

International Atomic Energy Agency

INDC(RUM)-11/LN

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

NDS LIBRARY COPY

Annual Report
on Nuclear Data Activities in Romania
1978-1979

Compiled by
 S. Rapeanu, G. Vasiliu

NDS LIBRARY COPY

December 1979

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

Reproduced by the IAEA in Austria
December 1979

79-10307

STATE COMMITTEE FOR NUCLEAR ENERGY

ANNUAL REPORT
on Nuclear Data Activities in ROMANIA

Compiled by

S. Răpeanu, G. Vasiliu

Bucharest, October - 1979

A B S T R A C T

This annual report contains the main nuclear data works performed during the years 1978-1979 in the Institute of Nuclear Power Reactors, the Institute of Physics and Nuclear Engineering, the Institute of Physics and Technology of Radiation Instruments and the Physics Faculty - University of Bucharest.

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

INTRODUCTION

The present report is a brief review on main nuclear data activities carried out during the period of the years 1978-1979 in the Romanian Research Institutes involved in.

A large effort has been devoted to develop high precision experimental methods for basic nuclear data and neutron flux-spectrum measurements as well as for nuclear data evaluation.

The selected abstracts present often, results reported in national or international scientific conferences. Each abstract is accompanied by associated INIS keywords.

The main topics abstracted herein are:

- Experimental measurements of fundamental nuclear data, regarding both nuclear structure and cross section data,
- Evaluation of neutron nuclear data for reactor calculations and dosimetry,
- Group constant calculations,
- Adjustement - amelioration of reactor group constants,
- Methods, development and experimental research on neutron spectrum,
- Computer codes,
- Liquid and solid state neutron measurements,
- Theoretical approaches for statistical model improvement.

During 1978 (3-7 October), Romania has been the host country of the 10th INDC - Meeting, held in Bucharest.

We are most grateful to IAEA and especially to NDS, for their permanent assistance and support for the above mentioned activities in nuclear data field.

COULOMB EXCITATION OF $^{135,137}\text{Ba}$ *

E. Drăgulescu, M. Ivaşcu, D. Popescu, G. Semenescu
Institute of Physics and Nuclear Engineering - Bucharest

R. Mişu

Physics Department, Bucharest University

In recent years, a considerable amount of attention has been directed towards obtaining a detailed understanding of nuclei near $N=82$ closed neutron shell. Particularly, the intermediate - coupling unified nuclear model has been used with some success to explain the structure of the odd barium isotopes due to the vibrational - like spectra in the even barium isotopes.

The Coulomb excitation experiments were carried out at U-120 Cyclotron with an α - beam of energy between 9.7 and 12.6 MeV. Isotopically enriched thick target (^{135}Ba : 76.2%; ^{137}Ba : 85.5%) in the form of powdered BaCO_3 pressed between two gold and tantalum foils were employed.

The γ - rays emitted after Coulomb excitation were detected by a 55 cm^2 Ge(Li) detector with an energy resolution of 2.3 keV FWHM at 1332 keV. The yield data were obtained with the Ge(Li) detector positioned at 55° to the incident beam. The γ - ray angular distributions were measured at every 15° between 0° and 90° to the beam direction.

A representative γ - ray spectrum obtained from bombardment of ^{135}Ba with 11.5 MeV α - particles is shown in Fig. 1. The procedure needed to extract the reduced transition probabilities $B(E2)^\uparrow$ and the mixing ratio δ from thick - target γ - ray direct yield and angular distributions are described.

In the Table 1 it is shown the strong collective behaviour of the levels 480.5, 587.9 and 874.5 keV in ^{135}Ba because the $B(E2)^\uparrow$ values are large.

One observes from Table 2 that for ^{137}Ba the number of the states which are populated by Coulomb excitation is much smaller than for ^{135}Ba . This can be explained by the fact that most of the levels of ^{137}Ba have excitation energies higher than 1 MeV, thus the probability of their population through

* Ba samples were supplied by NDS-IAEA

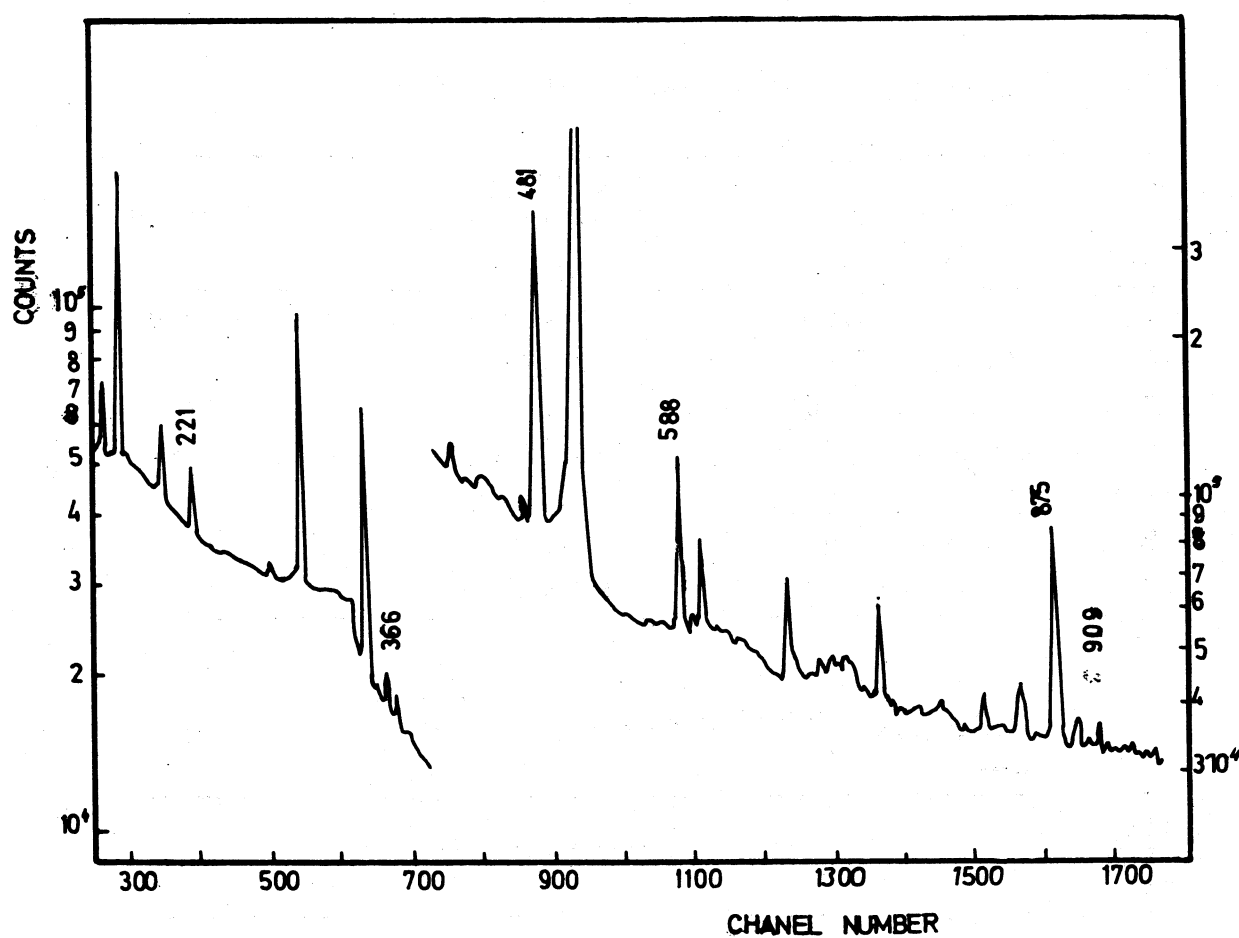


Fig.1. Gamma ray spectrum obtained from bombardment of ^{135}Ba with 11.5 Mev. alpha particles.

