COMITETUL DE STAT PENTRU ENERGIA NUCLEARA
INSTITUTUL DE FIZICA ATOMICA

ANNUAL REPORT

ON NUCLEAR DATA RESEARCH IN ROMANIA

during the year 1970

Compiled by

A. Berinde

BUCHAREST, 1971

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N O T E

This Annual Report contains information related to the field of the neutron nuclear data for reactors. The apparently two exceptions, namely the level density parameters and the photo neutron cross sections, are included in view of their possible use in neutron cross sections evaluation.

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

DYNAMICS STUDIES IN SOME HYDROGENOUS SUBSTANCES BY NEUTRON TRANSMISSION

S.Râpeanu, 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°K, 123°K, 78°K.

Table I. - The slope values

Substance \ Temperature	The slopes ($\Delta\sigma_s/\Delta\lambda_n$) b/Å - H		
	298°K	123°K	78°K
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.

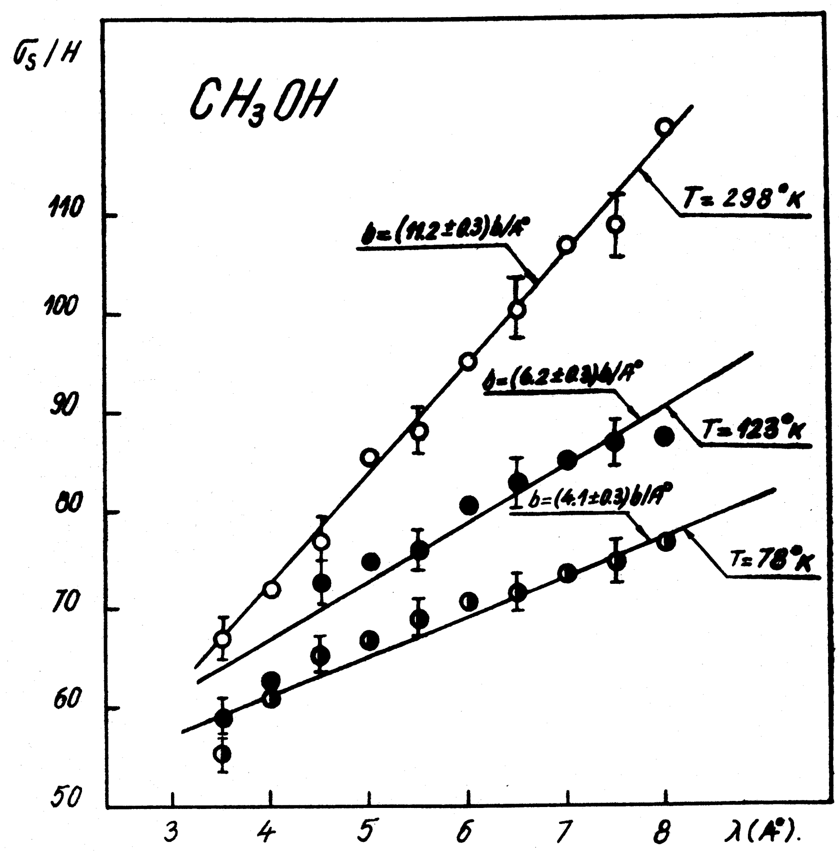

Fig. 1

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.

