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Annual Report on Nuclear Data in Romania 1977

Compiled by
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State Committee for Nuclear Energy

ANNUAL REPORT

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NOTE

This annual report contains the main nuclear data works performed during the year 1977 in the Institute of Nuclear Power Reactors, the Institute for Nuclear Physics and Engineering and the Institute for Physics and Technology of Radiation Apparata.

INTRODUCTION

The present report is a brief review on main nuclear data activities, carried out during 1977 in the Romanian Research Institutes involved in.

These activities performed are the followings:

- Evaluation of neutron nuclear data and data processing,
- Experimental measurements of basic nuclear data,
- Integral cross section measurements in ΣΣ-INPR assembly and multigroup cross section amelioration.

The first type of activity has been mainly focused on evaluation of some cross sections for heavy nuclei as Th-232 and U-233, and Doppler data processing. Multigroup processing of neutron data for reactor shielding and core calculation purposes has been made, as well. A sensitivity analysis of statistical model calculations versus partial radiative width values for some medium weight nuclei is also reported.

The second type of activity is concerned with (γ,p) cross section of ^{53}Cr measurement. Test measurements of a new method for absolute determination of thermal neutron fluxes are also reported.

The third type of activity is related to amelioration of nuclear data used in reactor dosimetry as well as nuclear data associated to structural materials, in ΣΣ type systems.

It is to be mentiones, that as in previous years, we have benefited of a permanent support of International Atomic Energy Agency, and especially of Nuclear Data Section, support which in 1977 have been enlarged and diversified.

The total and (n,γ) cross sections evaluation; multigroup constants and transfer matrixis of U-233

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

The total and (n,γ) cross sections for U-233 have been evaluated.

The references from which the experimental data had been obtained were briefly analysed, emphasizing the following aspects:

- the covered energy range, the number of experimental points, the energy-error, the corrections applied and the error analysis.

The (n,γ) evaluated data were verified comparing the resonance integrals computed with INTER program and the experimental ones, for different integration limits.

The calculations were performed using an 1/E spectrum, combined with a fission spectrum:

$$W(E) = \frac{4E}{\pi E_o^3} \cdot e^{-E/E_o} \qquad \text{where } E_o = 1{,}273 \text{ MeV}$$

The joint energy of these two spectra has been taken at 67,379 keV.

The resonance contributions from the Adler-Adler parameters were computed in advance with RESEND code, generating thus a point-wise file.

The elastic transfer matrix (P_3 is the highest order), as well as the (n,2n) and the inelastic transfer matrix, were also been computed.

Multigroup constants for reactor shielding

G. Vasiliu, V. Cuculeanu, S. Rapeanu, S. Mateescu,
G. Sindilaru
Institute of Nuclear Power Reactors

Multigroup constants for a certain concret containing the following elements were generated: H, O, Mg, Al, Si, K, Fe,

The evaluated data had been taken from the ENDL library.

The neutron flux has been calculated with the FLUX program, using the formula:

$$\Phi(E) = \frac{q(0)}{\xi(E)\ E\ \Sigma_t(E)} \exp[-\int_{E_j}^{E_{j-1}} \frac{\Sigma_c(E')}{\xi(E')\ \Sigma_t(E')} \cdot \frac{dE'}{E'}]$$

where Σ_t and Σ_c are the macroscopic total and capture cross sections of the concret and $\xi(E)$ depends on the macroscopic elastic,total inelastic, partial inelastic (on excited levels) cross sections and on atomic masses of all of the concret components.

The program FLUX, finally generates the averaging spectrum in 4000 energy mesh points in the range between 0,32 x 10^{-6} MeV and 0,736 MeV.

The multigroup cross sections themselves have been computed using this spectrum by code INTEND two groups.