Coulomb excitation being much decreased.

- /1/. D.C. Palmer et al., J.Phys. 6, Nucl.Phys. 2(1976) 421
 /2/. D.G. Alkazarov et al., Izv.Akad.Nauk, URSS, Fizics Ser.,
 27(1963) 27

KEYWORDS: COULOMB EXCITATION,
 BARIUM ISOTOPES,
 CYCLOTRONS,
 ENERGY LEVELS,
 GAMMA SPECTRA.

Table 1. $B(E2)↑$ values in ^{135}Ba

Level energy (KeV)	This paper	$B(E2)↑(e^2 b^2)$ D.C. Palmer et al.	Alkazarov et al.
221.0	0.0096 ± 0.0007	0.0094	0.0078
480.5	0.165 ± 0.01	0.178	0.087
587.9	0.078 ± 0.006	0.077	0.072
855.5	≤ 0.004	≤ 0.0041	-
874.5	0.162 ± 0.01	0.164	0.18
909.0	0.022 ± 0.003	0.026	-
980	≤ 0.004	≤ 0.0032	-

Table 2. $B(E2)↑$ values in ^{137}Ba

Level energy (KeV)	$B(E2)↑(e^2 b^2)$
279.2	0.025 ± 0.002
1251.5	0.104 ± 0.014
1293	≤ 0.019

STATISTICAL MODEL CROSS SECTIONS FOR THE MEAN AND
STRONG ABSORPTION IN THE $A=90$ RANGE*

G. Vlăducă, C. Stan

Physics Department, Bucharest University

A. Berinde, V. Zoran

Institute of Physics and Nuclear Engineering, Bucharest

The traditional variants of the statistical model are consistent with the S-matrix general properties only for the channels with very weak absorption. Recently, Tepel, Hofmann and Weidenmüller (THW) /1/, extended the statistical model for the mean and strong absorption, but this was not used in the current calculation.

The inelastic cross sections $^{89}\text{Y}(n,n')$ for the first nine excited states in the incident neutron energy range 2-4 MeV, the cross sections $^{93}\text{Nb}(n,n')$ for the first seven excited states at the incident neutron energies 0-3.5 MeV, and the differential inelastic cross sections at the neutron energy $E_n = 3.02$ MeV are calculated in this paper. The cross section $^{93}\text{Nb}(n,n')$ on the seven levels are shown in Fig. 1. The cross section of the $^{89}\text{Y}(p,n)^{89}\text{Zr}$ reaction generated by the THW model, shown in Fig. 2, fits very well the experimental data. The total cross sections of ^{89}Y and ^{93}Nb for the incident neutron energy 1.5 - 8.0 MeV as well as the differential elastic cross sections of ^{89}Y at $E_n = 5.50, 6.44, 7.66$ MeV and for ^{93}Nb at $E_n = 1.5, 2.0, 2.5, 3.0, 6.0, 7.0, 7.5$ MeV have been calculated.

In the calculation the optical parameter set determined by Finckh et al. /5/ for the mass region $A \approx 90$ from the analysis of the $^{91}\text{Zr}(p,n)^{91}\text{Nb}$ reaction via isobaric analogs resonances was used for neutrons.

The Johnson et al. /4/ parameters were used for the protons. The calculations were performed with GIGMF Code /6/.

The general agreement between the cross sections calculated with the THW model and the whole analysed experimental data allowed to get some spectroscopic information and led to the following remarks:

The optical model neutron parameters obtained by Finckh et al., for $A \approx 90$ are valid up to an incident neutron energy

Fig.1. The $^{93}\text{Nb}(n,n')$ cross section for the seven levels calculated with the THW model (solid line) and with the Hauser Feshbach statistical model (dotted line). The experimental data are from: [2] (empty circles), [3] (full circles).

