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Abstract

The $^{238}U(\gamma,n)^{237}U$ reaction cross section has been measured by activation at excitation energies from 6.07 to 9 MeV. The (γ,n) cross section thus obtained has shown the same structure of the photofission cross section for the same element what will imply in the same structure in the total photoabsorption cross section.

1. Introduction

The (γ,f) reaction at energies near threshold has been intensively investigated in recent years because of its theoretical implications. Particularly the ^{238}U photofission cross section has been measured by several authors due to the possibility of using gamma radiation with resolution of the order of KeV or even eV[1,2].

The structure observed[1,2,3] in this cross section measured even by us in a previous paper[4] led us to the study of the competition between photofission and photoneutron emission in function of the excitation energy[5].

For that we have measured the total photoneutron emission cross section $\sigma_{\gamma,N}$ using as neutron detector a 4π Halpern type long counter[6] and the photofission cross section with a fission chamber.

In order to get the photoneutron emission we have made some hypothesis about the number of neutrons emitted in photofission. Near threshold, we have

$$\sigma_{\gamma,N} = \sigma_{\gamma,n} + \nu\sigma_{\gamma,f}$$

Assuming for ν an equation of the type

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$$\nu = A + 0.160\,E \qquad {}^{7)}$$

and using the A value equal to 1.3 (measured for ^{235}U with gamma radiation from anihilation of positrons in flight) we got the photoneutron emission cross section $\sigma_{\gamma,n}$.

The $\sigma_{\gamma,n}$ cross section thus obtained has shown the same structure of the $\sigma_{\gamma,f}$ in the same element. This intermediate structure is somewhat surprising because in the (γ,f) cross section it has been attributed to the small number of states leading to fission. To find the same structure in the (γ,n) cross section indicates that the same states are involved in this process.

Although we have used monochromatic gamma ray lines obtained from neutron capture reaction in a reactor, the results of our experiment were confirmed by low resolution experiments using gamma rays of a continuous variable energy from a Compton scattering monochromator[8)].

However since the $\sigma_{\gamma,n}$ cross section determination was strongly dependent on the value attributed to the average number of neutrons emitted per fission ν, we decided to repeat the (γ,n) measurement in an activation experiment.

2. Experimental Arrangement

The gamma radiation employed was produced in several elements used as targets and placed near the IEA-R1 2Mw reactor core. This experimental arrangement produces monochromatic gamma lines from 5.43 to 11.83 MeV with a low neutron background and has been described in details in previous papers[9,10)].

Before the irradiation the uranium was radiochemically treated by the Chemical Engineering Department in order to clean the sample from its descendents mainly ^{234}Th with a 24.1 days half life which emits gamma rays with energy near the ^{237}U lines.

The uranium was then transformed in U_3O_8 pellets by the Metallurgy Nuclear Division. This pellets were shielded with paraffin and boron and cadmium for the irradiation in a position where the gamma flux is of the order of $10^{14}\ \gamma/cm^2/s$. The shielding was used to prevent the thermal fission of the ^{235}U and the (n,2n) reaction in ^{238}U. The experimental arrangement for irradiation is in fig. 1.

