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Yu.P.Gangrsky. K.A.Gavrilov, B.N.Markov,
Nguen Cong Khanh, S.M.Polikanov

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Introduction

The investigation of spontaneously fissioning isomers showed the unusual properties of these isomers: very high probability of spontaneous fission and strong forbiddenness for the gamma transitions despite a high excitation energy/1/ and low spin/2/ of the isomeric level. To explain these unusual properties G.N.Flerov and A.Bohr proposed a hypothesis/3/ about the large deformation of the nucleus in this state.

This hypothesis received a concrete form in the work of Strutinsky/4/ who calculated the shell-energy corrections to the fission barrier. It is possible that the isomeric states with the unusual high probability of spontaneous fission are the ground ones of nuclei in the second energy minimum on the way towards fission/4,5/ (Fig.I).

This point of view received probably an additional confirmation in the existence of the subbarrier resonances with the high fission widths, discovered at slow neutron capture by some nuclei/6,7/.

The experimental evidence of the showed hypothesis about the nature of the fissioning isomers are:

1. The identified up to now fissioning isomers are clustered around the neutron number 148, as it was obtained in the Strutinsky's calculation/4/.

2. The excitation energy of the isomer $^{242mf}Am$ determined in the experiment coincides with the value calculated by I.E. Lynn from the analysis of the subbarrier resonances in the slow neutron capture with the ^{241}Am nucleus /9/ (analysis performed on the basis of two-humped fission barrier).

3. The excitation function of the reaction ^{241}Am (n, γ) leading to the fissioning isomer ^{242}Am /10/ points out a certain barrier for this isomer production and this barrier is close to that of the ^{242}Am nucleus.

Let us consider the third evidence more fully. The cross section of the $^{242mf}Am$ production is seen to increase steeply with the neutron energy increase from 0.5 MeV to 1.5 MeV (fig.4). It is known /11/, that the prompt fission cross section increases in the same way in this neutron energy region. It is possible to explain this phenomenon, if we assume that the isomeric state is the ground one of a nucleus in the second potential well (fig.1). Indeed, in this case both the prompt fission and the isomer production are connected with the penetration of the barrier separating two potential wells. At the excitation energy near this barrier (it occured at 0.5-1.5MeV neutron capture) the cross-section behaviour of the both processes depends mostly on the barrier penetration.

It is interesting to find out the correlation of the $^{242mf}Am$ production and the prompt fission at the neutron energy lower than 0.5 MeV and in particular for the thermal neutron, when the barrier penetration is very low, but the capture cross section is large enough. There were a few attempts to determine the cross section of the fissioning isomer ^{242}Am production /12-14/, but only the upper limit $3 \cdot 10^{-28} cm^2$ /12/ was obtained.

Experimental Set

To observe the fissioning isomer ^{242}Am at the thermal neutron capture it is necessary to have the high intensity pulse neutron source with a low background in the beam-off periods. It is possible to fulfil the both requirements if we make use of the high energy proton beam. The use of high energy proton for pulsing beam of thermal neutron production was described by Canadian group/15/.

The present experiment was performed with the 660 MeV protons accelerated on the synchrocyclotron of Nuclear Problem Laboratory of JINR. The experimental equipment is shown in fig.2. The proton beam bombarded the lead absorber, and the neutrons were produced in the Pb(p, xn) reaction. These neutrons were slowed down in the tank with water.

There was used the ^{241}Am target of 20 mg weight and 50 cm^2 area on the 50 μ Al backing. The surface of the target was covered with a thin Ni layer (100 $\frac{\mu g}{cm}$) . The target was placed inside the spark counter filled with the mixture of Xe (4torr.) and He (760 torr.) This counter was used as a fission fragment detector, and its construction was described by W.F.Gerasimov/16/. Despite a very high alpha radiation of the ^{241}Am target the counter was insensitive practically to the alpha particles (α -radiation background was less than 5 counts per hour), but the fission fragment efficiency equaled 40%, approximately. The spark counter was connected with an electronic circuit recording a prompt fission fragment number and a time distribution of delayed fission fragment occuring between beam bursts. The proton beam bursts of synchrocyclotron had ≈ 200 μ sec lenght and 36 msec period. The delayd fission fragments were recorded in 5 msec after the proton burst. This time is long enough for the thermal neutrons disappearance in the water. It is known that the thermalisation time of 2-3 MeV neutrons is ≈ 20 μ sec and a life of a thermal neutron in water does not exceed 200 μ sec. The tank was surrounded with a Cd shield to protect the target from outer thermal neutrons. In the tank there was also a silicon surface barrier detector with a thin ^{235}U target to check the thermal neutron intencity.