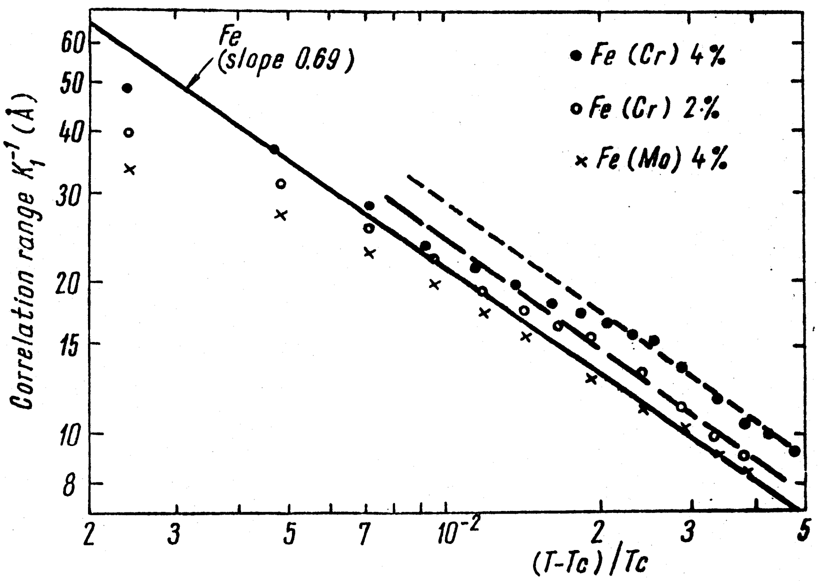

Fig. 1

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 keV 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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*Preprint IFA N.R.-33-1970

**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/ .

R e f e r e n c e s

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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

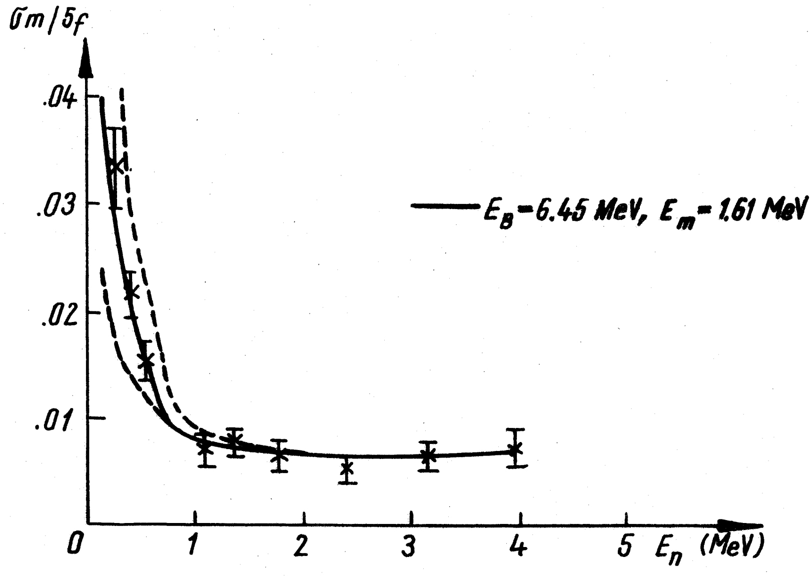

Fig. 1

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 com- pound 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 agre- ement 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