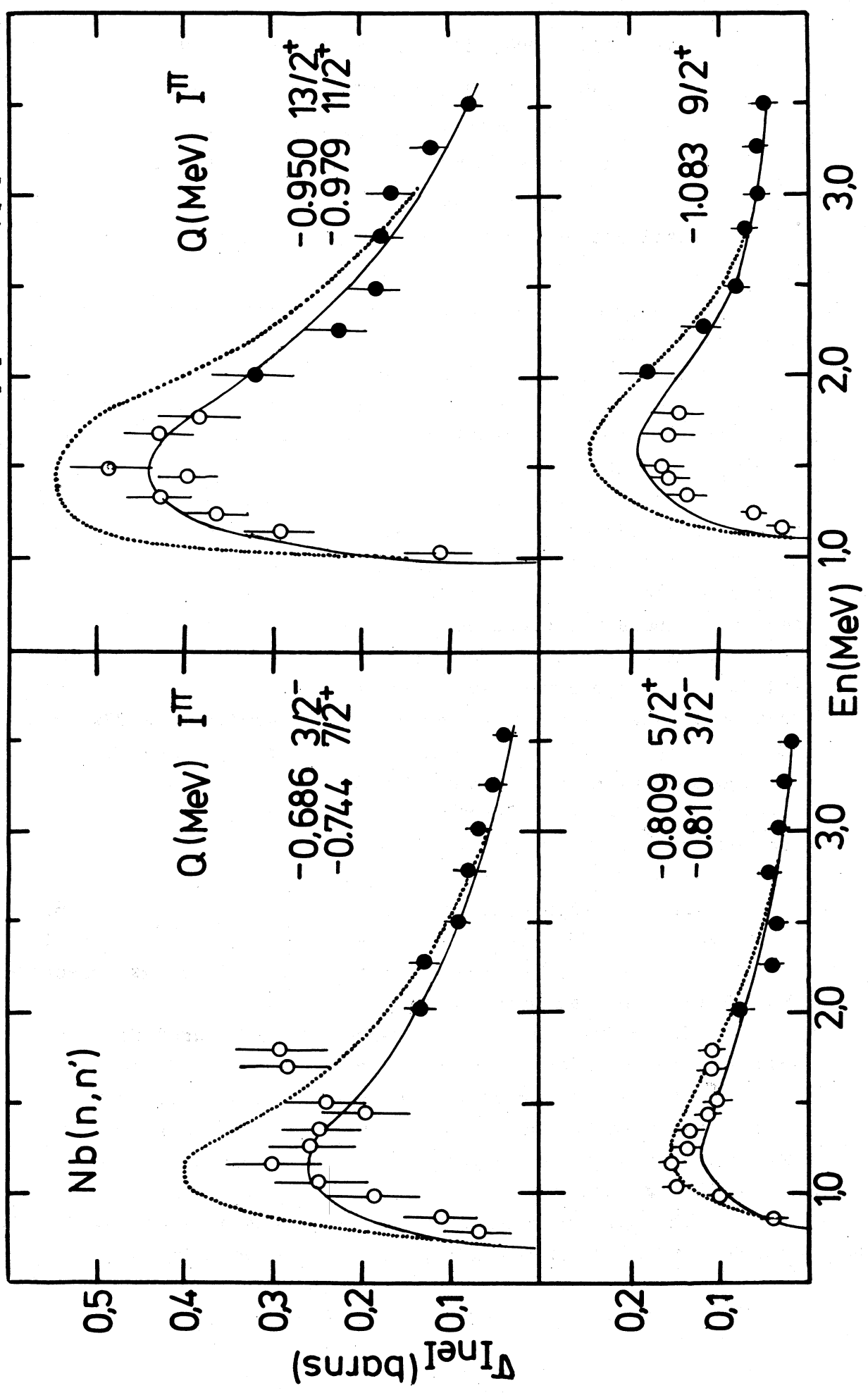
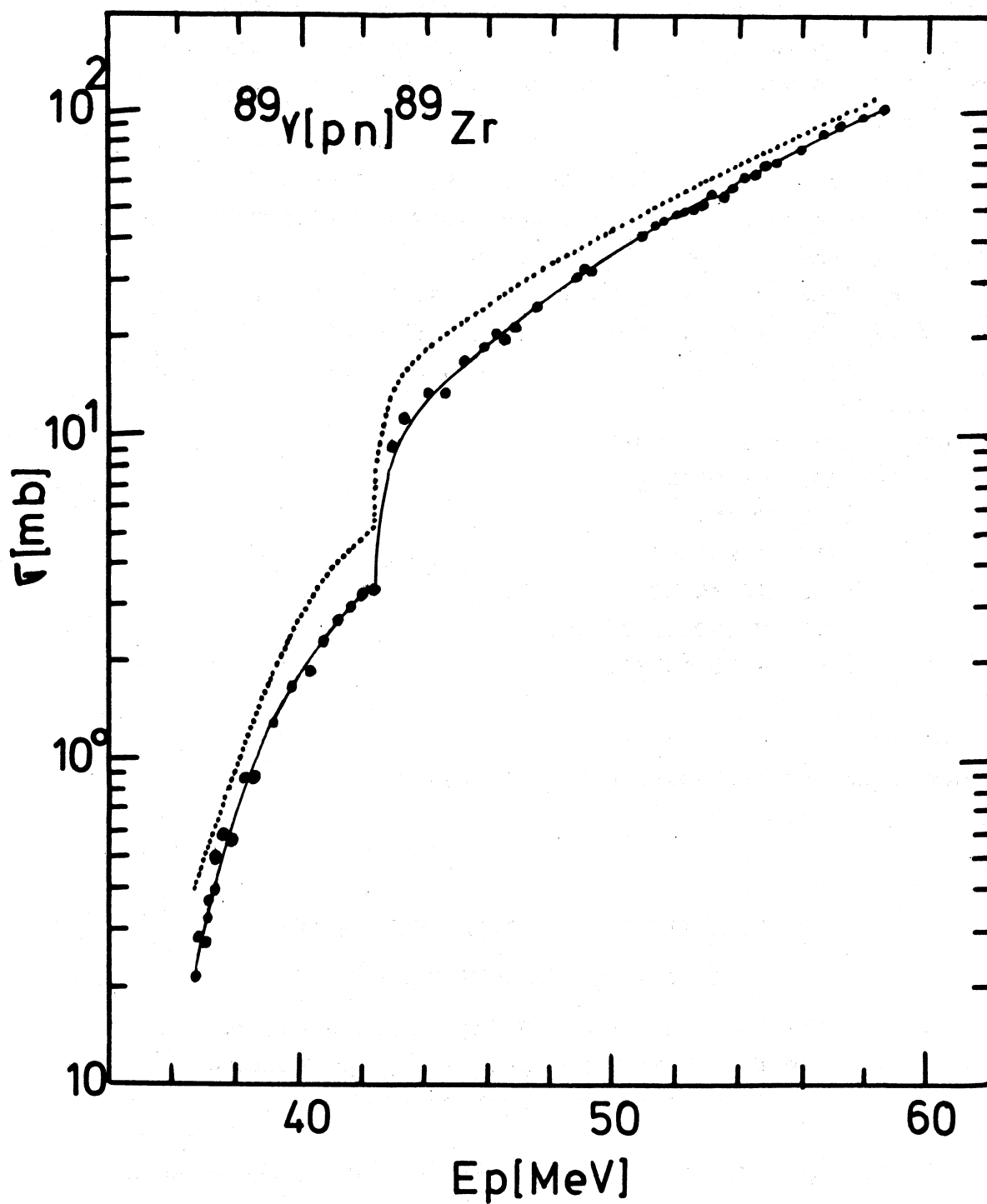


Fig.2. The cross section of the $^{89}\text{Y}(p,n)^{89}\text{Zr}$ reaction calculated with the THW model (solid line) and the Hauser-Feschbach statistical model (dotted line). The experimental data are from the paper [4].



$E_n \approx 8.0$ MeV, hence for an energy range larger than that, for which they were initially proposed. These parameters together with the proton ones of the Johnson et al. are appropriate to generate the nucleon interaction cross sections with nuclei in the $A = 90$ range.

The THW statistic model is superior to the traditional statistical models because of its possibilities to describe the mean and strong absorption processes, without breaking the S - matrix general properties, its independence of arbitrary parameters, as well as for its convenience and increased calculation speed.

- /1/. J.W. Tepel et al., Phys.Lett. 49B, (1974), 1
- /2/. V.C. Rogers et al., Nucl.Phys. A142 (1970), 100
- /3/. E. Almen-Ramström, AE-503 (1975)
- /4/. C.H. Johnson et al., Nucl.Phys., A107 (1969) 21
- /5/. E. Finckh et al., Phys.Rev., C1 (1970) 700
- /6/. G. Vlăduță et al., Preprint IPNE, NP-1-1978

KEYWORDS: STATISTICAL MODEL,
CROSS SECTIONS,
ABSORPTION,
OPTICAL MODELS,
ISOBARIC ANALOGS,
YTTRIUM ISOTOPES,
NIOBIUM ISOTOPES.

* Submitted for publication to Z. Physik

ABSOLUTE YIELDS OF DELAYED GAMMA-RAYS
IN URANIUM PHOTOFISSION *

G. Baciú, D. Catană, V. Gălățanu, M. Grecescu
Institute for Physics and Technology of Radiation
Instruments - Bucharest

The photofission reaction and the subsequent observation of the fission products by high-resolution gamma-ray spec-

troscopy may be employed for the development of an instrumental analytical method for the determination of fissile elements.

The gamma-ray spectra were recorded with a 40 cm^3 Ge(Li) detector and a 4096 channel analyzer. The processing of the gamma-ray spectra was performed with an adapted version of the SAMPO program.

