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Abstract

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ANISOTROPY OF FRAGMENTS I_{0°/I_{90° IN THE FISSION OF U^{233} BY NEUTRONS WITH ENERGIES OF 100–1000 keV

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The angular anisotropy of fission fragments is customarily understood as the difference in the number of fragments emitted at different angles to the direction of the flux of particles that induce fission. It has been found that the magnitude and character of the anisotropy change with changes in the energy of the particles (in our case, neutrons). Statistical theory explains this dependence in the following way. Fission may proceed through states with different angular momenta. The presence of particular states is associated with the energy of the neutrons. Depending on which states the fission proceeds through, the angular distribution of the fragments also changes.

It is of interest to study the dependence of the angular anisotropy on energy in the region of comparatively low neutron energies (100–1000 keV), where fission can proceed only through states with small angular momenta ($l = 1, 2$). In this case it is easier to determine precisely through which states fission proceeds. At present, the literature contains only fragmentary information on angular anisotropy in this neutron-energy region.

We measured the angular anisotropy in the indicated neutron-energy interval for U^{233}. The choice of this element is connected with the fact that in its cross section there is a small broad maximum (an increase of 10–15% compared with the smooth course of the cross section as a function of neutron energy) in the region of neutron energies $E_n = 350$ keV, where one may expect a contribution from only one p-wave ($l = 1$).

In our measurements we limited ourselves to determining the ratio of the number of fragments emitted in the direction of neutron motion to the number of fragments emitted perpendicular to this direction (I_{0°/I_{90°).

The neutrons were obtained from the reactions $\mathrm{T}(p,n)\mathrm{He}^3$ and $\mathrm{Li}^7(p,n)\mathrm{Be}^7$. After acceleration in an electrostatic generator, the proton beam struck a tritium or lithium target located sufficiently far from the walls of the measuring chamber (about 2 m). Layers of the fissionable material were placed at an angle of 45° to the direction of the proton beam (Fig. 1).

Fig. 1. Schematic representation of the chamber. 1 —tritium target, 2 —collimators, 3 —U^{233} layers, 4 —chamber electrodes

Figure 1: Fig. 1. Schematic representation of the chamber. 1 —tritium target, 2 —collimators, 3 —U^{233} layers, 4 —chamber electrodes

Layers of thickness ~ 2 mg/cm^2 were deposited on both sides of a flat aluminum ring. On each side a collimator, likewise in the form of a ring with holes (diameter 2.2 mm) arranged at an angle of 45° to the plane of the ring, was placed over the layer. The layers with collimators were placed in a chamber filled with a mixture of argon and methane and operating in the electron-collection mode. Pulses from fission fragments from each layer were recorded independently. Thus, with the chamber geometry indicated in Fig. 1, fragments emitted in the direction of the neutron flux were recorded from one layer, while fragments emitted at an angle of 90° to the direction of the neutron flux were recorded from the other. By rotating the chamber by 180° about an axis perpendicular to the proton beam, we interchanged the layers. This made it possible to determine the value of I_{0°/I_{90°, eliminating the influence of nonuniformity of the layers and of the efficiencies of pulse registration from each layer.

With the same angular resolution, the geometry chosen, in comparison with the usual one (using the neutron beam at 0°), made it possible to increase substantially the amount of fissile material placed in the chamber and thereby to increase the counting rate.

To reduce the chamber background caused by neutrons scattered by the walls of the measuring room, the chamber was placed in a cadmium cover with wall thickness 0.5 mm. In this case the chamber background from neutrons scattered by the walls amounted to $1 \div 2\%$. A more significant contribution came from fissions caused by neutrons scattered in the collimators and the chamber walls. These neutrons were distributed approximately isotropically and amounted to about 13% of the neutron beam with the direction selected by collimation.

Fig. 1. Schematic representation of the chamber. 1 —tritium target, 2 —collimators, 3 —U^{233} layers, 4 —chamber electrodes.

The total correction to the measured value of the anisotropy I_{0°/I_{90°, associated with allowance for the chamber background from isotropically scattered neutrons, did not exceed 1%. The correction to the anisotropy associated with allowance for the motion of the center of mass also did not exceed 1%. The root-mean-square collimation angle of the fragments in the described geometry was $\sim 9^\circ$. The correction to the anisotropy associated with it was $\sim 0.3\%$.

The spread in neutron energies was determined mainly by the magnitude of the solid angle used to irradiate the U^{233} layers and by the energy losses of the protons in the tritium target. The spread was ± 20 keV at $E_n \leqslant 350$ keV and increased to ± 40 keV at $E_n = 1000$ keV. The measurement results, with corrections taken into account, are given in Table 1.

Table 1

E_n, keV	$\frac{I_{0^\circ}}{I_{90^\circ}}$	$\Delta\frac{I_{0^\circ}}{I_{90^\circ}}$	E_n, keV	$\frac{I_{0^\circ}}{I_{90^\circ}}$	$\Delta\frac{I_{0^\circ}}{I_{90^\circ}}$
85	1.02	±0.035	350	1.08	±0.02
160	1.07	±0.03	455	1.045	±0.05
180	1.08	±0.02	630	1.08	±0.02
210	1.06	±0.03	710	1.085	±0.03
300	1.10	+0.07	1000	1.09	±0.04

Also indicated here are the measurement errors, which are determined mainly by the statistical accuracy of the measurements. In the literature there are data on the anisotropy of U^{233} at neutron energies of 500, 700, and 1000 keV (1, 2). The results of our measurements agree well with them.

The comparatively large magnitude and constancy of the anisotropy of U^{233} over a broad interval of neutron-energy variation (from 160 to 1000 keV) are noteworthy. This is surprising because it is difficult to suppose that throughout the entire interval of energy variation (160–1000 keV) the ratio between states with different angular momenta through which fission proceeds did not change.

The influence of angular momenta disappears only at a neutron energy equal to 85 keV ($I_{0^\circ}/I_{90^\circ} = 1.02$).

On the basis of the results obtained, no conclusions can be drawn about a correlation between the anisotropy and the behavior of the fission cross section of U^{233} in the indicated region of neutron-energy variation.

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