Experimental Results.

A decay curve for the delayed fission fragment (fig.3) corresponds to the half-life of $^{242mf}Am$ ($T_{½}$ = 14 msec) . We can conclude that the fissioning isomer ^{242}Am is formed at the thermal neutron irradiation of ^{241}Am . The cross section for the $^{241}Am(n, \gamma)^{242mf}Am$ reaction was calculated from the measured ratio between the delayed and prompt fission counts subtracting the background and applying corrections for a dead time of the spark counter. It was obtained that the ratio of the $^{242mf}Am$ production cross sections(σ_i) and of the ^{241}Am prompt fission (σ_f) is $(3 \pm 1.5) 10^{-5}$. It is known that for the thermal neutrons σ_f = 3.16 barns/17/, then the isomer production cross section σ_i = $(1.0 \pm 0.5)\ 10^{-28}\ cm^2$.

The same measurements were performed with the Cd shield of the spark counter. The yield of delayed fission fragments fell 6 times and coincides in the limits of errors with the background measured without neutron irradiation. The background sources were the Cm impurities and pile-up pulses of the ^{241}Am alpha particles. From the measured yield of the prompt fission induced with the epicadmium neutrons we obtained the upper limit of the cross section ratio $\frac{\sigma_i}{\sigma_f} < 10^{-4}$.

Discussion

The excitation functions of the ^{241}Am prompt fission/11,17/ and the fissioning isomer ^{242}Am production /10 a. the present paper/ is shown in fig.4. The correlation of both cross sections is observed.

Fig.5 shows the ratios of $\frac{\sigma_i}{\sigma_f}$ and $\frac{\sigma_i}{\sigma_g}$ (σ_g is the cross section of the ground state production of ^{242g}Am at the neutron capture) as a function of the ^{242}Am nucleus excitation energy. There is a very sharp difference between these dependences. In the 5.5-7.0 MeV range of excitation energies the ratio $\frac{\sigma_i}{\sigma_f}$ is nearly constant, but the ratio $\frac{\sigma_i}{\sigma_g}$ is changed about 10^3 times. The cross section for the thermal neutron capture is 620 barns /8/. For the 1.0-1.5 MeV neutrons σ_g was not measured, but it was estimated as $(10^{-25}-10^{-26})$ cm^2 from the neighbouring nuclei (^{238}U, ^{239}Pu) cross section extrapolation.

It is possible to explain the presented dependence of the ratios $\frac{\sigma_i}{\sigma_f}$ and $\frac{\sigma_i}{\sigma_g}$ on the basis of V.M. Strutinsky's hypothesis about the two-humped fission barrier. The ground and isomeric states of ^{242}Am are assumed to be separated with the potential barrier (fig.1), and the probability of isomer production is proportional to this barrier penetration- $P_I(E^*)$. This value decreases exponentially with the excitation energy (E^*) decreasing. The presented dependence of the ratio $\frac{\sigma_i}{\sigma_g}$ is explained with this barrier penetration decreasing.

The prompt fission probability is proportional to the product of the penetration of the first and second barriers $P_I(E^*)P_{II}(E^*)$.. Then the ratio $\frac{\sigma_i}{\sigma_f}$ is proportional to $\frac{1}{P_I(E^*)}$. If the second barrier is lower than the first one and if its height is close to the ^{242}Am nucleus excitation energy at the thermal neutron capture, the penetration $P_{II}(E^*)$ and the ratio $\frac{\sigma_i}{\sigma_f}$ changes not much at the neutron energy increasing in the limits of 0-1.5 MeV. The conclusion that the second barrier is lower than the first one was obtained also at the analysis of the excitation function of the reaction $^{241}Am(n,\gamma)^{242mf}Am$ /18/.

