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EXCITATION OF SPONTANEOUSLY FISSIONING ISOMER STATES ^{239}Pu AND ^{243}Am IN INELASTIC SCATTERING OF γ QUANTA

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An investigation of the mechanism of excitation of spontaneously fissioning isomer levels in different nuclear reactions is one of the principal methods of studying the nature of these states [1 - 4].

As shown in a number of papers [5, 6], the fission barrier has a complicated structure and the spontaneously fissioning isomer states are interpreted as the lower levels in the second potential well. Such a form of the barrier leads to the existence of two independent systems of levels and therefore the population of the states in the second well can result either from transitions from highly excited states of the nucleus, or from tunneling through the first barrier.

The energy of the quasistationary states in the second well usually lies in the 3 - 5 MeV range, and therefore to excite these levels it is tempting to use γ quanta whose energy can be regulated within any range. In the case of neutrons, the energy introduced by them always exceeds the binding energy ($\sim$6 MeV), and in (d, p) reactions the investigation is made complicated by the need for measuring the energy of the emerging particle.

We have investigated the inelastic scattering of γ quanta by the isotopes ^{239}Pu and ^{243}Am; this scattering leads to the formation of known spontaneously fissioning isomers with half-lives 8 and 6.5 msec, respectively [7]. The measurements were performed with the extracted beam from the microtron of the Institute of Physics Problems of the USSR Academy of Sciences, with 17 orbits, at electron energies from 7 to 11 MeV and an average current 20 - 25 μA.

The experimental procedure was described in our preceding paper [3]. The fission-fragment detector was a multifilament spark counter [8] surrounded by cadmium to protect it against thermal neutrons.

The targets weighed 2 mg each, with 95% enrichment.

The delayed-fission fragments were registered between the current pulses of the microtron with a delay of 2 - 3 μsec. To reduce the neutron background, the decelerating target was of aluminum 3 cm thick, and the γ-quantum beam was absorbed in a thick aluminum block after passing through the counter.

Control background measurements outside the γ-quantum beam have demonstrated the

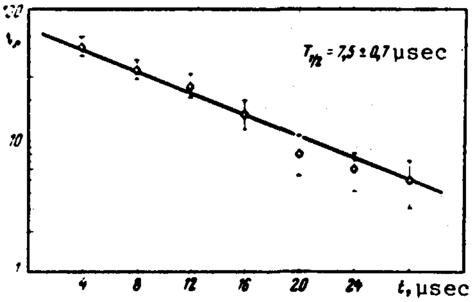

Fig. 1. Dependence of the number of fragments of the delayed fission (N_f) on the time (t) in the reaction ^{239}Pu(γ, γ')^{239mf}Pu at a γ-quantum end-point energy 11 MeV.

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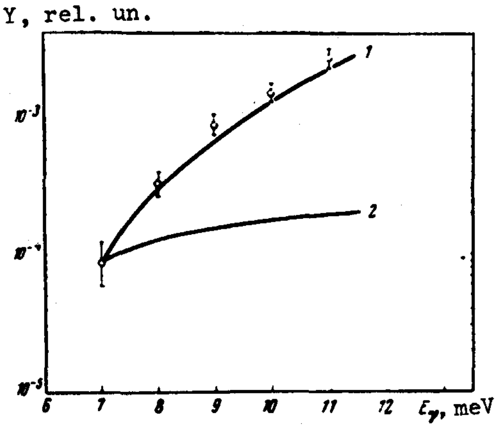

Fig. 2. Dependence of the yield of fragments of the delayed fission (Y) on the γ-quantum end-point energy (E_γ).

absence of fission fragments between the γ-radiation pulses. The identification of the produced isomers was based on their half-life. By way of an example, Fig. 1 shows the decay curve in the case of the reaction ^{239}Pu(γ, γ')^{239mf}Pu. The measured half-life agrees well with the known value [7].