The dependence of the gamma-ray yields on the degree of enrichment in ^{235}U was investigated using a set of enriched targets kindly provided by the IAEA-Vienna in the frame of the Targets and Samples Programme.

We have determined the yield of gamma-rays with energies between 228.16 KeV and 2972.0 KeV belonging to 19 photo-fission products ($87 \leq A \leq 143$) with half-lives from 14 m to 78.2 h.

The yields exhibit a linear dependence on the concentration of ^{235}U .

KEYWORDS: PHOTOFISSION,
GAMMA SPECTROSCOPY,
DATA PROCESSING,
FISSION PRODUCTS,
URANIUM 235,
DELAYED GAMMA RADIATION.

* U targets have been supplied by NDS - IAEA.

A SHORT-LIFE ISOMERIC STATE IN ^{121}Te
M.Ionescu-Bujor, A.Iordăchescu, E.A.Ivanov, D.Ploștinaru
Institute of Physics and Nuclear Engineering, Bucharest

The isomeric states populated in nuclear reactions were intensively studied in the last years. Usually these experiments were performed using the pulsed beam of an accelerator and the lifetime range depends on the used accelerator characteristics. From this point of view, The I.P.N.E. U-120 cyclotron, with its pulse systems is practically unlimited, the lifetime from a few nanoseconds up can be made evident. These facilities were intensively used in the isomeric states and hyperfine interaction studies.

The study of a new short life isomeric state in ^{121}Te is presented in this paper.

The state was excited on isotopic targets by nuclear reactions: $^{118}\text{Sn}(\alpha, n)$ and $^{121}\text{Sb}(d, 2n)$ with 24 MeV α particle and 12 MeV deuteron pulsed beams. The gamma radiation detection was performed with an intrinsic Ge detector and thin NaI(Tl) crystals. The level scheme study was performed by power gamma spectra measurements between irradiation pulses and only during the beam pulse. The gyromagnetic ratio of the isomeric state was measured on a liquid metallic ^{118}Sn target by the perturbed angular distribution method in the external magnetic field.

The analysis of the obtained analysis shows that the new isomeric state in ^{121}Te has a half-life of $T_{1/2} = 81.6$ (2) nsec, and by its decay the gamma rays of 212,4 (1) and 231,2 (1) KeV are emitted, the last one being the isomeric transition

The 212 KeV radiation corresponds to the transition between $\frac{3}{2}^+$ and $\frac{1}{2}^+$ known levels in ^{121}Te /1/ and it is a M1 - E2 mixture /2/. The gyromagnetic ratio experimental value $g = + 0,208$ (2) of the new isomeric state shows that the isomeric level is a neutron state $g_{7/2}$. To determine the internal conversion coefficient of the isomeric transition and hence the isomeric level spin and parity, the two gamma rays productivity measurements were performed, using the $^{118}\text{Sn}(\alpha, n)$ reaction. But, to obtain the isomeric transition multipolarity from these measurements is a difficult task due to the different values of the two gamma transition anisotropies and it is studied at present.

/1/. E.H. Spejewski et al., Nucl.Phys. A146 (1970) 182

/2/. A. Mäkelä et al., Ark.Fys., 37 (1969) 585

KEYWORDS: ISOMERIC NUCLEI,
TELLURIUM 121,
PULSE TECHNIQUES.

LOW ENERGY LEVELS IN ^{166}Ho

T. Bădică, C. Ciortea, A. Petrovici, I. Popescu
Institute of Physics and Nuclear Engineering, Bucharest

The odd-odd deformed nuclei are very interesting because their structure supplies the only possibility to get information about the residual n-p interaction; they can give information about Coriolis interaction, too.

Some levels of the ^{166}Ho were investigated by a few methods, but the magnetic moments had not been measured.

The aim of this paper is to study the low energy gamma spectrum, the directional angular correlation 28.23 - 54.24 MeV, and the magnetic moment of the 54.24 level by integral perturbed angular correlations in ^{166}Ho using thin detectors with high resolution (ELSCINT Ge(Li)) ($100\text{ mm}^2 \times 3\text{ mm}$) and ORTEC Ge ($100\text{ mm}^2 \times 7\text{ mm}$) with resolution at 6.5 KeV of 450 eV and 200 eV respectively).

The ^{166}Dy sources was made by 10 hours irradiations with thermal neutrons on DyO_3 enriched in ^{164}Dy (87.5%) by the successive capture reactions $^{164}\text{Dy}(n,\gamma)^{165}\text{Dy}(n,\gamma)^{166}\text{Dy}$.

The $\gamma - \gamma$ coincidence spectra were recorded with a slow-fast coincidence set-up ($Z = 18\text{ s}$) and a 4096 channel analyser; an automatic device for the angular correlation was used. The relative γ ray intensities with 20-85 KeV energy from the ^{166}Dy decay were determinated:

$$I_{28.23\text{ KeV}} : I_{54.24\text{ KeV}} : I_{82.47\text{ KeV}} = 8.2 \pm 0.6 : 5.9 \pm 0.9 : 100.$$

These intensities agree with the corresponding transitions multipolarities obtained from the internal conversion measurements. The directional angular correlations of the gamma cascade 28.23 - 54.24 KeV recording the coincidence spectra at 90° , 135° and 180° with the window on the range 53.5 - 55.0 KeV were measured. The angular correlation coefficient values we obtained for this cascade $A_2 = -0.242 \pm 0.015$ and $A_4 = 0.031$ are in good agreement with the theoretical ones, calculated taking into account the M1 and E2 character for gamma transi-

tions of 28.23 KeV and 54.24 KeV respectively, and the spin sequence for this cascade $1^- - 2^2 - 0^-$. The magnetic moment of the 54.24 KeV level was determined by IPAC measurements in the external magnetic field on the same gamma cascade. The obtained value of the magnetic moment is $\mu = (0.068 \pm 0.010) \mu_N$.

The low energy levels $2^-(54.24 \text{ KeV})$ and $1^-(82.47 \text{ KeV})$ in ^{166}Ho were assigned as rotational states built up on the ground state 0^- for which the configuration $\{p[532]\uparrow - n[633]\uparrow\}$ was proposed.

Motz et al. /1/ successfully explained the experimental energy spectrum taking into account the Coriolis interaction and the residual n-p interaction. Assuming only the Coriolis interaction (as in the present case the residual n-p interaction does not make changes) we obtained the best agreement between the experimental and theoretical value of the magnetic moment for the $2^-(54.24 \text{ KeV})$ ^{166}Ho level using the wave function:

$$|54.24 \text{ KeV}\rangle = \alpha \left\{ n \frac{7^+}{2} [633] - p \frac{7^-}{2} [532] \right\} I=2^-, k=0^+ \\ + \beta \left\{ n \frac{7^+}{2} [633] - p \frac{5^-}{2} [532] \right\} I=2^-, k=1$$

with $\alpha^2 = 0.63$ and $\beta^2 = 0.37$.

The obtained magnetic moment value is $\mu = 0.07 \mu_N$.

As other theoretical assumptions are not excluded, another experimental data would confirm the proposed mixture.