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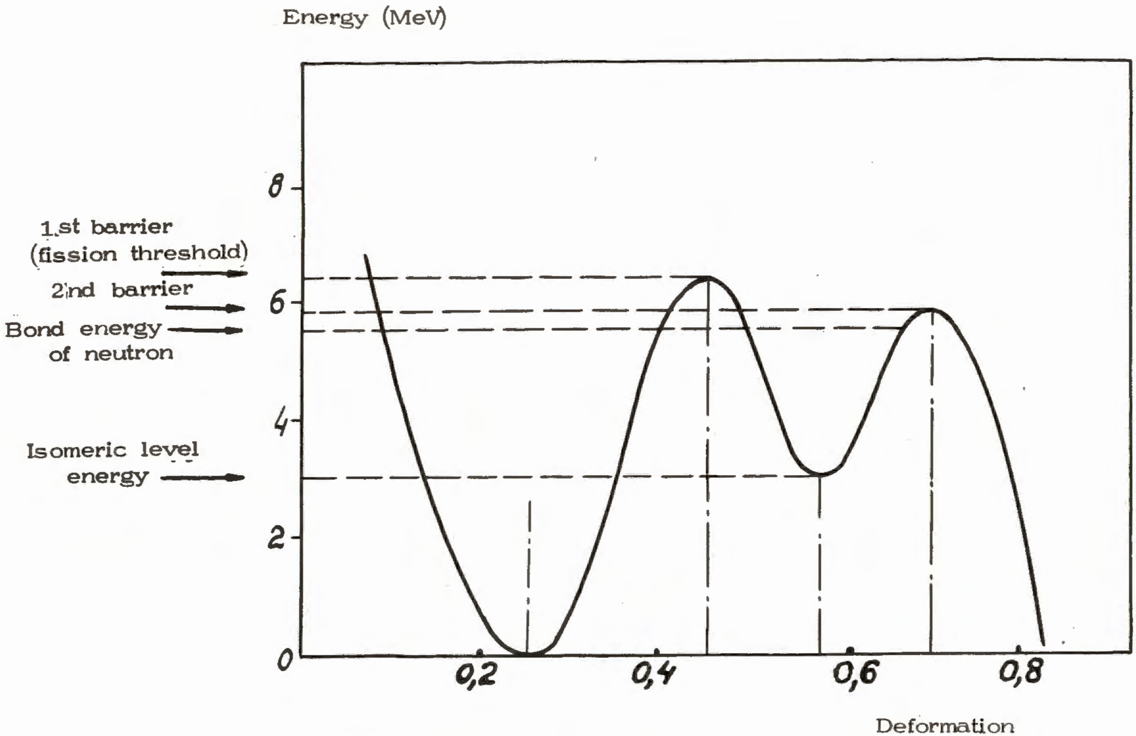

Fig.1. Nucleus potential energy as a function of deformation.