Evaluation of υ, η, α, for U-233

O. Bujoreanu

Institute of Nuclear Power Reactors

For the average number of neutrons emited per fission an evaluation was made between 0 - 15 MeV. The evaluation includes an analysis of the experimental data, normalizations of all the data to the new standard value [υ_p^{SF} (cf.252) / 3.731 ± ± 0.003] and the fits of the experimental points.

For the quantities $\alpha = \sigma_{n\gamma}/\sigma_{nf}$ and $\eta = \upsilon/(1+\alpha)$ a comparison was made between the experimental curves [$\alpha_{exp}(E)$ and $\eta_{exp}(E)$] and the calculated ones [$\alpha_{calc}(E)$ and $\eta_{calc}(E)$]. To obtain $\alpha_{calc}(E)$ and $\eta_{calc}(E)$, the evaluated quantities υ^{eval} , $\sigma_{n\gamma}^{eval}$ and σ_{nf}^{eval} had been used.

Evaluation of the resonance parameters for Th-232

E. Badescu

Institute for Nuclear Physics and Engineering

M. Ciodaru, D. Gheorghe

Institute of Nuclear Power Reactors

The evaluation of total, elastic scattering and radiative capture cross sections of Th-232 in the resolved resonance region has been done. The Breit-Wigner Single Level parameters had been used for the cross section calculation. The Doppler broadened cross sections were calculated, using the experimental parameters at 300^{o}K, with the program ETRES. The calculated and the experimental cross sections had been compared.

The final parameters had been included in the evaluated microscopic nuclear data library, DANEM, file 2, section 151.

Evaluation of the resonance parameters for U-233

M. Ciodaru, D. Gheorghe
Institute of Nuclear Power Reactors

E. Badescu
Institute for Physics and Nuclear Engineering

The evaluation of the total fission and radiative capture cross sections has been done in the resolved resonance region: 0.79 - 60.0 eV.

As the interference level terms are important for U-233, the evaluation of the cross sections was done with the multilevel Adler-Adler formalism. The cross sections had been calculated with the program ADLER, using the Adler-Adler parameters selected from the literature, and compared with the experimental cross sections. For some resonances the Adler-Adler parameters had been modified to obtain a better fit of the calculated cross sections with the experimental ones. The final parameters had been included in the evaluated nuclear data library DANEM, file 2, section 151.

Doppler broadened cross-section calculations for U-233

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

The U-233 total, elastic, inelastic, (n,2n), (n,3n), fission, partial inelastic and (n,γ) Doppler broadened cross sections had been computed for the following temperatures: 300°K, 600°K, 1000°K, 1200°K, 2000°K, using the SIGMA1 program.

The resonance contributions to the total, elastic, capture and fission cross sections had been previously calculated from Adler-Adler parameters using the RESEND program.

The SIGMA1 program allows as input ENDF/B format data with a linear energy dependence. That's why, all the cross sections had been linearized, with an error of 1%, using the LINEAR code.

At one run, the SIGMA1 program computes for a single element at a single temperature, all the cross sections we are interested in.

The results are presented on graphs and listing (ENDF/B format).

The (n,2n), (n,3n) and (n,f) cross sections for U-233 and Th-232, in the fast energy range computed by the STATMOD program

N. Drăgan, L.Pintiliescu
Institute of Nuclear Power Reactors

The paper presents the neutron evaporation model and on its basis one can finally obtain the evaporation probabilities for two or three neutrons followed by gamma decay, and the evaporation probabilities of one or two neutrons followed by the residual nucleus fission.

The cross section of the reaction with a compound nucleus formation, has been obtained with a program for the neutron transmission coefficients, using parameters quoted in literature and based on the optical model.

The evaporation probability expressions, the optical model program for the transmission coefficients calculation together with other necessary quantities (neutron, gamma and fission widths) are contained in STATMOD program.

Choosing some parameters so that the calculated cross sections should simultaneous fit the experimental or the evaluated data, the program supplies the cross sections mentioned above for energy range between 5 and 20 MeV. The average accuracy of this method is of about 10 %.