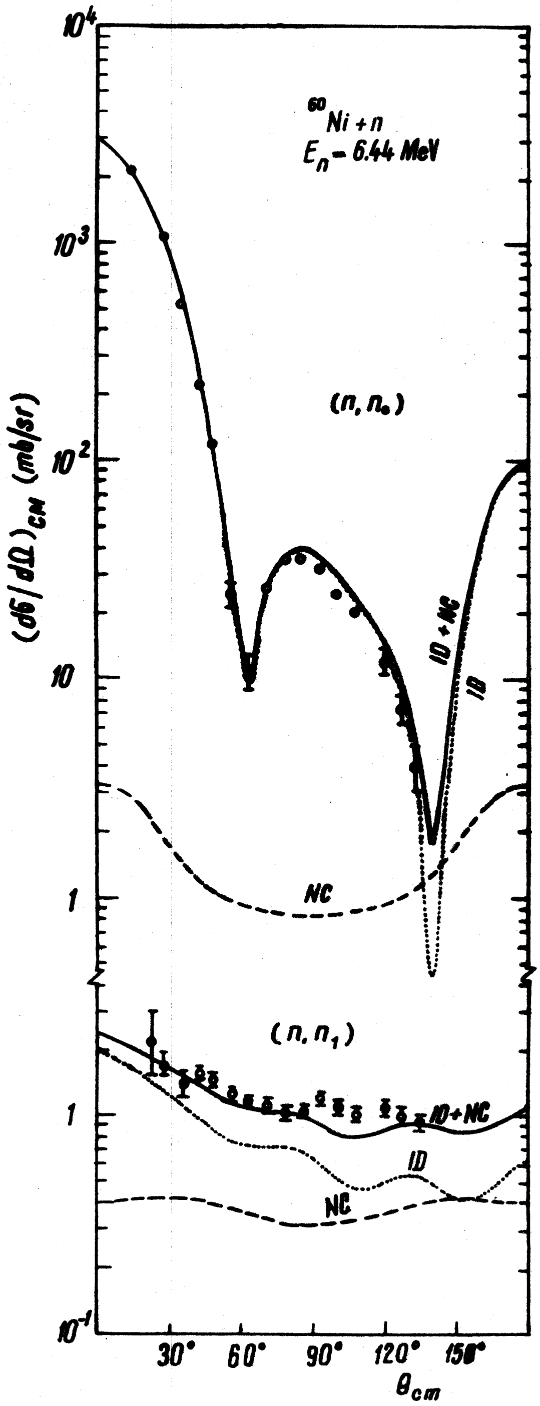

Fig. 1

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	$^{52}Cr(\alpha,n)$	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	$^{115}In(\alpha,n)$	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 brems - strahlung.

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:

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

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 /.

