In conclusion the writer desires to express her sincere thanks to Prof. A. I. Ansel'm for useful discussions and constant interest in the work.

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ANGULAR DISTRIBUTIONS OF PHOTOFISSION FRAGMENTS FROM URANIUM

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The angular distributions of photofission fragments from uranium at x-ray energies of 9.4, 12 and 26.5 Mev were determined using a 30 Mev synchrotron. The anisotropy was found to increase sharply with decreasing x-ray energy. The ratios of the anisotropic to the isotropic fission yields at the above energies 0.55 ± 0.09, 0.13 ± 0.05, and 0.05 ± 0.04 respectively.

THE angular distributions of photofission fragments from uranium were determined with nuclear emulsions. The source of the x-rays was the 30 Mev synchrotron of the Physics Institute of the Academy of Sciences.

Ilford D-1 plates of 100 and 200 μ thickness were impregnated with a saturated solution of uranyl acetate and were placed in the x-ray beam at a distance of 1 m from the synchrotron target. The method of Belovitskii and Romanova[1] of impregnation and final development of the emulsions was utilized. By a careful timing of the different steps in the processing of the emulsions we succeeded in obtaining clearly legible tracks of the fission fragments while the α-tracks were scarcely noticeable. The plates were irradiated at the following three synchrotron energies: 9.4, 12, and 26.5 Mev.

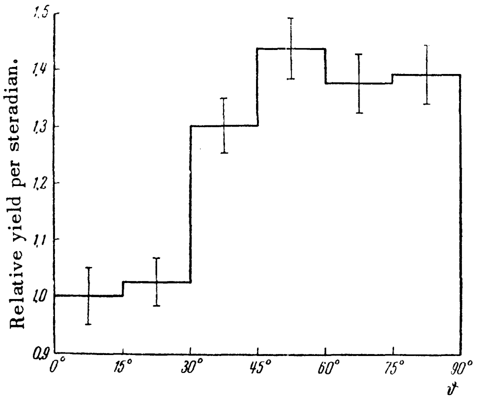
TABLE I. Angular distribution of photofission fragments from U^{238}

Maximum x-ray energy, E_{max} Mev	Number of tracks	Distribution of tracks (per steradian)		
		0 —30° 180—150°	30 —60° 150—120°	60—90° 120—90°
9.4	3901	1 ∓ 0.03	1.35 ∓ 0.04	1.36 ∓ 0.04
12	2053	1 ∓ 0.04	1.09 ∓ 0.04	1.16 ∓ 0.04
26.5	2507	1 ∓ 0.04	1.10 ∓ 0.04	1.06 ∓ 0.04

The scanning was performed with MBI-2 microscopes with a 60× objective and 5× ocular. In scanning, all tracks with dip angles greater than 15° were rejected. For the retained tracks the angles between the direction of motion of the fragments and the x-ray beam were measured. Since the origin of the tracks could not be determined the angles ϑ and $\pi - \vartheta$ were indistinguishable and the obtained angular distribution is actually $[I(\vartheta) + I(\pi - \vartheta)]$.

In order to determine the fraction of fissions due to background neutrons some of the uranium-impregnated plates were placed at the time of the irradiation outside of the x-ray beam. The fissions in these plates could be due to the background neutrons which are approximately uniformly distributed around the synchrotron, and to scattered γ-rays. The scanning of these plates revealed that for all x-ray energies the number of fissions due to neutrons was less than 2 — 3%. A similar result (less than 1%) was obtained when placing a plate in the beam behind a large lead block at an energy E_{max} = 12 Mev.

The results obtained for E_{max} = 9.4, 12, and 26.5 Mev are given in Table I. The relative yields per steradian are given for the indicated angular ranges. In natural uranium the isotope U^{238} has an abundance of 99.28%. Since the cross sections for photofission of the different isotopes of uranium differ only by a factor 2 — 3 (Ref. 2) the given data reflect the properties of U^{238}. As can be seen from the table the maximum of the angular distribution occurs at an angle of 90° to the x-ray beam. The anisotropy decreases sharply with increasing x-ray energy.



Angular distribution of fission fragments from irradiation with x-rays of maximum energy E_{max} = 9.4 Mev

In general the angular distribution from photonuclear reaction has the form

$$I(\vartheta) = a + b(\sin\vartheta + p\sin\vartheta \cdot \cos\vartheta)^2.$$

The term with forward-backward asymmetry is due to electric dipole—electric quadrupole interference in photon absorption. When adding the contributions for ϑ and $(\pi - \vartheta)$ the interference term disappears. In the present work the following distribution was determined:

$$I(\vartheta) + I(\pi - \vartheta) = a + b \cdot \sin^2\vartheta + c\sin^2\vartheta \cdot \cos^2\vartheta.$$

The coefficient a describes the isotropic part in the angular distribution and coefficients b and c are connected with dipole and quadrupole γ-absorption respectively. The ratio of the anisotropic to the isotropic part for all fission fragments is given by $\frac{2}{3}\frac{b}{a} + \frac{2}{15}\frac{c}{a}$.

The angular distributions obtained with E_{max} = 12 and 26.5 Mev can be represented within errors by $a + b\sin^2\vartheta$. The ratios b/a equal 0.20 ± 0.07 and 0.07 ± 0.06 respectively.

The angular distribution for E_{max} = 9.4 Mev is shown in the figure. It indicates both dipole and quadrupole abosrption. A least squares fit yields the following form for the distribution

$$1 + 0.55\sin^2\vartheta + 1.38\sin^2\vartheta\cos^2\vartheta \quad (b/a = 0.55 \mp 0.09;\ c/a = 1.38 \mp 0.41).$$

The following relation holds for the coefficients: $c/b = 5\sigma_{fq}/\sigma_{fd}$ where σ_{fq} and σ_{fd} are the cross sections for fission from absorption of electric quadrupole and dipole radiation respectively. The angular distribution for E_{max} = 9.4 Mev yields c/5b = 0.50 ∓ 0.14. A large contribution from quadrupole absorption at energies below 10 Mev is to be expected due to the suppression of dipole transitions in this energy region as pointed out by Migdal.[3]

TABLE II. Anisotropy coefficients for U^{238} photofission

E_{max} Mev	b/a	Ratio of anisotropic and isotropic fission yields $\left(\frac{2}{3}\frac{b}{a} + \frac{2}{15}\frac{c}{a}\right)$
9.4	0.55∓0.09	0.55∓0.09
12	0.20∓0.07	0.13∓0.05
26.5	0.07∓0.06	0.05∓0.04

The coefficients of the angular distributions for the three x-ray energies are collected in Table II.

Angular distributions of photofission fragments have also been obtained by Winhold and Halpern.[4] This work has been performed with a linear accelerator counting the β-activities of the fission fragments. They measured the ratio of the yield of fission fragments emitted parallel and normal to the x-ray beam at several electron energies between 6.5 and 14 Mev. Assuming that the angular distribution has the form $a + b\sin^2\vartheta$, one can obtain ratios a/b that agree within errors with the values of Table II of the present paper.

The scanning of the plates explored at E_{max} = 26.5 Mev was performed by the Scanning Group of the International Joint Institute for Nuclear Research under the direction of M. I. Podgoretskii. The authors express their deep gratitude to the scanning group and to M. I. Podgoretskii.

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