68g}Cu and ^{68m}Cu.

8. Excited Levels of ^{85}Sr - S.K. Basu and A.P. Patro - The decay of ^{85}Y-isomers (2.9 h. & 4.7 h.) to levels in ^{85}Sr has been studied using a high resolution Ge(Li) detector. Several gamma

rays have been identified in the respective decays. On the basis of the energies and relative intensities of the observed gamma rays, a tentative level scheme of ^{85}Sr has been constructed.

9. Half Life of the 687 KeV Level and the Energy Levels in ^{147}Pm - H.Singh and B. Sethi - The half-life of the 687.42 KeV level in ^{147}Pm is measured for the first time using the delayed coincidence technique incorporating a time to amplitude converter. A value of 252±100 psec. is obtained. Using the previous values of the conversion coefficients and the mixing ratios and the branching ratios from this work, transition probabilities λ(E2) and λ(M1) are calculated and compared with those of the single particle estimates. The gamma spectra in the decay of ^{147}Nd was recorded using 2.5 cc Ge(Li) detector. New gamma-rays of energies (intensities) 299.65(0.36),312.57 (0.13), 589.89(0.2), 680.79 KeV (0.19) were observed and assigned to ^{147}Pm from their decay origin. These new gamma rays are incorporated into the existing decay scheme of ^{147}Pm with additional levels at 723.48,681.01 KeV. Spins and partities of these levels are deduced.

10. Disintegration of Gallium-65 - D. Basu - Disintegration of Gallium-65 has beenstudied with Ge(Li) detector. Several new gamma rays have been observed. Following are the gamma-ray energies in keV: 54, 61, 115, 153, 207, 654, 660, 703, 715, 752, 769, 795, 813, 856, 867, 910, 932, 983, 1047, 1135, 1227, 1261, 1309, 1342, 1353, 1414, 1468, 1525, 1750, 1870, 1876, 1962, 1969 and 2218. Intensities have been estimated and a suitable level

scheme has been proposed.

11. On the Origin of Hard-Core - Kamales Bhaumik - We have tried to give a theoretical explanation of the origin of repulsive-core in N-N interaction. We have been able to form a successful OBEP model which can generate a soft repulsive core. This soft core is, of course, hard enough to account for the observed change in the sign of the $1S_0$ phase-shifts. The consistency of this model is being checked in explaining the experimentally observed quantities e.g. scattering lengths, effective ranges, phase-shift parameters etc.

12. M1 Transition Strenghts in the Odd-Mass Antimony Isotopes - S. Sen - Different M1 transition rates (particularly ℓ-forbidden cases) in the odd-mass Sb isotopes have been calculated in the framework of the core-particle coupling model. Detailed analysis of the role played by different configurations towards M1 transition strengths have been made. The results are analyzed with reference to the available experimental data and the calculations done by other authors.

D. ALIGARH MUSLIM UNIVERSITY, ALIGARH

1. On the Appearance of Plateau in the Neutron Total Cross Section - A.N. Saharia and I Ahmad - Occurence of plateau in the neutron total cross section when plotted as a function of the nuclear radius is analysed. It is found that the modified form of the Glauber high-energy potential scattering theory explains quite satisfactorily the existence of the plateau even in the relatively low-energy neutron total cross section data. Expression for the loci of the plateau in the $E-A^{1/3}$ plane is obtained.

2. Statistical Theory Calculations of Neutron Capture Cross Sections from 200 keV to 800 keV - H.V. Gupta, A.K. Chaubey and M.L. Sehgal - Neutron capture cross sections have been calculated using statistical theory of nuclear reactions in the energy range from 200 keV to 800 keV for ^{75}As, ^{79}Br, ^{115}In and ^{197}Au. These calculated cross sections were compared with the experimental values of capture cross section to test the validity of statistical theory in the energy range 200 keV to 800 keV. Some excited states in these nuclei have more than one spin. It was tried from the calculations of neutron capture cross-section that which spin is more suitable.

3. Study of P-Wave Neutron Strength Functions - A.K. Chaubey and M.L. Sehgal - P-wave neutron strength functions (Γ_n^1 /D) have been calculated using 24 KeV neutron capture cross sections and low energy resonance parameters. These values of strength

functions were compared with the previous reported values. Some interesting results have been obtained.

4. Statistical Theory Calculations of Neutron Capture Cross Sections at 130 KeV - J. Alam and A. Augusthy - Neutron capture cross-sections have been calculated using statistical theory of nuclear reactions at 130 KeV energy for a large number of cases. These calculated cross-sections are compared with the experimental values to obtain informations about the parameter $\xi_{cal} = \frac{D}{2\pi \Gamma_\gamma}$ These values of ξ_{cal} are then compared with the known experimental values of ξ_{obs} obtained from low energy resonance experiment to check the validity of the statistical theory.

5. 14.8 MeV Neutron Radiative Capture Cross-Section - S.S.Hasan, R. Prasad and M.L. Sehgal - Neutron radiative capture cross-sections have been measured for ^{103}Rh, ^{127}I and ^{175}Lu. Results of these measurements and those of earlier measurements have been used to check direct-semi-direct theory for radiative capture. A comparison of experimental and theoretical values reveals that for the nuclei near the closed neutron shell these agree well. However, for other nuclei only order of magnitudes agree. Shell effects in (n,γ) cross-sections at 14.8 MeV have also been observed.

E. LABORATORIES FOR NUCLEAR RESEARCH, ANDHRA UNIVERSITY, WALTAIR

1. New Isomaric Cross-Section Ratios in Neutron Capture Reactions - A. Lakshmana Rao, K. Parthasaradhi and J. Rama Rao - Experimental Isomer Ratios for neutron capture reactions at 25 KeV leading to the Isomaric pairs Ge-75m,g:Rb-86m,g: Pd-11m,g; Cd-117m,g: Sb-122m,g: Sn-125m,g: Eu-152m,m_2: and Pt-197m,g have been measured for the first time. Activation method and absolute gamma counting have been employed, using a calibrated well-type scintillator and a multichannel analyzer. The spin cut-off factors for these cases are being extracted using Huizenga and Vandenbosch formalism for comparison with the predictions of the Shifted Fermi gas model, Superconductormodel and Independent pairing model.

2. P-Wave Strength Functions in the Mass Region $140 < A < 160$ - B.V. Thirumala Rao, J. Rama Rao and E. Kondaiah - It is well known that there are significant discrepancies between the theoretical and experimental values of the p-wave neutron strength function,s , in the region $140 < A < 160$ corresponding to the valley of the giant resonances. To investigate this point, average neutron capture cross-sections in the isotopes Nd-146, Nd-148, Nd-150 and Gd-158 have been determined at 25 KeV using the activation technique. Employing the recebtly available s-wave resonance parameters (in the KeV region), the s-wave capture contributions are accurately subtracted out to obtain the p-wave cross-sections which were found to be more than 50% in all these cases.

The p-wave strength functions for these isotopes are being extracted for comparison with theoretical predictions.

3. P-Wave Neutron Capture in Heavy Nuclei at 25 KeV - M. Sriramachandra Murty, K. Siddappa and J. Rama Rao - A systematic investigation of the average neutron capture cross-sections at 25 KeV is undertaken to study the structure of giant resonances in the neutron strength functions. As a part of this programme and to plug the gaps in the existing cross-section data, the radiative capture cross-sections for the following isotopes have been measured: Se-74, Sr-84, Ag-109, Te-122, Tb-159, Yb-168, Tm-169, Yb-174, Yb-176, Hf-178, Hf-179, Ir-191 and Os-192. Activation method and absolute gamma counting have been employed.

4. Nuclear Energy Level Calculations of Barium Isotopes in the United Model - C.R. Chandran, M.N. Sitaramnath, M.V. Ramanamurty and S. Ramamurty - The low lying levels of the odd neutron Barium Isotopes are investigated using the intermediate coupling approach in the unified model. It is assumed that the last odd neutron in the s 1/2 and d 3/2 orbits is coupled to the quadrupole vibrations of the inert core of the nucleus. The resulting Hamiltonian is diagonalised including all states up to two phonons. The coupling strength and the energy spacing between the s 1/2 and the d 3/2 levels are varied within reasonable limits. The theoretical values obtained for the energy levels are in good agreement with the experimental energy levels.

5. Internal Conversion Coefficients Measurements in ^{133}Ba Decay - C. Narasimha Rao, B. Mallik, K.V. Ramanaiah and K.Venkata Reddy - The internal conversion coefficients for six transitions, 161,223,276,302,356 and 385 keV in Cs-133 have been measured by recording the conversion electron lines with a Seigbahm-Slatis beta ray spectrometer and using the published relative photon intensity data. These are calculated relative to the conversion coefficient of the 356 keV E2 transition.

6. Decay of ^{81m}Se(57 MIN) and ^{81g}Se(18 MIN) - S. Venkataratnam and V. Lakshminarayana - and M.V. Ramanaiah - Radiochemistry Division, Bhabha Atomic Research Centre, Bombay - The gamma rays following the beta decay of ^{81}Se isomers are investigated with a 2 cm^3 Ge(Li) detector. Sixteen gamma transitions are observed confirming several already known gamma rays as well as five new transitions. All these are fitted in a level scheme requiring two new levels at 815 keV and 1323 keV. Energies and relative intensities of the gamma rays and log ft values of the various beta branchings, populating levels in ^{81}Br are calculated & analysed in relation to their spin and parity assignments.

7. Angular Correlation Studies in Cobalt-59 - K. Venkata Ramana Rao, D.L. Sastry and V. Lakshminarayana - Angular correlation studies are carried out in Co.59 using a sum-peak coincidence arrangement for three cascades - (190-1100)KeV,(140-1290) KeV, and (330-1100) KeV. Assuming the spins of the ground,1100 and 1290 KeV states to be 7/2,3/2 and 5/2 respectively, the results

of the angular correlation studies are employed to obtain quadrupole contents of the transitions. The 190 keV transition is found to have quadrupole content of 9%. With 1/2 and 3/2 as possible spins for the 1430 keV state, the correlation studies are analysed. For a spin assignment of 1/2 for the state, the 1290 keV transition is found to be a pure M1. For a 3/2 assignment the 330 keV transition is found to have a quadrupole content of 21%, while for a 1/2 assignment the 330 keV transition is a pure M1.

8. Fission Properties of Super Heavy Nuclei - S. Rama Murty, M.V. Ramana Murty, C.R. Chandran, K. Partha Sarathy - The fission properties of about 50 super heavy nuclei Z = 110 to 134; A = 288 to 324 have been calculated. The energy release in binary, ternery and quarternary fission, the surface energy, the coulomb energy and the fissility parameter of the fission nuclei, the terparature, the kinetic energy and the excitation energy of the fission fragments and number of neutrons liberated per binary fission,have been estimated theoretically.

9. Level Density Parameter and Nuclear Shell Structure - S. Rama Murty,K. Partha Sarathy, M.V. Ramana Murty and C.R.Chandran - The influence of nuclear shell structure on the level density parameter has been investigated using Lang's formula and modified Newton values of effective angular momenta for about 130 nuclei in the vicinities of magic numbers Z,N=20,28,50 and 82. The numerical values have been explicitely tabulated.

10. Decay of Sr^{85m} - K.L. Narasimham, M.N. Seetaramanath and V. Lakshminarayana and A.P. Patro,Saha Institute of Nuclear Physics, Calcutta - The electron capture and gamma decay of Sr-85m (70m) is studied with a calibrated Ge(Li) detector. The energies and relative intensities of the gamma rays, and the intensity of the electron capture branch are obtained. The k-conversion coefficients for the 232 and 237 keV transitions are calculated from the published conversion electron data and the presnet results. These are consistant with an M1+E2 nature of the 232 keV transition and an E3 nature of the 237 keV transition The latter is in disagreement with the present $1/2^-$ assignment for the 237 keV state and supports a $3/2^-$ for its spin. These results are discussed in relation to the decay scheme of Sr-85m.

11. Beta-Gamma Directional Correlation Measurements in the Decay of Pr-142 - A Khayyoom, M.L. Narasimha Raju and D.L. Sastry- The 580 keV beta-1570 keV gamma directional correlation was measured with a slow fast coincidence scintillation spectrometer. The energy dependence of the angular correlation coefficient, A_2 is studied in the energy range 200 - 500 keV in steps of 100 keV. The observed A_2 coefficient is small and independent of energy within experimental errors. The results are consistent with the ξ approximation.

12. Gamma-Gamma Angular Correlations in Nd-147 - B.R. Sastry, K.L. Narasimham and D.L. Sastry - The gamma-gamma angular correlations in Nd-147 are investigated for cascades depopulating the

690, 533 and 490 keV levels using a sum-coincidence scintillation speċtrometer in order to infer about the spins of these levels and the multipolarities of the respective gamma transitions. The results of the present investigation will be discussed in relation to the level scheme of Pm-147.

F. BANARAS HINDU UNIVERSITY,VARANASI-5.

1. Measurement of (n,γ) Cross Section By Activation Technique in the keV Region - S.N. Chaturvedi, Rajendra Prasad and N.Nath - A specially shielded gamma counting set-up has been designed and fabricated for accounting low level activities employing a well type of NaI(Tl) crystal. A 10-Curie Sb(Be) neutron source was obtained from B.A.R.C., India for irradiation of target nuclei. The low counting,set up was used in measuring the (n,γ) cross section at $E_n = 24 \pm 3$ keV for more than ten nuclei. The standard reaction in this study was considered as $^{107}Au(n,\gamma)^{198}Au$ with $\sigma = (640 \pm 25)$mb. Cross section for almost all the nuclei were also calculated theoretically on the basis of optical model and a comparison has been made with the present experimental values and with those reported in earlier studies. Cross-section in the keV region are helpful in the reactor design, cosmological studies of element formation and in the nuclear reaction studies.

2. Characteristics of the α-α Interaction - P.C.Joshi and P.C. Sood - A systematic examination of the binding energies of alpha particle nuclei leads to some interesting features of the inter-alpha binding in these nuclei which can be used to caracter-rise the alpha-alpha interaction. We examine these characteristics vis-a-vis the nucleon-nucleon interaction. The saturation properties and the approach to the saturation value is found to be very similar in the two cases. As a first stop towards characterfing the α-α interaction we present an empirical formula for

the binding energies of alpha-particle nuclei.

3. Shell Model Description of $(d_{3/2})^n$ Nuclei - A.N. Mantri and P.C. Sood - A study of the low lying energy levels of nuclei with $(d_{3/2})^n$ configuration of n identical or non-identical particles has been made taking two body interaction as the effective interaction between two nucleons expressed in terms of the seniority, the isospin, and the reduced isospin quantum members. Using the Racah-Talmi approach the matrix elements of this effective interaction in n particle configuration are expressed as linear combinations of the matrix elements in two particle configuration. The interaction parameters are determined from the known energy levels of ^{34}Cl and ^{38}K. The low lying energy levels for several $(d_{3/2})^n$ nuclei are then calculated and compared with experimental data.

4. Shell Model Description of $(d_{3/2})^n$ Nuclei - A.K. Niagam and P.C. Sood - A study of the low lying energy levels of nuclei with $(d_{3/2})^n$ configuration of n identical particles has been made taking two body interaction as the effective interaction between two nucleons in the seniority scheme. Using Racah-Talmi approach the matrix elements of this effective interaction in a particle configurations are expressed as linear combinations of matrix elements in two particle configuration. The interaction parameters are determined from $(d_{3/2})^3$ nuclei and the predicted spectra for $(d_{5/2})^3$ nuclei are compared with the available experimental data.

G. BOSE INSTITUTE, CALCUTTA-9.

1. Analytical Formulation of K-Shell Photoeffect - M. Biswas, New Alipore College, Calcutta-53, S.C. Roy and A.M. Ghose, Nuclear Physics Laboratory - Theoretical calculation of photoeffect is not available in analytic form and extraction of photoelectric cross-sections for specific element and gamma energy require formidable amount of computation time. To remove this difficulty an analytical formula for K-shell photoeffect was developed semi-empirically valid for any elements of the periiodic table for any energy above 200 keV. The results are in good agreement with the theoretical calculation of Schmickley and Pratt.

2. Angular Dependence of Pair annihilation Radiation -M. Biswas, New Alipore College, Calcutta-53, S.C. Roy and A.M. Ghose - Contrary to the assumption of isotropic angular distribution of annihilated pair with respect to the direction of the incident gamma rays, certain angular variation of annihilation radiation is observed experimentally. This fact necessitates re-evaluation of pair production cross-section near threshold reported by previous workers. The measurement was carried out for lead using a special method of photopeak sharpending in scintillation spectrometers developed in our laboratory[1]. The nature of the angular dependence of annihilation pairs will be presented.

1. S.C. Roy, A. Chatterjee and A.M. Ghose-Nucl.Inst.& Methods, 67 (1969),318.

H. INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

1. Compton Scattering By K-Shell Electrons at 1.12 MeV* - P.N. Baba Prasad and P.P. Kane - The differential cross section for the compton scattering of 1.12 MeV gamma rays by the K-Shell electrons of gold at a scattering angle of 120° was reported last year. Similar measurements were made with a tantalum scatterer. Further measurements with thin Thorium, lead, gold and tin scatterers have been performed at 60°, and with the thorium and gold scatterers at 90°. The dependence of the ratio $d\sigma_K/d\sigma_{KN}$ on the bias level in the gamma channel has also been studied. Measurements of these cross sections have not been reported by other workers for gamma energies in excess of 1.01 MeV.

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I. INDIAN INSTITUTE OF TECHNOLOGY, KANPUR-16.

1. Neutron Distribution in Nuclei From Isobaric Analogue States - M. Murthy - The displacement energies between isobaric analogue states have been used to extract information about the distribution of neutrons in nuclei.

In isobaric analogue states, one of the excess neutrons in the parent state is converted into a proton in the analogue state. Our method is based on the fact that the radial distributions of the neutron excess (in the parent state) and that of the extra proton (in the analogue state) being identical, the corresponding displacement energy is given by the interaction of the proton (neutron excess) with the charge distribution of the protons in the core. Our calculations include the corrections due to the exchange term, the electromagnetic spin-orbit term and the charge dependence of the specifically nuclear forces.

2. Systematic of Rotational Nuclei on the Basis of Two-Centre Model - V.R. Irakash, B.M. Bahal and V.K. Deshpande - The possibility of reproducing rotational levels of deformed even-even nuclei on the basis of a two-centre model was previously investigated[1]. In the present work, the quadrupole moment data has been correlated with the moment of inertia on the basis of the model. The variation of the stiffness with neutron number and proton number has been studied. Fits are also obtained to the lowest beta-vibrational levels.

1. V.K. Deshpande, V.R. Prakash, B.M. Bahal, Proc.of the Nuclear Physics and Solid State Symposium, N90, (1969).

3. <u>Ge(Li)-Ge(Li) Coincidence Studies in ^{147}Pm</u> - R. Singh and G.K. Mehta - The decay scheme of ^{147}Pm has been investigated with Ge(Li)-Ge(Li) fast slow coincidence measurements. Besides the well established levels at 91, 410.1, 489.9, 531 and 685.8 keV, levels at 182 and 319.5 keV have been confirmed from coincidence studies. Indications of levels at 275, 680 and 725 keV are found only from singles spectra. No evidences are found for the existence of the levels at 120.5, 211, 231, 398.2, 471, 552 and 763 keV which were proposed by Bashandy et al. (E. Bashandy et al. Zeits Fur Nat. 22A, 154 (1967)).

4. <u>On the Decay of ^{115m}Cd</u> - S.N. Chaturvedi+, C.Rangacharyulu*, G.K. Mehta* and N. Nath++, '+'B.H.U., Varansi, '*' Indian Institute of Technology, Kanpur, '++' Kurukshetra University, Kurukshetra - The decay scheme of ^{115m}Cd has been studied using a Ge(Li) detector and a NaI(Tl) sum coincidence spectrometer with fast-slow condition. We confirm the existence of levels at 336, 650, 828, 864, 934, 1078, 1133, 1290, 1420 and 1450 KeV with an indication of a level at 970 KeV. In all twenty five transitions heve been observed in the present study. The existence of 106 and 492 KeV gamma transitions between the 934 and 336 KeV states reported earlier[1] has been confirmed. In addition to the well established gamma transitions following new gamma compenents have been observed: 144, 214, 250, 320, 355, 462, 528, 592, 597 and 970 KeV. A decay scheme hasbbeen constrcuted with the help of these observations. Relative intensities of most of the gamma transitions have been determined and compared with the earlier reported values.

1. G.E. Gordon et al P.R. 149,(67)884

5. <u>Sum Coincidence studies on ^{131}Ba</u> - C. Rangacharyulu and G.K. Mehta - A study of the energies of gamma rays in the decay of ^{131}Ba was carried out. A Ge(Li) detector of depletion depth 7mm was used to assign the energies of gamma rays. A sum coincidence spectrometer with slow-fast coincidence was employed to study the different cascade modes of various levels in ^{131}Cs. In addition to the already well established levels, there is evidence of a new level at 528 KeV and new gamma rays of energies 169, 312, 506 and 528 are observed. There is no evidence whatsoever for 323.9 KeV reported by Karlsson[1)] and the existence of 82.4 and 137.2 KeV transitions is doubtful. A decay scheme is constructed to fit in all the observed gamma rays.

1. K. Karlsoon Arkiv For Fysik 33, 47(67).

J. INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR-2.

1. Photodisintegration of the Alpha Particle - H. L. Yadav, D. Mahanti and B.K. Srivastava - We use Sum rules of Levinger and Bethe to calculate the Bremsstrahlung weighted cross-section and the integrated cross-section for the photodisintegration of the alpha particle. In our calculation the alpha particle is described by the Irving wave function whose parameters are determined by variational calculation of the binding energy of the alpha particle using the velocity dependent potential of Nestor et al. Our values agree reasonably well with experiments and with those given by earlier calculations.

K. OSMANIA UNIVERSITY, HYDERABAD-7.

1. Compton Scattering By K-Shell Electrons at Large Scattering Angle - V. Govinda Reddy, D.V. Krishna Reddy and D. S. R. Murty - The differential cross-section for the compton scattered gamma rays of energy 662 keV from a 6.0 curie source of Caesium-137 by the K-shell electrons of Plantinum, Bismuth and Thorium to the free electrons was experimentally studied at a scattering angle of 125°. The scattered energy spectrum was studied on a twenty channel analyser. NaI(Tl) scintillation spectrometers and fast-slow coincidence system have been used for the above studies. The effect of the target thickness on the differential cross-section ratio and energy spectrum has also been studied. The results have been compared with available theoretical results.

2. Inelastic Scattering of Gamma Rays by K-Shell Electrons - D.V. Krishna Reddy, E. Narasimhacharyulu and D.S.R. Murty - The differential cross-section $d\sigma_K$ for the inelastically scattered gamma rays of energy 662 K-Shell electrons of platinum, Bismuth and Thorium was studied at 70° and 105° by experiment. The energy spectrum of the scattered gammas was also studied on a 20 channel analyser. The scattered gamma rays were selected in coincidence with the accompanying K X-rays from the scatterer using the NaI(Tl) scintillation detectors and fast-slow coincidence method. The differential cross-section $d\sigma_K$ is compared with that of the Klein-Nishina cross-section $d\sigma_F$ for free and stationary electrons. The experimental results are analyzed in the light of existing theoreis.

L. PANJAB UNIVERSITY, CHANDIGARH

1. Configuration Mixing vs Effective-Shell Model - Raj K. Gupta and R.K. Bansal - The ARNL group has reported that many nuclear properties, in addition to the energy spectra, are highly insensitive to the configuration mixing. This claim has not been found to be true in general and calculations using electron scattering probe, on the so called pseudo-nuclei having non-mixed parity states, in particular, have disputed this claim.

In the present study we investigate the problem of mixed confirugation v.s. effective shell model, for pseudo nuclei having mixed parity states.

2. The Decay of ^{131}I - K.K. Suri* and P.N. Trehan - The level structure of ^{131}I has been investigated emplying scintillation spectrometers in 4π sum-peak coincidence and sum-coincidence modes. On the basis of these investigations, the existence of the weak gamma transitions of energy 318, 325, 358, 405 and 643 keV and a weakly populated level at 405 keV is verified. It has, however, not been possible to confirm the existence of 272 keV gamma ray as reported earlier. Further from the sum-coincidence spectrum with the gata set at 503 keV and the result of Graeffe et al., it is inferred that 503 keV gamma ray and 326-177 keV cascade arise in the decay of a level at 667 keV. The K-conversion coefficient for the 80 keV transition has been measured to be 1.31 ± 0.08, which ahows the transition to be pure

* Department of Applied Sciences, Panjab Engineering College, Chandigarh.

M1 in character. Also on the basis of gamma gamma angular correlation measurements for the 284-80 keV cascade an assignment of character $1/2^+$ has been confirmed for the level at 80 keV.

3. <u>The Decay of ^{160}Tb to Levels in ^{160}Dy</u> - K.K. Suri* and P.N. Trehan - In the decay of ^{160}Tb a level at 1538 keV and its decay modes have been established by fast-slow coincidence and sum-coincidence spectrum studies. Also from the coincidence data, the positions of weak gamma transitions of energy 1005, 1115 and 1251 keV have been verified. The directional correlation measurements on seven gamma ray cascades: 299-966, 299-879, 879-87, 962-87, 1178-87, 1272-87 and 216-962 keV have been performed. As a consequence of these measurements, spin-parity assignments 3^+ and 2^- have been confirmed for the levels at 1049 and 1359 keV respectively and the multipole characters of the 299, 879, 962, 1178, 1272 and 216 keV gamma transitions determined.

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* Department of Applied Sciences, Punjab Engineering College, Chandigarh.

M. SHIVAJI UNIVERSITY, KOLHAPUR

1. The Binding Energy of ^{10}B Nucleus - K.L. Narayana and Shamrao B. Desai - A correlated nuclear wave function of the type

$$\Psi = \sum_i C_i \phi_i (1,2) [1 + P_{12}]$$

with the property of optimum convergency has been used to calculate the ground state energy of Boron nucleus, with P_{12} as the space exchange operator of the two outermost nucleons, and including the spin and isospin function based on a dual core model. A δ-force of strength about -10 MeV to furnish the experimentally observed binding energy of the boron nucleus indicates either a predominantly 1p-character or a highly correlated motion of the two nucleons. An important result of the present calculations is the predication of a low % analogous 1s-shell orbital for both the cases in conformity with the studies on Quasi-free (p,2p) reaction cross-sections.

N. UNIVERSITY OF ROORKEE, ROORKEE.

1. The Dependence of Nuclear Matter Binding Energy of the High Energy Phase Shifts - M.K. Srivastava - The dependence of the binding energy per particle in nuclear matter on the phase shift, beyond 350 MeV laboratory energy, is investigated by using the reference spectrum method. Self-consistency with respect to the reference spectrum gap parameter and the effective mass for the occupied spectrum is achieved by iteration. Second rank separable potentials are used. These have been obtained by solving the inverse scattering problem as suggested by Fiedeldey[1] It is found that the results are rather insensitive to the form of the phase shifts in the high energy region in agreement with the findings of Elliott et al[2].