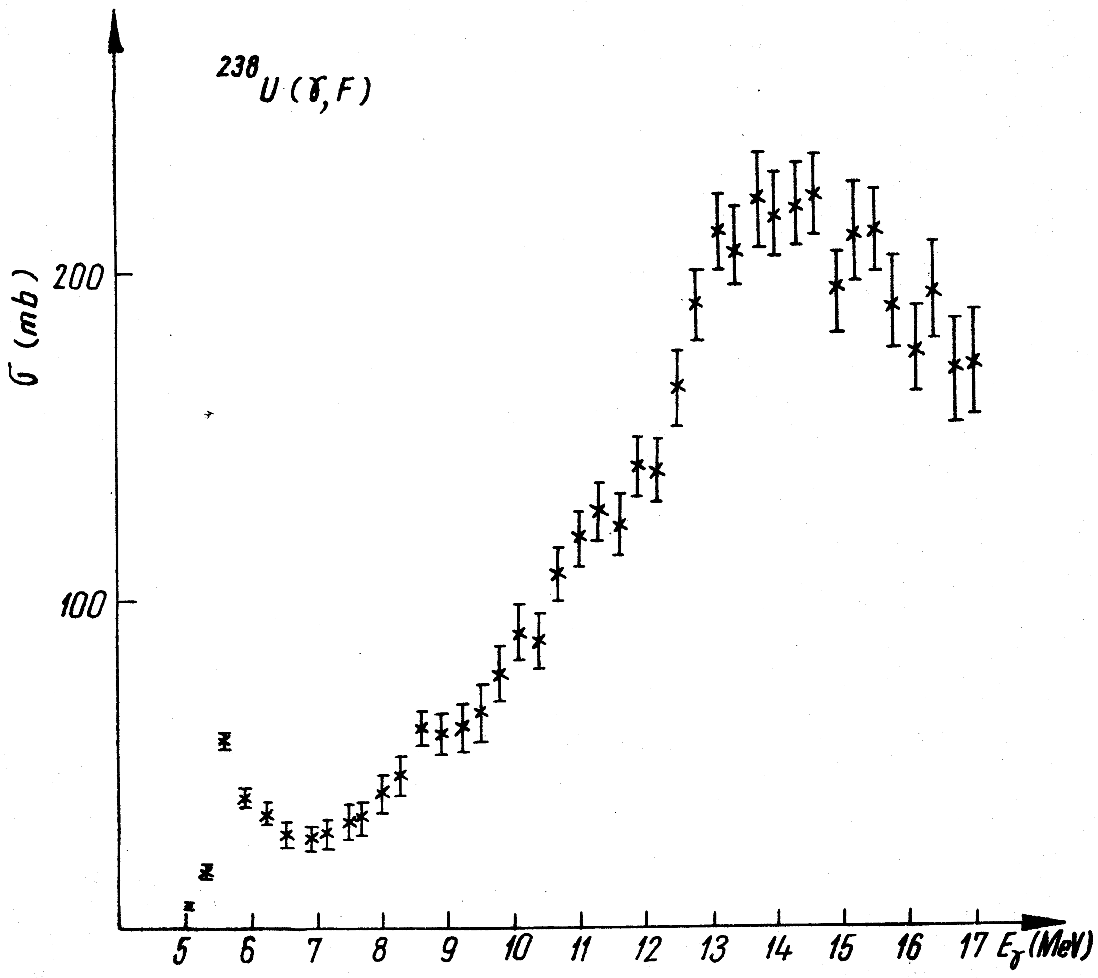

Fig. 1

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

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THE FINE STRUCTURE OF THE In(γ,Σn) 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 (γ, Σn) 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 (γ,Σn) 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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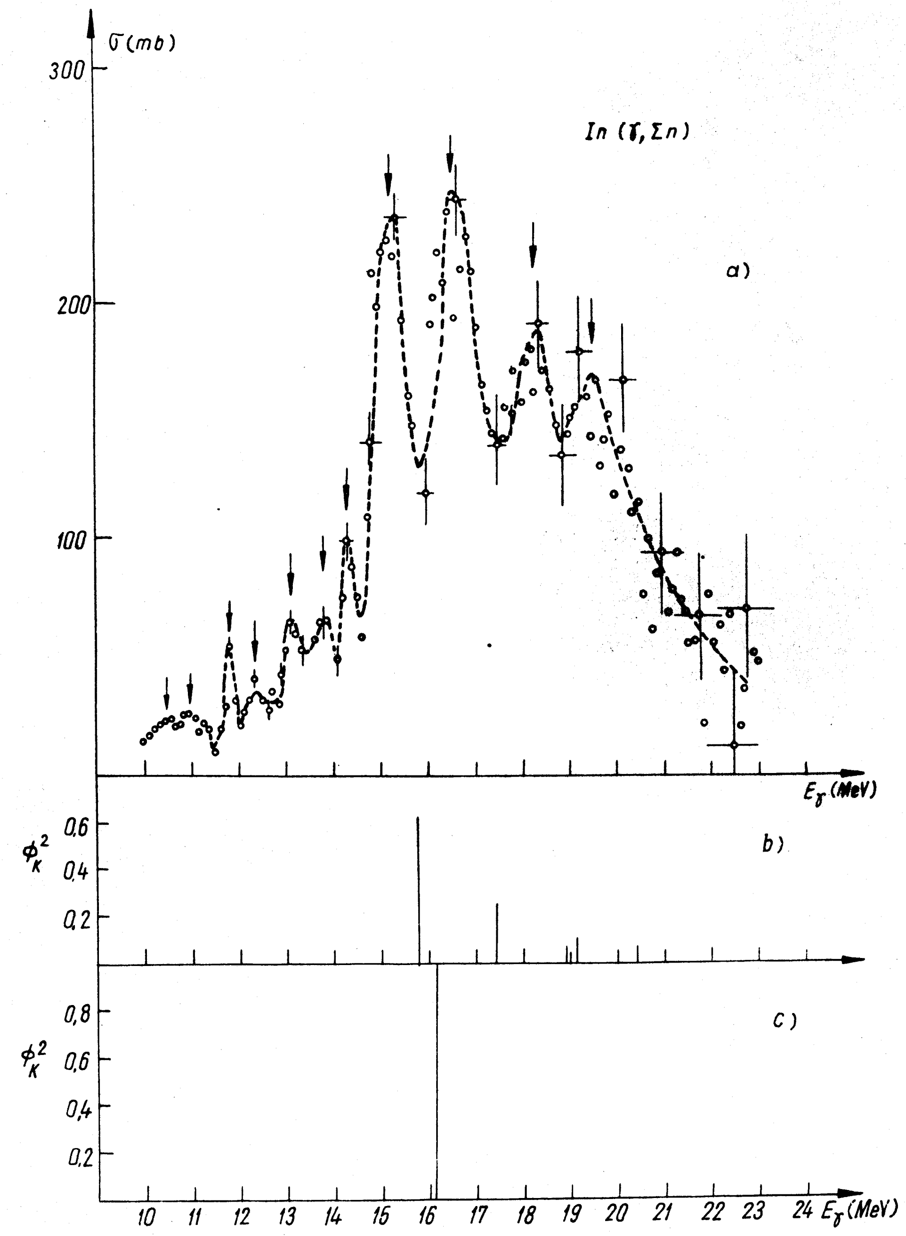

Fig. 1

a) Experimental cross section of In(γ,Σn) reaction;
b) Dipole strengths Φ_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