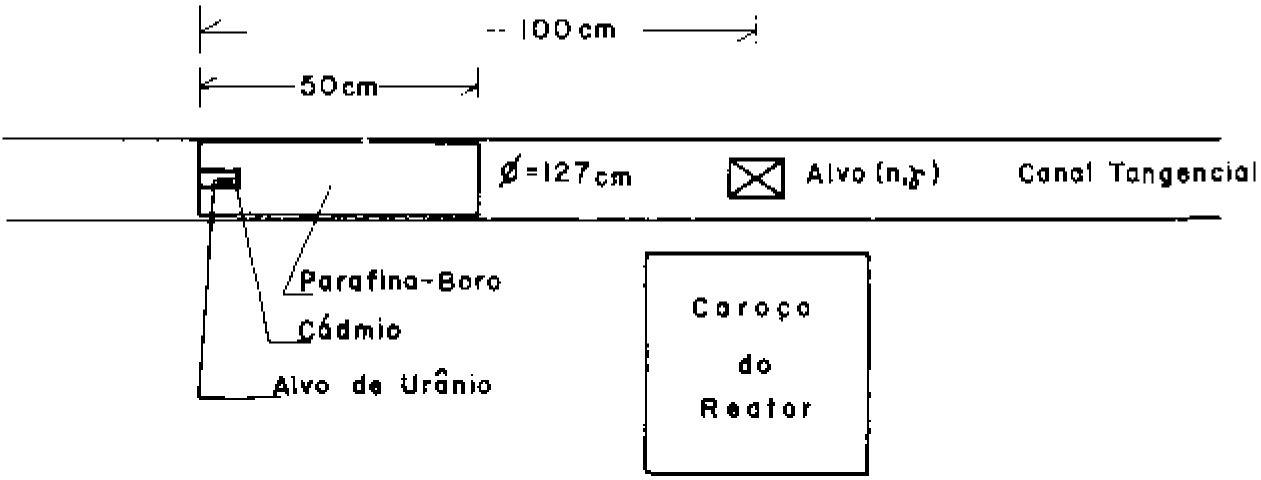

Fig. 1 — Experimental arrangement for irradiation.

Tantalum foils were used as flux monitor.

After the irradiation the γ-rays from the ^{237}U were measured with a 18.2 cc GeLi detector. An experimental spectrum of the irradiated uranium with all the lines identification is shown in fig. 2.

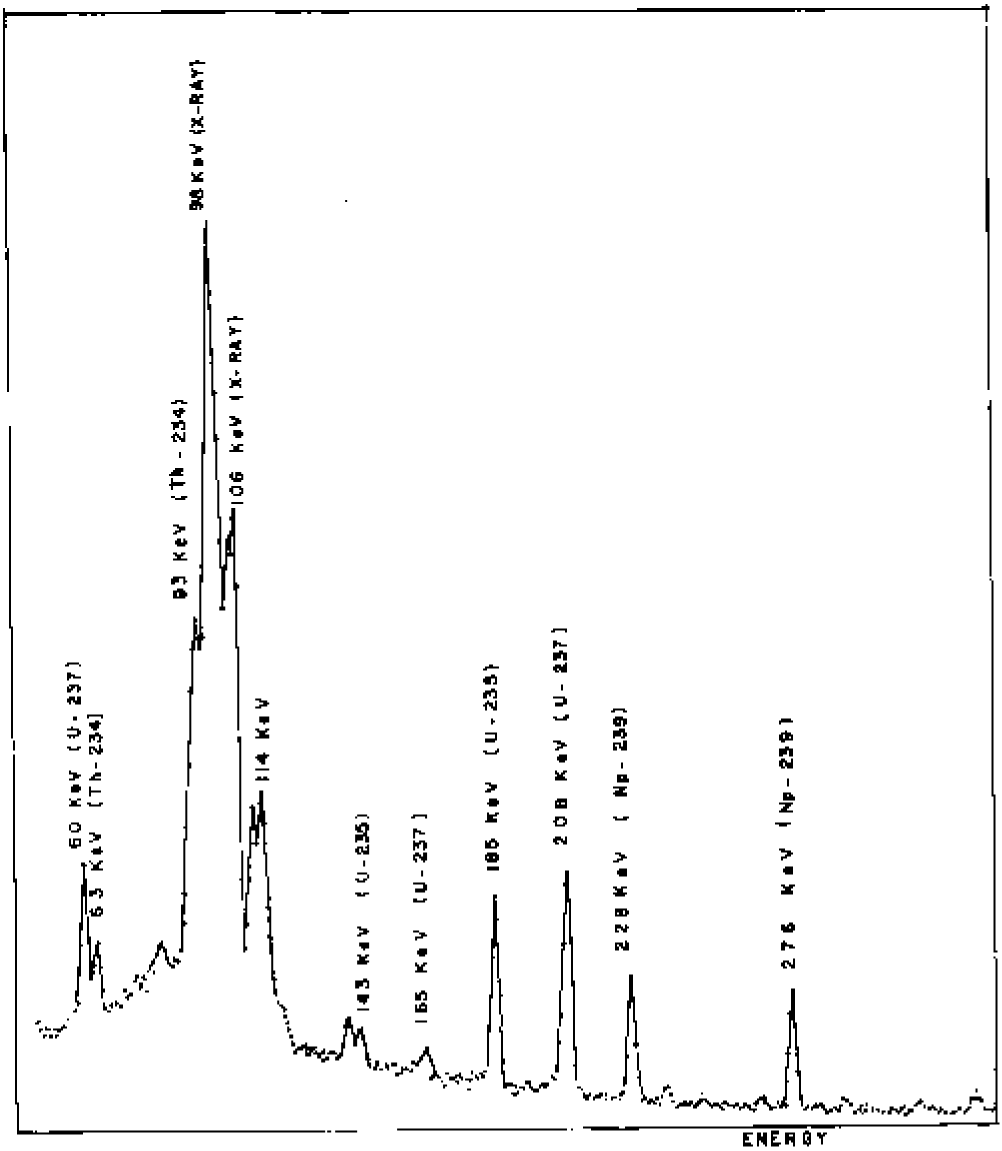

Fig. 2 — Uranium spectrum after irradiation.