/1/. H.T. Motz et al., Phys.Rev. 155 (1967) 1265

KEYWORDS : ENERGY LEVELS,
HOLMIUM 166,
RESIDUAL INTERACTIONS,
GAMMA SPECTRA,
COINCIDENCE SPECTROMETRY,
MAGNETIC MOMENTS,
PERTURBED ANGULAR CORRELATION.

FISSION BARRIERS FOR THE ACTINIDE NEUTRON-DEFICIENT
NUCLEI

D. Galeriu, M. Marinescu
Institute of Physics and Nuclear Engineering, Bucharest

The fission process delayed because of the β decay and heavy ion reactions leads to the population of some neutron - deficient nuclei, most of them artificially created and little experimental and theoretical investigated.

The experimental results interpretation needs a theoretical study of the deformation energy and of the fission dynamics barriers for the neutron-deficient actinides, using a shell model with two centers.

The model parameter extrapolation is performed taking into account the nucleonic compositions of the considered nuclei and the resulting systematic error size are discussed.

The dynamic and static characteristics of the considered nuclei and their influence on the quantities involved in nuclear reactions are discussed.

KEYWORDS : ACTINIDES,
FISSION BARRIER,
NEUTRON-DEFICIENT ISOTOPES.

A NEUTRON CROSS SECTION MEASUREMENT METHOD AT

VERY LOW ENERGIES IN THE RANGE 10^{-3} - 10^{-6} eV

I. Berceanu, C. Borcea, I. Brîncuși, A. Buță, S. Dobrescu,
C. Grama, I. Lazăr, I. Mihai, M. Petrașcu, M. Petrovici,
V. Simion

Institute of Physics and Nuclear Engineering, Bucharest

The neutron cross section knowledge, essentially the very low energy fission cross sections, are very interesting. As it is known, to explain the energy dependence of these cross sections in thermal range it is necessary to admitt the existence of the negative resonance /1/ closed to the neutron binding energy. The presence of such resonances would have the direct results of essential changing of the $1/v$ behaviour of the cross section at very low neutron energy. The measurements in this range are extremely difficult because of the relative small neutron number in the spectrum. In a previous work the fission cross sections up to 7 MeV energy were measured using a quartz crystal in neutron beam and a thermal neutron chopper, essentially reducing the background due to the epithermal neutrons /2/.

The method presented here consists of the disposal of the targets on a rotating disk tangentially seen by a collimated neutron beam. As a base to perform this method the $\emptyset = 40$ cm chopper is used with a speed ^{-up/}to 14000 rot/min, which permits a tangential speed up to 300 m/sec. As a rule, the neutron cross sections up to 10^{-6} eV energies can be measured, using a previously prepared neutron beam (mechanical monochromatism and filtration) for the 10^{-13} Å range which corresponds to a speed of 300-400 m/s.

Thus, the measurements equivalent to those in the ultra cold neutron range, but with much higher intensities are approachable.

In this paper, the aspects regarding the resolution and the counting rate expected within this method are analysed.

- /1/. E. Vogt, Phys.Rev., 118 (1960) 724
- /2/. N. Grama et al., Rev.Roum.Phys. no.7 (1967)

KEYWORDS: NEUTRON REACTION,
CROSS SECTIONS,
MEASURING METHODS,
MILI EV RANGE,
NEGATIVE ENERGY STATES.

DETERMINATION OF THE SPECIFIC HEAT AND DEBYE TEMPERATURE
FOR POLYCRYSTALLINE SOLIDS USING NEUTRON INELASTIC
SCATTERING

I. Pădureanu, S. Răpeanu, C. Crăciun, C. Rotărescu, M. Ion
Institute of Nuclear Power Reactors, Pitești

In this paper the specific heat and Debye temperature on the aluminium and bismuth are calculated. The calculations are performed by means of the frequency spectra obtained from inelastic scattering of the slow neutrons ($E_0 = 5$ meV). The experimental frequency spectra $g(\omega)$ are obtained on the basis of a method proposed by a group of Soviet physicists /1-3/. They show that $g(\omega)$ could be derived for coherent scatterers if one realizes an averaging over a large range of scattering angles. The quantities $\vartheta_D(T)$ and $C_V(T)$ were calculated from $g(\omega)$ in the temperature range (0-200°K). The comparison of the results with $\vartheta_D(T)$ and $C_V(T)$ obtained by other methods is satisfactory.

- /1/. U.M. Bredor et al., Soviet Phys.Solid.St. 9, 1 (1967)
- /2/. V.S. Oskotskij, Ibid. p.2.
- /3/. B.A. Kotov et al., Soviet Phys.Solid St., 9, 9(1968)

KEYWORDS: SPECIFIC HEAT,
DEBYE TEMPERATURE,
POLYCRYSTALS,
SLOW NEUTRONS,
INELASTIC SCATTERING.

STATUS AND ACCURACY OF EXPERIMENTAL NEUTRON
DATA FOR THE IMPORTANT ISOTOPES TO THE ^{232}Th - ^{233}U
FUEL CYCLE IN THE THERMAL AND RESONANCE RANGE *

G. Vasiliu, S. Mateescu, M. Ciodaru, O. Bujoreanu

Institute of Nuclear Power Reactors, Pitești

The status and accuracy of experimental neutron data for thermal and resonance range are analysed for Th-231, 232, 233, Pa-231, 232, 233 and U-232, 233, 234, using EXFOR library.

Some general information as spin and nuclear parity, the mode of decay, half-life, natural abundance, the energy of the first positive resonance, Q-value for the inelastic process, and the corresponding threshold energy are given.

The surveyed types of data namely, total, fission and absorption cross sections, resonance parameters, α and γ values, fission and absorption resonance integrals, total, prompt, and delayed average numbers of neutrons per fission, are analysed according to their availability in EXFOR library versus WRENDAs requirements.

It is to be pointed out that for Th-231, 233 and Pa-233 there are no experimental data available in thermal and resonance range.

* Rev. Paper No. B 3a - Second Advisory Group Meeting on
Transactinium Isotope Nuclear Data - Cadarache, France, May, 1979

KEYWORDS: NEUTRON REACTIONS,
THORIUM ISOTOPES,
URANIUM ISOTOPES,
NUCLEAR DATA COLLECTIONS,
PROTACTINIUM ISOTOPES,
EV RANGE,
KEV RANGE,
ACCURACY.

SCATLAW: A CODE OF SCATTERING LAW AND CROSS SECTIONS
CALCULATION FOR LIQUIDS AND SOLIDS

I. Pădureanu, S. Răpeanu, Gh. Rotărescu, C. Crăciun

Institute of Nuclear Power Reactors, Pitești

This paper presents a code for calculation of the scattering law $S(Q, \omega)$, differential and double differential cross sections and scattering kernels in the energy range $E(0 - 683 \text{ meV})$ and wave vector transfer $Q(0 - 40 \text{ \AA}^{-1})$. The code can be used both for solids and liquids which are coherent or incoherent scatterers. For liquids, the calculations are based on the most recent theoretical models involving the correlation functions and generalized field approach. The phonon expansion model and the free gas model are also analysed in terms of frequency spectra obtained from inelastic neutron scattering using time-of-flight technique. Several results on liquid sodium at $T=233^\circ\text{C}$ and on liquid bismuth at $T=286^\circ\text{C}$ and $T=402^\circ\text{C}$ are presented.