References:

1. H. Fiedeldey, Nuc.Phys. A135(1969)353

2. J.P. Elliott, A.D. Jackson, H.A. Mavromatis, H.A. Sanderson and B. Singh, Nucl Phys.A121 (1968)241.

2. Triple Gamma Coincidence and Angular Correlation Studies in Cd^{110} From the Decay of Ag^{110m} - U.S. Pande and B.P. Singh - The gamma-gamma-gamma coincidence studies are done in Cd^{110} from the decay of Ag^{110m}. The two triple gamma cascades thus studied are 1384 keV 884 keV-658 keV and 937 keV-884 keV-658 keV.

For the coincidence and also for angular correlation studies, three NaI(Tl) detectors have been used. The mounting of these detectors have been done in the two geometries (i) Putting all the three detectors in the plane of the table, equidistant

from the source. Two of them are fixed and one is movable.
(ii) Two detectors are in the plane of the table and one perpendicular to the plane of the table. All the three are equidistant from the source. Two detectors,one in the plane of the table and other perpendicular to the plane of the table are fixed and one in the plane of the table is movable.

The triple gamma angular correlation coefficients A_2 and A_4 are given. The spin values for 2925 keV and 2479 keV levels are discussed. The multipole mixture for 1384 keV gamma transition is given.

3. Gamma-gamma-gamma Directional Angular Correlation Studies in Dy^{160} From the Decay of Tb^{160} - U.S. Pande and B.P. Singh - Triple gamma angular correlation studies are one in Dy^{160} from the decay of Tb^{160} using three NaI(Tl) detectors. For these studies pulses from one of the detectors detecting 87 keV in 2 volts channel width (2 volts-20 keV) and pulses from other detector detecting high energy gamma rays using as integral spectrum above 500 keV are fed to a double coincidence unit. The output of this coincidence unit forms as gate for one of the input of second coincidence unit and the pulses for the second input of the second coincidence unit are taken from the third detector which scans the spectrum in one volt channel width. The triple gamma coincidence spectrum is given which predominently gives 298 keV-879 keV-87 keV triple cascade. The triple gamma angular correlation studies are made in two geometrical considerations of these three detectors (spectrometers). The angular correlation coefficients are given. The multipole mixture for

879 keV gamma transition and spin of excited levels are considered.

4. <u>Beta-Gamma-Gamma Directional Correlation Studies in Ba^{134} from the Decay of Cs^{134} and Cd^{110} from the Decay of Ag^{110m}</u>

- H.S. Dahiya and B.P. Singh - An experimental set up for the study of Beta-gamma-gamma directional correlation studies is described. The beta-gamma-gamma coincidence studies are done in Ba^{134} from the decay of Cs^{134} for the following (i) The beta group of 410 keV and gamma rays of 1038 keV and 605 keV (ii) The beta group of 660 keV and gamma rays of 796 keV and 605 keV. Beta-gamma-gamma coincidence studies are done in Cd^{110} from the decay of Ag^{110m} for the following: (i) Beta group of 87 keV and gamma rays of 1384 keV and 884 keV (ii) Beta group of 529 keV and gamma rays of 937 keV and 884 keV.

The angular correlation studies are done for these cascade. The angular correlation coefficients 'A_2' and 'A_4' for these cascades are given and the results are discussed.

O. CALCUTTA UNIVERSITY

1. Internal Bremsstrahlung Spectrum From ^{32}P - M. Nath, S. Mitra, A.K. De, A.K. Das and P.C. Bhattacharya - An experimental study of internal bremsstrahlung accompanying beta decay of ^{32}P has been carried out for the clarification of the contradictions among the various experimental investigations. Bremsstrahlung spectrum is measured by a sodium iodide scintillation spectrometer with a modified geometrical arrangement. The experimental results in the energy region 60-1200 keV are compared with the experimental results of other authors and with theoretical calculations from KUB-Lewis and Ford-Nilsson theory.

P. PANJABI UNIVERSITY, PATIALA

1. Internal Bremsstrahlung From ^{32}P - M.S. Pawar and M.Singh - The experimental results of earlier workers on the Internal Bremsstrahlung energy spectrum and photon yield for ^{32}P disagree among themselves as also with the KUB theory corrected for Nuclear Coulomb effects. A study of the energy spectrum and photon yield due to internal bremsstrahlung from the allowed beta decay of ^{32}P, with different methods of measurements to investigate the reasons for the disagreement of earlier measurements, is in progress.

2. Measurement of the (82L-212 γ) Angular Correlation in ^{121}Te - Measurement of the angular correlation of 11/2 - 3/2 - 1/2 cascade in ^{121}Te has been performed with L-conversion electrons and γ rays. The measured value of the correlation A_{22} = -0.020±0.03 agrees with the findings of Marelius et al[1] but differs very much from the result A_{22} = 0.007±0.007 of Goldberg and Frankel[2] using a thin lens beta spectrometer as a fixed detector for electrons and a scintillation counter for the movable detector. The L-subshell particle parameter for the 82 keV M_4 transition has been evaluated and compared with the theory of Hager and Seltzer.

1. A. Marelius, R. Pettersson, S. Tornkvist, S.E. Hagglund and R. Dumitrescu, Arkiv fur Fysik, 37,435,(1968).

2 N. Goldberg and S. Frankel, Phys.Rev.100,1350,(1955).

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. -267	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

Progress Report on

Nuclear Data Activities in Iran

Compiled by H. Rouhaninejad

May, 1971

TEHRAN UNIVERSITY NUCLEAR CENTRE
Nuclear Data Programme.
1971.

Introduction.

At present the only nuclear facility at Tehran University Nuclear Center is a 5MW pool type reator, the regular utilisation of which for irradiation started in August 1970. A 3mev Van de Graff machine is also being installed. This is expected to be in operation before the end of 1971. Consequently the n.d.p. at this center is at an early stage. The following projects reflect the status of T.U.N.C. in this respect. No report concerning activities in this line has so far been received from other institutes in Iran.

1- Decay Scheme of ^{92}Sr

The level structure of ^{92}Y has been investigated through the study of the decay of ^{92}Sr. Sources were prepared by irradiating samples containing about 100 mg of uranyl nitrate U02(N03)2. $6H_2O$ of natural isotopic composition in the Tehran University Nuclear Center 10-15 minutes with a flux of $2x10^{13}n\ cm^{-2}\ Sec^{-1}$, following the irradiation, target was cooled for half of an hour and then the samples were radiochemically separated and Strontium activity was stripped out as Sr Co3. The complete separation procedure took about 2 hours. Gamma rays emitted in the decay of ^{92}Sr were studied through the use of a $40\text{-}em^3$Ge(Li) detector. Gamma rays of energies (and relative intensities) 241.4(2.9), 352.5(0.06), 430.7(3.4), 463.4(0.04), 491.2(0.32), 651.2(0.21), 892.8(0.08), 953.3(4.0), 1142.4(3.0), and 1383.9(100) Kev have been observed. Gamma-gamma coincidences in the decay of ^{92}Sr were studied with a NaI(TI) Ge(Li) set-up. A decay scheme is proposed, based on energy sums and coincidence results of the gamma-ray transitions. All but two of the gamma rays emitted are placed in the proposed decay scheme. (the full text is being prepared for publication).

2- Standard Spectrum Studies.

In view of the fast developments in the field of the nuclear reactors there has been a great need to determine the necessary nuclear data to the target accuracy of ± 1 %. As such it has become important to determine the fission spectrum, the fission yield of U^{235} and neutron cross sections averaged over the fission spectrum. Tehran University Nuclear Center has decided to initiate some measurements in the line.

Irradiation facility:

In order to produce the U^{235} fission spectrum a Uranium metal disc, highly enriched, 50 mm diameter and 1 mm thick affixed on an aluminium box, will be installed in a cavity, lined with Boral, in the thermal Columm of the Tehran University Research Reactor. The cavity is cylindrical shaped, 150 cm high and 120 em in diameter. A hole is provided in the base to let the neutrons impinge on the neutron converter. At the point of the uranium disc thermal flux is not more than 10^{10} n/cm^2-sec. The generated heat is removed from the disc by air blow. During the reactor operation for other users a cadmium shutter is used to stop thermal neutrons reaching the Uranium disc. A gadget is used to place foils at specified distances from the disc.

Method:

In these measurements threshold detectors are used. The irradiation period depends on the cross section and the half life of the produced isotope. The foils are counted on a3 "x3" NaI crystal or a Ge(Li) detector available at this Institute. There are two multichannel analyzers, which will be used for this purpose.

A code (photopeak analysis) is used to calculate the net count under the photopeak. This programme fits a Gaussian equation to the photopeak from which the area under the peak is obtained. A least square program has been prepared, to fit a polynominal to the measured activity along the vertical axis to the Uranium disc.

3- Neutron Beam Facility Project.

The swimming pool type research Reactor of Tehran University Nuclear Center is facilitated with seven beam tubes of different sizes and shapes. Two of these, both 6 "in diameter, will be equipped by the end of 1971 mainly for the following purposes:

Solid state physics measurements.
Neutron Spectrometry.
Neutron Irradiation.
Cross Section Measurements.
Shielding Studies.

The related equipment for some of these projects have been ordered.

Two collimators for the two 6 "beamtubes are in the designing stage and their construction will follow after the completion of this stage.

It is hoped that in time more information and complete details of the research projects in this line will be available.

Progress Report on

Nuclear Data Activities in Korea

(for the period January 1970 to December 1970)

Compiled by M.K. Chung

PROGRESS REPORT ON NUCLEAR DATA PROGRAMME OF A.E.R.I.

by

M.K.Chung

Liaison Officer of INDC, Physics Division, Atomic Energy Research Institute. Republic of Korea

(1) CURRENT STATUS

After establishment of Korean Nuclear Data Centre at Physics Division, A.E.R.I. in 1970, several members including a liaison officer have been engaged in the works of collection and classification of nuclear data, neutron cross-section sets and processing codes etc.

At present efforts are paid more on the collection of neutron data and generating group constants which are necessary for fast critical assembly design than the evaluation of nuclear data or cross-section measurements.

However during the year 1970, the following experiments were carried out by our research members:

(a) Total Cross Sections of ^{45}Sc, ^{47}Ti, ^{49}Ti, ^{53}Cr and ^{61}Ni in the keV Region

A research staff of physics division, Mr. M.Cho, was sent to Karlsruhe to gain experiences in cross-section measurements in keV region. During his staying in Germany above mentioned measurements were carried out with the collaboration of Karlsruhe staffs and the results were presented to the 2nd International Conference on Nuclear Data for Reactors at Helsinki , 1970. (Proc. of 2nd Int. Conf. on Nuclear Data for Reactors at Helsinki, vol. 1, p.p. 619, 1970)

(b) Phonon Excitations in Titanium Hydride and Deutride by Low Energy Neutrons (Y.J.Lee and H.D.Kang)

A newly constructed twin crystal neutron monochromator installed at the tangential beam tube of TRIGA MARK -11 reactor was used to measure the energy dependence of the neutron cross-section of hydrogen and deuterium bound in titanium metal lattice.

Titanium hydride and deuteride were prepared by diffusion method.

Total cross-section was calculated from the observed transmission for tatanium dihydride powder sample as a function of neutron energy between 0.05 eV and 0.22 eV. A cross-section minimum was observed at the neutron energy of 0.122 $\pm$ 0.005 eV which corresponds to the threshold energy of phonon excitation.

A cross-section minimum of titanium deutride occurs at 0.145 eV of neutron energy and this value can also be taken as the threshold energy of phonon excitation of the optical level in the titanium lattice.

A more refined experiment is now being undertaken in the same laboratory.

(c) Radiative Capture Spectroscopy (M.K.Chung et al.)

For precise analysis of complex gamma-ray spectra due to thermal neutron radiative capture, a single flat crystal monochromator in combination with a Ge(Li) diode detector was constructed and is now under test. And semi-empirical approach was tried to determine full-peak detection efficiency of Ge(Li) detector and gave excellent agreement with observed data.

(2) FACILITIES AVAILABLE FOR NEUTRON PHYSICS EXPERIMENTS

The following facilities have been used for neutron physics experiments.

(i) A twin crystal neutron monochromator

(ii) Two sets of double axis neutron monochromator spectrometers

(iii) Two slow choppers

(iv) A rotating crystal spectrometer is nearly at completion of construction

(v) 14 MeV neutron generator

Almost all the experiments in the field of neutron physics were performed by utilizing TRIGA MARK 11 (250 KW). However due to the insufficient usable neutron flux from TRIGA MARK 11, TRIGA MARK 111 (2 MW) reactor is under construction to fullfill the required flux and will be critical toward the end of 1971.

(3) FACILITIES PLANNED

(i) Installation of a 5.5 MeV Van de Graaff is planned and its construction will start at the begining of 1972 after the final approvement for budget by a government authority.

(ii) A small scale fast critical facility will be designed and constructed thoroughly by our research staffs. This project will start in 1972 and will end in 1976. The characteristics of our FCA will be almost the same as the critical facility which is now under construction at BARC in Trombay.

For this project compilation of cross-section data, group constant sets and related processing codes were already started at A.E.R.I.

(4) DATA REQUEST

We already requested evaluated microscopic cross-section data on several nuclides including ^{239}Pu in the form of magnetic tape to INDC and waiting for its delivery.

Progress Report on

Nuclear Data Research in Poland

(for the period of May 1970 to April 71)

Compiled by A. Marcinkowski

Polarization of neutrons from the $^3H(d,n)^4He$ reaction at low deuteron energies.

J.Rondio, M.Siemiński, Z.Wilhelmi, W.Zych and P.Żuprański

Institute of Nuclear Research, Warsaw
and
Institute of Experimental Physics, Warsaw University.

Polarization of neutrons from the $^3H(d,n)^4He$ reaction appears to be negligible for deuteron energies up to 300 keV confirming the description of the reaction as an S-wave formation of a 3/2 + state in ^5He. For deuteron energy of 1.8 MeV in the region of 90° c.m. the polarization amounts to as much as 16% /1/.

We have performed polarization measurements just in the region of transition from a non - polarizing resonance to a region of rapidly increasing polarization. Using the method and aparatus described in ref /2/ we have measured the angular distribution of polarization at deuteron energy 1.4 MeV and the energy distribution of polarization for angles 60° and 90° for deuteron energies from 0.5 MeV up to 1.6 MeV. The results are shown in Figs 1 and 2.

The results of polarization measurements have been analysed together with the date on total and differential cross section. The compound nucleus formation has been assumed to be mainly responsible for the reaction. Results of the analysis point to the existence in ^{5}He of a 5/2 + state at an excitation energy of about 20 MeV and of a 1/2 + state situated near the well known 3/2 + state at excitation energy 16.70 MeV.

References:

1. I.Levintov, A. Miller, V.Shamshov, JETP 34, 1030 (1958).
2. M.Siemiński, Z.Wilhelmi, W.Zych, P.Żupranski, Nucl. Instr. and Meth., 64, 77 (1968).

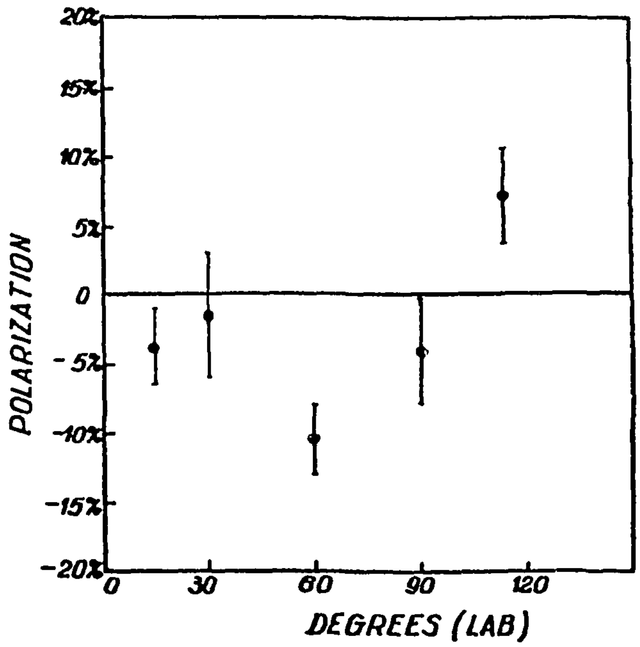

Fig. 1 . The angular dependence of neutron polarization at deuteron energy 1.4 MeV .

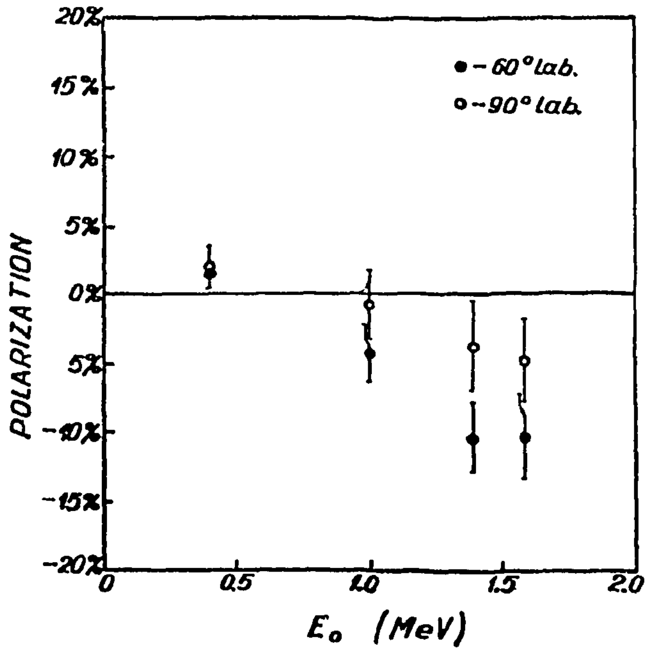

Fig. 2 . The energy dependence of polarization of neutrons emitted at 60^0 and 90^0 in the lab. system.

Cross Sections for the $^{71}Ga(n,p)^{71m}Zn$, $^{71}Ga(n,2n)^{70}Ga$, $^{75}As(n,p)^{75m}Ge$, $^{75}As(n,p)^{75}Ge$, $^{75}As(n,2n)^{74}As$, $^{80}Se(n,2n)^{79m}Se$, $^{80}Se(n,np)^{79}As$, $^{82}Se(n,2n)^{81m}Se$, $^{117}Sn(n,p)^{117}In$, $^{117}Sn(n,n')^{117m}Sn$ and $^{118}Sn(n,2n)^{117m}Sn$ Reactions in the Neutron Energy Range from 13 to 18 MeV.

P.Decowski, S.El-Konsol+, W.Grochulski, A.Marcinkowski, J.Piotrowski, I.M.Turkiewicz, Z.Wilhelmi.

Institute of Nuclear Research, Warsaw

and

Institute of Experimental Physics of Warsaw University

The absolute cross sections for the $^{71}Ga(n,p)^{71m}Zn$, $^{71}Ga(n,2n)^{70}Ga$, $^{75}As(n,p)^{75m}Ge$, $^{75}As(n,p)^{75}Ge$, $^{75}As(n,2n)^{74}As$, $^{80}Se(n,2n)^{79m}Se$, $^{80}Se(n,np)^{79}As$, $^{82}Se(n,2n)^{81m}Se$, $^{117}Sn(n,p)^{117}In$, $^{117}Sn(n,n')^{117m}Sn$ and $^{118}Sn(n,2n)^{117m}Sn$ reactions were evaluated from the gamma activity measurements with the use of the scintillation spectrometer. The reaction final products were identified by their characteristic gamma-ray transition energies and the least square analysis of the decay curves. The neutrons were obtained in the Van de Graaff accelerator from a $^{3}H(d,n)^{4}He$ reaction. The proper choice of the irradiation angle and the deuteron energy allowed to get neutrons in the energy range from 13 to 18 MeV. The measurements were refered to the well known cross section of the $^{56}Fe(n,p)^{56}Mn$ reaction. The results are shown in Tables 1 - 11 .

Table 1

Cross Section for the $^{71}Ga(n,p)^{71m}Zn$ Reaction

E_n MeV	mb
13.36 ± 0.14	10.4 ± 0.1
13.90 ± 0.09	9.5 ± 0.1
14.47 ± 0.11	10.4 ± 0.3
15.06 ± 0.17	11.5 ± 0.1
15.36 ± 0.20	9.6 ± 0.2
15.88 ± 0.19	7.1 ± 2.0
16.51 ± 0.11	9.5 ± 2.1

Table 2

Cross Section for the $^{71}Ga(n,2n)^{70}Ga$ Reaction

E_n MeV	mb
13.36 ± 0.14	1098 ± 26
13.90 ± 0.09	1153 ± 25
14.47 ± 0.11	1135 ± 25
15.06 ± 0.17	1130 ± 32
15.36 ± 0.20	1148 ± 23
16.51 ± 0.11	1046 ±127

Table 3

Cross Section for the $^{75}As(n,p)^{75m}Ge$ Reaction

E_n MeV	mb
13.02 ± 0.14	12.4 ± 1.6
13.36 ± 0.14	23.3 ± 0.5
13.90 ± 0.09	20.7 ± 0.7
14.47 ± 0.11	21.1 ± 0.7
15.06 ± 0.17	18.2 ± 0.8
15.36 ± 0.20	17.9 ± 0.7
15.88 ± 0.19	10.7 ± 1.2
16.51 ± 0.11	8.9 ± 1.1

Table 4

Cross Section for the $^{75}As(n,p)^{75}Ge$ Reaction

E_n MeV	mb
13.02 ± 0.14	28.5 ± 0.9
13.36 ± 0.14	28.8 ± 0.7
13.90 ± 0.09	38.1 ± 0.8
14.47 ± 0.11	31.2 ± 1.0
15.06 ± 0.17	26.5 ± 0.8
15.36 ± 0.20	30.4 ± 0.8
15.88 ± 0.19	27.6 ± 0.9
16.51 ± 0.11	19.9 ± 0.6
17.32 ± 0.20	12.5 ± 1.0
17.78 ± 0.15	12.4 ± 0.8

Table 5

Cross Section for the $^{75}As(n,2n)^{74}As$ Reaction

E_n MeV	mb
13.02 ± 0.14	955 ± 15
13.36 ± 0.14	890 ± 6
13.90 ± 0.09	955 ± 21
14.47 ± 0.11	1027 ± 10
15.06 ± 0.17	1109 ± 14
15.88 ± 0.19	1299 ± 19
16.51 ± 0.11	1312 ± 20
17.32 ± 0.20	1245 ±186
17.78 ± 0.15	1321 ±122

Table 6

Cross Section for the $^{80}Se(n,2n)^{79m}Se$ Reaction

E_n MeV	mb
13.02 ± 0.14	193 ± 37
13.36 ± 0.14	196 ± 4
13.90 ± 0.09	165 ± 6
14.47 ± 0.11	189 ± 5
15.06 ± 0.17	203 ± 14
15.36 ± 0.20	186 ± 5
15.88 ± 0.19	192 ± 36
16.51 ± 0.11	178 ± 32
17.32 ± 0.20	190 ± 36
17.78 ± 0.15	180 ± 21

Table 7

Cross Section for the $^{80}Se(n,np)^{79}As$ Reaction

13.36 ± 0.14	3.8 ± 3.0
14.47 ± 0.11	1.0 ± 3.2
15.06 ± 0.17	8.4 ± 4.4
15.36 ± 0.20	7.3 ± 2.4
15.88 ± 0.19	4.1 ± 9.2
16.51 ± 0.11	13.2 ± 4.2
17.32 ± 0.20	35.3 ±10.6
17.78 ± 0.15	71.2 ±13.5

Table 8

Cross Section for the $^{82}Se(n,2n)^{81m}Se$ Reaction

E_n MeV	mb
13.02 ± 0.14	1506 ± 285
13.36 ± 0.14	1702 ± 20
13.90 ± 0.09	1692 ± 37
14.47 ± 0.11	1587 ± 37
15.06 ± 0.17	1628 ± 18
15.36 ± 0.20	1616 ± 18
15.88 ± 0.19	1796 ± 190
16.51 ± 0.11	1715 ± 161
17.32 ± 0.20	1520 ± 231
17.78 ± 0.15	1425 ± 142

Table 9

Cross Section for the $^{117}Sn(n,p)^{117}In$ Reaction

E_n MeV	mb
13.02 ± 0.14	10.7 ± 2.1
13.36 ± 0.14	10.6 ± 0.3
13.90 ± 0.09	10.0 ± 0.3
14.47 ± 0.11	10.1 ± 0.4
15.06 ± 0.17	12.7 ± 1.4
15.36 ± 0.20	11.6 ± 0.3
16.51 ± 0.11	16.9 ± 2.6

Table 10

Cross Section for the $^{117}Sn(n,n')^{117m}Sn$ Reaction

E_n MeV	mb
13.36 ± 0.14	287 ± 31
13.90 ± 0.09	272 ± 14
14.47 ± 0.11	284 ± 14
15.06 ± 0.17	255 ± 25
15.36 ± 0.20	286 ± 8

Table 11

Cross Section for the $^{118}Sn(n,2n)^{117m}Sn$ Reaction

E_n MeV	mb
13.02 ± 0.14	624 ± 80
13.36 ± 0.14	761 ± 41
13.90 ± 0.09	808 ± 28
14.47 ± 0.11	745 ± 59
15.06 ± 0.17	805 ± 21
15.36 ± 0.20	890 ± 34
15.88 ± 0.19	1055 ±164

Calculations of the Compound Reaction Cross Sections with Accounting for the Effect of the Gamma - Particle Competition.

P.Decowski, W.Grochulski, A.Marcinkowski, J.Piotrowski

Institute of Nuclear Research, Warsaw

and

Institute of Experimental Physics of Warsaw University.

An algol program for the statistical model calculations was elaborated. In the calculations the competition of the gamma radiation was taken into account with respect to the neutron and proton emissions on each step of the reaction. When the experimental strenghts of the E1,E2 and M1 transitions were used a satisfactory agreement between the measured and calculated cross sections was obtained.

The superconductivity level density formulae [1] were modified in order to introduce the rotational spin cut - off ("yrast levels"). At low excitation energies the real level sequences were used as far as their exact energies, spins and parities were known.

The results show that for neutron induced reactions at 14 MeV the influence of the "yrast levels" on the cross sections is much lower than of the gamma-ray emission.

It was found that the calculated cross section of the (n,n′) reaction is distinctly influenced by the (n,γ n′) process.

An extensive program of calculation of the (n,n′) (n,2n) and (p,γ) cross sections for a wide range of nuclei is in progress.

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Energy Spectra of Alpha Particles from the $^{153}Eu(n,\alpha)^{150}Pm$, $^{160}Dy(n,\alpha)^{157}Gd$, $^{162}Dy(n,\alpha)^{159}Gd$ and $^{164}Dy(n,\alpha)^{161}Gd$ Reactions with 14.2 MeV Neutrons.