Sensitivity analysis of statistical model calculations versus partial radiative width value $\overline{\Gamma}_\gamma(B_n)$

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Institute of Nuclear Power Reactors

The importance of the average partial radiative width at the neutron binding energies, $\overline{\Gamma}_\gamma(B_n)$, among the parameters needed in the statistical model calculations has many times been emphasized. However, a recent analysis of $^{27}Al(^{16}O,pn)^{41}Ca$ reaction[1] proved a slight dependence of the activation cross section on $\overline{\Gamma}_\gamma$ as long as $\overline{\Gamma}_\gamma \neq 0$. The same effect has been tested for $^{138}Ba(n,2n)^{135}Ba$ reaction.

The calculations were performed by means of the Hauser-Feshbach computer code STAPRE[2], on the IBM 370/135 Bucharest computer. An optical model routine was attached for transmission coefficients internal computing, to aid in problem calculation. Transmission coefficient data files, possible to use as input, may also be external generated.

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1) I.Dauk, K.P.Lieb and A.M.Kleinfeld, Nucl.Phys. A241, 170 (1975)

2) M.Uhl, Proc. IAEA Consultants Meeting on the use of nuclear theory in neutron nuclear data evaluation, Trieste 1975, IAEA-190, vol. II, 361 (1976)

The analysis was performed between 9 and 20 MeV incident energy for Γ_γ = 0.1 meV, 10 meV and 1000 meV. For cross sections greater than 55 % of σ_{non} a relative weak dependence of the activation cross section on the radiative width has been observed.

Otherwise, a charge in $\Gamma_\gamma(B_n)$ by one order of magnitude has modified the cross section by more than 10%.

The $^{53}Cr(\gamma,p)^{52}V$ cross section

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Institute for Physics and Technology of
Radiation Apparata

Today, much effort is devoted to the study of (γ, p) reactions, especially for medium nuclei which for $N \neq Z$.

In a continuing series of photonuclear experiments at the 30 MeV betatron the photoproton cross section of the $^{53}Cr(\gamma, p)^{52}V$ reaction was measured by activation method up to 27 MeV.

The ^{53}Cr sample used consisting of chemically pure chromium with natural isotopic abundance.

The efficient energy control and stabilisation (± 10 keV) system used allowed us to perform the unfolding of the yield curve in 100 keV intervals.

The bremsstrahlung beam was monitored by a thick - walled ion chamber of NBS type calibrated in absolute units.

Contribution from $^{52}Cr(n,p)V^{52}$ and $^{54}Cr(\gamma,np)$ were taken in account.

The yield curve has been analysed according to Cook's method using the Schiff bremsstrahlung spectrum.

The cross section data are presented in Fig. 1, the vertical bars are the errors due to the reproductibility of the points on the yield curve, the horizontal bars represent the resolution function for relevant peaks.

The integrated cross section between 14.4 MeV and 26.4 MeV has a value of 162 ± 26 mb MeV.

The isospin splitting of the dipole giant resonance is $E_{>} - E_{<} = 3.9$ MeV in agreement with the calculated one (3.96).

The value of 95 mb MeV of the integrated cross section covered by $E_{>}$ components lead to the conclusion that part of the contribution to the $E_{>}$ component is due to (γ,n) reactions.

Optical model parameters optimization to fit the elastic scattering cross section of fast neutrons on U-233

M. Avrigeanu
Institute of Nuclear Power Reactors

On the existing evaluated data of the elastic scattering of 15-, 12-, 10-, 8-, and 6 MeV neutrons on U-233, searches of optical model parameters have been made, using the Perey program.