KEYWORDS: CROSS SECTIONS,
COMPUTER CODES,
PHONONS,
NEUTRONS,
INELASTIC SCATTERING,
SODIUM,
BISMUTH.

THE ANALYSIS OF THE $^{59}\text{Co}(n,p)^{59}\text{Fe}$ AND $^{54}\text{Fe}(n,\alpha)^{51}\text{Cr}$
CROSS SECTIONS FOR THEIR USE IN REACTOR DOSIMETRY*

S. Mateescu, G. Vasiliu

Institute of Nuclear Power Reactors, Pitești

Based on experimental differential and integral data, as well as on integral computed data, after renormalization and evaluation of experimental points, the $^{59}\text{Co}(n,p)^{59}\text{Fe}$ and $^{54}\text{Fe}(n,\alpha)^{51}\text{Cr}$ cross sections, have been carefully analysed.

*AG/160-4 - Proceedings of the Advisory Group Meeting on Nuclear Data for Reactor Dosimetry, Vienna, Nov. 1978, (INDC(NDS)-103/M)

The consistency of newest differential experimental data for $^{59}\text{Co}(n,p)$ with the recommended average cross section value, and the discrepance between the same data type for $^{54}\text{Fe}(n,\infty)$ cross section, are pointed out. New experimental differential and integral data, especially for the second reaction, are necessary for better estimation of these two excitation functions.

KEYWORDS: NEUTRON REACTIONS,
COBALT 59,
IRON 54,
DOSIMETRY,
COMPARATIVE EVALUATIONS.

EVALUATION OF THE ELASTIC ANGULAR DISTRIBUTION FOR
Th-232 BY THE OPTICAL MODEL. THE LEGENDRE COEFFICIENTS
CALCULATION

S. Mateescu, G. Vasiliu, S. Răpeanu
Institute of Nuclear Power Reactors, Pitești

The calculations of the neutron elastic scattering on Th-232 nucleus had been performed with the ELIESE-3 code for a few incident energies.

The results are compared with the experimental data as well as with the calculations performed with the JUPITOR code using coupled channel theory, taking into account the Th-232 nucleus deformation, using the same optical model parameter set.

The Legendre expansion coefficients of the angular distributions for the storage in an ENDF/B type library, as the maximum order of this expansion for each incident neutron energy were calculated by the SAD code as well.

KEYWORDS: ELASTIC SCATTERING,
ANGULAR DISTRIBUTION,
LEGENDRE POLYNOMIALS,
OPTICAL MODELS,
COMPUTER CODES.

NUCLEAR DATA EVALUATION FOR $^{232}\text{Th}^*$

G.Vasiliu, S.Mateescu, D.Gheorghe, M.Ciodaru, N.Drăgan,
O.Bujoreanu, C.Crăciun, L.Pintilie, M.Zaharcu, D.Popescu,
T.Stadnicov, V. Avrigeanu

Institute of Nuclear Power Reactors, Pitești

E. Bădescu

Institute of Physics and Nuclear Engineering, Bucharest

The main neutron nuclear data of interest for ^{232}Th for reactor calculations, have been evaluated in ENDF/B-IV format, on the energy range 10^{-5} eV - 20 MeV.

The file contains total, elastic, inelastic, radiative capture, fission, (n,2n), and (n,3n) cross sections.

In addition, the elastic angular distributions (Legendre coefficients) the average cosine of the scattering angle ($\bar{\mu}_L$), the average logarithmic energy decrement (ξ) for elastic scattering, the prompt, delayed and total average numbers of neutrons per fission, the decay data and the fission yields are included as well.

Breit-Wigner Single Level parameters for resolved resonances, optical coupled channel model and double humped fission model as well as evaporation model have been used in the analysis and evaluation process.

It is only (n,3n) cross section that is based exclusively on theoretical calculations.

EXFOR-data base has been extensively used.

The evaluated data set was checked against the format correctness and physical consistency.

The data are available upon request.

* Work performed under IAEA - INPR Contract 206/ /RB.

KEYWORDS: THORIUM 232,
NEUTRON REACTIONS,
NUCLEAR DATA COLLECTIONS,
CROSS SECTIONS,
ANGULAR DISTRIBUTION,
RESONANCE,
DATA PROCESSING.

NEUTRON DATA EVALUATION FOR ^{231}Pa

G.Vasiliu, N.Drăgan, S.Mateescu, M.Ciodaru, O.Bujoreanu,

S. Răpeanu

Institute of Nuclear Power Reactors, Pitești

An evaluation for ^{231}Pa regarding total, elastic, capture, fission, inelastic, nonelastic, (n,2n), (n,3n) cross sections, $\bar{\nu}$, and resolved resonance parameters was performed up to 18.5 MeV, using the experimental data and theoretical calculations.

Breit-Wigner resonance parameters have been evaluated and used for total, elastic, and capture cross section calculations up to 100 eV.

The total cross section between 100 eV and 2.14 KeV was evaluated from experimental data and above 2.14 KeV as sum of partial cross sections.

For elastic cross section above 0.01 MeV has been adopted the Drake's data /1/.

Double humped fission model and giant resonance model have been used for fission and capture cross sections and also for inelastic cross section evaluations up to 3 MeV.

The corresponding parameters have been obtained from Lynn's systematics.

The calculations have been performed using MASTER code, an improved version of FISINGA code.

The fission (n,2n) and (n,3n) cross sections above 3 MeV have been estimated using the evaporation model with STATMOD code.

The $\bar{\nu}$ data have been estimated based on Howerton's systematics, taking into account the multiple fission chances supplied by STATMOD code.

x

/1/. M.K. Drake, P.F. Nichols, GA-7462 (1967)

KEYWORDS: PROTACTINIUM 231,
NEUTRON REACTIONS,
NUCLEAR DATA COLLECTIONS,
CROSS SECTIONS,
RESONANCE,
COMPUTER CODES.

NEUTRON DATA EVALUATION FOR ^{232}Pa

N. Drăgan, O. Bujoreanu

Institute of Nuclear Power Reactors, Pitești

An attempt to evaluate some neutron nuclear data for ^{232}Pa has been performed using theoretical models in the absence of any experimental data between 0.01 MeV and 18 MeV.

MASTER code, based on double humped fission model and giant resonance model, has been used for fission and capture cross section evaluation and for inelastic cross section up to 3 MeV. The corresponding parameters have been obtained from Lynn's systematics.

Above 3 MeV, using STATMOD code based on evaporation model, the fission, (n,2n) from 5.5 MeV, and (n,3n) from 12 MeV have been computed.

Also, $\bar{\nu}$ data have been estimated based on Howerton's systematics, taking into account the multiple fission chances, supplied by STATMOD code.

KEYWORDS: PROTACTINIUM 232,
NEUTRON REACTIONS,
NUCLEAR DATA COLLECTIONS,
CROSS SECTIONS,
COMPUTER CODES.