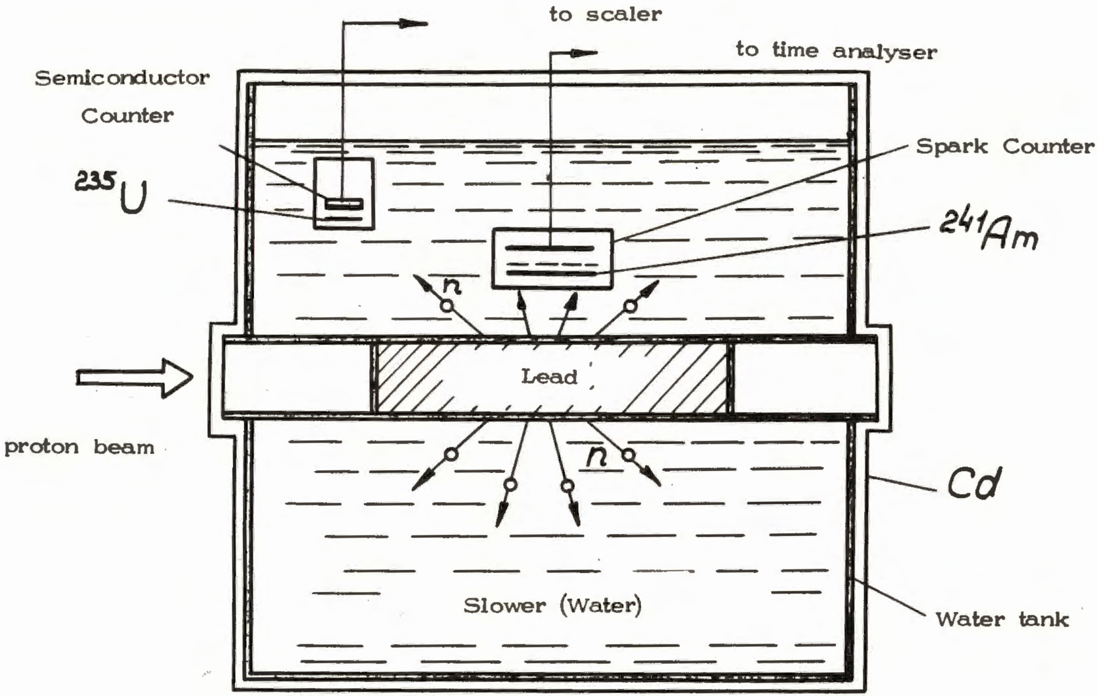

Fig. 2. Schematic diagram of the experimental set.

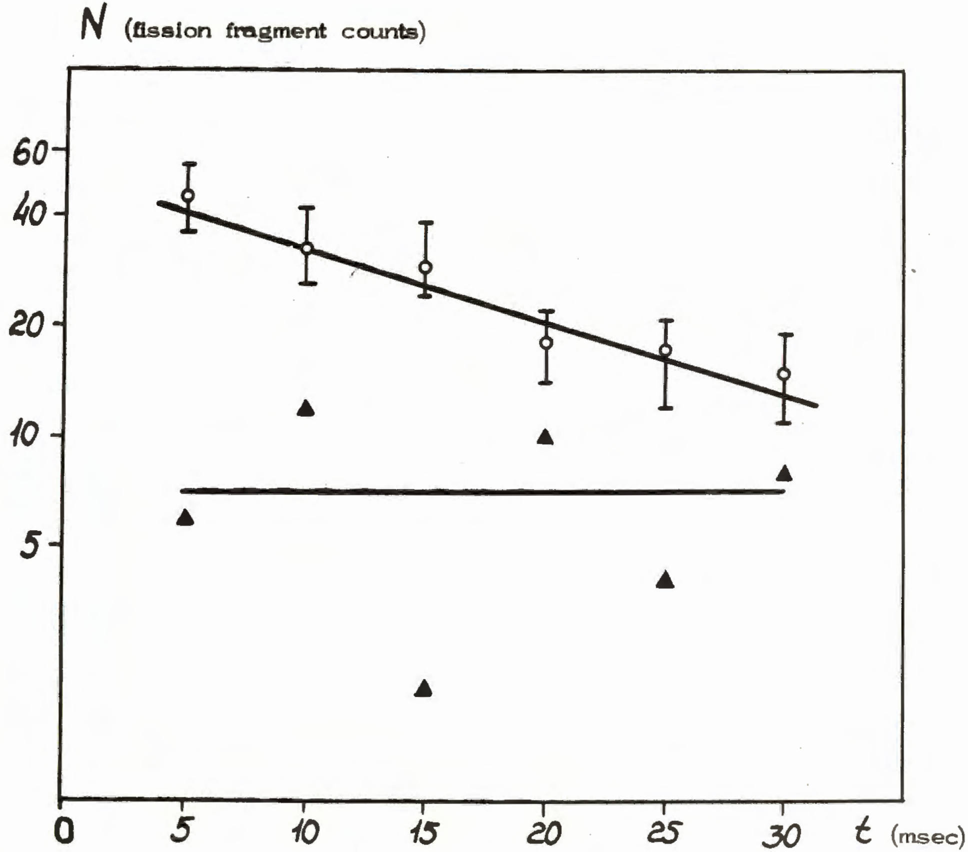

Fig.3. Decay curve of the fissioning isomer produced in the thermal neutron irradiation of ^{241}Am.
○ the unshielded spark counter
▲ the shielded with Cd spark counter.