L.Głowacka, M.Jaskóła, W.Osakiewicz, J.Turkiewicz, L.Zemło, B.Zych.
Institute of Nuclear Research, Warsaw
and
Institute of Experimental Physics, University of Warsaw

The studies of the energy distributions of alpha particles emmited in the (n,α) reactions induced by 14.2 MeV neutrons on rare earth isotopes, have been continued. In addition to the energy spectra of alphas from the 14.2 MeV reactions induced on ^{139}La, ^{159}Tb, ^{162}Dy, ^{163}Dy, ^{166}Er, ^{168}Er and ^{169}Tm, which were earlier described /1/ /2/, /3/, /4/ the present work gives results with ^{157}Eu, ^{160}Dy, ^{162}Dy and ^{164}Dy targets.

The 14.2 MeV neutrons used in the experiment were obtained from $^{3}H(d,n)^{4}He$ reaction with deuterons accelerated up to 500 keV in a Van de Graaff accelerator. A neutron energy spread due to the deuteron energy loss in the neutron target and geometrical conditions was about ± 150 keV. The neutron flux incident on the target was monitored by counting the recoil protons from a thin polyethelene foil. The accuracy of neutron monitoring was better than 2%.

The targets were made of oxides and deposited on thick carbon backings by means of sedimentation from the suspensions in isopropyl alcohol.

A description of the investigated targets is given in Table 1.

Table 1

target	isotopic abundance %	chemical compound	Thickness mg/cm^2
^{153}Eu	90	Eu_2O_3	3.0
^{160}Dy	77.6	Dy_2O_3	3.9
^{162}Dy	94.0	Dy_2O_3	5.4
^{164}Dy	97.8	Dy_2O_3	4.9

The alpha particle energy was measured using n-type surface barrier silicon detectors of 15 mm diameter. The experimental arrangement was described in our earlier work /3/.

The results of alpha aprticle spectra measurements are shown in Figs 1-2. All the spectra were measured for the forward angles ($0^o \pm 60^o$). The error bars in the figures refer to statistical errors only.

In Figs 1 and 2 the theoretical predictions obtained by applying the Weisskopf-Ewing formula are also shown. The energy dependence of the level density was taken in the high excitation energy limit of the free fermion gas model with the density parameter "a" given by Erba et al. /5/.

The values used for inverse cross sections were taken from the calculations of Huizenga and Igo /6/. The calculated curves are not normalized and are given to indicate the shape and the position of the evaporation spectra only.

All experimental spectra are significantly shiffted towards higher energies in comparison with the predictions of the statistical theory. In addition from plots of the reduced spectra the values of the level density parameters much smaller than those reported by Erba et al./5/ were found. The comparison of these a-values is shown in table 2.

Table 2

Nucleus	Level density parameter a (MeV^{-1})	
	present work	Erba et al./5/
^{150}Pm	7.7	-
^{157}Gd	4.9	20.2
^{159}Gd	7.2	21.6
^{162}Gd	5.0	22.8

This disagreement and the existence of high energy alpha particles in experimental spectra suggest the strong contribution of direct processes in the investigated reactions.

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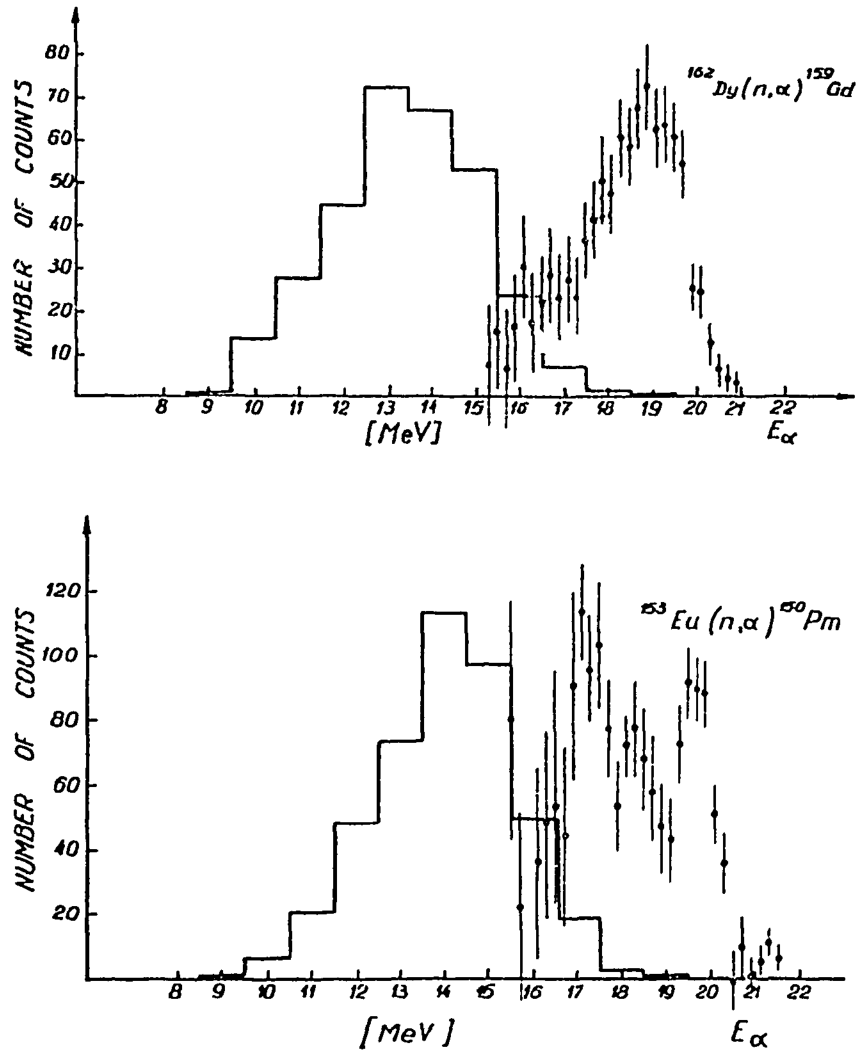


Fig.1. The experimental α - particle spectra from the ^{162}Dy(n,α)^{159}Dg and ^{153}Eu(n,α)^{150}Pm reactions, and the predictions of the statistical theory.

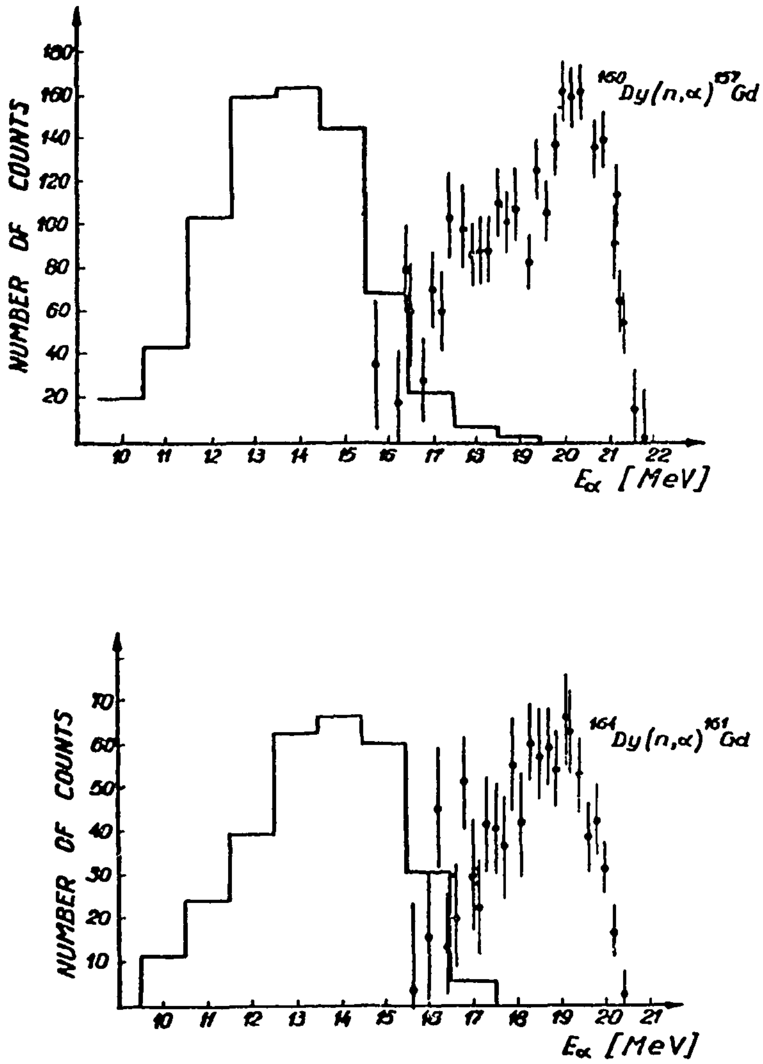


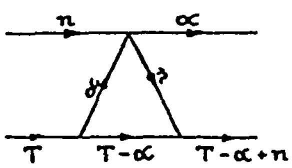
Fig.2. The experimental α - particle spectra from the $^{160}Dy(n,\alpha)^{157}Gd$ and $^{164}Dy(n,\alpha)^{161}Gd$ reactions, and the predictions of the statistical theory.

On the Knock-On Mechanism in the (n,α) Reactions

M.Kozłowski, M.Jaskóła, W.Osakiewicz, J.Turkiewicz
Institute of Nuclear Research, Warsaw
and
Institute of Experimental Physics, Warsaw University

During the past few years the (n,α) reactions on the rare-earth nuclei were investigated in our laboratory /1-4/. It was shown that the compound nucleus mechanism for these reactions must be excluded due to unphysical (too small) values of the density level parameters which would have been used.

The existence of high energy α-particles in experimental spectra and the small values of the separation energy of α-like structure in rare-earth nuclei suggests the assuming of the direct mecnanism of the investigated reactions. The incident neutron remove the α-particle from nuclei and occupies the one-particle state in nuclear well. These types of reactions correspond to the triangular graphs of the dispersion theory of nuclear direct reactions developed by I.S. Shapiro /5/.



The cross section for the reaction (n,α) which is dominated by the knock-on mechanism may be written as follows:

$$\frac{d\sigma}{d\omega} = \frac{xy}{z + w\cos\theta}\left[\operatorname{arc\,tan}\left(\frac{z + w\cos\theta}{y}\right)^{1/2}\right]^2$$

$$x = x(E_n, \gamma_\alpha, \gamma_n, Z, Q)$$

$$y = y(E_\alpha^B, E_n^B) \qquad (1)$$

$$z = z(E_n, Q)$$

$$w = w(E_n, Q)$$

In the formula (1) E_n is the kinetic energy of neutrons in Lab. system, Z is the charge of the final nucleus. The γ_α, γ_n are the reduced widths of the α-particle and neutron respectively. The Q is the mass difference of the entrance and exit channels. The E_α^B and E_n^B are the binding energies of the α-particle and neutron. The formula (1) can be applied only for those nuclei for which $E_\alpha^B > 0$, $Q > 0$.

In this report we present the analysis of the reaction $^{162}Dy(n,\alpha)^{159}Gd$. The experimental arrangement was the same as described in our previous papers /1-4/. Fig.1 shows the relative cross-sections measured for the forward angles as the functions of the excitations energy of the final nucleus. The solid line represents the calculated relative cross sections. The neutron reduced width were computed numerically. The Saxon-Woods well was assumed /6/. The excitation energies of neutrons were taken from Nilsson model. The final state interactions of α-particle with final nucleus were also taken into account /7/. Taking into account uncertainty in the assignement of the energy scale the overall agreement of the theoretical predictions with experimental data is quite good. The investigation of this model in the case of other nuclei are in progress.

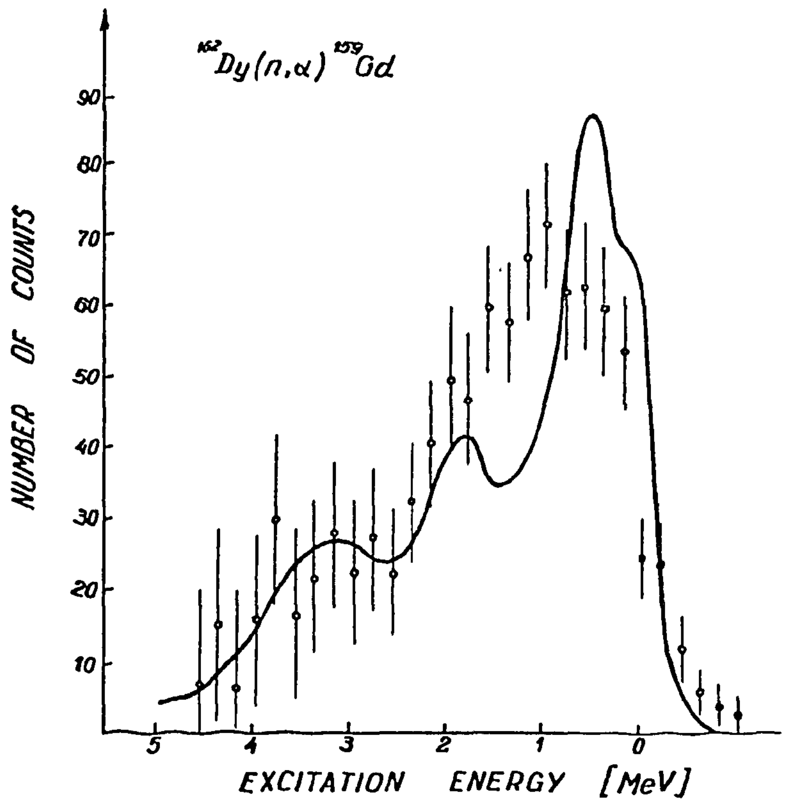


Fig. 1. The experimental and theoretical energy spectra of α- particles from the $^{162}Dy(n,\alpha)^{159}Gd$ reaction.

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Energy - angular distribution of alpha particlos emitted during the thermal neutron fission of ^{235}U

E. Piasecki, M. Dakowski, T. Krogulski, J. Chwaszczewska and J. Tys

The energy - angular distribution of alpha particles emitted during a thermal neutron fission of ^{235}U has been measured. The FWHM of the angular distribution is equal 20 ± 3 degrees, which is about 50 per cent less then in the case of ternary fission of ^{252}Cf, as measured by Fraenkel [1/]. It suggests that the kinetic energy of fragments at the scission moment can be much less then 40 MeV, as calculated in ref. 2.
Unexpectedly high rate of the alpha particles was registered at angles close to 0° and 180° /about 5 per cent of the total tripartition yield/. The energy spectra of these particles evidences that there are evaporated in flight from the fully accelerated fragments. The anisotropy of emission in the center of mass system can be caused by the angular momentum of fragments.

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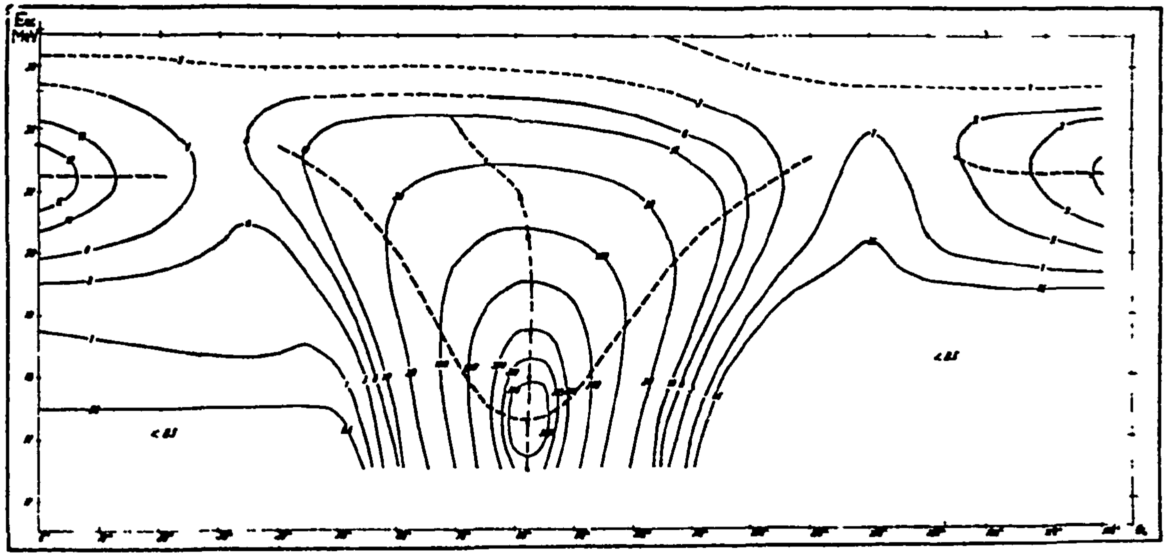

Fig. 1. Contour diagram of the $Y(E_\alpha, \theta)$ distribution. The intensity is given in arbitrary units. The dashed contour lines display results extrapolated using the energy spectra of alpha particles. The cross dashed line - energy dependence of the maximum of the angular distribution, the thick dashed curves - the angular dependence of the mean value of α particle energy distribution.

Investigation of the neutron capture high energy gamma rays

J.S.Brzosko, E.Gierlik, A.Sołtan Jr., Z.Szefliński and Z.Wilhelmi

"Stefan Pienkowski" Institute of Experimental Physics, University of Warsaw

The measurement of γ-ray spectra from (n,γ) reaction for heavy nuclei; In, Sb, I, Cs, Zb, Ho, Ta, Au and U have been performed in the neutron energy range 0.03 - 1.5 MeV. The experimental set-up is described in ref /1/. Some spectra for the neutron energy E_n = 400 keV are shown in figs 1,2 and 3. A distinct reinforcement of the γ-ray intensity in the high energy part of the γ-ray spectrum is observed.

The ratios $\sigma_\gamma(E_\gamma > 3.75\ \mathrm{MeV})/\sigma_{tot}$ versus neutron energy for In, Ta and Au nuclei are shown in fig.4.

The cross-sections $\sigma_\gamma(E_\gamma > 3.75\ \mathrm{MeV})$ and ratios $\sigma_\gamma/\sigma_{tot}$ at 400 keV neutron energy for In, Sb, I, Cs, Tb, Ho, Ta, Au and U nuclei are summarised in table I.

The theoretical predictions of cross-sections and cross-section ratios obtained with the assumption of compound nucleus mechanism /2/ are shown in figs 1,2,3 as solid lines and in table I. Comparison of the experimental values with theoretical ones points to the correctness of the description. The quantitative and qualitative agreement is obtained when in the probability of the γ-ray emission an existance of a "pigmy" resonance /2/ is taken into account.

The theoretical expectation based on direct interactions are three orders of magnitude lower then the measured ones (table I).

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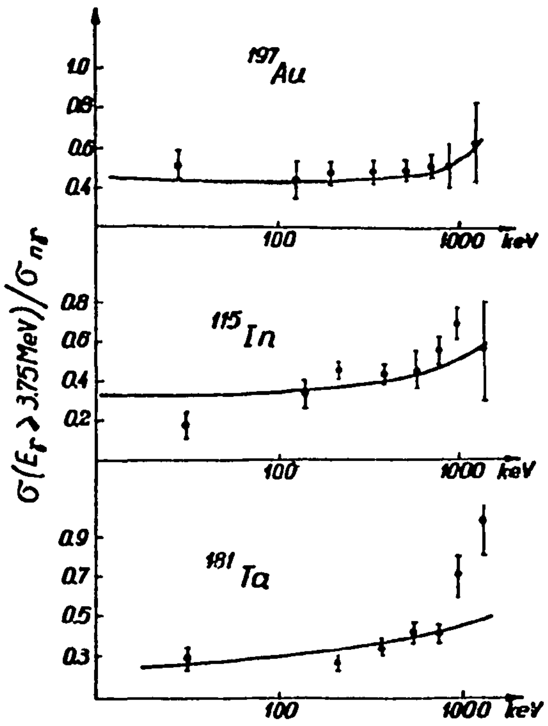

Fig. 4 . $\sigma_\gamma(E_\gamma > 3.75$ MeV) - the cross section of the (n, γ) reaction with emission of high energy γ- rays ($E_\gamma > 3.75$ MeV ; σ_{tot} - cross section of the (n, γ) reaction.

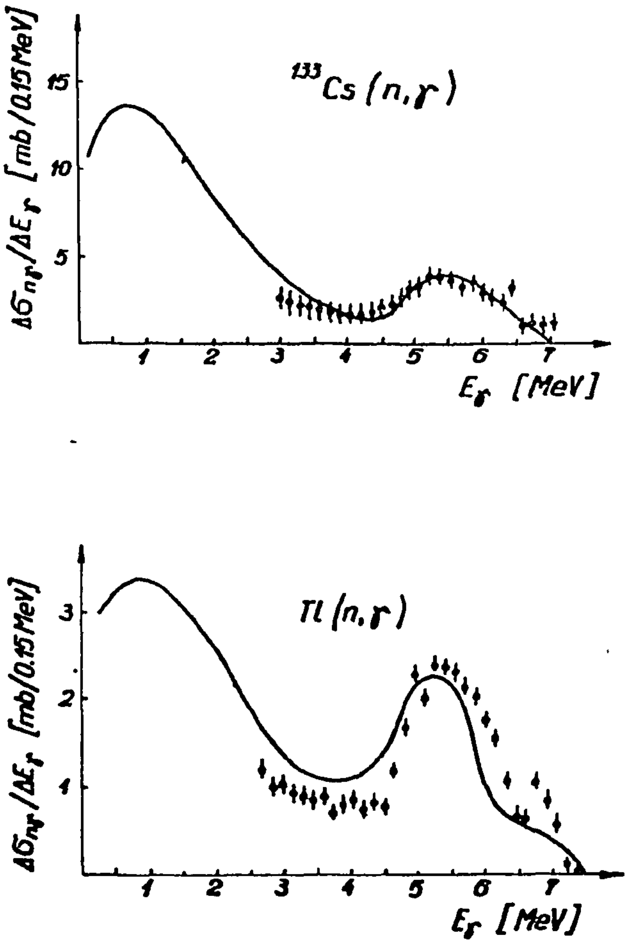

Fig. 1 - 3 . The gamma-ray spectra at neutron energy 400 keV.

Table I

Target	Measured values $E_n = 0.4$ MeV			Theoretical calcul $\sigma_{n\gamma}(E_\gamma > 3.75$ MeV$)$	
	$\sigma_{n\gamma}(E_\gamma > 3.75$ MeV$)$ (mb)	$\sigma_{n\gamma}$ (mb)	$\sigma_{n\gamma}(E_\gamma > 3.75$ MeV$)/\sigma_{n\gamma}$	CN (mb)	DI (μb)
^{115}In	108 ± 7	250	0.43 ± 0.05	127	0.026
Sb	65 ± 5	130	0.50 ± 0.05	74	0.1
^{127}I	67 ± 5	150	0.44 ± 0.03	67	0.17
^{133}Cs	60 ± 15	150	0.40 ± 0.08	65	230
^{159}Tb	129 ± 9	350	0.37 ± 0.05	145	—
^{165}Ho	102 ± 7	300	0.37 ± 0.05	107	0.055
^{181}Ta	68 ± 5	205	0.34 ± 0.05	55	0.08
^{197}Au	104 ± 8	190	0.53 ± 0.03	108	0.021
Tl	28 ± 3	40	0.70 ± 0.07	32	0.1
^{238}U	6.3 ± 0.5	127	0.050 ± 0.005	7.1	—

V.S. Evseyev[+], T. Kozłowski[x], V.S. Rogsnov[+]
and J. Wojtkowska[x]

NEUTRON ENERGY SPECTRA FROM NEGATIVE MUON ABSORPTION ON COMPLEX NUCLEI

It has been proposed in some theoretical works [1-4], that in nuclear muon capture the excitation of collective states of the intermediate nucleus is dominant. These states should be the isotope analogues of the giant dipole resonance states excited by photon absorption or inelastic electron scattering. An indirect confirmation of this mechanism was the agreement of the experimental total muon capture rates with the theoretical ones obtained under this assumption. It was shown by theoretical calculations that more direct evidence should be the measurements of the energy spectra of neutrons emitted from these particle unstable giant resonance states. In these spectra some structure similar to those observed in the particle spectra from photo absorption, should be seen. In this work the results of neutron energy spectra measurements from muon capture on ^{16}O, ^{32}S, ^{40}Ca and Pb /previously reported [5]/, are presented. This work was performed using pure muon

+ JINR - Dubna
x Institute of Nuclear Research - Świerk near Warsaw

beam with momentum 150 MeV/c, from the muon channel of the Dubna 680 MeV synchrocyclotron. Detector and target configuration is shown in Fig. 1. Muon stop events were detected by $123\bar{4}$ coincidences. The target thickness in neutron counter direction was 2 g/cm^2, 4 g/cm^2, 4 g/cm^2, 6 g/cm^2 for water, melted sulfur, metallic calcium and lead, respectively. As neutron detector the stilbene crystal 30 mm in diameter and 20 mm thick with 56 AVP photomultiplier was used. Neutron events were separated from gamma events by pulse shape discrimination system [6]. Pulses from neutron detector passed 0.05 μsec after muon stopping were registered during 2 μsec, 1 μsec, 1 μsec and 0.3 μsec time interval for water, sulfur, calcium and lead, respectively. In muon stopping and neutron spectrometer channel the anti-pile-up circuits with 6 μsec dead time were used. The background was measured with LiH as a target. The energy calibration of neutron spectrometer was performed using γ-ray, Po-Be sources, and 14 MeV neutrons from a neutron generator. The pulse height spectra were transformed into recoil proton energy spectra. These spectra were then differentiated and corrected for the efficiency of neutron detector. The energy resolution /FWHM/ for neutrons was: 0.6 MeV for E_n = 3 MeV and 1 MeV for E_n = 10 MeV.

No corrections for multiple scattering in the stilbene crystal and the target were applied.

In Fig. 2-5 neutron energy spectra from muon capture on ^{16}O, ^{32}S, ^{10}Ca and Pb are presented. As can be seen in these spectra there are some narrow peaks and continuous background. The latter for sulfur, calcium and lead can be interpreted as due to the evaporation mechanism. Dotted curves in Figs. 3 and 4 present the evaporation neutron spectra assuming constant nuclear temperature [7]. In the case of lead, Fig. 5, the part of the spectrum below 5 MeV can be described by Le Couteur's many neutrons evaporation formula. The oxgen data, Fig. 2, show the large peak centered at about 4.5 MeV which was theoretically predicted [4], as result of the transition from 2^- giant resonant state in ^{16}N to ground state of ^{15}N.
In general all these spectra are similar to photoabsorption particle spectra. The resonance mechanism of nuclear muon capture is supported by this experiment. It is concluded that nuclear muon capture can be applied to the investigations of high excited nuclear states which cannot be reached in another way.