THE MULTIGROUP PHOTON INTERACTION CROSS SECTION

CALCULATION

G. Vasiliu, L. Pintilieșcu, S. Mateescu

Institute of Nuclear Power Reactors, Pitești

To calculate the biological shielding of the nuclear reactors the multigroup absorption, scattering and pair production cross sections from the gamma rays interaction with the shielding materials have been computed for a number of isotopes.

To obtain these data the MUG code was implemented and the Livemore evaluated data library (UCRL-50400- Vol.6) was used.

The practical use of these data required the writing of a code to obtain unblocked data from the original tape having blocked data with constant blocking factor and variable length of the records, as well as to generate an input data library in a file format consistent with MUG code.

KEYWORDS: PHOTONUCLEAR REACTIONS,
NUCLEAR DATA COLLECTIONS,
COMPUTER CODES,
DATA PROCESSING.

THE MODIFIED VERSION OF MISSIONARY CODE TO
TRANSLATE THE EVALUATED DATA FROM THE ENDF/B
FORMAT TO UKNDL FORMAT

G. Vasiliu, S. Mateescu
Institute of Nuclear Power Reactors, Pitești

To implement the original version of the code on the IBM 370/135-IPNE Computer, the overlay structure has been used. Also, to save the running time and the memory requirements, the removal of the resonance cross section calculation from the resonance parameters was preferred. This calculation is done separately by the RESEND code.

As the original version needs 64 scratch files, changes were performed in 11 subroutines of the code and 6 new subroutines had been written to use only the 11 scratch files available at the IPNE Computer.

The identic test case was obtained in a CPU time of 5 minutes.

KEYWORDS: COMPUTER CODES,
NUCLEAR DATA COLLECTIONS,
DATA PROCESSING,
CROSS SECTIONS.

NUCLEAR DATA DETERMINATION OF THE PSEUDO-FISSION
PRODUCT BY CAPTURE SERIES METHOD

D.Popescu, M.Zaharcu

Institute of Nuclear Power Reactors, Pitești

Among other quantities, the macroscopic neutron absorption cross section of the fuel is needed in the cell codes. The fission products have a significant contribution to this cross section. To treat the fission products the pseudo-fission product concept was previously adopted. This is a fictitious element with such nuclear data that it replaces a number of fission product. In the present paper the absorption cross section and the fission yield of a pseudo-fission product which represents all the fission products, except for the 32 nuclides individually considered in the WIMS code, are calculated, using a new code PD1.

The code builds-up capture series and determines the capture cross section per initial nuclid for each head of fission product series in terms of the burn-up degree. Then, the total cross section of the pseudo-fission product is fitted with the function $f(\omega) = \gamma_p \sigma_p e^{-\sigma_p \omega}$, from which the yield (γ_p) and the absorption cross section (σ_p) of the pseudo-fission product are calculated at different ω burnup degrees.

KEYWORDS : FISSION PRODUCTS,
ABSORPTION,
DATA PROCESSING,
CROSS SECTIONS.

DETERMINATION OF INVENTORY FISSION PRODUCTS VERSUS
BURN-UP DEGREE WITH THE FISSPROD PROGRAMME

M.Zaharcu, D.Popescu, G.Vasiliu, L.Pintilieșcu

Institute of Nuclear Power Reactors, Pitești

The nuclear fuel burn-up generates over 800 fission products. The knowledge of their accumulation in the reactor is important especially for their influence on the neutron balance.

In the last time great efforts had been done experimentally and theoretically, both for the more accurate knowledge of the nuclear data of the fission products and for the determination of the accumulated quantities after irradiation.

The FISSPROD code is one of the best programmes dedicated to this purpose. This one has been implemented on the IBM-370/135 - IPNE Computer.

The total accumulation of the fission products per element was calculated using different burn-up steps. The analysis of the obtained curves enables the selection of information on the saturation of different fission products.

KEYWORDS: FISSION PRODUCTS,
COMPUTER CODES,
DATA PROCESSING.

NUCLEAR DATA NEEDS FOR TOKAMAK FUSION REACTORS

G. Vasiliu, V. Avriganu, S. Mateescu
Institute of Nuclear Power Reactors, Pitești

The status of different neutron nuclear data types, as well as of photon production and photon interaction data, from the point of view of TOKAMAK fusion reactor needs, is analysed.

The following data types are taken into account: reaction cross sections, reaction Q values, angular and energy distributions of secondary particles, γ -multiplicities for elastic and inelastic scattering, reactions emitting neutrons and charged particles, radiative capture, etc., for neutron interactions, and coherent and incoherent scattering, photo-electric effect, pair-production, as well as photo-nuclear reaction data, etc., for photon interaction data.

The data needs are analysed from the point of view of the main effects produced in different regions of the TOKAMAK reactor (plasma, first wall, blanket, magnet, shielding, etc.).

KEYWORDS: TOKAMAK DEVICES,
NUCLEAR DATA COLLECTIONS,
NEUTRON REACTIONS,
PHOTONUCLEAR REACTIONS,
PAIR PRODUCTION.

ADJUSTMENT - REEVALUATION COMPARISON ON ABBN-64

NUCLEAR DATA SET

V. Cuculeanu, P. Ilie, D. Mocioiu

Institute of Nuclear Power Reactors, Pitesti

The purpose of the present work is to compare the results obtained by a nuclear data adjustment procedure based on "maximum likelihood principle" with those based on microscopic data reevaluation. Taylor expansion of integral data around the known cross sections underlines the mathematical procedure.

Let M be a set of integral quantities:

$$Q_i = Q_i(\sigma_1, \sigma_2, \dots, \sigma_N) \quad (i = 1, 2, \dots, M)$$

and σ_j^0 ($j = 1, 2, \dots, N$) a set of nuclear parameters approximating the exact values " σ_j ". Then one can write:

$$Q_i = Q_i(\sigma_1^0, \sigma_2^0, \dots, \sigma_N^0) + \sum_{j=1}^N \left(\frac{\partial Q_i}{\partial \sigma_j} \right) \bigg|_{\sigma_j = \sigma_j^0} \cdot (\sigma_j - \sigma_j^0)$$

$$(i = 1, 2, \dots, M)$$

Defining:

$$Y_i = \sigma_j - \sigma_j^0$$

$$Y_{N+1} = \frac{Q_i - Q_i^{\text{calc}}}{Q_i^{\text{calc}}}; \quad Q_i^{\text{calc}} = Q_i(\sigma_1^0, \sigma_2^0, \dots, \sigma_N^0)$$

the problem is to determine the vector Y which gives rise to the minimum error between the calculated and the experimental integral data.

In order to perform nuclear data adjustment, ABBN-64 data set was used as well as the integral data obtained on the existing fast reactors with different compositions and sizes.

The published reevaluated cross sections are compared with those obtained by the adjustment procedure.

KEYWORDS: NUCLEAR DATA COLLECTIONS,
CROSS SECTIONS,
DATA PROCESSING,
MAXIMUM-LIKELIHOOD FIT,
COMPARATIVE EVALUATIONS.