Figure 2 shows the dependence of the yield of the isomer ^{239mf}Pu on the γ-quantum end-point energy. Analogous results were obtained for ^{243mf}Am. The isomer yield was small and amounted to ∿100 counts/hr at an anergy 10 MeV and a current 15 μA. This prevented us from going below 7 MeV. The cross section for the production of the isomer ^{239mf}Pu in the investigated reaction, for the indicated energy range, depends little on the energy and amounts to ∿10 μb.

On the basis of the experimental data presented in Fig. 2, we can ascertain how the predominant population of the isomer levels takes place in the reaction investigated by us.

We have analyzed two possible methods of exciting the isomer state: 1) excitation of the levels lying above the fission barrier (in the energy range 6 - 10 MeV) and their de-excitation with the aid of radiative transitions to the level of the second well and further to the isomer state; 2) excitation of the levels in the first well below the fission barrier (with energy 3 - 6 MeV) with subsequent tunneling to the second potential well.

We calculated the excitation functions of the spontaneously fissioning isomer state for both methods of population (curves 1 and 2 of Fig. 2). In the calculations we used the known energy dependence of the γ-quantum absorption cross section [9].

It is seen clearly from Fig. 2 that the population of the spontaneously fissioning isomer state proceeds predominantly from levels lying above the fission barrier (curve 1 on Fig. 2). The barrier separating the first and second potential wells leads to a large hindrance for transitions between levels lying in different wells.

The results of our investigation point to the possibility of investigating the properties of spontaneously fissioning isomers in reactions of inelastic scattering of γ quanta. The use of a larger amount of investigated matter makes it possible to drop to lower excitation energies, and by the same token to investigate in greater detail the mechanism of population of the isomer state and to establish the structure of the nuclear fission barrier.

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EXPERIMENTAL OBSERVATION OF ROTATION OF THE PLANE OF LINEAR POLARIZATION OF γ QUANTA IN MAGNETIZED FERROMAGNETS

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Recent experiments on the investigation of the left-right asymmetry in the scattering of γ quanta by oriented electrons in ferromagnets [1 - 3] have shown the existence of asymmetry (1 - 4) × 10^{-4}, connected with the multiple scattering of the γ quanta.

Further study of this process has shown that a large asymmetry arises when the γ quantum travels after the first scattering along the magnetization direction, and the magnitude of the resultant effect increases with the distance traversed by the γ quantum in the ferromagnet.

The most probable explanation for this has been the rotation of the plane of the linear polarization of the γ quantum (the Faraday effect), which arises after the first scattering. Since the second scattering is an analyzer of the linear polarization resulting from the first scattering, rotation of the polarization plane in a direction that depends on the quantity $(\vec{B}\cdot\vec{k})$, where $\vec{B}$ is the magnetization vector and $\vec{k}$ the momentum of the γ quanta after the first scattering, causes azimuthal asymmetry of the intensity of the second scattering when the magnetization direction is changed.

Such a mechanism explains most of the singularities of the left-right asymmetry effect [1 - 3]. Since, however, a direct observation of the Faraday effect for γ quanta with energy 0.1 - 0.5 MeV had not been carried out and its value was unknown, we undertook an investigation of this effect in the apparatus shown schematically in the figure.

The γ-quantum source was the isotope ^{198}Au, which emits 411-keV γ quanta. The activity of the employed sources was 500 Curie. The γ quanta were collimated into a beam with cross section 10 - 20 mm, which was scattered by an aluminum scatterer. The γ quanta scattered at 90° (in one of the experiments this angle was 60°) were collimated and passed through iron or permalloy plates magnetized in the propagation direction of the γ quanta (the angle between the direction of magnetization and the γ-quantum momentum ranged from 30 to 75°). The plate thickness was also varied.

The γ quanta passing through the plates and the investigated collimator were scattered by a polyethylene scatterer through an angle of 80° and registered by a Ge(Li) detector with volume 10 cm^3. The spectrum and intensity of