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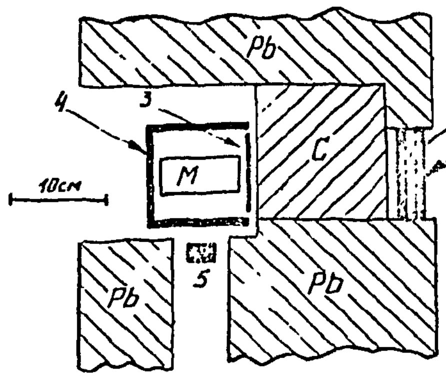

Fig. 1 .

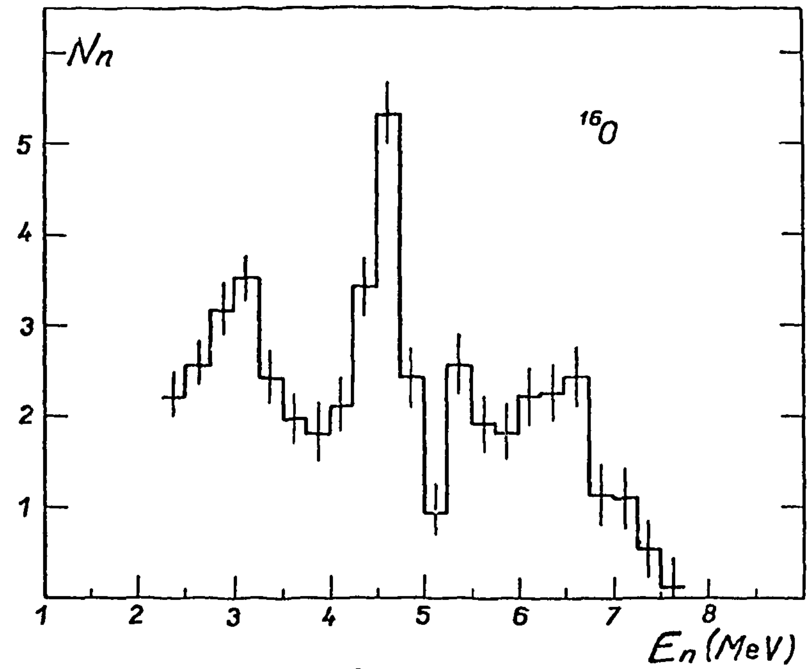

Fig. 2 .

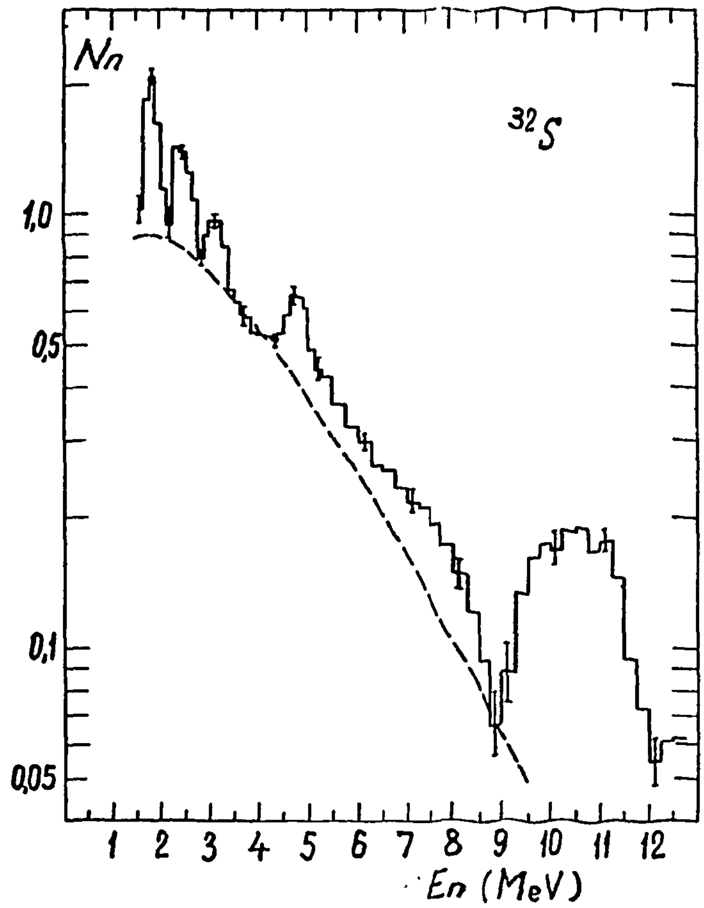

Fig. 3 .

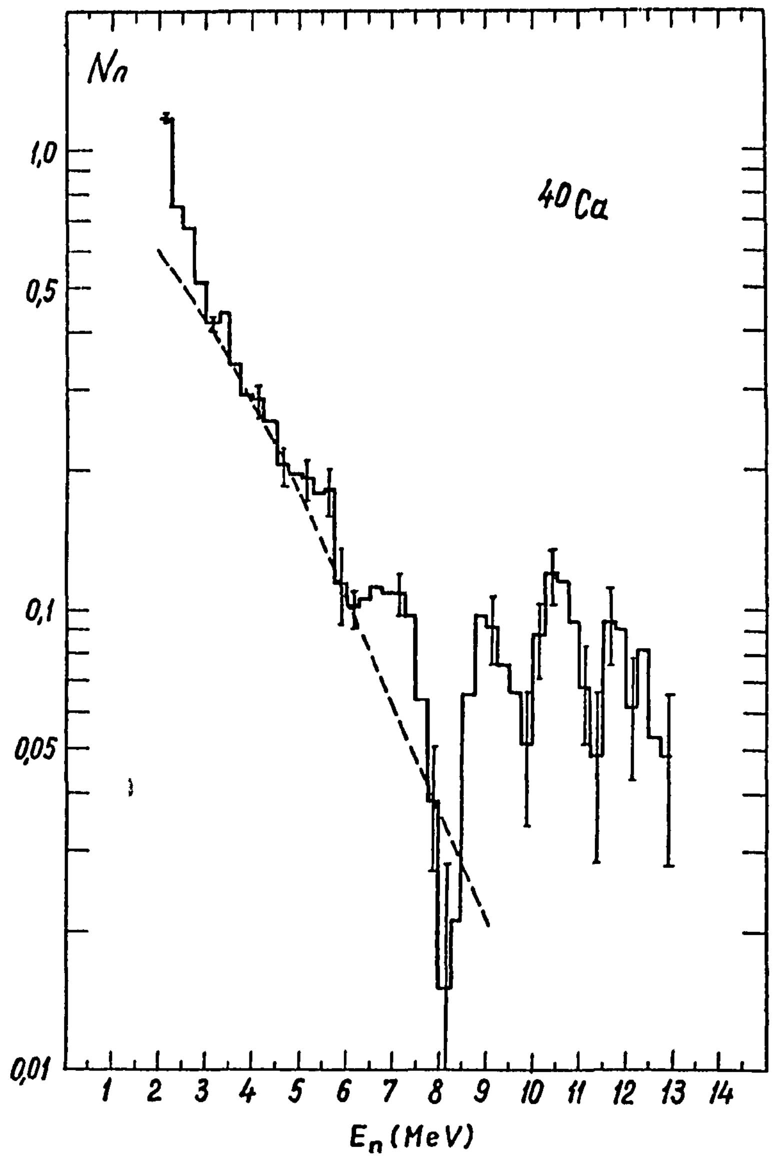

Fig. 4 .

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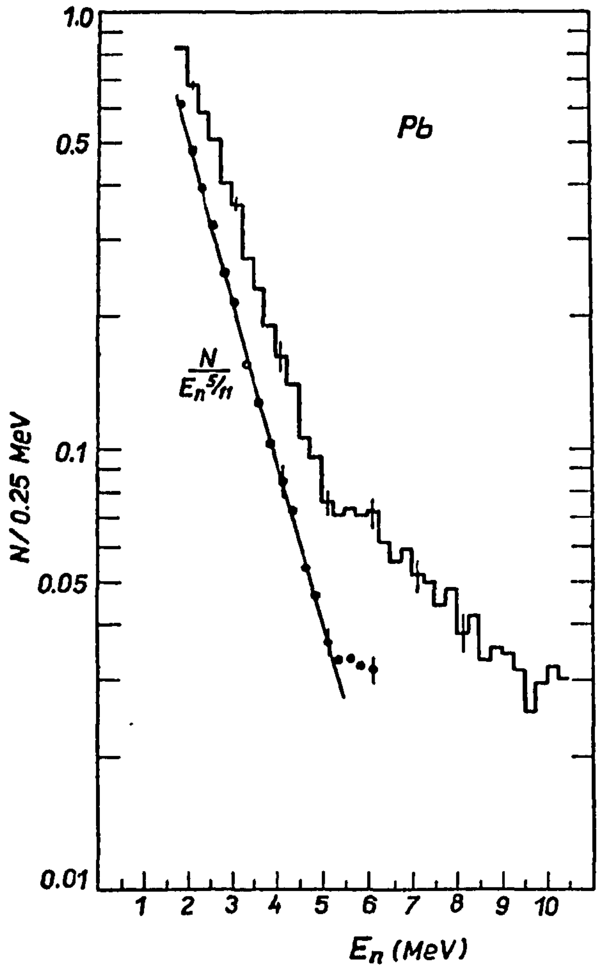

Fig. 5 .

Excitation of isomeric activities in Rb, Y, Pd, Cd, W, Os and Pb using 14.8 MeV neutrons

E. Rurarz, J. Chwaszczewska, Z. Haratym, M. Pietrzykowski and A. Sulik

Institute of Nuclear Research
Department of Physics IA
Świerk near Otwock

Activation cross-sections of ^{84m}Rb, ^{86m}Rb, ^{89m}Y, ^{107m}Pd, ^{109m}Pd, ^{111m}Cd, ^{185m}W, ^{190m}Os and ^{203m}Pb for 14.8 MeV neutrons were measured using Ge(Li) and NaI(Tl) detectors. The following values in millibarns were obtained: $^{85}Rb(n,2n)^{84m}Rb$ (20.5 min.) 412 ± 40; $^{87}Rb(n,2n)^{86m}Rb$ (1 min.) 43? ± 45; $^{89}Y(n,n')^{89m}Y$ (16.5 s) 438 ± 44; $^{108}Pd(n,2n)^{107m}Pd$ (21 s) 590 ± 60; $^{110}Pd(n,2n)^{109m}Pd$ (4.8 min.) 554 ± 55; $^{112}Cd(n,2n)^{111m}Cd$ (48 min.) 812 ± 80; $^{111}Cd(n,n')^{111m}Cd$ (48 min.) 167 ± 17; $^{186}W(n,2n)^{185m}W$ (1.7 min.) 1152 ± 110; $^{190}Os(n,n')^{190m}Os$ (10 min.) 15 ± 1.5; $^{204}Pb(n,2n)^{203m}Pb$ (6.1 s) 1020 ± 100.

Excitation of 3 min activity in ^{190}Re in $^{190}Os(n,p)^{190}Re$ reaction using 14.8 MeV neutrons.

E. Rurarz and B. Mysłek

Institute of Nuclear Research, Świerk/Otwock

and

P. Obložinský

Institute of Physics, Slovak Academy of Sciences,

Bratislava.

Introduction

After irradiation of natural osmium with 14 MeV neutrons gamma lines with the 3 min. half-life have been observed. They have been assigned to the decay of the ^{190}Re ground state to excited states of ^{190}Os [1] . The nucleus considered was a subject of considerable number of studies by neutron capture gamma-ray spectroscopy [2,3], charged particle excitation [4], decay of the ground and isomeric states of ^{190}Ir [5] and decay of the ^{190}Re ground

ground state created in $^{192}Os(\gamma,pn)$ reaction[1]. The aim of the present work was to study the production of ^{190}Re in the $^{190}Os(n,p)^{190}Re$ reaction.

Experimental procedure

Radioactive sources of Re were produced through the (n,p) reaction on natural osmium metal powder (5g) of spectroscopic purity, using 14.8 MeV neutrons. The neutron flux varied at the sample position between $5 \cdot 10^8 - 1 \cdot 10^9$ neutrons/sec·cm^2. The gamma spectrum was measured using a 5 cm^3 Ge(Li) spectrometer. In view of small intensities of gamma lines from the decay of Re, the Ge Li detector was shielded with 15 cm Pb (Cd+Cu lined). In this experiment a cycle of 10 min. irradiation and one minute pause to avoid the 6 sec ^{192}Re activity from the $^{192}Os(n,p)^{192}Re$ reaction, and 10 min. counting period was applied.

Results and discussion

The measured gamma spectrum of ^{190g}Re and ^{190m}Os is shown in fig. 1. The energy values and intensities of gamma lines from the decay of ^{190g}Re are in good agreement with the results of Haustein and Voigt[1] . These authors show that one particular level 3^- in ^{190}Os at 1387 keV is populated in ~ 100% beta decay branch. Besides the gamma lines from thb decay of ^{190g}Re there are prominent lines belonging to the 10 min. isomer in ^{190}Os. This fact allows us to determine the $^{190}Os(n,p)^{190g}Re$ reaction cross section relative to the $^{190}Os(n,n'\gamma)^{190m}Os$ reaction by comparing the intensities of the neighbouring lines in the spectrum belonging to Re and Os respectively. The conversion coefficients and branching ratios were taken from refs. [1,5]. Using the $^{190}Os(n,n'\gamma)^{190m}Os$ reaction cross-section as the internal monitor with $\sigma = 15 \pm 1.5$ mb [6], the cross section of the $^{190}Os(n,p)^{190g}Re$ reaction was found to be $\sigma = 1.95 \pm 0.20$ mb.

Attempts were made to produce the 2.8 h activity reported by Baro et al. [7] and Aten and de Feyfer [8] and ascribed to the isomer of ^{190m}Re. Our results confirm the existence of few lines with similar half-life. The half -life of the strongest line with energy 187 keV was found to be $T_{1/2} = 3 \pm 0.5$ h.

Acknowledgment : The authors are indebted to A. Sulik for operation of the 200 kV accelerator.

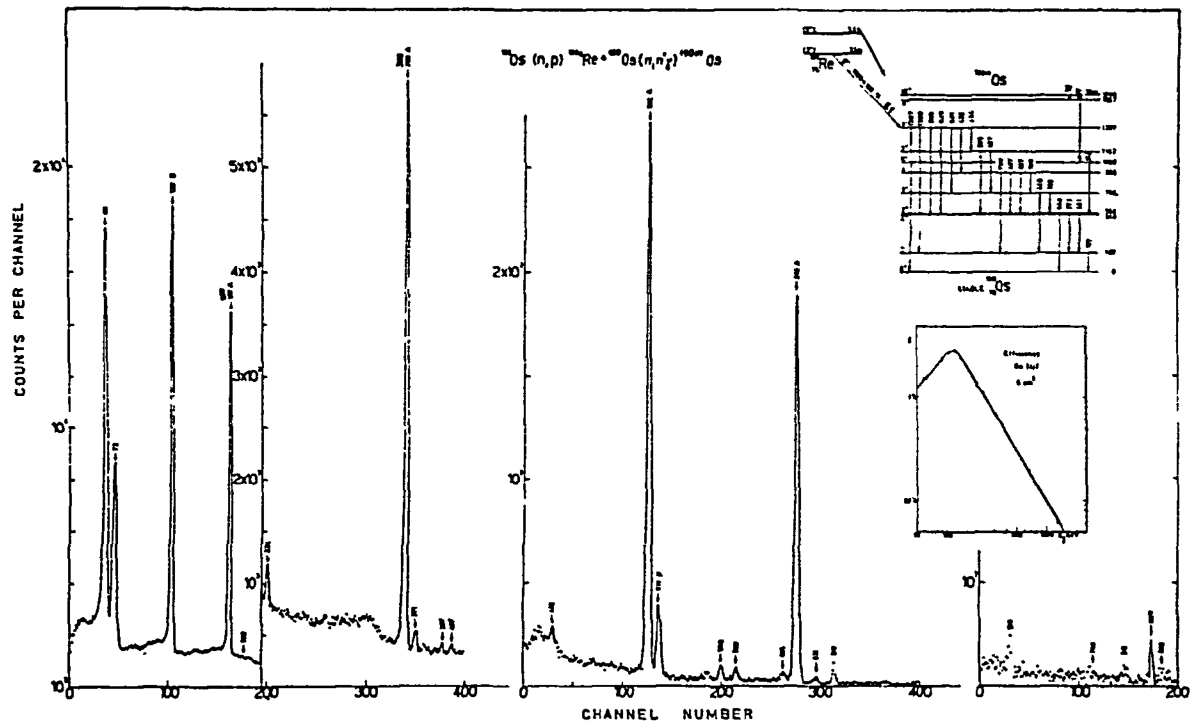

Fig. 1 . Gamma-ray spectrum of the ^{190g}Re and ^{190m}Os source after 10 min. irradiation, 1 min. delay and 10 min. counting periods repeated 7 times for each energy range. Energies in keV.Unlabelled: ^{190}Re transitions, A: ^{190m}Os transitions, B: ^{191}Os transisions.

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The decay scheme of ^{232}Pa ×/

R. Kaczarowski, W. Kurcewicz, A. Płochocki and J. Żylicz
Institute of Nuclear Research, Dept. of Physics/IA/, Świerk

Abstract: Magnetic and semiconductor /Ge and Si/ spectrometers were used to study the $^{232}Pa \longrightarrow {}^{232}U$ decay scheme. The following γ lines, new with respect to the earlier data reported by Bjørnholm et al.[1/], were observed: 922.7, 1003.3, 1016.4, 1051.4, 1055.4, 1085.4, 1125.1, 1132.7 and 1164.5 keV. Conversion coefficients and multipolarity assignments were determined for several of these transitions. Due to the e-γ coincidence studies it was possible to show that the 1125.1 and 1055.4 keV E1 transitions feed respectively the 2^+ and 4^+ levels of the ^{232}U ground state band. This indicates the existence of the new ^{232}U levels at 1172.8 and 1212.1 keV which are interpreted as 2^- and 3^- members of the $K^{\pi} = 1^-$ octupole band. Another new level is proposed at 1132.9 keV. As deduced from β-γ coincidence experiments, the

×/ Institute of Nuclear Research Report 1232/IA/PL /1970/ Acta Physica Polonica /in print/

1/ S. Bjørnholm, F. Boehm, A.B. Knutsen and O.B. Nielsen, Nucl. Physics 42 /1963/ 469

1052.6, 3^+) and the octupole bands ($K^\pi = 0^-$: 508.20, 1^- and 571.71, 3^- : $K^\pi = 1^-$: 951.91, 1^- ; 971.70, 2^- and 1012.2, 3^- : $K^\pi = 2^-$: 1079.20, 2^- and 1127.85, 3^-). The $^{230}Pa \rightarrow ^{230}Th$ decay energy, Q, is deduced from the measured relative probabilities of the K capture transitions to several excited states in ^{230}Th: $Q = 1315^{+15}_{-10}$ keV. For ^{230}U, the first excited 2^+ state is observed at 51.72 keV and the bandhead state of the $K^\pi = 0^-$ octupole band is proposed at 366.5 keV. The experimental data are discussed in terms of nuclear models, with emphasis on the band-mixing effects.

The Code FLANGE - AL 4

J.Arkuszewski, W.Baran, K.Kowalska

Institute of Nuclear Research, Świerk, Poland

The code based on the algorithm of the General Atomic FLANGE code computes the double differential scattering cross section $\sigma(E',\mu)$, the zeroth and first Legendre moments of the scattering kernel $\sigma_0(E'\to E)$, $\sigma_1(E'\to E)$, the zeroth and first Legendre moments of the single differential scattering cross section $\sigma_0(E')$, $\sigma_1(E')$. All these quantities are calculated from the scattering law incoherent inelastic thermal scattering of neutrons from polycrystalline materials.
IBJ/1260/XXI/PR Report.

The Code HEXSCAT - S

S.Bogumił, K.Kowalska

Institute of Nuclear Research, Świerk, Poland

The code based on the General Atomic HEXSCAT code calculates the zeroth and first Legendre moments of the coherent elastic neutron scattering cross section for polycrystalline moderators with hexagonal lattice.
IBJ/1300/XXI/PR Report.

decay energy of ^{232}Pa is equal to 1337 ± 10 keV. The discussion of experimental data in terms of nuclear models is concentrated on the octupole bands and their Coriolis interaction.

Levels of ^{230}Th and ^{250}U fed in the decay of ^{230}Pa */

W.Kurzcewicz, K.Stryczniewicz and J.Zylicz
Institute of Nuclear Research, Dept. of Physics /lA/,
Swierk near Warsaw, Poland
S.Chojnacki **/, T.Morek **/ and I.Yutlandov
Joint Institute of Nuclear Research, Dubna, USSR

Abstract: The ^{230}Pa decay to levels of ^{230}Th and ^{230}U is investigated using Si(Li) and Ge(Li) spectrometers for singles-spectra measurements, and a Ge(Li) spectrometer combined with a six-gap β spectrometer or with a NaI(Tl) detector coincidence measurements. The decay scheme is proposed with accounts for all but one of the 50 transitions observed in the present investigation. the following bands of the ^{230}Th excited states are established or proposed (in parentheses: level energies in keV, spin values and parities of the levels); the ground-state band (53.19, 2^+ and 174.12 4^+), the quadrupole bands (β: 634.7, 0^+ and 677.8, 2^+; γ: 781.4, 2^+ and 825.4, 3^+; $\beta + \gamma$ (?): 1009.61, 2^+ and

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*/ Institute of Nuclear Research, Report 1251/IA/PL(1970). Acta Physica Polonica /in print/

**/ Permanent address: The Warsaw University, Warsaw

The Routine Production of Thin Tritium-Titanium, Tritium -Zirconium and Deuterium-Titanium, Deuterium-Zirconium Targets.

R.Plejewski, R.Sochacka
Institute of Nuclear Research, Warsaw

A method of production of thin D and T targets has been devised. The targets posess the following desireable features:

1. Negligible loss of hydrogen in vacuum.
2. Negligible loss of tritium and deuterium in temperatures up to 300°C.
3. Strong binding between the absorbing metal and the backing.

The targets produced have been used in a range of experiments conducted in the Institute of Nuclear Research IBJ.

Also, targets of special construction have been produced such as targets with a copper backing on which 15 μ silver and subsequently 0.45 mg/cm^2 of titanium with 0.8 Ci tritium absorbed were deposited. Typical targets have following characteristics:

<u>Tritium targets</u>

Targets are made of a thick metod backing covered by a thin layer of titanium or zirconium deposited in vacuum.

The tritium is absorbed in the titanium or zirconium. The tritium/titanium, tritium/zirconium atomic ratio varies from 1.2 - 1.9 .

tritiated titanium zirconium Ø mm	titanium zirconium μg/cm²	backing Ø mm	backing thickness mm	Average act.Ci (± 10%)
	200-350			1,1
25.4	350-600	28.5	0.5	2.2
	600-900			3.5
	200-350			1.1
25.4	350-600	38.0	0.5 or 1	2.2
	600-900			3.5

Backing metal—cooper or silver.

Deuterium Targets

Deuterium targets are manufactured exactly in the same way as tritium targets. (see above)

The same dimensions are available.

The deuterium titanium - deuterium zirconium atomic ratio varies from 1.4 - 1.9 .

The amount of deuterium varies from 0.5 - 2 ml according to thicknes of titanium or zirconium layer.

Tritium targets emit bremsstrahlung radiation with a continuous spectrum of maximum energy 18 keV. This provides means of differentiating between tritium and deuterium targets, as well as providing a rough check on the tritium content of a target.

Annual Report on

Nuclear Data Research in Romania

(during the year 1970)

Compiled by A.Berinde

May, 1971

DYNAMICS STUDIES IN SOME HYDROGENOUS SUBSTANCES BY NEUTRON TRANSMISSION

S.Răpeanu, I.Pădureanu, N.Iliescu and O.Dumitru

Cold neutron spectrometry became an powerful tool for providing information on the molecular dynamics of hydrogenous liquids and on the chemical bond of hydrogen in the molecules.

Recently in the design of nuclear reactors an increasing interest was paid to the organic moderators which have a high boiling temperature and a good stability to radiation, a fact which led to an increasing interest in the study of hydrogenous liquids.

For cold neutrons, the total scattering cross section σ_s, is proportional to the neutron wavelength λ_n , and may be plotted as $\sigma_s = a + b.\lambda_n$, the slope $b = \Delta\sigma_s/\Delta\lambda_n$ is correlated with the molecular dynamics processes.

Methanol, ethanol and ethylen glycol were investigated to get scattering cross-section as a function of wavelength (Fig.1), which from to derive informations concerning the temperature effect on the rotational freedom of the atoms or groups of atoms within the molecules.

The transmission of the neutrons were measured using a crystal spectrometer, and a BF_3 detector, with a resolution in λ_n, $\approx 3\%$, in the energy range $E_n = 5.4 - 8.0$ meV.

Transmission measurements were carried out at temperatures 298^oK, 123^oK, 78^oK.

Table I. - The slope values

Temperature / Substance	The slopes ($\Delta\sigma_s/\Delta\lambda_n$) b/Å - H		
	298^oK	123^oK	78^oK
CH_3OH	11.2 ± 0.3	6.2 ± 0.3	4.1 ± 0.3
C_2H_5OH	9.4 ± 0.3	5.2 ± 0.3	3.4 ± 0.3
$C_2H_4(OH)_2$	7.8 ± 0.3	4.5 ± 0.3	2.3 ± 0.3

The changes of the slopes ($\Delta\sigma_s/\Delta\lambda_n$) put in evidence the role of the CH_3 and CH_2 groups on the scattering neutrons in such a hydrogenous liquids and at the same time the role of the hydrogen bond(OH-groups) on the rotation motions of the molecules.

This work was performed at the VVR-S reactor of I.A.P.

