Asymmetry and anisotropy in the photofission of radium-226 near threshold

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We measured the yields and angular anisotropy of the symmetrical and antisymmetrical components in the fission of ^{226}Ra in the range of bremsstrahlung limiting energies 11–15 MeV. In this energy interval, the two components have practically the same angular distribution.

One of the pressing and still not fully understood questions in the physics of nuclear fission is the mass distribution of the fragments in the fission of heavy nuclei. It is well known that both in spontaneous fission and at low excitation energies, for nuclei heavier than thorium asymmetrical fission predominates, with a mass ratio of the most probable heavy and light fragments ~1.5. In the fission of light actinides, the fragment yield curve, starting with a nuclear excitation energy 1.5–2 MeV, turns out to have three humps, i.e., the contribution of the symmetrical fission becomes appreciable. This fact was clearly demonstrated, for example, in recent studies[1,2] of the fission of odd isotopes of Ra and Ac. In addition, these studies seemed to imply that symmetrical fission corresponds to a higher barrier (by approximately 1–2 MeV). This conclu-

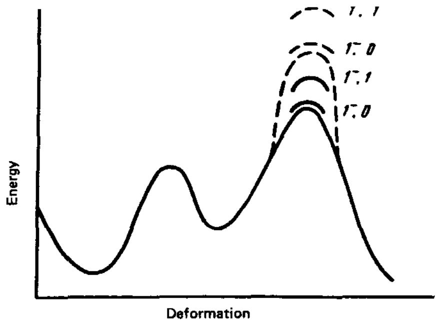

FIG. 1. Schematic representation of the fission barrier of light actinides and fission channels with different K on the barrier B. The dashed lines show the proposed symmetrical—fission barrier.

sion is supported also by a number of theoretical calculations by the Strutinskiĭ shell-correction method.[3-5]

As is well known, the shape of a fissioning nucleus, within the framework of liquid-drop-model calculations, is stable against asymmetrical variations. Introduction of the shell correction into the potential energy of the deformation shows that the shapes corresponding to two minima and the first barrier are symmetrical, while the second barrier is unstable against asymmetry for all actinides. Thus, for asymmetrical shapes, the height of the second barrier is several MeV lower than for symmetrical deformation. For the light actinides, the height of the second barrier (B) is much larger than that of the first (A) and it is therefore the external barrier that determines the fission threshold.

If the mass distribution of the fragments is established on the barrier, then the predicted shape of the fission barrier of the light actinides should lead to equal angular distributions of the fragments of symmetrical and asymmetrical fission, formed on the barrier B (see Fig. 1). This should be particularly clearly manifest in photofission, when the number of possible channels is limited and the only states realized in practice are those with angular momentum $J=1$ and corresponding to dipole absorption. The angular anisotropy of the fragment spreading, i.e., the ratio of the fragment yields at angles 90 and 0°, is determined by the excitation of the nuclei above the barrier and by the energy difference between the states with $J=1^-$, $K=0$ and $J=1^-$, $K=1$ (0.5 MeV).

This has induced us to investigate the fragment anisotropy separately for the symmetrical and antisymmetrical components in the photofission of ^{226}Ra near the barrier. The experiments were performed with the extracted electron beam of the microtron of our Institute[6] in the energy range 11—15 MeV. The procedure used to separate fragments belonging to the symmetric and asymmetric fission components was based on the dependence of the diameter of the fission-fragment tracks in glass on the kinetic energy.[2,7] Glass detectors with aluminum filters 1.5 mg/cm^2 thick were mounted at angles 0 and 90° to the direction of the incident γ-quantum beam on the periphery of a vacuum chamber of 100 mm diameter. The ^{226}Ra target (200 mg/cm^2 thick) was prepared by evaporating radium fluoride

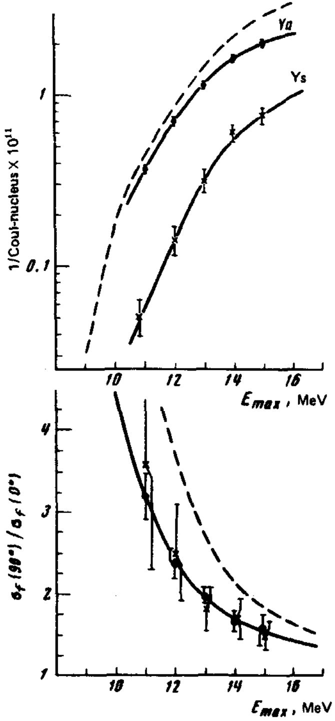

FIG. 2. Top—integral yields of symmetrical (Ys) and asymmetrical (Ya) fission components; the dashed curve shows the fragment yield in the photofission of ^{226}Ra.[8] Bottom—angular anisotropy of the fragment emission for the symmetrical (x) and asymmetrical (•) components. Solid curve—data on the anisotropy of all the fragments,[8] dashed—the same curve shifted 1.5 MeV towards higher energies.

in vacuum. The decelerating target was 1 mm W + 15 mm Al.

The experimental results are shown in Fig. 2. We note the main features of the obtained data: (1) The relative contribution of the symmetric fission decreases continuously as the barrier is approached, and has been observed by us up to an excitation energy ~10.5 MeV (about 2 MeV above the barrier). (2) The energy dependences of the symmetric and asymmetric fissions seem to indicate a difference of ~1.5 MeV between the symmetric and asymmetric barriers, in analogy with the previously performed—measurements of the odd isotopes of Ra and Ac. (3) The angular distribution of the fragments remains practically the same at all excitation energies, for both symmetric and asymmetric fission.

We consider the latter circumstance to be the most important. It indicates most readily that the components of the symmetric and asymmetric fission correspond to one and the same saddle point. On the other hand, this means that the fragment mass distribution is established during the final stage of the nuclear fission process, in the course of dropping from the saddle point to the scission point. The probabilities of the symmetric and asymmetric fission are determined by statistical factors, but of course with allowance for the shell effects in the course of fragment formation. We see at present no other explanation of the obtained experimental data.

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