P-parity nonconservation in the total cross section for the interaction of thermal neutrons with ^{233}U

V. A. Vesna, and É. A. Kolomenskiĭ, I. S. Okunev, A. N. Pirozhkov,
L. M. Smotritskiĭ, and E. V. Shul'gina
B. P. Konstantinov Leningrad Institute of Nuclear Physics, Academy of Sciences of the USSR

A. F. Kornyushkin, and N. A. Titov
Institute of Nuclear Research, Academy of Sciences of the USSR

S. M. Solov'ev
V. G. Khlopin Radium Institute

V. M. Lobashev
B. P. Konstantinov Leningrad Institute of Nuclear Physics, Academy of Sciences of the USSR; Institute of Nuclear Research, Academy of Sciences of the USSR

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An upper limit is found on the difference between the cross sections for the interactions of thermal neutrons with opposite helicities with ^{233}U: $P=(\sigma_t^+ - \sigma_t^-)/(\sigma_t^+ + \sigma_t^-) < 1.5\times 10^{-6}$ (at a 90% confidence level). This result contradicts the value $P = 10^{-4}$–10^{-5} estimated under the assumption that the 0.17-eV level is a p-wave level.

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Effects of a nonconservation of spatial parity have been observed in the fission of heavy nuclei in measurements of the asymmetry of the emission of fragments with respect to the spin of the captured thermal neutron.[1] An explanation which has been offered for the observed effects includes an assumed mixing of states of different parities of a hot compound nucleus; this mixing persists without loss into the cold stage of the fission and determines the asymmetry of the fragment emission.[2] In the absence of data on the characteristics of the mixed states it has not previously been possible to compare the model of Ref. 2 with experimental data beyond order-of-magnitude accuracy. In a study of the energy dependence of the asymmetry of the fragment emission, Val'skiĭ *et al.*[3] observed a change in the sign of the effect in ^{233}U fission near a weak resonance at 0.17 eV. This effect was interpreted in accordance with Ref. 4 in such a manner that the 0.17-eV level is identified as a level of opposite parity (a p-wave level) which is mixed with the s-wave capture state.[4] The magnitude of the weak matrix element can be estimated by assuming that the observed effect results from the mixing of the 0.17-eV state with one of the adjacent s-wave levels.[3] This mixing should also give rise to a dichroism—a dependence of the transmission of the sample on the helicity of the neutrons—due to an interference of p- and s-wave capture states.[2,5,6] An estimate of the magnitude of the effect on the basis of Refs. 2 and 4 with the matrix elements from Ref. 3 yields $P = (\sigma_t^+ - \sigma_t^-)/(\sigma_t^+ + \sigma_t^-) = 10^{-4}$–$10^{-5}$. in the two-level approximation.

The experiment which we are reporting here was carried out in a beam of polarized thermal neutrons at the VVR-M reactor at the Leningrad Institute of Nuclear Physics. The apparatus was similar to that described in Ref. 5. It uses an integral method to detect the neutron beam transmitted by the sample, with synchronous detection of the change in the intensity resulting from a change in the polarization sign of the neutrons. There is also parallel detection of a signal proportional to the reactor power for use in correcting the results for fluctuations in the neutron flux density.

The target is U_3O_8 enriched to 83% ^{233}U, held in a hermetically sealed duralumin container with entrance and exit windows 0.5 mm thick. The target is surrounded by a 20-cm-thick layer of polyethylene for shielding against the fast neutrons that are formed. The detector is positioned 1 m from the target and is surrounded by a cadmium shield with a window no greater than 15 cm^2 in area.

Spurious measurement effects are eliminated by carrying out the measurements with two directions of the static guiding field at the target and in the on-off state of an rf flipper.[5] The results of the measurements are

$$a^+ = (1.0 \pm 1.1)\times 10^{-6}, \quad a^- = (0.1 \pm 1.1)\times 10^{-6}.$$

The final result, corrected for the degree of polarization of the beam (0.95) and for the number of relaxation lengths in the target (1.26) is, for an average neutron energy of 0.01 eV ($\lambda = 2.7$ Å), $P = (-0.4 \pm 0.7)\times 10^{-6}$.

This result is lower by a factor of about 30 than the estimate found under the assumption that the 0.17-eV level is a p-wave level.There are at least five possibilities for reconciling the present result with that of Ref. 3.

(1) If an admixed s-wave level lies at a negative energy, we would have $P \sim [\Gamma_p/(E - E_p) + \Gamma_s/(E - E_s)]$, where $E_{s,p}$ and $\Gamma_{s,p}$ are the positions and widths of the s and p levels. Since the characteristics of these s levels are not known accurately, there may be a cancellation at the thermal point. (2, 3) In the case of a mixing of effects associated with several p- or s-wave levels, there could also be a random cancellation of the corresponding contributions. Such a strong cancellation of this sort seems improbable; furthermore, in the first two cases it could occur only at a single point, and it should be disrupted upon an energy shift. In particular, near the 0.17-eV level we would have $P = 10^{-3}$–10^{-4}.

There are two alternative interpretations of Ref. 3, according to which the 0.17-eV level is an s-wave level and does not determine dichroism effects, while a p-wave level lies outside the energy interval studied. (4) The asymmetry of the emission of the fragments changes sign near both the p level and the s level in the case of an interference of capture states with different angular momentum. This mechanism, studied in Ref. 2, operates in a channel with $K = 0$. (5) In contrast with the assumptions of Ref. 4, the phase difference φ between the regular and admixed fission amplitudes may not be small.[2] The asymmetry zero lies at the point $E_p - (\Gamma_p/2)\tan\varphi$, not at E_p whose coincidence with the 0.17-eV level is purely fortuitous. The latter explanation seems the most likely. For a final resolution of this question we would like to see a study of both *P*-odd effects and the *P*-even left-right asymmetry over a broader energy range.

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