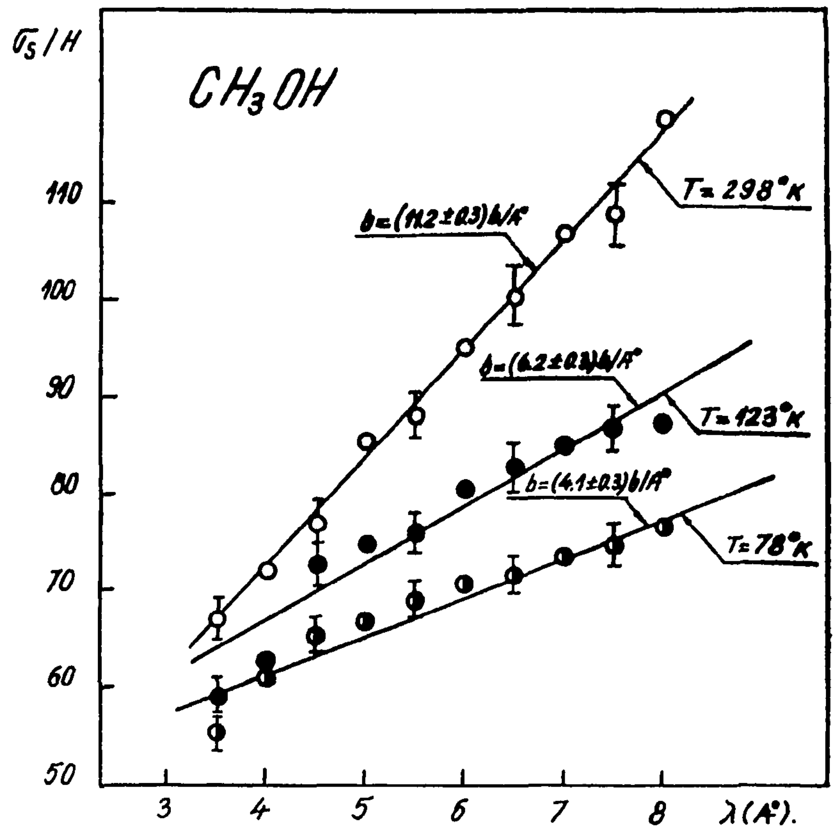

Fig. 1

Neutron scattering cross-section per hydrogen atom in the methanol molecule versus the neutron wave - length (λ_n= 3.5 - 8 Å)

IMPURITY INFLUENCE ON NEUTRON CRITICAL SCATTERING IN FERROMAGNETICS

D.Bally, M.Totia, A.M.Lungu and M.Popovici

Neutron small-angle critical scattering in Fe(Cr) and Fe(Mo) dilute alloys has been investigated. The measured angular distributions were found to be similar to those of iron. They are sensitive to the spin dynamics outside the hydrodynamic region. A special attention was therefore paid to the inelasticity corrections following Als-Nielsen /1/ , These corrections were introduced by using the dynamic scaling function $f(k_1/q)$ calculated by Résibois and Piette /2/ . The scattering inelasticity outside the hydrodynamic region was found to account for the shift to temperatures above T_C of the scattered intensity observed in this region in fixed angle measurements on iron /3,4/ and for the apparent limitations of the Ornstein Zernicke correlation function reported in several papers / 3 - 5 /.

The temperature dependence of the correlation range k_1^{-1} is shown in fig. 1 in a log - log plot against $(T - T_C / T_C)$ The critical exponent description of the dilute alloys appears to be valid only for temperatures at which the correlation range is smaller than twice the mean impurity spacing. A remarkable feature of the data in fig. 1 is the increase of the correlation range for $(T - T_C/T_C) > 10^{-2}$ by the presence of chromium impurities.This may have a connection with the observed increase of the Curie temperature (by 1.12 % and 1.28 % for 2% and 4% Cr respectively; 4% Mo decreases T_C by 0.7%).

The work was performed at the VVR-S reactor of I.A.P.

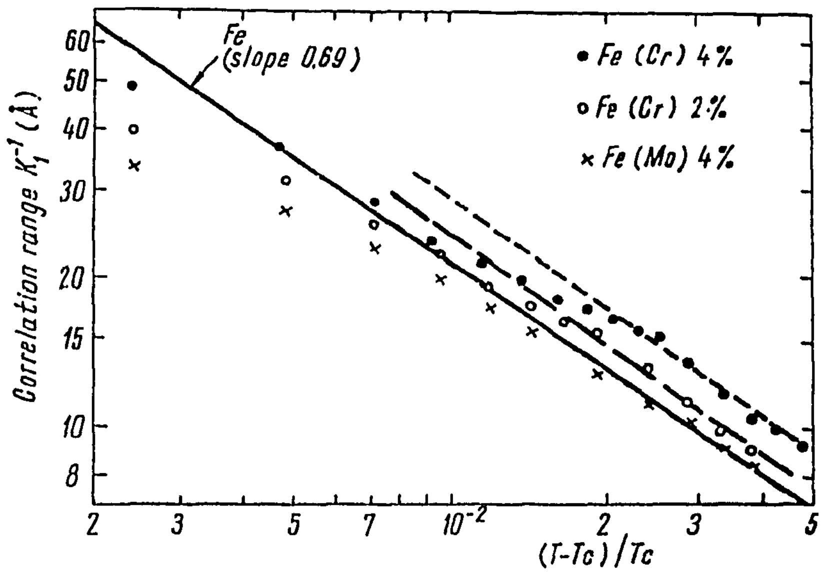

Fig. 1

Log - log plot of the temperature dependence of the correlation range in Fe(Cr) and Fe(Mo) dilute alloys. The solid line represents the data for iron / 4 / .

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ABSOLUTE MEASUREMENT OF PU^{239} FISSION CROSS-SECTION FOR 2200 M/SEC NEUTRONS*) **

C. Borcea, A. Borza, A.Buţă, A.Isbăşescu, L.Marinescu
I.Mihai, T.Năşcuţiu, M.Petraşcu, V.Savu and V.Simion.

An absolute Pu^{239} fission cross-section measurement was performed by using a method /1/ in which the reference to an intermediate cross-section for the flux determination is avoided. The neutron flux was obtained from VVR-S reactor in Bucharest, the 2200 m/sec neutrons being selected by the time of flight technique.

For the absolute cross-section measurement the determination of the following quantities was necessary: the neutron flux, the detection efficiency and the density of nuclei in the target.

The neutron flux is determined by using a thick B^{10} detector - target, the neutrons being detected through the 477,4 eV gamma rays of Li^7 counted with a NaI spectrometer. The gamma ray detection efficiency ε_γ was determined by using gold foils irradiated in the same geometry as the B^{10} target. The activity of the gold foils was measured absolutely with a $4\pi\beta-\gamma$ counter.

The efficiency of fission fragments detection have been determined with two Pu^{239} targets (a thick and a thin one) in a double fission chamber (a gaseous scintillation chamber and an ionization chamber), counting the number of events corresponding to the thick and thin targets n_F and n'_F respectively and knowing the ratio between the target densities ρ/ρ' and the ionization chamber efficiency (100%).

The density of Pu^{239} nuclei in the target was determined from the alpha activity measured in a low geometry arrangement with a lithium drifted silicon detector.

Many corrections have been taken into account :

- the attenuation of the neutron beam due to the chamber walls, k_1.
- the beam attenuation in air between the fission chamber and the B^{10} target, k_2.
- the photopeak correction for the gamma ray detection, k_3

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**This work was performed under the research contract RB-422 supported by I.A.E.A. Vienna.

- the area correction for the Pu^{239} and B^{10} targets, k_s

In the table I the quantities entering the cross-section formula :

$$\sigma_f = \frac{N_F}{N_\gamma} \frac{n'_F}{n_F} \frac{1}{1 - K_3} \quad \frac{K_\gamma}{K_2} \frac{\eta}{K_s} \frac{1}{\rho'}$$

are presented (N_F and N_γ being the number of fission events and neutron number respectively).

Table I

The quantities entering the cross-section formula

$\frac{N_F}{N_\gamma} \frac{n'_F}{n_F}, \frac{1}{1 - k_3}$	$(1.9450)10^{-3} \pm 0.7\%$
ρ'	$(2.543)10^{16} \pm 0.4\%$
ε_γ	$(1.345)10^{-2} \pm 0.4\%$
k_1	$(0.805) \pm 0.2\%$
k_2	$1.021 \pm 0.25\%$
k_3	1.010
k_s	$1.013 \pm 0.2\%$
η^*	$0.9348 \pm 0.1\%$
σ_f (barns)	741.0 ± 7.0

*) According to De Juren /2/

The value of 741.0 ± 7.0 barns obtained for σ_f is in good agreement with that calculated in the thermal neutron region using the R matrix formalism. /3/ .

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A STUDY OF THE $^{236mf}U$ ISOMERIC FISSION THROUGH THE $^{235}U(n,\gamma)$ REACTION IN THE ENERGY RANGE 0.25 - 4MeV*)

I.Boca, M.Sezon, I.Vîlcov and N.Vîlcov

The excitation function of the reaction $^{235}U(n,\gamma)^{236mf}U$ was measured in the neutron energy range 0.25 - 4 MeV.

The reaction $^{7}Li(p,n)$ was used as a fast neutron source (energy dispersion $\pm$ 450 keV in the energy range 0 - 3 MeV) . The fission fragments were detected with a self-designed spark counter filled with nitrogen at a pressure of 300 torr. We used the cyclotron natural modulation, three out of each four beam pulses being deflected with an electrically driven beam chopper. The time analysis of induced and isomer fission fragments was made with a time - amplitude converter over the 300 - 400 ns intervals separating the neutron bursts (the isomer exponential decay is observable 100-150 ns after the neutron burst).

We measured a half-life $T_{1/2}$ = 80 $\pm$ 20 ns, in agreement with data given in /1/ , /2/.

The ratio isomeric fission to induced fission cross - section was in fact the experimentally determined quantity as a function of the incident neutron energy (fig. 1).Its behaviour can be explained in terms of the double-humped barrier model and the kinetics of fission isomer population, assuming the same statistical parameters for the isomer potential well and the second hump.

The ratio σ_m/σ_f is proportional to ρ_m/ N_B /3/ where ρ_m is the level density in the isomer potential well and N_B is the number of transition states at the second hump saddle-point.At high energies above the second barrier $\rho_m/N_B \sim$ ct. In the E_B barrier neighbourhood N_B increases sharply with the energy and σ_m/σ_f increases. A comparison between theory and experiment is also made in terms of the constant temperature model.

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* Preprint IFA, CRD-42-1970

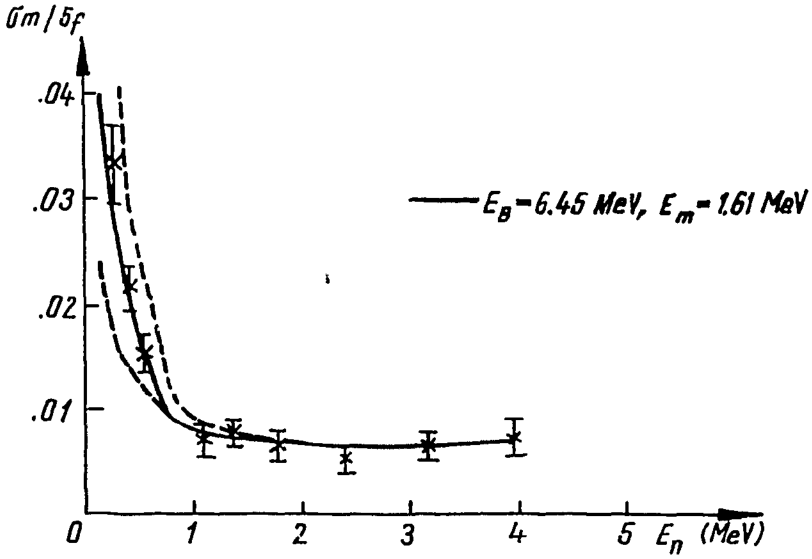

Fig. 1

Isomeric ratio σ_m/σ_f vs neutron energy. The full curve represents the theoretical isomeric ratio calculated for E_B = 6.45 MeV and for a value of the isomer energy E_m = 1.61 MeV; the upper and lower dotted curves correspond to a ± 100 keV bias of both parameters E_B and E_m respectively.

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CALCULATION OF THE (n, n) AND (n, n') CROSS SECTIONS ON ^{60}Ni

A.Berinde , R.Dumitru, N.Martalogu, N.Scîntei, C.M.Teodorescu
G.Vlăducă*/ and V.Zoran

Differential cross sections for elastic and inelastic neutron scattering on ^{60}Ni at E_n = 6.44 MeV are analysed by using the optical model, Hauser - Feshbach theory and DWBA method. The experimental data are taken from ref. / 1 /.

The local equivalent of the non-local optical potential, obtained by Wilmore and Hodgson /2/ is used in optical model ana - lysis as well as in DWBA calculations. The value of the deformation parameter is 0.20. The Hauser - Feshbach calculations are perfor - med with Auerbach and Perey's transmission coefficients, computed by using the non-local optical potential of Perey and Buck.

The (n, p) channels are taken into account. The (n,α) reaction channels, having a contribution less than 1% in the compound nucleus cross section, are neglected. The contribution of the unknown levels from the residual nuclei is included, by using the Gilbert and Cameron / 3 / level density formula. The good agreement between the theoretical results and experimental data can be seen in fig. 1.

A similar analysis, with rather good results, was per - formed for the neutron elastic and inelastic scattering on ^{32}S at E_n = 5.8 MeV.

This approach will be used for the calculation of the (n, n) and (n, n) differential cross sections from ^{60}Ni and other Ni isotopes, at several neutron incident energies. This work is pertinent to request 373 of RENDA / 4 /.

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*) Department of Physics, Bucharest University

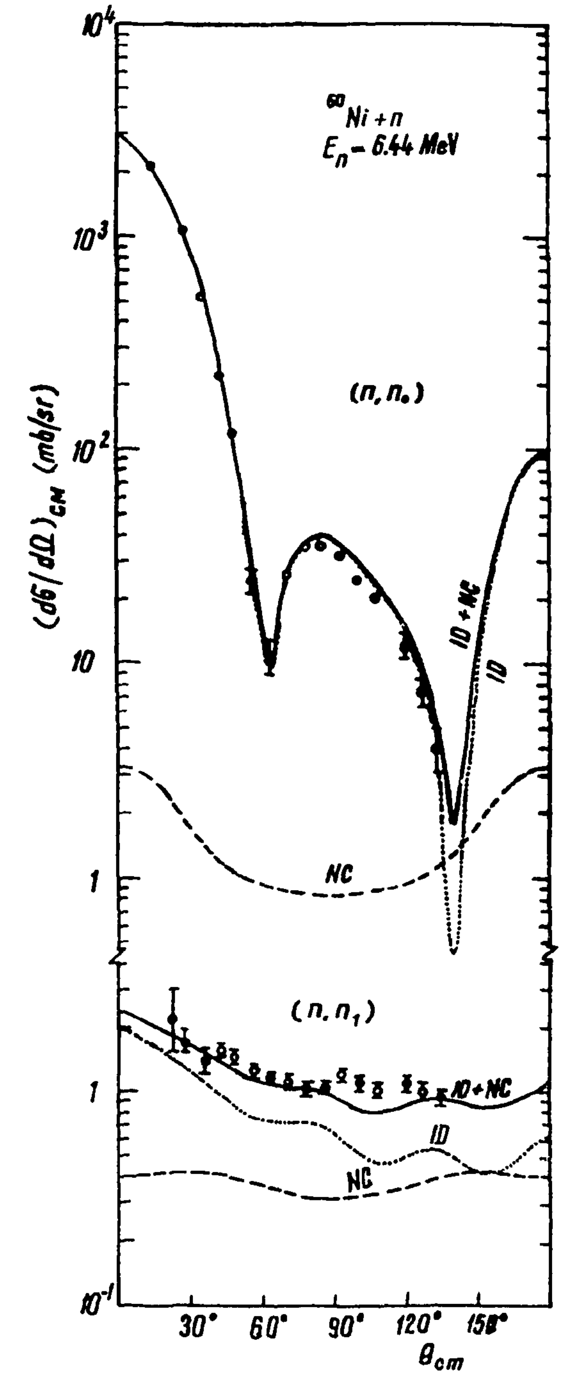

Fig. 1

The theoretical cross sections (full line) represent the sum of the direct interaction (dotted curves) computed by using the optical model and DWBA and the compound nucleus contribution, computed with the Hauser - Feshbach theory (dashed curves).

LEVEL DENSITY DETERMINATION FROM STATISTICAL REACTIONS

A.Alevra, R.Dumitrescu, I.R.Lukas, M.T.Magda, D.Plostinaru, E.Truţia

As a part of our programme of level densities determinations, following nuclei were excited through (p,n) and (α,n) reactions: ^{55}Fe, ^{85}Sr, ^{118}Sb, ^{138}La.

Energy and angular distributions have been measured at the IAP - cyclotron, the experimental set-up being a classical time- of - flight spectrometer, described earlier / 1 /.

In order that the analysis performed in the frame of the statistical model be reliable, only pure statistical parts of the spectra were taken into account , non statistical contribution being avoided by criteria as shape of the angular distributions and determination of the range of excitation energies where the precompund processes are important. The results obtained are included in the table 1.

Table 1

Residual nucleus	Reactions	Bombarding energy	a $(MeV)^{-1}$	T (MeV)
^{55}Fe	^{52}Cr(α,n)	17 20	6.6 ± 0.6	1.3 ± 0.2
^{85}Sr	^{85}Rb(p,n)	8	11.9 ± 1.4	0.78 ± 0.08
^{118}Sb	^{115}In(α,n)	16 18 20	18.0 ± 2.0	0.67 ± 0.07
^{138}La	^{138}Ba(p,n)	7	17.2 ± 1.0	0.52 ± 0.05

The measured a-level density parameters and nuclear temperatures can be used for level density calculations, required in neutron cross section evaluation.

Reference

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THE CROSS SECTION OF PHOTOFISSION ON THE ^{238}U

D.Catană and G.Baciu

The yield of the photofission reaction on ^{238}U was measured using the bremsstrahlung beam of the 25 MeV betatron of the Institute of Atomic Physics - Bucharest. The range 5 - 7 MeV was covered , with a measuring bin of 200 keV. Photofission fragments were detected by Si(Li) semiconductor detectors. The uranium target was made by evaporating a uranil nitrate solution on an aluminium support having a thickness of 2 mg/cm^2. Target thickness was evaluated at 100μg/ cm^2.

Special measures were taken to minimize the photoneutron background in the experimental hall. The fast neutron background in the high-energy bremstrahlung beam was reduced by means of a paraffin cylinder set-up along the axis of the beam. It also absorbed nearly 10% of the number of photons at the high-energy end of 15 MeV bremsstrahlung.

The Penfold-Leiss analysis method /1/ was used to obtain the cross-section from the yield curve. According to this method :

$$\sigma(E_m) = \frac{N}{E_m}\frac{1}{\Delta}\sum_{i=a}^{m} B(E_m, \Delta, E_i)\ Y^*(E_i)$$

where E_m is the photon energy for which the cross section is computed, N-Avogadro's number, Δ -energy bin used for analysis, $Y^*(E_i)$ - photofission yield in number of fragments per atom-gram cm^{-2}, and E_i - the maximum energy of the bremsstrahlung spectrum used in the measurement.

B numbers given in /1/ were corrected for the absorbtion in the paraffin cylinder .

Fig. 1 shows the photofission cross section. The cross section represents a summation of concurrent processes:

$$\sigma(\gamma,F) = \sigma(\gamma,f) + \sigma(\gamma, n\ f) + \sigma(\gamma, 2nf\ ) + \ldots$$

The minimum in cross section curve at about 7 MeV could be accounted for by the (γ,n) reaction which has the threshold near 6 MeV / 2 /. The shoulders appearing at 9 MeV and 12 MeV could be given by the reactions (γ,nf) and (γ ,2nf) coming in concurrence.The

200 mb value at 14 MeV is in good agreement with the one found by R.B.Duffield / 3 /.

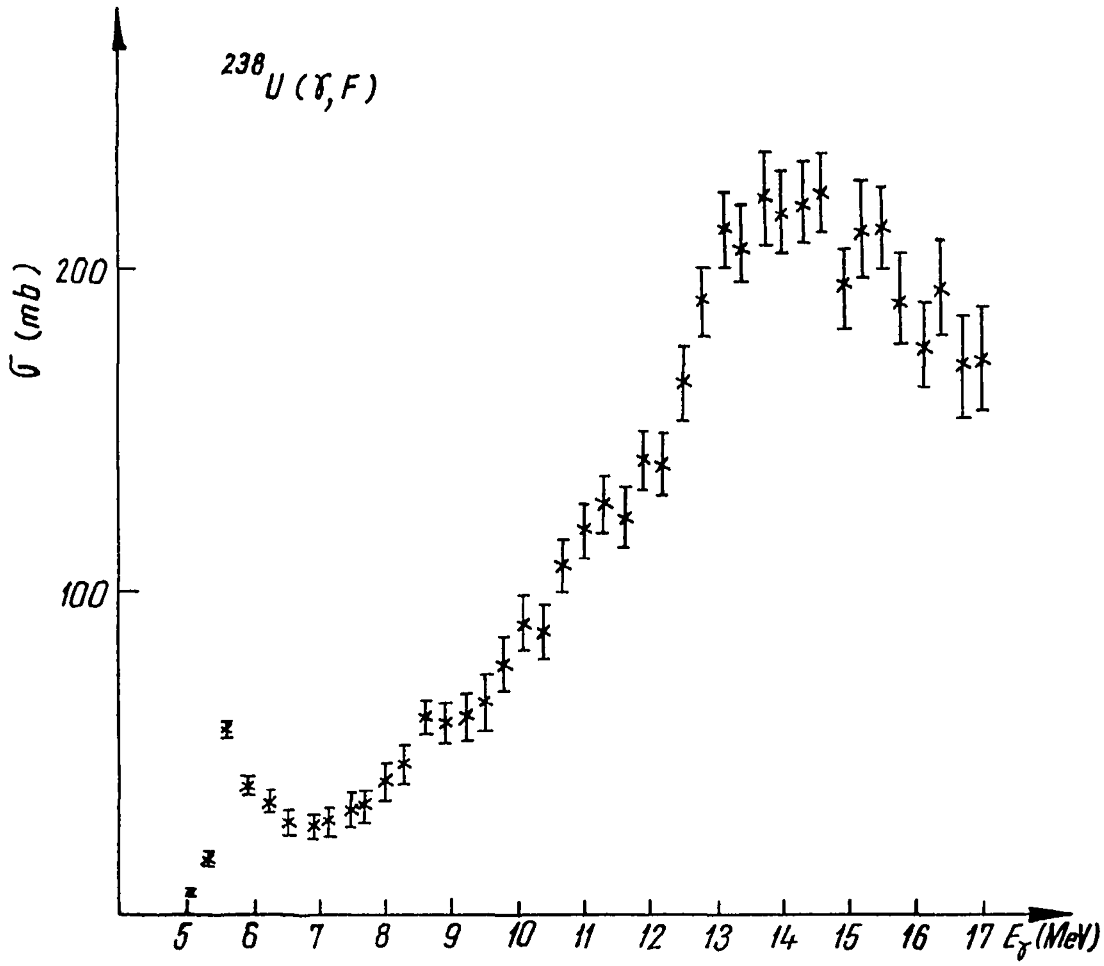

Fig. 1

The cross section of the ^{238}U (γ,F) reaction.

R e f e r e n c e s

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THE FINE STRUCTURE OF THE In$(\gamma,\Sigma n)$ REACTION

D.Catană, G.Baciu, C.Iliescu

In a continuing series of experiments, the photonuclear research group from the betatron of the Institute of Atomic Physics in Bucharest developed an improved method for measuring the $(\gamma, \Sigma n)$ yied curve, with a small bin (about 70 - 100 keV).

This method allowed a good resolution in cross section measurements to be obtained. The main improvements are : a high stability of the betatron energy scale ($\pm$ 10 keV), a reduction of the drift of the detection system / 1 / , and a dosimetric system with a reproducibility within $\pm$ 0.4% / 2 /. The yield curve of the In $(\gamma,\Sigma n)$ reaction from 10 MeV to 24 MeV has been measured with a bin of 95 keV and a statistical error of 0.9%. Using the Penfold-Leiss analysis method the cross section of the reaction given in fig. 1, was calculated. The vertical and horizontal bars are due to the method of analysis.

A fine structure in the cross section of the reaction was resolved.

A qualitative comparison of the present results with the theoretical calculations of the Frankfurt group /3/ is presented in fig. 1b.One should note that the agreement is obtained only for the giant resonance region. Fig. 1c shows the position and strength of the transverse mode for an axially symmetric deformation,

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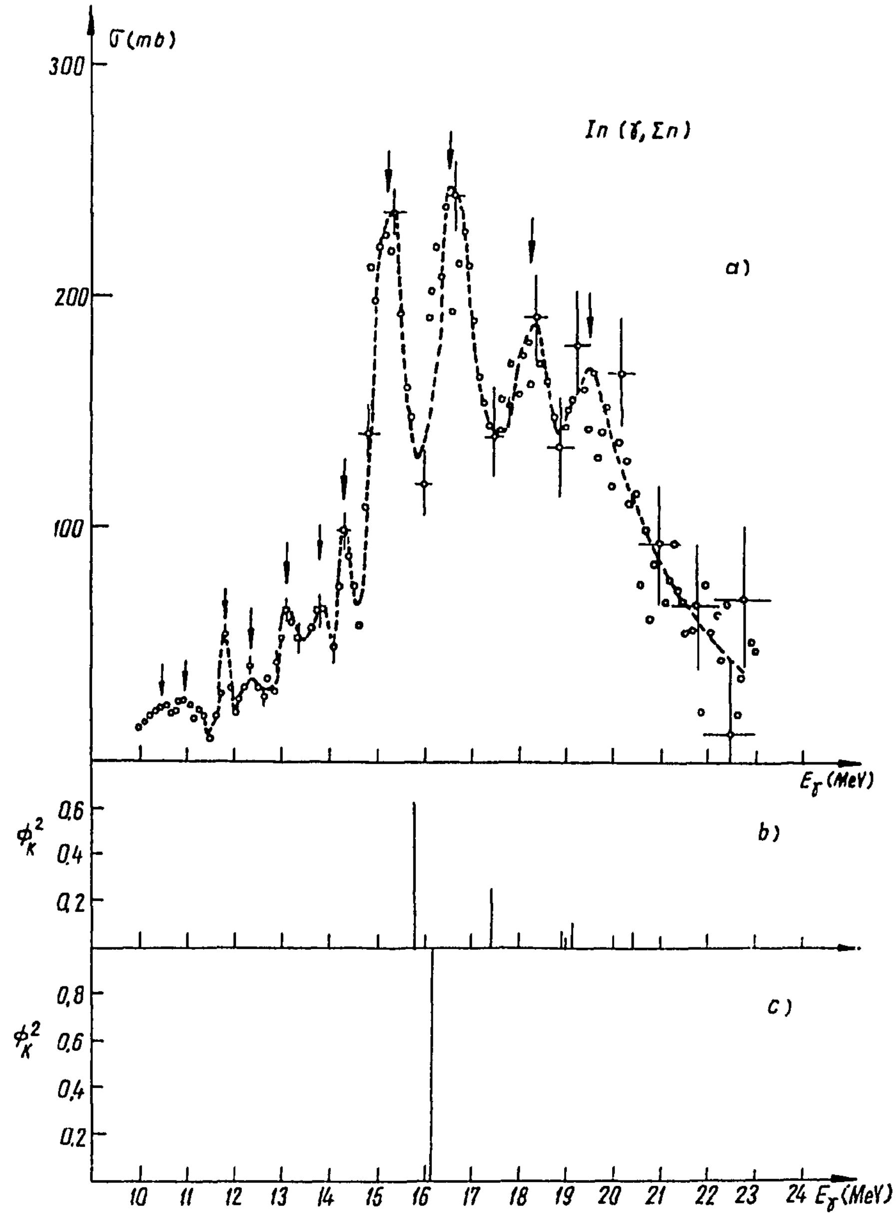

Fig. 1

a) Experimental cross section of In(γ,Σn) reaction;
b) Dipole strengths $\bar{\Phi}_k^2$ for β_o = 0.16, E_1 = 16,125 MeV
E_2 = 1,6 MeV, N_{phonon} = 8 / 3 /; c) the position
and strength of the transverse mode for an axially
symmetric deformation

Progress Report on

Nuclear Data Activities in the Republic of South Africa

(for the year 1970)

Compiled by D. Reitmann

REPUBLIC OF SOUTH AFRICA

PROGRESS REPORT TO THE INDC

1970

Compiled by D. Reitmann

1. Southern Universities Nuclear Institute, Faure, Cape Province

A considerable amount of time was spent during 1970 on the installation and improvement of the new pulsing and bunching system in the 5.5 MV accelerator. Problems with ion source behaviour and bunching of different mass particles were largely solved and a carbon foil stripper was installed in the accelerating tube. Research projects in neutron physics during the year include the following:

1.1 Level structure of ^{93}Nb and ^{115}In from (n,n'γ) studies

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

Inelastic neutron scattering[1] and (n,n'γ) reaction studies[2] have contributed to the knowledge about excited states in ^{93}Nb. The spins of all known levels below 1.5 MeV were determined very recently by Rogers et al.[3]. These spin assignments were based on Hauser-Feshbach calculations of inelastic scattering excitation functions and γ-ray transition probabilities are in qualitative agreement with shell model calculations.