The optical model parameter calculations is based on a χ^2 test, namely on the following expression minimization:

$$\chi^2 = \sum_i \left(\frac{\sigma_{exp}(\theta_i) - \sigma_{th}(\theta_i)}{\Delta\sigma_{exp}(\theta_i)}\right)^2$$

The optical potential used here is of Wood-Saxon type:

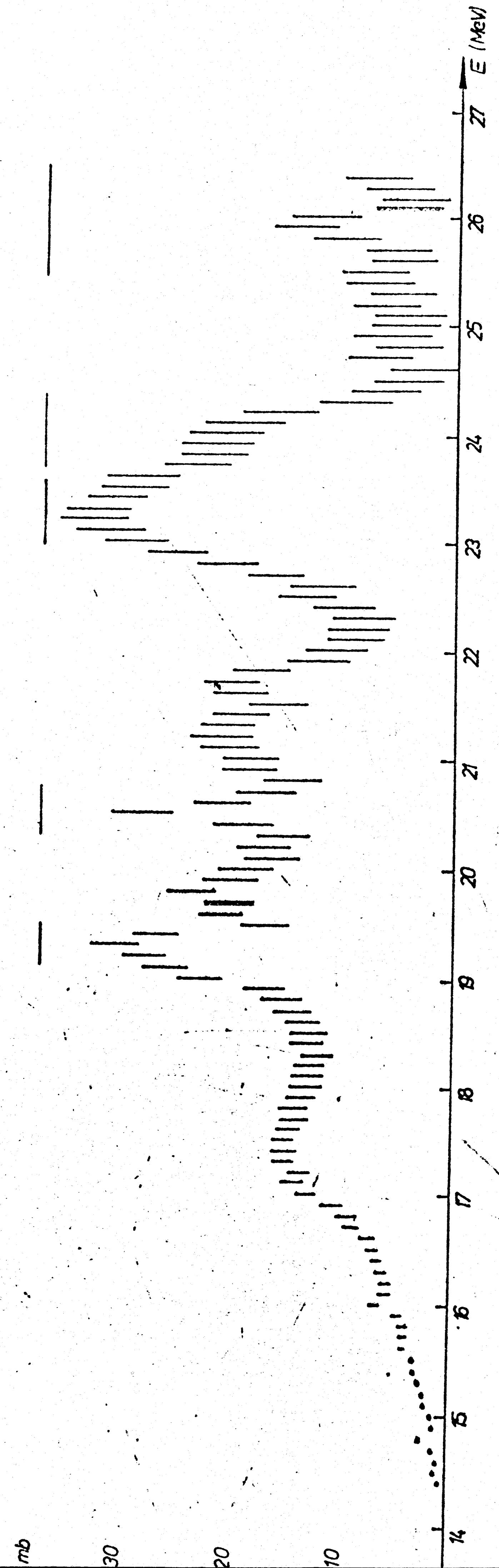

fig. 1

$$U(r) = - V f(r, R_R, A_R) - i4 A_D W_D \frac{d}{dr} f(r, R_D, A_D) -$$

$$- (\ell \cdot \sigma) V_{SO} (\frac{h}{2m_p \ell}) \frac{1}{r} \frac{d}{dr} f(r, R_{SO}, A_{SO})$$

where:

$$f(r, R_i, A_i) = \frac{1}{1 + e^{(r-R_i)/A_i}}$$

A set of optical model parameters can be considered the best one, when:

- for χ^2 one can obtain an accuracy of at least 1 %,
- the elastic scattering cross section, calculated with this set of parameters equals the evaluated one,
- the total cross section of the analysed process, calculated with the same set of parameters equals the evaluated one .

Test measurements of a new method for absolute determination of thermal neutron fluxes[x)]

C. Borcea, A.Buta, I.Brancus, I.Lazar, I.Mihai, M.Petrascu, M.Petrovici, V.Simion

Institute for Physics and Nuclear Engineering

A new method for absolute determination of neutron fluxes based on the $4\pi\alpha - \gamma$ coincidences resulted from the thermal neutron capture by a thin ^{10}B target was recently proposed [1)].

