ANGULAR DISTRIBUTION OF GAMMA RAYS PRODUCED IN THE FISSION OF U^{235}, U^{233}, *AND* Pu^{239} *BY THERMAL NEUTRONS*

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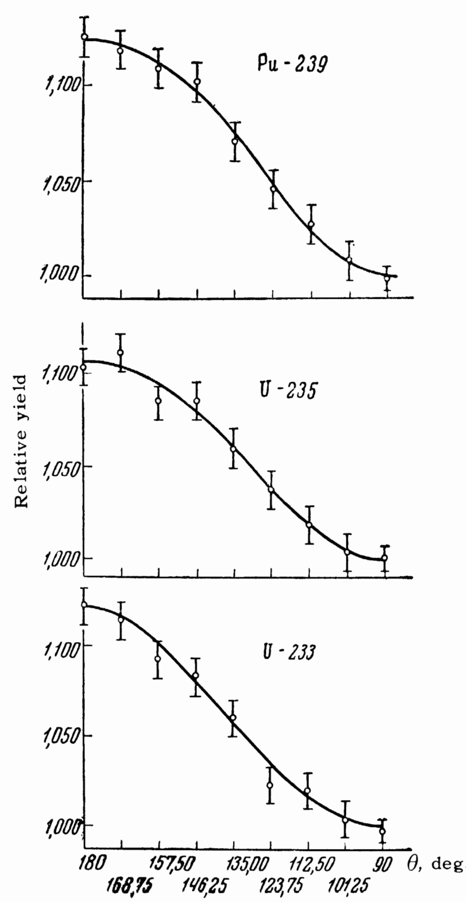
The relative yields of γ rays produced in the fission of U^{235}, U^{233}, and Pu^{239} have been measured for 9 angles between the directions of the recorded γ-ray and fission fragments. The data are treated by the method of least squares for a function of the form (1). For all three nuclei the probability of γ-ray emission in the direction of fission was higher than in the perpendicular direction. The anisotropy values are (11 ± 1), (13 ± 1), and (16 ± 1)% for U^{235}, U^{233}, and Pu^{239} respectively.

IN a previous paper [1] we showed that the probability of emission of energetic γ rays accompanying the fission of U^{235}, U^{233}, and Pu^{239} is 12–14% higher in the direction of emission of the fission fragments than in the perpendicular direction. It was also found that the anisotropy did not change within the limits of experimental error over the γ-ray energy range 100–600 keV. In the present work we have studied the shape of the γ-ray correlation function for energies above 200 keV.

The experimental setup has been described in our earlier report. [1] The fission fragments were counted by a gold-silicon np type semiconductor detector, and the γ rays by a 40×60 mm NaI(Tl) crystal and an FÉU-13 photomultiplier, located 70 cm from the target. The fissile material was deposited on a thin aluminum backing (20 mb/cm^2), in the form of a disk 5–10 mm in diameter and 0.5–1 mg/cm^2 thick. The fission fragment detector and the target were located in a thin-walled cylindrical vacuum chamber along whose axis passed a beam of neutrons from a channel of a VVR-M reactor. The angle between the axes the γ-spectrometer and the fission fragment counter was varied by rotating the vacuum chamber about the beam axis. The electronics consisted of a fast-slow coincidence circuit and a time-to-pulse-height converter. Pulses from the converter were recorded by a 100-channel pulse-height analyzer type AI-100.

In the experiment, for each angle between the detectors from 90–180°, we recorded the spectrum from the time-to-pulse-height converter, the number of pulses from the fission counter, the number of fast coincidences, and the number of pulses from the fast-slow coincidence circuit. Monitoring of the amplifier stability was achieved by periodic measurements at 90°.



Angular distribution of γ rays.

The values obtained for the relative γ-ray yields at 9 angles were analyzed by the method of least squares for a function of the type

$$W(\vartheta) = 1 + A_2P_2(\cos\vartheta) + A_4P_4(\cos\vartheta). \qquad (1)$$

The results of the analysis are shown in the figure. The statistical errors, which are of the order of 1%, are indicated.

After correction for the finite solid angle of the fission detector (no correction was made for the solid angle of the γ-detector), the correlation functions have the final form:

$$U^{235}: W(\vartheta) = 1 + (0.076 \pm 0.007) \times P_2(\cos\vartheta) - (0.008 \pm 0.008) P_4(\cos\vartheta),$$

$$U^{233}: W(\vartheta) = 1 + (0.079 \pm 0.007) \times P_2(\cos\vartheta) + (0.004 \pm 0.008) P_4(\cos\vartheta),$$

$$Pu^{239}: W(\vartheta) = 1 + (0.089 \pm 0.007) \times P_2(\cos\vartheta) - (0.013 \pm 0.008) P_4(\cos\vartheta).$$

The values of the anisotropy

$$A = \left(\frac{1 + A_2 + A_4}{1 - A_2/2 + 3A_4/8} - 1\right) \cdot 100\%$$

for U^{235}, U^{233}, and Pu^{239} are (11 ± 1)%, (13 ± 1)%, and (16 ± 1)%, respectively, which are in good agreement with our earlier measurements [1] and the data of Blinov et al [2] for U^{235}. Recently Hoffman [3] has published data on γ-ray anisotropy in fission of the U and Pu isotopes. Hoffman's values of anisotropy are in good agreement with our data, but our measurements show a sharper variation of γ-ray yield for angles of 135–180°. Calculations show that taking into account the motion of the fragments obviously does not explain the observed anisotropy in emission of γ rays, and therefore the data obtained uniquely indicate the existence of an anisotropy of γ-ray emission in the center-of-mass system. This can be explained by the existence in the fragments of an appreciable angular momentum oriented in a definite way with respect to the axis of fission. For dipole γ radiation the data indicate an orientation of the momentum along the fission axis, and for quadrupole radiation—perpendicular to the axis.

The multipolarity of the fission γ rays is evidently not higher than quadrupole, which is also indicated by measurements of the time of γ-ray emission. [4,5] Hoffman draws the conclusion from his data [3] that the correlation is due mainly to quadrupole transitions. However, it seems very doubtful that such a conclusion can be reliably drawn with the statistical errors indicated in his work. Measurements of fission γ spectra at angles of 0 and 90° will perhaps permit drawing more definite conclusions on the multipolarity of the γ radiation responsible for the correlation and on the validity of a number of other conclusions drawn by Hoffman. As can be seen from the data obtained in this experiment, the anisotropy increases as we go from U^{235} (spin $7/2$) to U^{233} ($5/2$) and Pu^{239} ($1/2$), which argues in favor of the hypothesis of a disorienting influence of the target nucleus spin on the angular momentum arising in fission. [6]

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