The energy levels in ^{115}In have been studied mainly through β-decay of ^{115}Cd and coulomb excitation by helium or oxygen ions.

1) D. Reitmann et al., Nucl.Phys. 48(1963)593

2) L.E. Beghian et al., J. Phys.Soc.Jap. 24, Suppl.1(1968)190

3) V.C. Rogers et al., Nucl.Phys. A142(1970)100

In the shell model the level scheme should be given by the coupling of states available to single proton holes in the closed Z = 50 shell to vibrations in the ^{116}Sn core. In its simplest form this coupling explains the observed strong ground state transitions but it is unable to reproduce the spin sequence or branching ratios.

In the present experiment a 30 cc Ge(Li) detector was used to observe the γ-rays produced when cylindrical samples of Nb or In were bombarded with neutrons from the $^{7}Li(p,n)$-reaction. Time gating was used to discriminate against background and neutron events in the detector. A typical time resolution was about 10 ns. A large number of spectra at 90^{o} were recorded for neutron energies between 0.75 and 2.7 MeV.

In the case of ^{93}Nb, the level scheme deduced from the present experiment includes levels at 29, 743.7, 808.4 (doublet), 949.6, 978.7, 1082.1, 1296.4, 1315.9, 1334.3, 1367.9, 1393.6, 1482.9, 1490.7, 1499.5, 1602.9, 1679.6, 1682.6, 1686.1, 1706.4, 1729.9, 1913.8, 1918.2 and 1940.8 keV. Up to 1296 keV this scheme is essentially the same as that found by Rogers et al. The doublet at 808 keV is based on the existence of γ-rays at 779.4 and 808.4 keV. The behaviour of their relative intensities can not be reconciled with the known spins of $\frac{9}{2}^{+}$ and $\frac{1}{2}^{-}$ for the ground- and 29 keV states if both originate from a single level at 808 keV. The excitation curves for the two γ-rays are also different and indicate that, above 1.3 MeV in neutron energy, the 779.4 keV γ-ray is being fed through cascades from higher levels.

In the energy range covered by the two experiments, present results confirm the existence of levels at 1334.3, 1482.9 and 1499.5 keV. New levels were found at 1315.9, 1367.9, 1393.6 and 1490.7 keV. Levels at 1465 and 1528 keV, based by Rogers et al. on the existence of 656 and 720 keV γ-rays, were not observed. The 656.4 keV γ-line observed in the present experiment was attributed to a different reaction. However, a γ-ray at 653.4 keV was observed at incident neutron energies above 1700 keV. This, together with a line at 1602.9 keV with the same threshold, was attributed to the decay of a new level at 1602.9 keV.

The level scheme of ^{115}In, based on thresholds and excitation curves for observed γ-rays, contain levels at 336.6, 597.1, 828.7, 864.2, 933.6, 941.2, 1041.6, 1077.6, 1132.6, 1291.3, 1418.6, 1448.4, 1461.9, 1484.3, 1496.0, 1600.7, 1606.3, 1736.5, 1759.3, 1908.0, 1971.4, 1977.1 and 1998.0 keV. Up to 1450 keV this scheme agrees well with that derived from the decay of ^{115}Cd. New levels at 941.2 and 1041.6 keV are based on γ-transitions at 941.2 and 705.3 keV which were first observed at incident neutron energies of 1 and 1.1 MeV respectively.

It is known that angular distributions of γ-rays from levels excited by inelastic neutron scattering, provide information on the spins of the excited states, provided these spins are larger than that of the ground state. This is especially true near threshold where the population of magnetic substates is limited. Unfortunately, both ^{93}Nb and ^{115}In have ground states with spin $\frac{9}{2}$, so that γ-ray angular distributions can not provide unique spin assignments. Inelastic scattering cross sections were therefore derived from the γ-ray excitation functions and branching ratios in order to compare these with Hauser-Feshbach predictions.

1.2 Gamma transitions from excited states of ^{75}As

P.J. Celliers and W.R. McMurray

The study of the ^{75}As level scheme was motivated by the observation of resonance fluorescence from levels near 1 MeV excitation (P.J. Celliers and W.L. Mouton). The (n,n'γ) reaction is being used to give necessary information about the level structure and branching ratios of the decay gammas. The gamma detection system incorporated a time-of-flight-gated Ge(Li) detector of 57 cc. Using ^{75}As powder in a thin walled aluminium container, (n,n'γ) spectra have been obtained at incident neutron energies ranging from 300 to 2200 keV. Excitation curves for the observed gammas have been obtained. Measurements with an Fe sample were interpolated to enable absolute cross sections to be determined. The analysis of the data is not yet complete but the observed γ-rays fit into a level scheme with excited states at 199.5, 265.7, 280.6, 401.0, 469.0, 572.3, 617.8, 822.1, 861.1, 865.2, 887.2, 1016.0, 1064.1, 1075.2,1129.1, 1205.0, 1301.0, 1304.8, 1310.6, 1350.8, 1371.3, 1432.1, 1607.7 and 1656.8 keV.

1.3 Neutron polarization measurements

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

The determination of the neutron polarization in n-p scattering using the direction sensitive PSD effects observed in anthracene crystal scintillators has been continued using 22 MeV neutrons of known polarization from the T(d,n)^{3}He reaction. These results are being analyzed.

The possibility of using n-d scattering in a deuterated anthracene crystal was also investigated as it is known that the polarization produced in this scattering is greater than in n-p scattering. Various other possibilities for improving the quality of the results are also being looked into.

1.4 Other relevant projects

F.D. Brooks and co-workers

Projects under this heading which are still in an early stage of development include the investigation of the $^{2}H(n,2n)^{1}H$ reaction at 22 MeV by using a deuterated scintillator, a search for spontaneously fissioning isomers of ^{236}U and ^{239}U and a search for super heavy elements.

2. Nuclear Physics Research Unit, University of the Witwatersrand, Johannesburg

During 1970 the only major research facility was a 1 MV Cockcroft-Walton accelerator which produces high energy neutrons by means of the (D+T)-reaction. An order has been placed with H.V.E.C. for an EN-tandem.

2.1 Cross sections for reactions ^{28}Si + n for neutron energies between 12.8 and 16.2 MeV

D.W. Mingay, J.P.F. Sellschop and P.M. Johnson

Total cross sections for the $^{28}Si(n,\alpha)^{25}Mg$ and $^{28}Si(n,p)^{28}Al$ reactions have been measured for neutron energies between 12.8 and 16.2 MeV, for the ground and first four resolved excited states of ^{25}Mg and the unresolved pairs consisting of the ground and first excited, and second and third excited states of ^{28}Al. The neutron energy resolution was less than 30 keV.

An analysis in terms of Ericson fluctuation theory, which is also compared with Hauser-Feshbach calculated cross sections, is being completed which shows that the region studied has many broad overlapping levels with good statistical properties which leads to the extraction of an improved value for the mean compound nuclear lifetime, which is lower than the previously quoted value, as a result of the fine structure details revealed in these excitation function measurements.

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

The program of neutron physics research was continued at the 3 MV pulsed van de Graaff as well as the 20 MW research reactor, Safari I. The CDC-1700 computer at the accelerator was used for data processing and some simple on-line data collection applications. A new thermal neutron beam tube for capture studies was installed in the reactor.

3.1 Nuclear spectroscopy from (n, γ)-reactions with slow neutrons

M.A. Meyer, C. Hofmeyr and B.C. Winkler

The original tangential thermal beam tube in Safari I was used as a neutron source and γ-rays were detected in a Ge(Li)-detector used singly or in conjunction with NaI-crystals in a pair spectrometer arrangement. The latter system produced much simpler spectra, especially at high γ-energies, but also reduced the overall detection efficiency due to the threefold coincidence requirement.

The investigation of energy levels in ^{71}Ge has been nearly completed and a number of spectra have been recorded from the (n, γ) reaction in ^{58}Ni.

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

Fast neutrons from the $^{7}Li(p,n)^{7}Be$-reaction and the pulsed accelerator were used to excite levels up to about 1.5 MeV in several stable nuclei. A 40 cc Ge(Li)-detector, used in time-gated mode, was used to detect the resulting γ-rays.

The investigation of energy levels and their decay modes in ^{197}Au has been completed and the results accepted for publication in Nuclear Physics. The level schemes for ^{203}Tl and ^{205}Tl have been published[1] and a similar study on ^{127}I was accepted for publication in Zeitschrift für Physik. The results from Sb(n,n'γ) have been submitted for publication in Nuclear Physics and the experimental work on Cs, the two isotopes of Rb, Br and Ho has been completed. In most cases several new energy levels in these stable isotopes were discovered.

3.3 Fast neutron scattering

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

The results from an investigation of inelastic neutron scattering from ^{209}Bi, combined with those on total cross sections and elastic scattering as measured by A.B. Smith of ANL, have been published[2]. A detailed study up to 1.4 MeV of total cross sections as well as elastic and inelastic neutron scattering cross sections for ^{45}Sc has been completed and the results submitted to Zeitschrift für Physik.

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1) Nucl.Phys. A157(1970)130

2) ANL-7636(1969) and Nucl.Sci. & Eng. 41(1970)63

Inelastic scattering cross sections for Ti, combined with elastic and total cross section measurements by an ANL-group, are being analysed at ANL. Measurements of inelastic scattering cross sections for ^{238}U were presented at the Helsinki conference (June 1970). The results from total, elastic and inelastic scattering cross section measurements on Cs and Rb are still being analysed. A series of high resolution measurements on the 90° differential inelastic scattering cross section for the 126 keV level in Mn has been started and data have been taken in 5 keV steps from 400 to 1040 keV.

Progress Report on

Nuclear Data Research in Uruguay

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June, 1971

NEUTRON CROSS SECTIONS WITH SINGLE AND DOUBLE PARTICLE EMISSION

N. AZZIZ - E. HORJALES
Dpto.de Fisica Nuclear.
INSTITUTO DE FISICA

Abstract:

The cross sections (n, n), (n, 2n), (n, α), (n, α n), (n, nα), (n,p) etc., for energies in the MeV region, were predicted using an statistical model and no normalization factor was needed. As an application Cu^{65} was taken as a target. The experimental and theoretical predictions show satisfactory agreement.

I) Introduction:

The nuclear density formula derived by Gilbert and Cameron has been modified at low energy and applied to calculate fast neutron cross sections using the nuclear statistical model. This very simple picture of the nucleus used carefully reproduces the experimental data satisfactorily. Contrary to most calculations, no normalization factor was used and satisfactory agreement with the experiment was obtained.

The capture cross sections, necessary for the calculations, were obtained from experiment, when available, or theoretical calculations which were based on an optical potential model for the nucleus.

The code called Reduce and written for this purpose will be available at Argonne National Center Code Distribution.

II) Theory:

As is well known, the statistical model of the nucleus is based in the compound nucleus theory of Bohr and on the time reverse invariance of the nuclear reactions. This model is an oversimplification of the actual complex phenomena that occur during a nuclear reaction. However, in certain neutron energy range this is the only model which allows a reasonable mathematical treatment of the problem. The future closed shell and pairing effects of the nucleus, which we know are important, were included into the model throughout the nuclear temperature parameter.

Two or more particle emission:

Suppose we are dealing with a reaction where α is the incoming particle, and β , δ and ε are emitted in a successive manner passing through different residual nuclei.

Diagrammatically this looks like,

$$\begin{array}{ccc} A + \alpha & \longrightarrow & B^* + \beta \\ & & \downarrow \\ & & C^* + \delta \\ & & \downarrow \\ & & D^* + \varepsilon \end{array}$$

During this first step we may assume with N. Bohr that the cross section of β emission is given by

$$\sigma(\alpha,\beta) = \sigma(\alpha)\,\frac{\Gamma(\beta)}{\Gamma(c)} \qquad (1)$$

Where $\sigma(\alpha)$ is the capture cross section of α by A, $\Gamma(\beta)$ the probability of emission of β and $\Gamma(c)$ the total probability of emission of β and any other particle,

$$\Gamma(c) = \sum_i \Gamma(i)$$

similarly for two particle emission,

$$\sigma(\alpha,\beta,\delta) = \sigma(\alpha)\,\frac{\Gamma(\beta,\delta)}{\Gamma(c)} \qquad (2)$$

where $\Gamma(\beta\delta)$ is the compound probability of β and δ emission in a successive manner.

Accordingly, to the time reverse invariance of the nuclear reactions, for the one particle emission the following relationship holds

$$k_\alpha^2\,\Gamma(\beta)\sigma(\alpha) = k_\beta^2\,\Gamma(\alpha)\sigma(\beta)$$

By this relationship (1) may be written as

$$\sigma(\alpha,\beta) = \sigma(\alpha)\left[k_\beta^2\,\sigma(\beta)/\sum k_i^2\,\sigma(i)\right] \qquad (3)$$

If the particle β may be released with a spectrum of energy, then the probability $k_\beta^2\sigma(\beta)$ for emission of a particle β is replaced by the integral $\Gamma(\beta)$

$$\Gamma(\beta) = \frac{g_\beta}{2\pi^2\rho_c(v_c)}\int_0^{E_\beta^{max}} dE_\beta\,k_\beta^2\,\sigma(\beta)\,\rho_\beta(v_\beta) \qquad (4)$$

The statistical weighting factor g_β is equal to $(2S_\beta+1)$ for a particle whose spin is S_β. If the emitted object is a gamma ray, then $g_\beta k_\beta^2$ is replaced by $(2E_\beta/c)^2$, C is the speed of light and E_β the energy of the gamma ray. The quantities $\rho_c(v_c)$ and $\rho_\beta(v_\beta)$ are the nuclear densities of the nuclear densities of the nuclei (A + α) and B at the excitation energies ν_c and ν_B respectively. Theoretically the capture cross section $\sigma(\beta)$ should be calculated at the excitation energy ν, however, in practice it is done with the nucleus B in its ground state.

In analogous way to equation (4) the compound probability $\Gamma(\beta\delta)$ may be written as

$$\Gamma(\beta\delta) = \frac{g_\beta}{2\pi^2 \rho_A(\nu_A)} \int_0^{E_\beta^{max}} dE_\beta \, k_\beta^2 \, \sigma(\beta) \, \rho_B(\nu_B) \, P_{\beta\delta}$$

where the probability $P_{\beta\delta}$ is given by

$$P_{\beta\delta} = \frac{R_{\beta\delta}}{\sum_i' R_{\beta i}}$$

where

$$R_{\beta i} = \frac{g_i}{2\pi^2 \rho_\beta(\nu_B)} \int_0^{E_i^{max}} dE_i \, k_i^2 \, \sigma(i) \, \rho_c(\nu_c)$$

The maximum energy of the emitted particle i E_i^{max} is related to the energy of the β particle (see figure 1) by

$$E_i^{max} = E_\beta^{max} + Q_{\beta c} - E_\beta$$

where

$$E_\beta^{max} = E_\alpha + Q_{AB}$$

The residual nucleus after the emission of particle i is C = A + α
The Q values for the reaction A (α, γ) (A + α), A (α, β) B and B (γ, i) C are indicated by $Q^A_{\alpha\beta}$, Q_{AB}, Q_{BC}
The excitation energies ν are given by

$$\nu_A = E + Q^A_{\alpha\gamma}$$

$$\nu_B = E_\beta^{max} - E_\beta$$

and

$$\nu_c = E_i^{max} - E_i$$

It should be pointed out that we denominate $\sigma(\alpha,\beta)$ the cross section which is free of contributions from any other particle emission. That is, after β is emitted, the nucleus B is left in its ground state or in an excited state that may only decay by γ emission,

$$\sigma(\alpha,\beta) = \sigma^*(\alpha,\beta) - \sum_{\delta\neq\gamma} \sigma(\alpha,\beta,\delta)$$

where $\sigma^*(\alpha,\beta)$ is determined by (3) and (4).

III. Nuclear Density:

We have used the nuclear density given by Gilbert and Cameron[1]

$$\rho(U,J) = \frac{1.11}{A}\,\frac{\exp(2\sqrt{aU})}{aU^2}\,(2J+1)\exp\left[-(J+\tfrac{1}{2})^2/2\sigma^2\right] \qquad (5)$$

where

$$\sigma^2 = 0.0888\,A^{2/3}\sqrt{aU}$$

The observable density is given by the sum of $\rho(U,J)$ over all possible J values.
In absence of other information this summation is replaced by an integral in J from zero to infinity. The result is

$$\rho(U) = \frac{0.2}{A^{1/3}}\,\frac{\exp(2\sqrt{aU})}{a^{1/2}\,U^{3/2}} \qquad (6)$$

The parameter a is according to Bethe proportional to the mass number A. Gilbert and Cameron have included the shell correction S in the expression of a. Since the nuclear density is deduced assuming that the nucleus is a Fermi sea without surface effect or any nuclear interaction, shell and pairing effect should be included in a semi-empirical fashion.

Thus they proposed to write

$$a/A = \alpha S + \beta$$

where α and β are constant to be determined from experiment. The pairing effect is taken into account by reducing the excitation energy by the amount δ_o. This means that δ_o must be expended before the system can be considered as formed by independent nucleons.

Below we explain how the density at low energy was alleviated. In this regard we point out that in spite of it is meaningless to talk about nuclear density at low energy, the numerical calculations depend quite critically on its value. We have taken a simple expression of ρ similar to (6) but the value of δ_o, the pairing parameter, was modified.

For odd-even and even-even nuclei δ_o was reduced with respect to its value at high energies. For odd-odd, δ_o being zero, the desired effect was obtained by creating a negative pairing effect.

In summary

$$\delta = \delta_o \left(1 - \frac{6 - \mathcal{V}}{12}\right) \quad \text{for even-even,} \quad \mathcal{V} < 6 \text{ MeV}$$

$$\delta = \delta_o \left(1 - \frac{6 - \mathcal{V}}{6}\right) \quad \text{for odd-even,} \quad \mathcal{V} < 6 \text{ MeV}$$

$$\delta = \frac{5 - \mathcal{V}}{6} \quad \text{for odd-odd and} \quad \mathcal{V} < 5 \text{ MeV}$$

Using this simple criterion, a remarkable agreement of the modified ρ at low energy and the temperature model $\exp[(\mathcal{V} - E_o)/T]$ whose parameters E_o and T are reported by Gilbert and Cameron, was found. Besides the continuity of ρ between low and high energy is automatically obtained because the same analytic form (6) is used for both regions. Finally at very low energy $\mathcal{V} < 0.2$ MeV was assumed to an exponential function joining smoothly ρ for $\mathcal{V} \geq 0.2$ MeV. The procedure described here gives very good agreement with the observable level separation distance.

IV. Capture Cross Sections

The neutron capture cross section is quite known experimentally. However, the α, p, and γ capture are not so well known and we have used theoretical models for their prediction. The α capture cross section was obtained using the model of Hizenga and Igo. This model uses an optical model given by

$$V(r) = (V_o + iW_o) \Big/ \left[1 + \exp \frac{r - R}{a}\right]$$

where $V_o = -50$ MeV, R = 1.17 A + 1.77, a = 0.576 and W ranges between 5 and 30 MeV. The coulomb potential used in this model is the one proposed by Hill and Ford(3)

$$V_c = \frac{2Ze^2}{R_c}\left[\frac{1}{m^2} + \frac{1}{2} - \frac{1}{6}x^2 + \frac{e^{-m}}{m^2}\left(\frac{1 - e^{mx}}{mx} + \frac{1}{2}e^{mx}\right)\right] \Big/ \left(\frac{1}{3} + \frac{2}{m^2} + \frac{e^{-m}}{m^3}\right) \quad \text{for } x < 1$$

$$V_c = \frac{2Ze^2}{R_c}\left[\frac{1}{x} - \left(\frac{(1/x + m/2)\, e^{m - mx}}{e^{-m} + 2m + \frac{1}{3}m^3}\right)\right] \quad \text{for } x > 1$$

where $x = \frac{r}{R_c}$ and $R_c = 1.17\ A^{1/3}$

The value of n is 10 for heavy elements and is in general, proportional to $A^{1/3}$.

To calculate the proton capture cross sections, an optical model with the following parameters is used.

$$V_{opt}(r) = V_{re}(r) + iV_{im}(r) + \left(\frac{m}{m\hbar c}\right)^2 V_{so}\ \frac{1}{r}\left[\frac{d}{dr}\left(V_{re}(r)\right)\right]\bar{l}\cdot\bar{\sigma}$$

where,

$$V_{re}(r) = \frac{V_0}{1 + \exp\left[(r - R_1)/a\right]}$$

$$V_{im}(r) = \frac{W_0}{1 + \exp\left[(r - R_2)/b\right]}$$

$$V_{so} = 5.5\ \text{MeV} \quad , \quad R_1 = R_2 = 1.25\ A^{1/3}\ \text{fm}$$

and $a = 0.65$ fm , $b = 0.90$ fm

The depth V_0 of the real part was calculated from the formula

$$V_0 = -48.6 + 0.3\,(E - \bar{V}_c) - 30\ \frac{N-Z}{A} \quad \text{MeV}$$

deduced from a microscopic many-body theory[4]

The last term is equivalent to the symmetry term in the semi-empirical mass formula.

The incoming proton energy is indicated by E and $\bar{V}_c$ represents the effect of the slowing down of the proton in nuclear matter due to the Coulomb effect.

If we include a diffusivity effect on the Coulomb distribution, V_c becomes

$$V_c = \frac{6}{5}\cdot\frac{Ze^2}{R}(1 - d) \qquad \text{MeV}$$

The factor (1-d) is of the order of 0.65 for medium and heavy elements. The γ capture cross section was predicted using the formula proposed by Brink. This formula accounts for the giant dipole resonance with the empirical value of the resonance energy

$$E_R = 80\ A^{-1/3} \quad \text{MeV}$$

and a width $\Gamma_R = 5$ MeV. The formula is a classical Lorentzian distribution and reads:

$$\sigma_\gamma = \left[\frac{0.013\,A}{\Gamma_R} (\mathrm{MeV}) \right] \frac{E^2 \Gamma_R^2}{(E^2 - E_R^2) + E^2 \Gamma_R^2} \quad \text{barns}$$

V. Results and Conclusions

In Figs. 4 to 11 we show our theoretical predictions by solid curves. The experimental ones, when available, are indicated in the same figures by arrows. Shaded areas represent the ispersion of such experimental data.

The experimental sources for the capture cross sections were taken from BNL 325. In the calculation of certain cross sections as (n,p) the capture cross section in the inverse reaction, plays an important role. For energies less than 4 MeV, close to the threshold, the optical model used to calculate the p capture was not very adequate. In that case we took, for energies less than 4 MeV the experimental capture cross sections given in reference 6.

The experimental values of the one and two particle emission used to amke the comparison with the theoretical predictions, were taken from BNL 325.

As a conclusion we may say that in spite of the simplicity of the model, when it is worked out carefully, it becomes a powerful tool for the predictions of fast neutron cross sections.

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Figure Captions

Fig. 1 Neutron capture cross section for Cu^{65}. The σ_c for the other isotopes were found to be quite close (in a 5%) to this one.

Fig. 2 Alpha capture cross section for Co^{62}. Obtained from calculations with an optical model as explained in section IV.

Fig. 3 Proton capture cross section for Ni^{65}, obtained from calculations and experiment as explained in sections IV and V.

Fig. 4 Cu^{65} (n,n') Cu^{65} reaction cross section. The solid curve represents the theoretical predictions.

Fig. 5 Cu^{65} (n,α) Co^{62} reaction cross section. The solid curve represents the theoretical predictions.

Fig. 6 Cu^{65} (n,p) Ni^{65} reaction cross section. The solid curve represents the theoretical predictions. The dispersion of the experimental data is indicated with a shaded area.

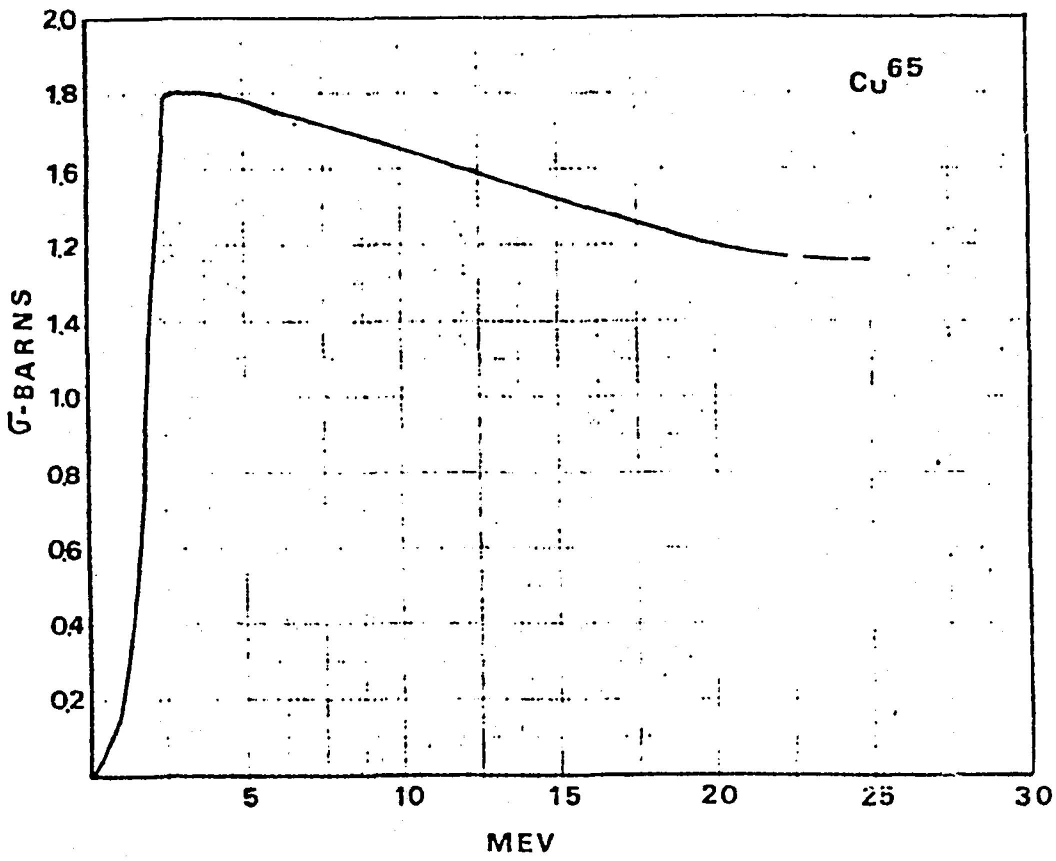
Fig. 7 Cu^{65} (n,γ) Cu^{66} reaction cross section. The solid curve represents the theoretical predictions. The dispersion of the experimental data is indicated with a shaded area.