For a comparison in table 1 the mainly lines of ^{235}U, ^{234}Th, ^{237}U and ^{239}U are shown[11].

Table 1

^{235}U

γ (MeV)	relative yield
0.143	11 %
0.185	54 %
0.204	5 %

^{237}U

γ (MeV)	relative yield
0.026	2 %
0.060	36 %
0.165	2.0 %
0.208	23 %
0.267	0.76 %
0.332	1.4 % doublet
0.370	0.17 % doublet

^{239}U

0.044	4 %
0.075	51 %

^{234}Th

0.063	3.5 %
0.093	4 %

After the irradiation the activity of the ^{237}U was measured by the cascade 60 - 208 KeV after waiting approximately 14 hours in order to allow the short lived fission products to decay. The fission products could be eliminated after the irradiation using a new radiochemical treatment but this would bring problems related to the loss of material during the processing, geometry variation for the various samples and weight variation due to different drying conditions.

With the GeLi detector the ^{237}U lines can be very well identified and its activity is proportional to the counts under the photopeaks.

The fission products and other reaction products that occurs during the irradiations have gamma lines of clearly distinguishable energies, the only disturbing reaction being (n,2n) that also leads to ^{237}U. To estimate the contribution of the (n,2n) reaction an aluminum foil was irradiated with each target and from the threshold reaction (n, α) the fast neutron flux at the uranium sample position was measured. With this information it was possible to estimate (n,2n) contribution that was, at the irradiation position, in the worst conditions of the order of 30%. The fast flux had to be measured each time because the different targets produced a different flux depression and neutron scattering.

The ^{237}U activity was also measured by a strobbed coincidence system where the 60 KeV line was used to trigger a multichannel analyser permiting the 208 KeV line to be analysed with GeLi detector.

The gamma flux was mesured in each case outside the beam hole by a NaI(Tl) 3" x 3" crystal. The flux at the sample position was obtained using the law of variation of the flux along the beam hole obtained by the activation of tantalum foils.

3. Results and Discussion

The cross section for each irradiation can be obtained through equation (1) if the target emits just one line.

$$\sigma \exp = \frac{A_t}{K F \phi \frac{m N_o}{A} (1 - e^{-\lambda t_i}) e^{-\lambda t_e}} \qquad (1)$$

where

A_t	is the target absolute activity
KF	extrapolation factor to get the flux at the irradiation position
ϕ_A	is the measured flux
N_o	is the Avogadro's number
A	the mass number
λ	the disintegration constant
t_i	the irradiation time

t_e the time elapsed after irradiation before measurement

Since each target emits a number of secondary lines (eventhough with the low relative intensity with respect to the principal line) it is necessary to correct for their contribution using a linear equation system.

$$\Sigma r_i \sigma_i = \sigma_{exp} \tag{2}$$

Where r_i are the relative intensities and σ_i are the cross sections for each line. Using successive approximations it was possible to get the cross sections.

The results obtained are in fig. 3 and show the same structure we got previously which means the same structure is present in the (γ,n) and (γ,f) cross section The errors signed includes statistics and calibration.

To find the same structure in the (γ,n) and (γ,f) cross section indicates that the same states are involved in the two process what is rather unexpected because the states observed in fission should be the saddle point ones and the states observed in photoneutron emission are the states of the compound nucleus.

The proeminent peak at 6.73 MeV in (γ,n) and (γ,f) cross section imply in a predominant peak in the total photoabsorption cross section because

$$\sigma_a(\gamma) = \sigma_{\gamma\gamma} + \sigma_{\gamma,n} + \sigma_{\gamma,f}$$

Since $\sigma_{\gamma\gamma}$ is small above the neutron separation energy[12]

The same behaviour of $\sigma_a(\gamma)$ and the reemission cross section would imply that absorption and reemission are not independent process dependent only in the energy, angular momentum and parity