A COMPARISON BETWEEN PRESEC-CAIN AND 1DX
PROGRAMMES FOR SELF-SHIELDED CROSS SECTION AND CRITICALITY
CALCULATIONS FOR FAST REACTORS

V. Cuculeanu, I. Iftode
Institute of Nuclear Power Reactors, Pitești

The PRESEC programme prepares the nuclear multigroup constants for fast reactors using self-shielding factor formalism.

The supplied data are taken by CAIN code, which calculates the neutron parameters of the fast reactor core in multigroup diffusion approximation.

The 1DX programme contains both the nuclear constant preparing subroutine and the neutron parameter calculation part.

The interpolation rules of the self-shielding factors as well as the methods for solving the diffusion equation are various.

The comparison for the existing fast reactors of different sizes and compositions, with uranium and plutonium fuel is made.

Moreover, the effect of the iteration in the scattering matrix on the neutron multiplication effective coefficient is estimated.

KEYWORDS: FAST REACTORS,
GROUP CONSTANTS,
SELF-SHIELDING,
CRITICALITY,
COMPUTER CODES.

ABSOLUTE GAMMA MEASUREMENTS BY HIGH RESOLUTION
Ge-Li SPECTROMETRY

I. Gârlea, C. Miron, F. Popa, G. Fodor
Institute of Nuclear Power Reactors, Pitești

The absolute efficiency of the Ge-Li crystal (Camberra type) of 100 cm^3 was determined by means of two standard sources:

CEN Saclay and Radiochemical Centre Amersham - England, and an Eu^{152} source from PTB - FRG.

The standardizations were performed in the energy range: 60 KeV - 1.4 MeV, for the source-crystal spacing of 5, 10, 25 and 50 cm.

The associated errors were determined taking into account the uncertainties of the absolute source activities and of the relative intensity of the used gamma rays.

The SAMPO code was used to fit the gamma peaks and to obtain the absolute efficiency.

KEYWORDS: Li-DRIFTED Ge DETECTORS,
GAMMA SPECTROSCOPY,
CALIBRATION STANDARDS,
COMPUTER CODES,
ERRORS.

ABSOLUTE FISSION RATE MEASUREMENTS BY DIELECTRIC
TRACK METHOD (SSTR)

I. Gârlea, C. Miron

Institute of Nuclear Power Reactors, Pitești

The results of the U-238 fission rate determination in the $\Sigma\Sigma$ -IRNE system, using the dielectric track method (SSTR) are presented.

The irradiated natural uranium and depleted uranium (160 ppm) samples together with Makrofol foils of 60 μm thickness were used in the middle of the $\Sigma\Sigma$ -IRNE system.

The irradiation and measurement corrections in order to find the absolute reaction rate are described. The measurements were performed with Quantimet 720 system. The results are compared with the absolute fission rates obtained in the measurements with NBS-USA and CEN-Saclay absolute fission chambers.

KEYWORDS: FISSION,
DIELECTRIC TRACK DETECTORS,
URANIUM 238,
CORRECTIONS,
COMPARATIVE EVALUATIONS.

INTEGRAL CROSS SECTIONS IN THE $\Sigma\Sigma$ SPECTRUM
FOR SOME REACTIONS USED IN REACTOR DOSIMETRY

I. Gârlea, C. Miron, F. Popa, M. Lupu
Institute of Nuclear Power Reactors, Pitești

The measured spectrum averaged cross sections for the following reactions: $\text{Fe}^{56}(\text{n,p})\text{Mn}^{56}$, $\text{Mn}^{55}(\text{n},\gamma)\text{Mn}^{56}$, $\text{Co}^{59}(\text{n},\alpha)\text{Mn}^{56}$, $\text{Cu}^{63}(\text{n},\gamma)\text{Cu}^{64}$, $\text{Cu}^{65}(\text{n,p})\text{Ni}^{65}$, as well as for the reactions: $\text{Co}^{59}(\text{n,p})\text{Fe}^{59}$, $\text{Co}^{59}(\text{n},\gamma)\text{Co}^{60}$, $\text{Co}^{59}(\text{n},2\text{n})\text{Co}^{58}$, $\text{Fe}^{54}(\text{n,p})\text{Mn}^{54}$, $\text{Ag}^{109}(\text{n},\gamma)\text{Ag}^{110\text{m}}$, the last ones being of interest to determine the integrated (thermal and fast) flux in the irradiation experiments and the shielding experimental schedules, are presented.

New improved values of the cross section for $\text{Ti}^{46}(\text{n,p})\text{Sc}^{46}$, $\text{Ti}^{47}(\text{n,p})\text{Sc}^{47}$, $\text{Ti}^{48}(\text{n,p})\text{Sc}^{48}$ reactions are also reported.

KEYWORDS: CROSS SECTIONS,
NEUTRON REACTIONS,
TITANIUM ISOTOPES,
IRON ISOTOPES,
MANGANESE ISOTOPES,
COBALT 59,
COPPER ISOTOPES,
SILVER 109.

IRNE TYPE PROTON RECOIL COUNTERS APPLICATION TO
THE NEUTRON SPECTRUM MEASUREMENT IN THE $\Sigma\Sigma$ IRNE

I. Gârlea, A. Thurzo, P. Ilie, M. Stancu, O. Răducu, F. Popa
Institute of Nuclear Power Reactors, Pitești.

Two types of proton recoil counters have been manufactured and tested in the laboratory:

- spherical counters of 30 mm diameter,
- cylindrical counters of various sizes.

The geometrical and functional characteristics are given.

These counters had been used to determine the fast neutron spectra in the $\Sigma\Sigma$ -IRNE system. The energy standardization methods, the spectrum measurement methods, the correction appli-

cation and the determination of the neutron spectra from the recorded proton recoil spectrum are described. The results are compared with the calculations done on this system of generation of the fast neutron spectra and with the measurements performed by other laboratories using the same method, in the $\Sigma\Sigma$ reference system.

KEYWORDS: PROTON RECOIL DETECTORS,
NEUTRON SPECTRA,
COMPARATIVE EVALUATIONS.

NEUTRON FLUX-SPECTRUM MEASUREMENT METHODS TO
START-UP THE TRIGA-IRNE REACTOR

I.Gârlea, C.Miron, A.Thurzo, N.Stănică, M.Lupu, M.Selariu,
F. Popa

Institute of Nuclear Power Reactors, Pitești

A method for the TRIGA reactor start-up is proposed.

The measurement ensemble to find the neutron flux-spectrum absolute value at the TRIGA-IRNE reactor irradiation channels is presented. The thermal spectrum shape by the spectral index method (relative to reference thermal spectrum in the 50 cm diameter cavity made in the thermal column of the VVRS-IFIN reactor) and the fast neutron spectrum shape in the 50 KeV - 2 MeV range (using proton recoil spectrometers) will be established.

To determine the neutron flux-spectrum absolute value the following are to be measured:

- the absolute fission rates (with miniature fission chambers, CEN-Saclay type),
- the absolute activation rates (by high resolution gamma spectrometry).

Starting from the determined spectral shape and using the measured values of the absolute reaction rates, by means of SAND II code, the neutron spectrum absolute value is determined.

KEYWORDS: NEUTRON SPECTRA,
MEASURING METHODS,
REACTOR CHANNELS,
NEUTRON FLUX,
TRIGA TYPE REACTORS.