Fig. 8 Cu^{65} (n, 2n) Cu^{64} reaction cross section. The solid curve represents the theoretical predictions. The dispersion of the experimental data is indicated with a shade area.

Fig. 9 Cu^{65} (n, np) Ni^{64} and Cu^{65} (n,pn) Ni^{64} reaction cross sections. The solid curve represents the theoretical predictions.

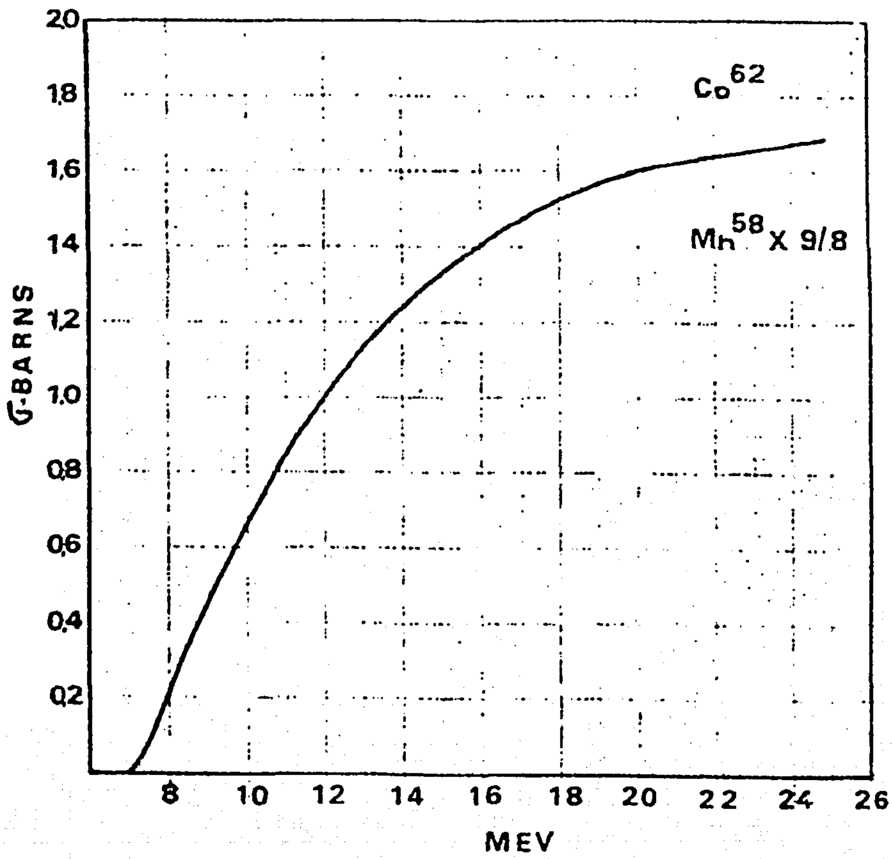
Fig. 10 Cu^{65} (n, nα) Co^{61} reaction cross section. The solid curve represents the theoretical predictions. The dispersion of the experimental data is indicated with a shade area.

Fig. 11 Cu^{65} (n, α n) Co^{61} reaction cross section. The solid curve represents the theoretical predictions.



Cu^{65}
σ-BARNS
2,0
1,8
1,6
1,2
1,4
1,0
0,8
0,6
0,4
0,2
5
10
15
20
25
30
MEV

Fig. 1



Co^{62}
Mn^{58} X 9/8
σ-BARNS
2,0
1,8
1,6
14
1,2
1,0
0,8
0,6
0,4
0,2
8
10
12
14
16
18
20
22
24
26
MEV

Fig. 2

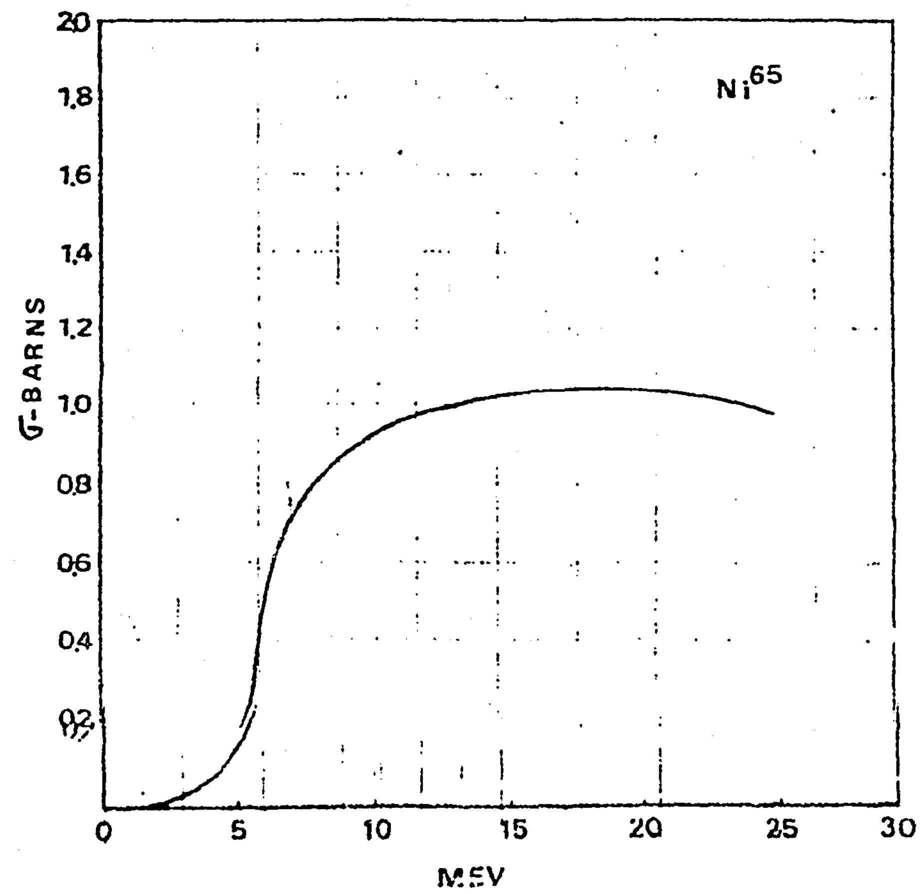

Ni65
σ-BARNS
MEV
0
5
10
15
20
25
30
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2

Fig. 3

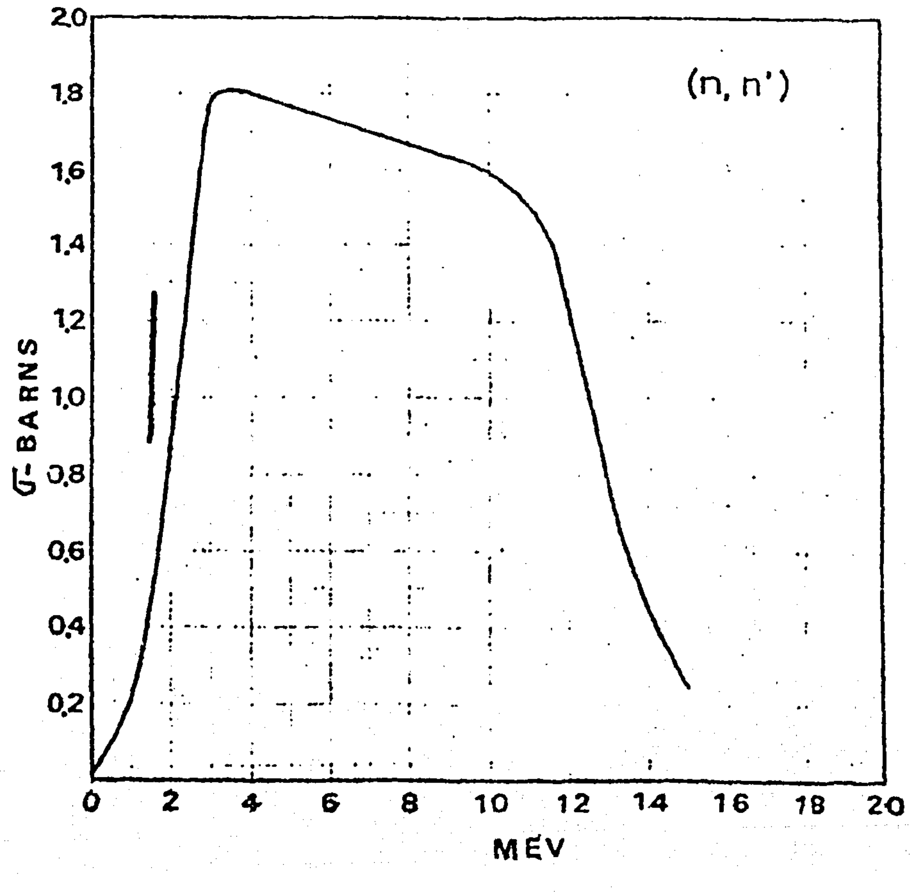

(n, n')
σ- BARNS
MEV
0
2
4
6
8
10
12
14
16
18
20
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2

Fig. 4

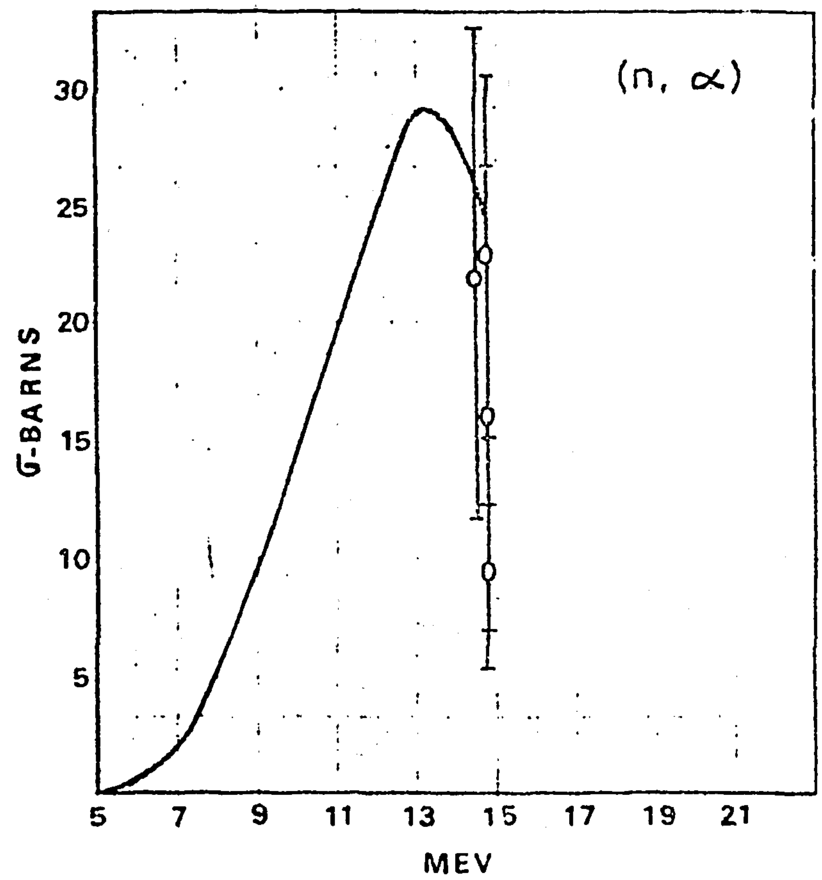

(n, ∝)
σ-BARNS
30
25
20
15
10
5
5
7
9
11
13
15
17
19
21
MEV

Fig. 5

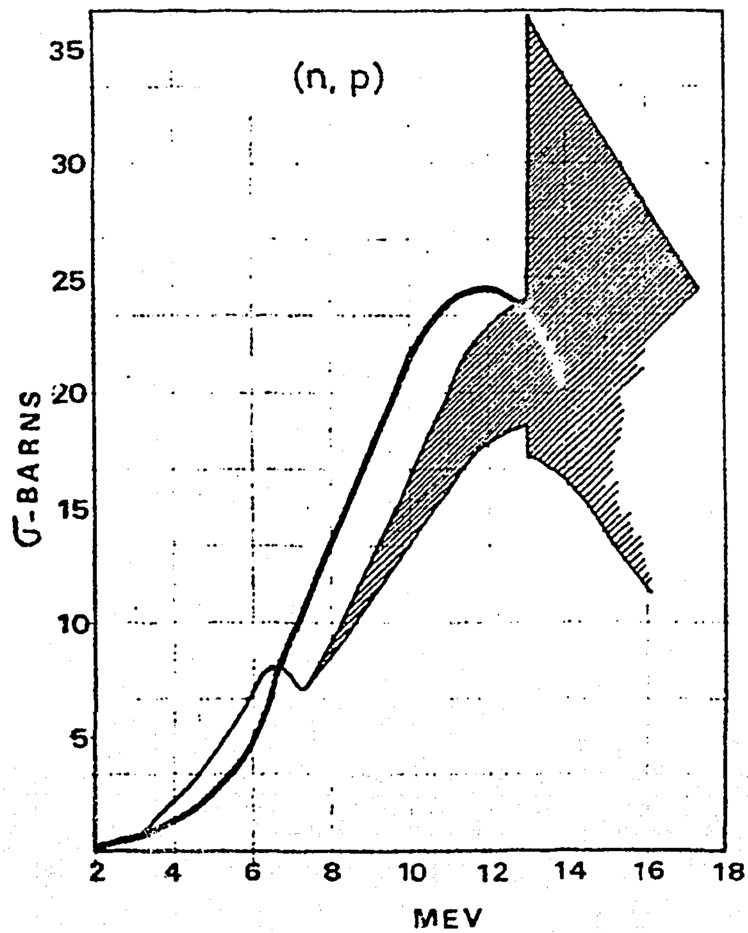

(n, p)
σ-BARNS
35
30
25
20
15
10
5
2
4
6
8
10
12
14
16
18
MEV

Fig. 6

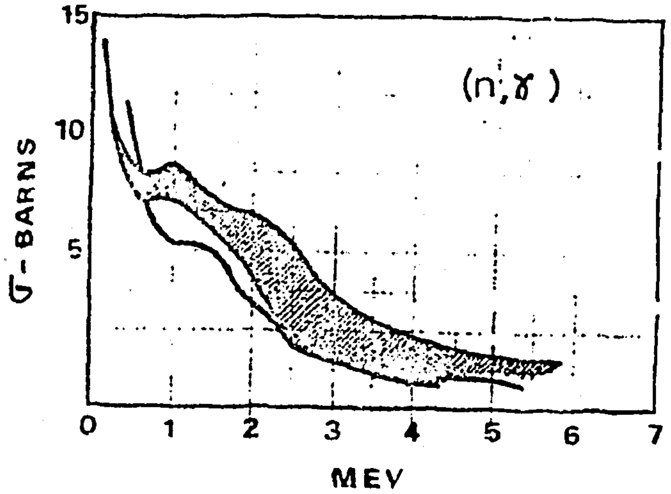


Fig. 7

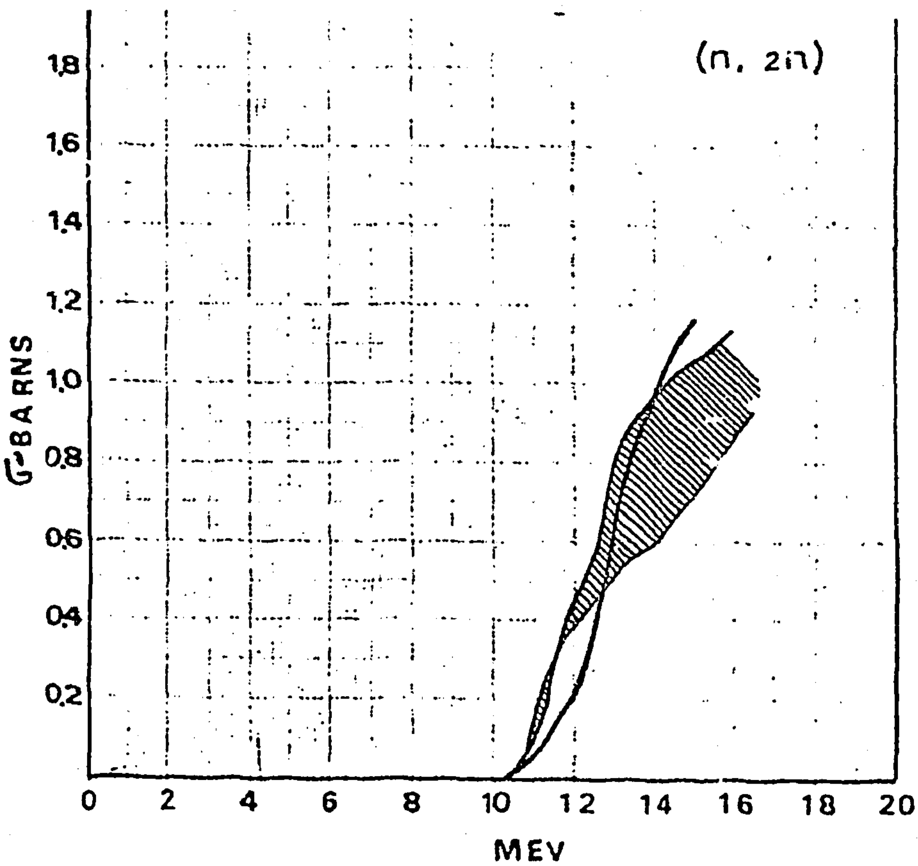


Fig. 8

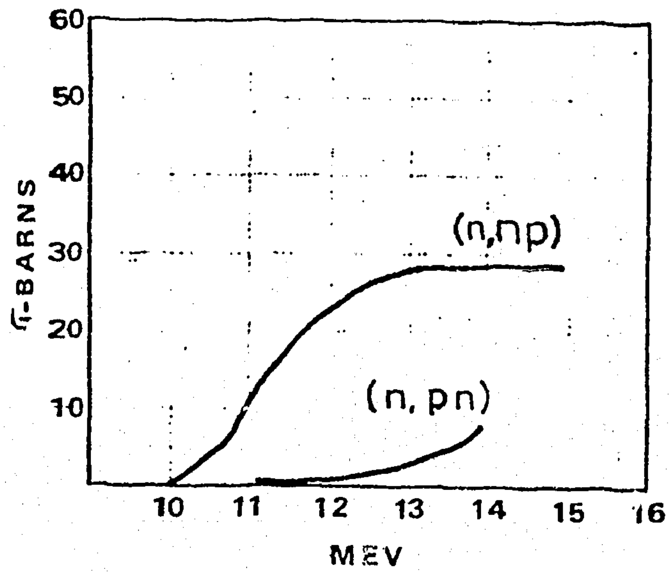


Fig. 9

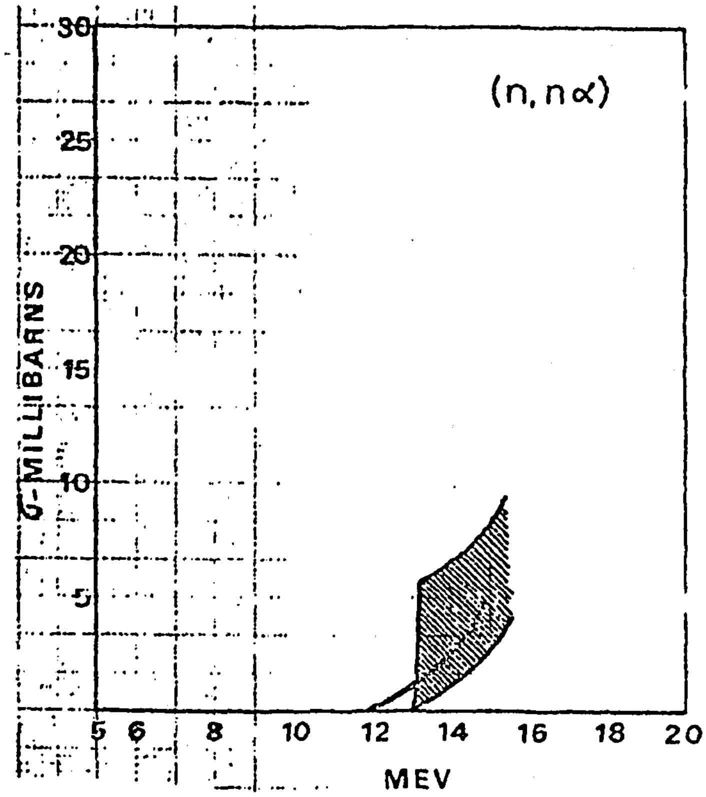

(n, nα)
σ-MILLIBARNS
30
25
20
15
10
5
5
6
8
10
12
14
16
18
20
MEV

Fig. 10

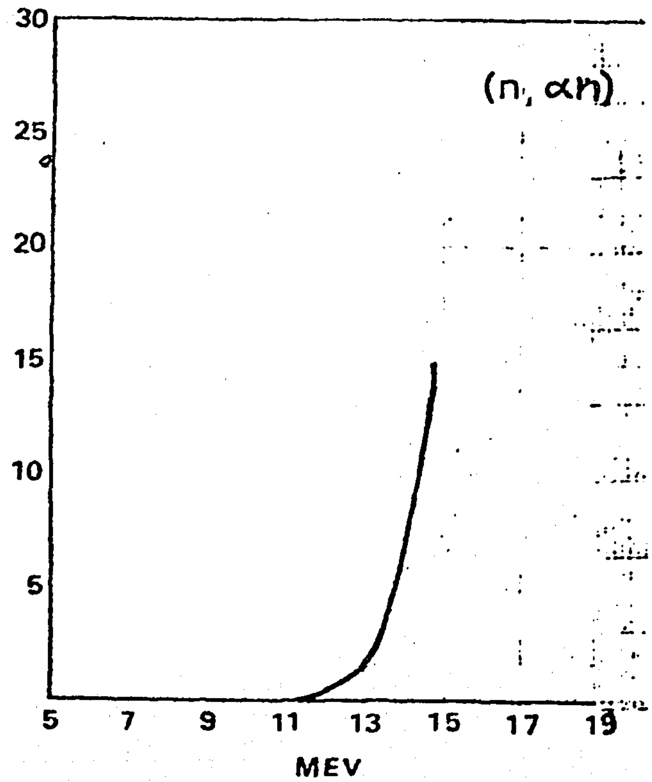

(n, αn)
30
25
20
15
10
5
5
7
9
11
13
15
17
19
MEV

Fig. 11

Progress Report on

Neutron Physics Research in Yugoslavia

Compiled by I. Slaus

June, 1971

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

Institute "Ruđer Bošković", Zagreb:

Department of Nuclear and Atomic Physics
chairman Prof.dr. P. Tomaš

Department of Theoretical Physics
chairman Prof.dr. G. Alaga

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

Institute "Boris Kidrič", Vinča

Department of Physics
chairman Prof.dr. B. Lalović

Institute "Jožef Stefan", Ljubljana

Department of Physics
chairman Prof.dr. D. Jamnik

Neutron Physics Research

1. S. Lulić, P. Strohal and I. Šlaus:
The Study of (n,2p) Reactions at 14 MeV
Nuclear Physics A154 (197o) 273-282

The study of (n, 2p) reactions can yield important information about reaction mechanisms and nuclear spectroscopy which cannot be obtained by charged particle induced reactions[1].

Attempts aimed so far to determine the cross section for the (n, 2p) reaction leading to radioactive nuclei with suitable properties have not been successful. Only upper limits have been quoted[6,7], the values ranging from 3 μb to 840 μb (refs.[6,7]). Husain et al. have measured the ^{103}Rh(n, 2p)^{102m}Tc reaction and found 7 ± 4 μb (ref.[8]). However, an upper limit of 3 μb is quoted for this reaction in ref.[7]. The advent of high resolution Ge(Li) detectors and on-line computers, with refined chemical separation techniques, is making the study of (n, 2p) reactions much more promising.

The present investigation relies on the activation method employing Ge(Li) detectors in conjunction with a PDP-8 computer used as a 1024-channel analyser, and the chemical separation of Z-2 elements from predominantly Z and Z-1 materials.

The cross section was determined by using the internal monitor, i.e. comparing the intensity of photopeaks belonging to the investigated (n, 2p) reactions with those from the product of (n, alpha) reactions. The error due to the efficiency of the chemical separation procedure was therefore eliminated, since the products of (n, 2p) and (n, alpha) reactions belong to the same chemical element. The uncertainty in the absolute cross section of the (n,2p) reactions depends upon the accuracy of the (n, alpha) cross section. Only for TiO_2, V_2O_5 and $Y(NO_3)_3$ the monitor was the (n,p) reaction. The targets used in this study, the monitor reaction, the value of its cross section and the half-life are given in table 1.

