P-odd asymmetry of neutron emission in the fission of ^{240}Pu

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It was observed in the fission of ^{239}Pu by thermal polarized neutrons that the fission neutrons are emitted predominantly counter the direction of the spin of the fissioning nucleus, with an asymmetry $a_n = (-6.7 \pm 0.7) \times 10^{-5}$.

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P-odd symmetry of the fragment emission along and against the nuclear spin was observed in[1-3] in the fission of ^{233}U, ^{235}U, and ^{239}Pu by polarized thermal neutrons. It turned out that the light ^{240}Pu fission fragments are emitted predominantly counter to the spin direction of the fissioning nucleus. Since the fission neutrons are emitted predominantly along the direction of motion of the light fragments,[4] one can count on increasing the yield of the fission neutron in a direction opposite to the spin of the ^{240}Pu nucleus.

We have investigated neutron emission in the fission of ^{239}Pu by thermal polarized neutrons obtained by reflecting from magnetized cobalt mirrors a neutron beam from the heavy-water reactor of the Institute of Theoretical and Experimental Physics. The metallic ^{239}Pu sample absorbed 92% of the neutrons incident on it. The fission neutrons were registered by two plastic scintillators of 7 cm diameter and 10 cm height. One of them registered the neutrons emitted in the direction of polarization of the neutron beam, and the other neutrons emitted in the opposite direction. To decrease the γ background from the sample, we used filters 4 cm thick. Four pulse-height discriminators separated four energy bands of the recoil protons.

The registration system operated jointly with a computer that controlled the experiment. To reduce the influence of the instability of the apparatus and of the fluctuations of the beam intensity, the beam polarization direction was reversed at a frequency 8 Hz. To take into account the apparatus asymmetry, the measurements were made in 12-minute runs alternately with a polarized and depolarized beam. Control experiments have shown that the spatial oscillations of the beam, the oscillations of its intensity, and the instability of the apparatus are all within limits that ensure an asymmetry measurement accuracy better than 10^{-5}.

To compare the asymmetry of the neutrons with the fragment asymmetry obtained in[2], a calibration experiment was performed. In place of the main sample, thin ^{239}Pu samples (0.1 mg/cm^2) and semiconductor fragment detectors were placed in the path of the beam. The coincidences of the pulses from the scintillators with the pulses from the light and heavy fragments were counted. The measurements were made at different angles between the fission axis and the direction to the neutron detector. From the results of these measurements we determined the calculated asymmetry of the neutrons for each of the four energy bands. It was assumed in the calculation that the angular distribution of the fragments is of the form $N(\theta)=1+a_f\cos(\theta)$, where θ is the angle between the momentum of the light fragment and the neutron spin direction. According to[2], $a_f=(-4.8\pm0.8)\times10^{-4}$. The calculated asymmetries are given in the last column of Table I.

The scintillators registered, besides the neutrons, also some of the γ rays from the β decay of the fragments, and some of the capture and fission γ rays. The background due to the β decay of the fragments was determined experimentally by abruptly ($\sim$0.1 sec) blocking the neutron beam, and amounted from the 6 to 14% in the various ranges. The capture γ-ray background was estimated by replacing the ^{239}Pu sample in the beam with mercury, and amounted to 4–14%. The background of the prompt fission γ rays is present also in the calibration experiment and therefore does not influence the comparison of our results with those of[2]. Since the γ background includes many independent γ lines, it can be assumed that its contribution to the measured asymmetry is quite small.

The principal measurements lasted 143 hours. The averaged results of two neutron detectors, corrected for the γ background, are presented in Table I:

TABLE I.

E, MeV	$a_{pol}\cdot10^5$	$a_{depol}\cdot10^5$	$a_n\cdot10^5$	$a_{calc}\cdot10^5$
0.7 - 1.0	- 4.5 ± 0.8	0.9 ± 0.8	- 6.4 ± 1.3	- 3.3 ± 0.7
1.0 - 1.5	- 6.6 ± 0.7	- 0.6 ± 0.7	- 6.2 ± 1.2	- 3.9 ± 0.8
1.5 - 2.0	- 7.0 ± 0.9	- 1.2 ± 0.9	- 6.8 ± 1.4	- 4.5 ± 1.0
2.0	- 7.5 ± 0.8	- 0.9 ± 0.8	- 7.7 ± 1.3	- 6.1 ± 1.4

The first column indicates the range of the registered recoil protons. The second column gives the values of the asymmetry:

$$a = (N_+ - N_-)/(N_+ + N_-),$$

obtained with a polarized neutron beam. The third column gives the asymmetry obtained with a depolarized beam. In the fourth column is given the difference of these quantities, referred to 100% beam polarization. The summary neutron asymmetry over the entire energy band is $a_n=(-6.7\pm0.7)\times10^{-5}$; the calculated asymmetry for all neutrons is $a_{calc}=(-4.1\pm0.7)\times10^{-5}$.

The results attest to violation of spatial parity in the fission of ^{240}Pu. The sign of the asymmetry points to a preferred emission of the neutrons in a direction opposite to the spin of the nucleus. Comparison of the measured and expected asymmetry of the neutrons demonstrated the qualitative agreement between the present work and[2]. The difference between these quantities is apparently due to the fact that processes that violate spatial parity exert their influence on the neutron-emission process.

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[1]G.V. Danilyan, V.V. Novitskiĭ, V.S. Pavlov, S.P. Borovlev, B.D. Vodennikov, and V.P. Dronyaev, Pis'ma Zh. Eksp. Teor. Fiz. **24**, 380 (1976) [JETP Lett. **24**, 344 (1976)].
[2]G.V. Danilyan, B.D. Vodennikov, V.P. Dronyaev, V.V. Novitskiĭ, V.S. Pavlov, and S.P. Borovlev, Yad. Fiz. **26**, 197 (1977) [Sov. J. Nucl. Phys. **26**, 186 (1977)].
[3]B.D. Vodennikov, G.V. Danilyan, V.P. Dronyaev, V.V. Novitskiĭ, V.S. Pavlov, and S.P. Borovlev, Pis'ma Zh. Eksp. Teor. Fiz. **27**, 68 (1978) [JETP Lett. **27**, 62 (1978)].
[4]J.S. Fraser, Phys. Rev. **88**, 536 (1952).