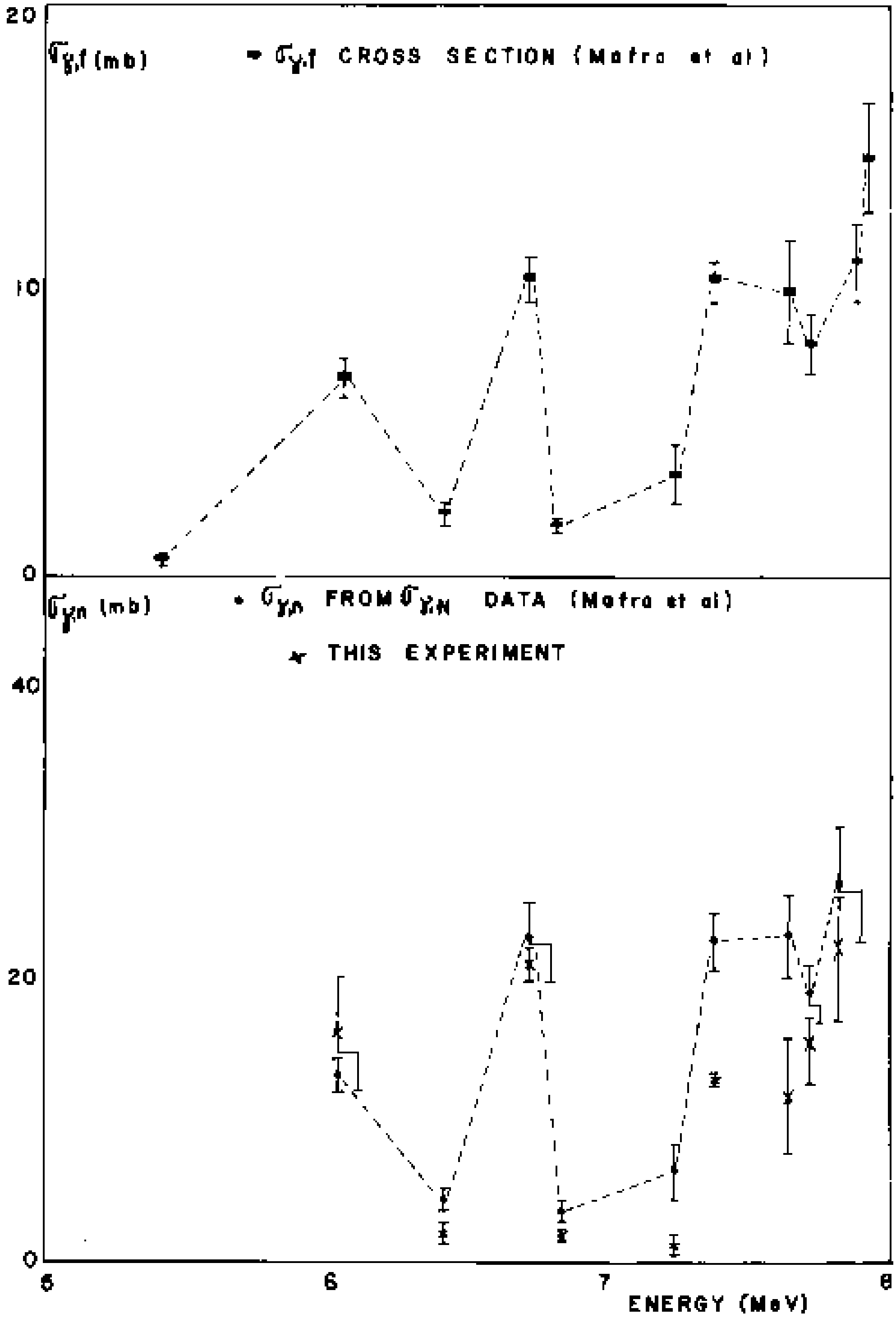

Fig. 3 — Comparison of $\sigma_{\gamma,f}$ and $\sigma_{\gamma,n}$ cross section in ^{238}U.

Resumo

A seção de choque para a reação $^{236}U(\gamma,n)^{237}U$ foi medida através da ativação do urânio, para energias de excitação de 6,07 a 9 MeV. A seção de choque (γ,n) assim obtida mostrou a mesma estrutura da seção de choque de fotofissão para o mesmo elemento, o que implica no mesmo comportamento para a seção de choque total de fotoabsorção.

Résumé

La section efficace pour la reaction $^{236}U(\gamma,n)^{237}U$ a eté mesurée a travers de l'activation de l'uranium pour les energies d'excitation de 6,07 a 9 MeV. La section efficace pour la reaction (γ,n) ainsi obtenue a presentée la même structure de la section efficace pour la photofission pour le même element. Ce veux dire que la même structure será presenté dans la section efficace pour photoabsorption totale.

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