Table 1

Targets and monitors

Target	Chemical separation performed	Monitor				
		reaction	product half-life	value used (mb)	other values	ref.
KNO_3	yes	$^{41}K(n,\alpha)^{38}Cl$	37.3min	30 ± 6 [a]	31.4 ± 5	14)
Sc_2O_3	yes	$^{45}Sc(n,\alpha)^{42}K$	12.4h	63 ± 12 [a]	56 ± 4	15)
					63 ± 12	16)
TiO_2	no	$^{50}Ti(n,p)^{50}Sc$	1.7min	28 ± 6 [a]	17 ± 2	17)
					9 ± 2	18)
					27 ± 3	19)
V_2O_5	no	$^{51}V(n,p)^{51}Ti$	5.8min	55 ± 12 [a]	37 ± 3	20)
					53 ± 15	21)
					30 ± 6	22)
					25 ± 4	23)
MnO_2	no	$^{55}Mn(n,\alpha)^{52}V$	3.7min	33 [b]	32.5 ± 1.5	24)
					31 ± 5	25)
As_2O_3	yes	$^{75}As(n,\alpha)^{72}Ga$	14.1h	9.3 ± 3.1 [a]	10 ± 0.8	15)
					12 ± 1.1	14)
$RbNO_3$	yes	$^{87}Rb(n,\alpha)^{84}Br$	31.8min	59 ± 12 [c]	39 ± 16	14)
$Y(NO_3)_3$	yes	$^{27}Al(n,p)^{27}Mg$	9.5min	82 ± 10 [d]	87.2 ± 7	26)
					93 ± 10	27)
					52.4 ± 9.4	14)
					77 ± 8	16)
					53 ± 5	19)
Nb_2O_5	yes	$^{93}Nb(n,\alpha)^{90}Y$	3.1h	5.9 ± 2 [e]	5 ± 2	28)
$CsNO_3$	yes	$^{133}Cs(n,\alpha)^{130}I$	12.3h	1.0 ± 0.9 [a]	1.9 ± 0.2	12)
$La(NO_3)_3$	yes	$^{139}La(n,\alpha)^{136}Cs$	13.7d	1.87 ± 0.19 [f]	1.3	29)

a) Ref.[6]), b) Ref.[8]), c) Ref.[9]), d) Ref.[10]), e) Ref.[11]), f) Ref.[12]).

Gamma-ray spectra were measured using a 20cm^3 Ge(Li) detector coupled to the PDP-8 used as a 1024-channel analyser. Only the activity produced by irradiation of the TiO_2 target was studied using a 7.6x7.6cm NaI(Tl) scintillation counter in connection with a 256-channel analyser.

Gamma-ray spectra were analysed and the decay curves of characteristic photopeaks in the spectra were measured for several half-lives. Activities due to a specific radionucleide were calculated from the area under the photopeak.

The cross sections were determined taking into account all necessary corrections, such as branching ratios and the efficiency of the spectrometer as a function of the γ-ray energy.

The quality of the experimental arrangement was tested investigating the activities of Z-2 products for nuclei where the Q-value for (n,2p) reactions is less than -14.5 MeV and thus cannot occur at our bombarding energy.

The targets Sc_2O_3, V_2O_5, As_2O_3, $Y(NO_3)_3$, Nb_2O_5, $CsNO_3$ and $La(NO_3)_3$ were irradiated and the chemical separation of Z-2 products was performed for all targets, except for V_2O_5.

Table 2 shows the experimental results for (n, 2p) reactions. Columns 1 and 2 list the target and the residual nucleus, respectively. The Q-values of the reactions are given in column 3, and half-lives in column 4. The reaction cross sections in μb obtained in this experiment are listed in column 5, and the experimental errors are given in column 6. The upper limits for the investigated reactions given by Bramlitt and Fink are quoted in the last column.

Table 3

Cross sections for (n,2p) reactions

Target	Residual nucleus	Q-values (MeV)	Half-lives	σ (μb)	Exp.error ($\pm$ μb)	Upper limit (μb)
^{45}Sc	^{44}K	-12.21	22.0 min	25	10	210
^{51}V	^{50}Sc	-13.74	1.7 min	$\approx$ 60		30
^{75}As	^{74}Ga	-11.72	7.8 min	52	29	500
^{89}Y	^{88}Rb	-11.53	18.0 min	50	40	30
^{93}Nb	^{92}Y	- 8.87	3.7 h	50	20	500
^{133}Cs	^{132}I	- 8.95	2.3 h	25	20	5
^{139}La	^{138}Cs	-10.85	32 min	30	20	46

2. M. Dikšić, P. Strohal and I. Šlaus:
(n,^{3}He) and (n,t) reaction cross sections at 14 MeV

The experimental data on (n,^{3}He) and (n,t) reactions are very scarce and even when the data exist they are often contradictory, the results range e.g. for ^{103}Rh(n,^{3}He)^{101}Tc from upper limit of 0.4 μb[8] to 1500-3500 μb[3]. The successful measurement of (n,^{3}He) and (n,t) reaction cross section requires sensitive experimental techniques which can enable to discriminate the low yield of (n,^{3}He) and (n,t) reaction in the presence of large yields of (n,2n), (n,α), (n,nα) and (n,p) reactions. The high resolution gamma spectroscopy coupled with the radiochemical separations are basic features of our experimental method. In case of (n,^{3}He) reactions radiochemical separations exclude all radioactive products from (n,p) and (n,2n) reactions.

The present investigations were performed using the activation method. In some cases radiochemical separation was also applied, mostly for the separation of (Z-2) elements from the target material.

Experimentally determined cross sections for (n,^{3}He) and (n,t) reactions are presented in Tables 1 and 2. All cross sections correspond to measured values calculated on the basis of characteristic photopeaks of their gamma ray spectra. Tables 1 and 2 show the experimental results for (n,^{3}He) and (n,t) reactions. Columns 1 and 2 list target and residual nucleus, respectively. Target materials are given in column 3, while Q-values are present in column 4, and half-lives in column 5. The reaction cross sections obtained in this work are expressed as weighted mean values and listed in column 6. Cross section values and upper limits of investigated reactions are listed in column 7, while column 8 indicate the corresponding references.

TABLE 1

Cross sections for $(n,{}^3He)$ reactions

Target nucleus	Residual nucleus	Target material	Q-value	half life	cross section (mb)	values of other autors	Ref.
^{31}P	^{29}Al	red phosphorus	-13.0795	6.6 min	222±100	700 500	2 3
^{41}K	^{39}Cl	KNO_3	-12.599	55.5 min	848±320	2500	2
^{55}Mn	^{53}V	MnO_2	-12.7017	2 min	800±320	2000-6000 50 420	3 4 2
^{59}Co	^{57}Mn	Co-foil	-11.6126	1.7 min	62±30	25 1000-3000 100	4 3 2
^{63}Cu	^{61}Co	^{63}Cu (sep. isot.)	-9.5130	99 min	113±40	3200±1100 80	5
^{71}Ga	^{69}Cu	Ga_2O_3	-11.0446	3 min	66±20		
^{75}As	^{73}Ga	As_2O_5	-10.1481	294 min	578±200	3000-7000 510 500	3 2 4
^{96}Zr	^{94}Sr	ZrO_2	-13.4697	1.35 min	136±50		
^{93}Nb	^{91m}Y	Nb_2O_5	- 7.7154	50.3 min	17.9±9.0	60	9
^{103}Rh	^{101}Tc	Rh-foil	- 8.5503	14 min	16±7	1500-3500 1.2±1 2.0±0.6 90 0.4 19	3 6 7 2 8 4

Table 1

^{109}Ag	^{107}Rh	$AgNO_3$	- 8.7193	21.7 min	23±10
^{115}In	^{113}Ag	In-foil	- 9.3409	5.3 h	33±15
^{130}Te	^{128}Sn	^{130}Te (sep.isot.)	-10.7969	59.0 min	15±8
^{187}Re	^{185}Ta	Re_2O_7	- 6.5999	50 min	4+3

TABLE 2

Cross sections for (n,t) reactions

Target nucleus	Residual nucleus	Target material	Q-value (MeV)	Half-life	Cross section (microbarns)	value of other autors	Ref.
^{32}S	^{30}P	sulphur powder	-12.6942	2.5 min	154±70	4±1	15
						20±5	16
						7.5±9	17
						2200±11%	18
						17	19
						10	20
^{40}Ca	^{38g}K	$CaCO_3$	-12.9401	7.71 min	310±180	20000±20%	18
						100	16
						15	20
						20	15
^{54}Fe	^{52m}Mn	^{54}Fe (sep.isot.)	-12.422	21.1 min	351±150	600±100	21
^{64}Zn	^{62}Cu	$ZnSO_4$	-10.0658	9.76 min	33.7±10	100	15
^{89}Y	^{87}Sr	$Y(NO_3)_3$	- 9.6919	2.83 h	15.4±10		

3. M. Furić, V. Valković, Đ. Miljanić, P. Tomaš and B. Antolković:
Neutron-Proton Bremsstrahlung at 14.4 MeV
Nuclear Physics A156 (197o) 1o5-112

A kinematically complete experiment on the neutron-proton bremsstrahlung at a neutron energy of 14.4 MeV was performed. Protons and neutrons were detected on opposite sides of the neutron beam. Protons were identified and their energy measured. The associated particle method and the neutron-proton time-of-flight difference were used to reduce the background. An upper limit of 400 $\mu b \cdot sr^{-2}$ was found for the neutron-proton bremsstrahlung differential cross section at the detector setting $\theta_p = \theta_n = 30^o$.

4. Đ. Miljanić, M. Furić and V. Valković:
A Study of (n,d) and (n,t) Reactions on ^7Li
Nuclear Physics A148 (1970) 312-324

Charged-particle spectra from neutron irradiation of ^7Li were measured at several angles. The angular distribution of deuterons from the $^7Li(n,d)^6He(g.s.)$ transition was compared with the DWBA prediction. The absolute value of the cross section was in satisfactory agreement, but the shape of the measured angular distribution was not well reproduced by the calculations.

The angular distribution of tritons in the peak of the spectra was compared with the DWBA prediction for the pickup of two nucleons. The shape of the angular distribution was reproduced reasonably well. A discrepancy in the absolute value was interpreted as a consequence of quasifree n-t scattering.

5. V. Valković, M. Furić, Đ. Miljanić and P. Tomaš:
Neutron-Proton Coincidence Measurement from the
Neutron-Induced Breakup of the Deuteron
Physical Review C, No.4 (1970) 1221-1225

A method for measuring neutron-charged-particle coincidences from the 14.4 MeV neutron-induced reaction has been developed. The $n+d \longrightarrow p+n+n$ reaction has been studied by the coincidence detection of the outgoing proton and neutron. The cross section has been measured as a function of five independent kinematic variables. A contribution of neutron-proton quasifree scattering has been observed. The cross section for $\theta_n=\theta_p=30^o$ is found to be $\sigma=37.5\pm5.8 mb/sr^2$. This result is in fair agreement with the data for proton-proton quasifree scattering from the $p+d \longrightarrow p+p+n$ reaction.

6. B. Antolković:
The study of $^{10}B(n,\alpha\alpha t)$, $^{7}Li(n, n\alpha t)$ and $^{12}C(n,n\alpha\alpha\alpha)$
(work in progress)

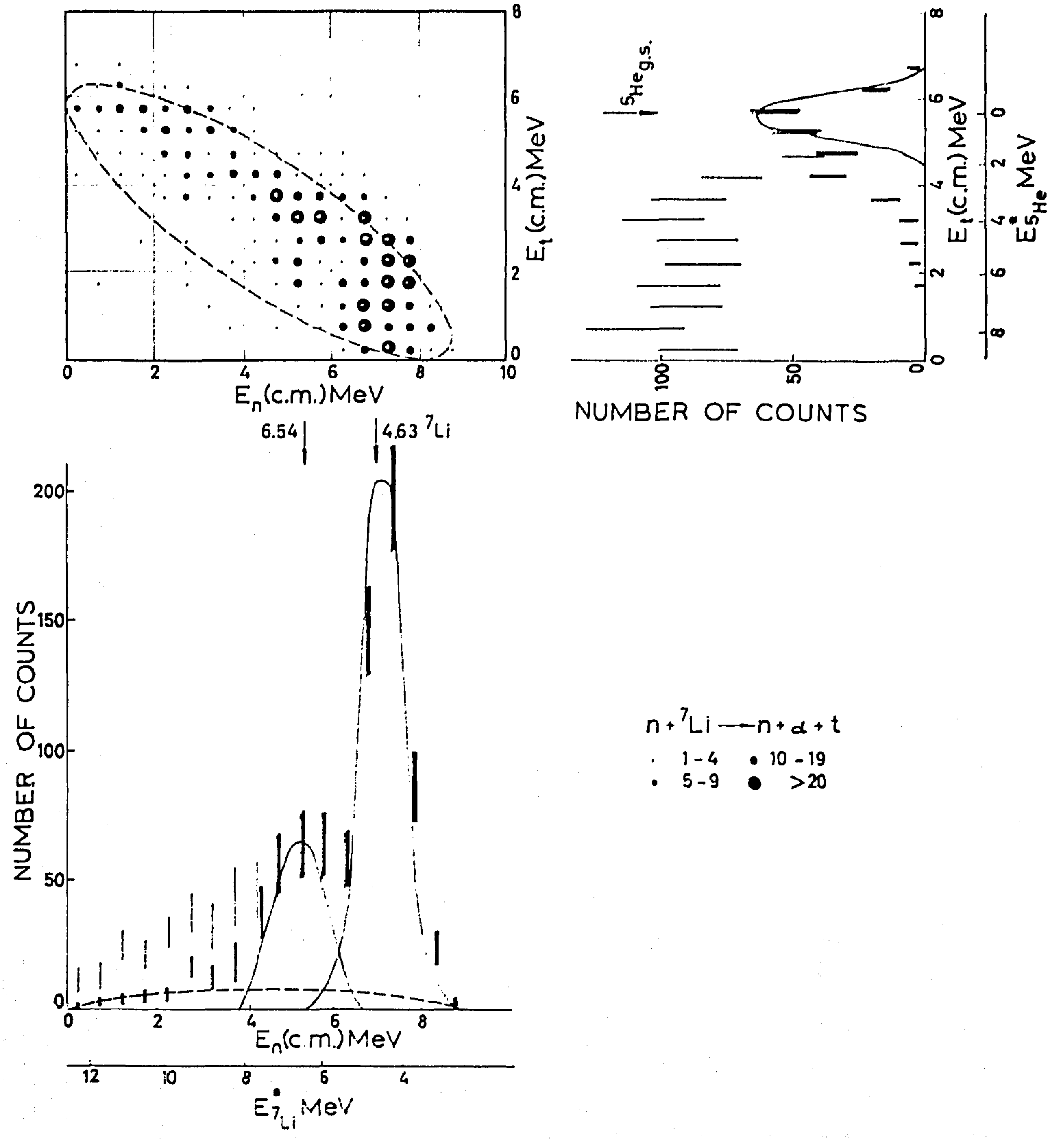
These reactions have been measured using the photographic plates. The measurement is a kinematically complete experiment.

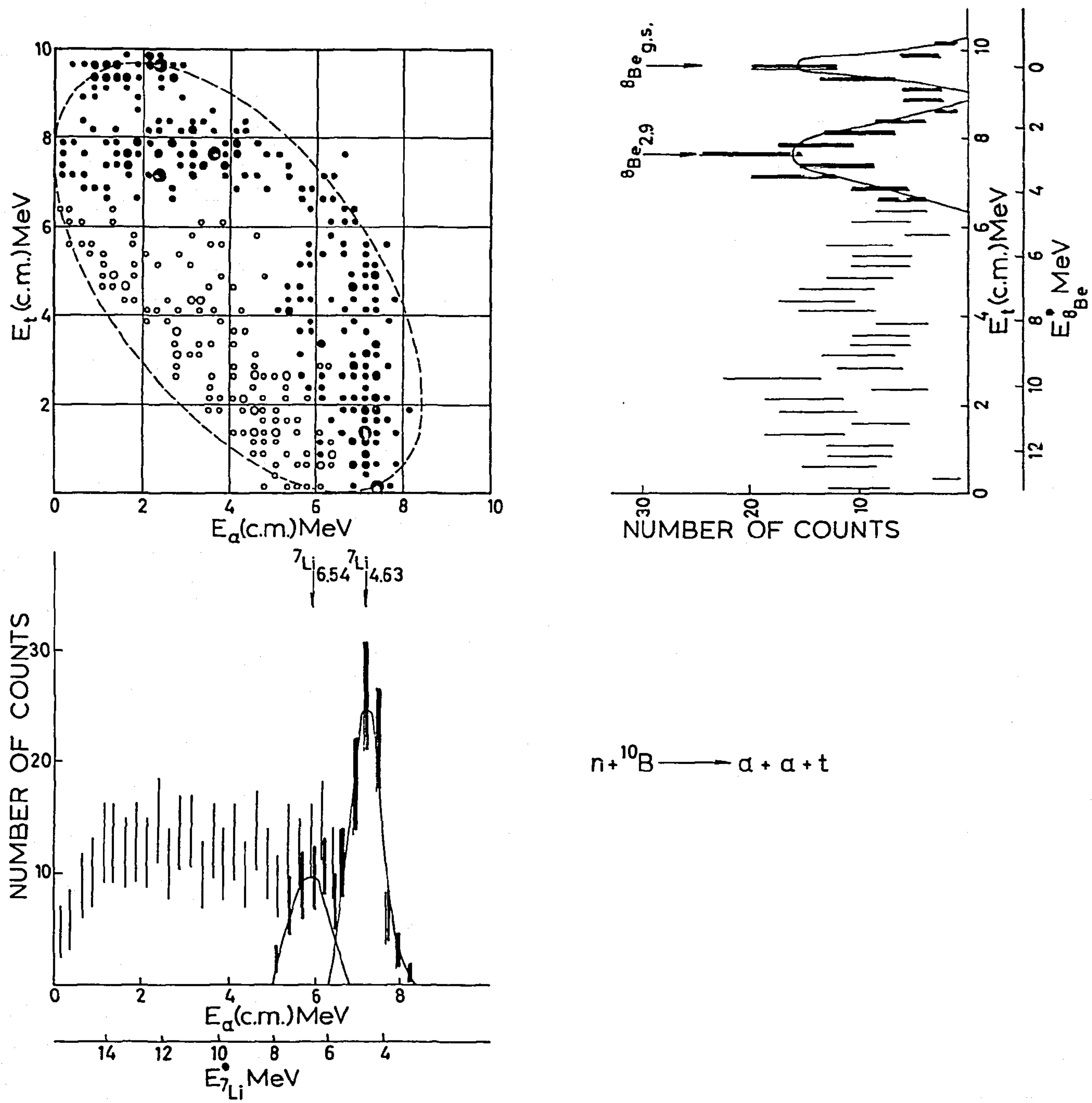
The results of the measurement are shown in Figs 1.and 2.

The cross reactions are

$^7Li(n,t)^5He_{gs}$	50mb
$^7Li(n,n')^7Li^*_{4.63}$	182mb
$^7Li(n,n')^7Li^*_{6.54}$	68mb
$^{10}B(n,t)^8Be_{gs}$	9.3mb
$^{10}B(n,t)^8Be_{2.9}$	21.4mb
$^{10}B(n,\alpha)^7Li_{4.63}$	19.2mb
$^{10}B(n,\alpha)^7Li_{6.54}$	10.3mb

All errors are $\sim$ 10%.


E_n(c.m.)MeV
E_t(c.m.)MeV
NUMBER OF COUNTS
5He g.s.
E*5He MeV
6.54
4.63 7Li
E*7Li MeV
n + 7Li → n + α + t
1 - 4
5 - 9
10 - 19
>20



$n + {}^{10}B \longrightarrow \alpha + \alpha + t$

7. I. Šlaus, J.W. Sunier, G. Thompson, J.C. Young, J.W. Verba, D.J. Margaziotis, P. Doherty and R.T. Cahill:
   Neutron-Neutron Quasifree Scattering
   Physical Review Letters Vol.26 (1971) 789-792

In collaboration with the group in The University of California, Los Angeles, the reaction D(n,2n)p was studied. The data are shown in Fig. 3.

The effective range, r_{nn}, has been extracted. The preliminary value is 2.4 ± 1.6 fm. The upper limit for nd Bremsstrahlung was determined to be 2mb/sr^2.

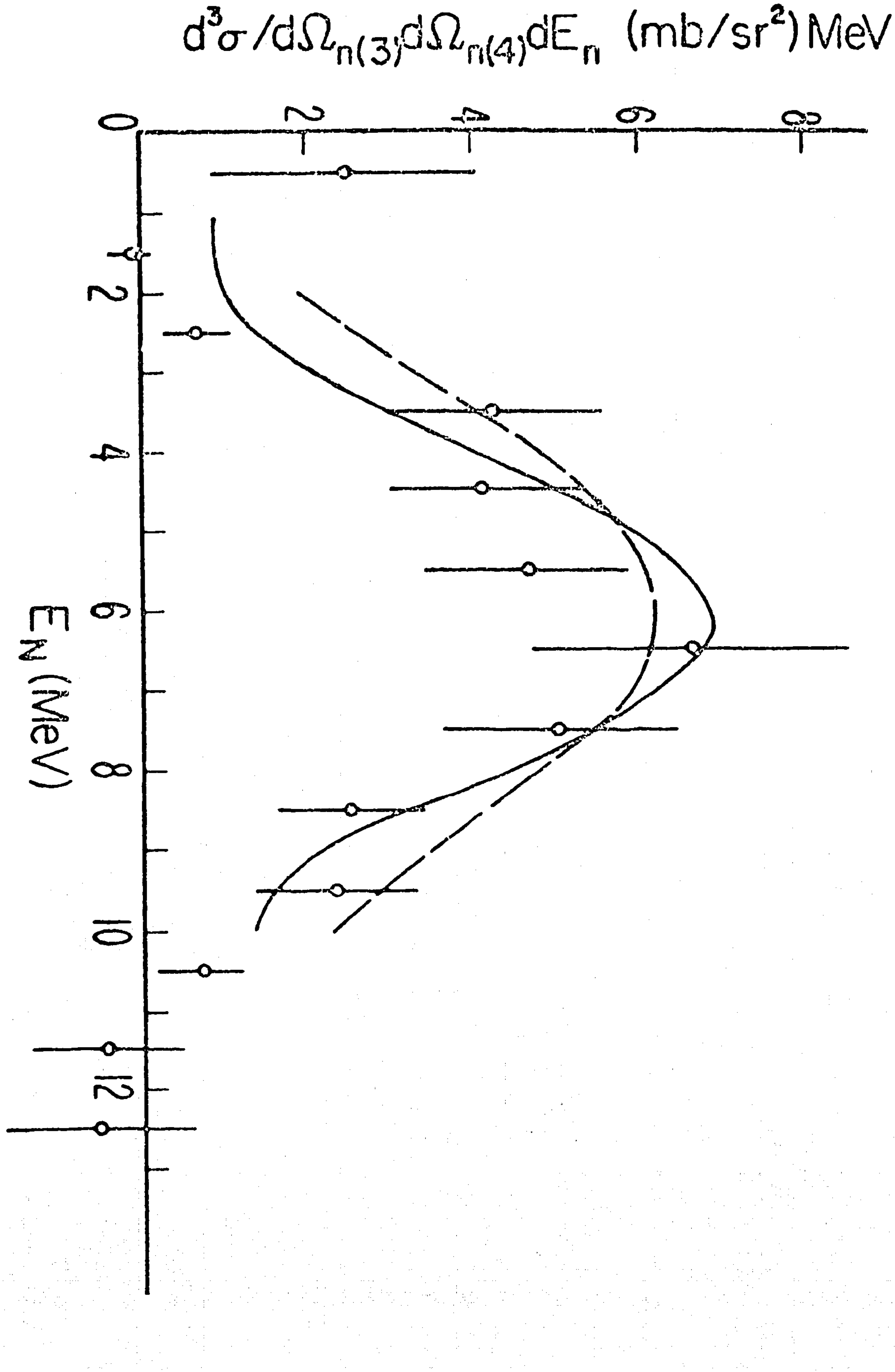
8. Đ. Miljanić, V. Valković, D. Rendić and M. Furić:
   Angular Distribution of tritons from the $^{11}B(n,t)^9Be$ Reaction at 14.4 MeV
   Nuclear Physics A156 (197o) 193-198

The differential cross sections for the $^{11}B(n,t)^9Be$ reaction are shown in table 1.

Table 1

Differential cross section for the $^{11}B(n,t)^9Be$(g.s.)reaction

$\theta_{c.m.}$	$\frac{d\sigma}{d\omega}$(mb/sr)
0^o	2.57 ± 0.08
$13^o18'$	2.15 ± 0.09
$26^o31'$	1.95 ± 0.08
$39^o33'$	1.55 ± 0.07
$52^o19'$	1.07 ± 0.09
$64^o43'$	0.81 ± 0.08


d³σ/dΩn(3)dΩn(4)dEn (mb/sr²) MeV
0
2
4
6
8
10
12
EN (MeV)

Experimental facilities

In the Institute Rudjer Bošković there are two Cockcroft-Walton accelerators and it is considered to use the internal beam of the 16 MeV cyclotron to produce neutrons.

The experimental techniques are improved:

1. V. Valković and P. Tomaš:
   A Position Sensitive Counter Telescope for the Study of Nuclear Reactions Induced by 14 MeV Neutrons
   Nuclear Instruments and Methods 92 (1971) 559-562

A counter telescope consisting of two multiwire proportional chambers and a residual-energy charged-particle detector is constructed. Instead of using a standard proportional counter, two batteries of a gas proportional counter were incorporated into the tandem arrangement of the detectors. The position sensitive part was made from stainless steel wires, 0.02mm in diameter with a wire spacing of 5mm. The distance between the mesh and the wires was 15mm. The lumped delay-line method was used to determine the identification pulse that is position sensitive. The spectra of the energy loss in the chamber were measured in the proportional region.

2. I. Šlaus, J.W. Sunier, G. Thompson, J.C. Young, J.W. Verba, D.J. Magaziotis, P. Doherty and R.T. Cahill
   Physical Review Letters Vol.26 (1971) 789-792

Neutron-neutron QFS was studied by bombarding a cylindrical 2-in.x2-in. C_6D_6 target with the 14.1-MeV neutron beam defined by associated alpha particles. Two outgoing neutrons were detected at $\theta_{n(3)}=\theta_{n(4)}=30^{o}$, $\phi=180^{o}$. The overall angular resolution was $\pm 6^{o}$. The main experimental problem is the large background from γ's and from direct and elastically scattered neutrons. The background was reduced by requiring the four detectors (alpha, target, neutron-right, and neutron-left) to be in coincidence and by kinematically over-determining the process by measuring the time of flight and the scattering angles of the two neutrons and the energy of the recoil proton (E_T). A further reduction in background of 20-25% was achieved by requiring that the neutron energy derived from the scintillator light output be compatible with the energy derived from neutron time of flight. Real and accidental events were accumulated simultaneously.

Information on the research in Institutes "Boris Kidrič", Vinča, and "Jožef Stefan", Ljubljana are not complete due to the reason stated in the Preface.

Institute "Jožef Stefan":

Dr. N. Cindro has received some data from Ljubljana and he should be able to inform the I.N.D.C. The results of some (n, γ) studies are given in: Nucl. Phys. 130, 401; ibid 138, 412 and 158, 251, as well as in Fizika 2, 41.

Institute "Boris Kidrič":

1) Capture of thermal neutrons on caesium and lanthanum (work in progress).
   J. Simić, B. Lalović, V. Ajdačić, I. Slavić and B. Koički
   The new decay schemes have been determined.

2) The activation analyses and the study of reactor material (work in progress).
   T. Tasovac, V. Bulović, R. Drašković et al.

3) Neutron total cross section measurement on light nuclei
   F. Boreli,
   A part of this has been published in Fizika 2, 97 (1970)