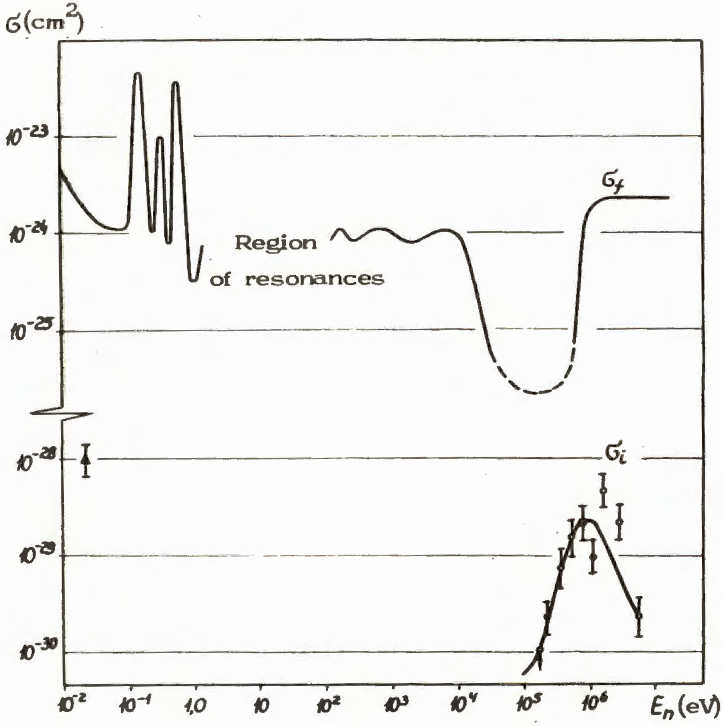

Fig.4. Cross section of the prompt fission (σ_f) and cross section of the isomer ^{242}Am production (σ_i) as neutron energy functions.

o – ref.

▲ – present work.

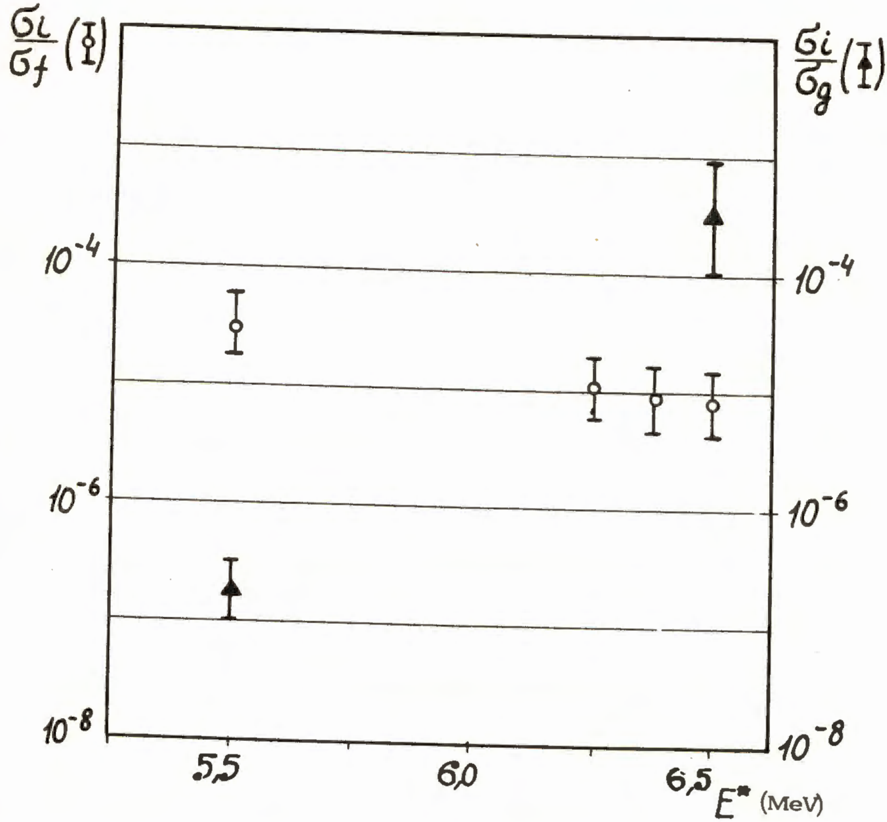

Fig.5. Ratios $\frac{\sigma_i}{\sigma_f}$ and $\frac{\sigma_i}{\sigma_g}$ as excitation energy (E*) ^{242}Am nucleus function.