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x) Work supported by IAEA-Vienna under the contract no.1776/R/RB

1) M.Petrascu et al., Scientific Session of the Centr.Inst.Phys. (1976) - 51

The advantage of the 4π geometry comes from the elimination of the incertainity conected with the backscattered α particles. The method allows the determination of the detection efficiency ε_γ for the γ rays of 477.8 keV emitted at the neutron capture by the ^{10}B nuclei. The efficiency ε_γ is given by the relation:

$$\varepsilon_\gamma = \frac{N_C}{N_\alpha}$$

where N_C is the number of $\alpha - \gamma$ coincidences and N_α is the number of α particles detected by a impulse ionisation chamber working in the 4π geometry. A Ge(Li) detector of 71 cm^3 and 2.2 keV resolution for the energies of 660 keV was used for the γ ray detection. The $\alpha - \gamma$ conincidences were recorded by means of a time to pulse height converter.

The time resolution of the whole measuring system was found to be of about 100 ns. The efficiency ε_γ was determined by setting windows of various widths on the α peack corresponding to the γ line of 477.8 keV. The targets used in the measurement were $\sim$ 50 $\mu g/cm^2$ ^{10}B deposited by electrospray on a 15 $\mu g/cm^2$ carbon backings.

Preliminary results show the possibility to determine the efficiency ε_γ with an error less than 0.4 %. Implicitly, with this same error it is also determined the thermal neutron flux by choosing the ^{10}B target thick enough to stop the whole thermal spectrum.

Integral cross-section measurements in ΣΣ spectrum for some reactions used in reactor dosimetry

I. Garlea, C.Miron
Institute of Nuclear Power Reactors

ΣΣ - ITN system (under operation in Institute of Nuclear Power Reactors - Romania) has been used for the integral cross section determination:

- for the reactions which give short-life isotopes currently used in reactor dosimetry:
  $^{55}Mn(n,\gamma)$, $^{63}Cu(n,\gamma)$, $^{65}Cu(n,p)$, $^{56}Fe(n,p)$, $^{59}Co(n,\alpha)$
- for the following reactions which lead to long-life isotopes, used in spectral fluence measurements in the material testing and shielding programs:
  $^{59}Co(n,\gamma)$, $^{59}Co(n,2n)$, $^{54}Fe(n,p)$, $^{109}Ag(n,\gamma)$, $^{58}Fe(n,\gamma)$, $^{63}Cu(n,\alpha)$, $^{46}Ti(n,p)$, $^{47}Ti(n,p)$, $^{48}Ti(n,p)$.

Nickel multigroup cross-section amelioration by spherical transmission method

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Institute of Nuclear Power Reactors

There were used the following configurations (type ΣΣ) placed in the cavity hollowed in VVR-S reactor thermal column (cavity diameter = 50 cm):

^{nat}U driver dimensions

ϕ_{ext} = 305 mm and ϕ_{ext} = 305 mm
ϕ_{int} = 285 mm and ϕ_{int} = 245 mm

Ni shell dimensions

I	ϕ_{ext} = 285 mm	ϕ_{int} = 245 mm
II	ϕ_{ext} = 245 mm	ϕ_{int} = 185 mm
III	ϕ_{ext} = 185 mm	ϕ_{int} = 145 mm

The neutron spectra were determined by means of proton recoil spectrometers over the range 50 KeV - 1.5 MeV. There wer also determined the following reactions:

- fission reactions: $^{235}U(n,f)$, $^{238}U(n,f)$, $^{239}Pu(n,f)$, $^{237}Np(n,f)$, $^{232}Th(n,f)$
- activation reactions: $^{55}Mn(n,\gamma)$, $^{115}In(n,\gamma)$, $^{115}In(n,n')$, $^{197}Au(n,\gamma)$

The experimental data are used in FLUXPERT code, for ameliorations of multigroup cross sections.

These works are made under cooperation between our institute and CEN/SCK Mol Belgium.