Observation of parity nonconservation in the total cross section and in the cross section for the radiative capture of polarized thermal neutrons in ^{79,81}Br

V. A. Vesna, É. A. Kolomenskiĭ, V. M. Lobashev,[1)] A. N. Pirozhkov, L. M. Smotritskiĭ, and N. A. Titov[1)]
B. P. Konstantinov Institute of Nuclear Physics, Academy of Sciences of the USSR

(Submitted 14 March 1982)

Pis'ma Zh. Eksp. Teor. Fiz. **35**, No. 8, 351–353 (20 April 1982)

Parity (P) nonconservation effects have been measured in the total and radiative cross sections in ^{79,81}Br: $(\sigma_{\text{tot}}^{+} - \sigma_{\text{tot}}^{-})/(\sigma_{\text{tot}}^{+} + \sigma_{\text{tot}}^{-}) = (9.8 \pm 1.0) \cdot 10^{-6}\sigma_{\text{tot}}) = 15.5$ b and $(\sigma_{\gamma}^{+} - \sigma_{\gamma}^{-})/(\sigma_{\gamma}^{+} + \sigma_{\gamma}^{-}) = (15.5 \pm 1.5) \times 10^{-6}\sigma_{\gamma} = 9.8$ b, where the $\pm$ correspond to opposite neutron helicities. It follows from the results that the P-odd effect in the total cross section is determined by radiative capture, within the experimental error.

PACS numbers: 25.40.Lw, 25.40. — h, 24.70. + s, 27.50. + e

Several parity nonconservation effects during the passage of slow neutrons through matter have been observed in recent years.[1–5] These effects are analogous to optical dichroism.

The first study along this line revealed a rotation of the polarization plane of cold neutrons passing through a ^{177}Sn sample.[1] The observed effect was anomalously high in comparison with the estimates which had been made at the time, and the nature of the effect accordingly came under question. Flambaum and Sushkov[6] have offered a very natural explanation: In the neutron resonance region the parity nonconservation effects have, in addition to the so-called dynamic enhancement,[7] an additional enhancement factor of $\Gamma_n^s/\Gamma_n^p)^{1/2} \sim 10^2$–$10^3$ directly at the neutron p resonance, where Γ_n^p and Γ_n^s are the neutron widths of the p and s resonances.

For nuclei which have p resonances near the thermal point, it is possible to observe several effects for thermal neutrons, including a dependence of the total cross section and of the radiative-capture cross section on the neutron helicity.

These effects were first observed by Kolomensky *et al.*[2] for thermal neutrons in the nuclei ^{117}Sn and ^{139}La; the results of those studies furnished unambiguous evidence of a relationship between the measured effects and compound resonances. Slightly later, Alfimenkov *et al.*[3,4] found a dependence of the total cross section on the neutron helicity directly at the p resonance. The same effect has recently been observed[5] at the p resonance with an energy of 0.88 eV for a natural isotopic mixture of bromine.

In this letter we are reporting measurements of the dependence of the total cross section and of the cross section for the radiative capture of thermal neutrons on the helicity for a natural isotopic mixture of bromine. The measurements were carried out in a beam of polarized thermal neutrons from the VVR-M reactor of the Leningrad Institute of Nuclear Physics. The integrated neutron flux was 6×10^7 n/s, the polarization was $P = 95\%$, and the average neutron wavelength was $\lambda_{av} = 2.7$ Å. The measurement apparatus was described in Ref. 2.

The beam of longitudinally polarized neutrons passed through the sample, which was encased in ^6LiF shielding, which absorbs the scattered neutrons. As γ detectors we used NaI(Tl) crystals 150 mm in diameter and 100 mm long with FÉU-49B photomultipliers, on both sides of the sample. The neutrons which were transmitted through the sample were detected by a proportional chamber filled with a mixture containing ^3He. The polarization of the neutron beam was rotated each 2 s by an rf adiabatic flipper. The measurement procedure was similar to that of Ref. 2. As a signal for cancelling the fluctuations in the reactor power we used the output signal from the γ detector in an apparatus used to study the circular polarization in the reaction $np \to d\gamma$, whose intensity is proportional to the reactor power. The variable component of the output signals from the γ detectors, the output signal from the proportional chamber used to detect the transmitted neutrons, and the output signal from a monitor were each integrated separately over 2-s intervals; the results were converted into numerical code and recorded on magnetic tape for subsequent analysis. The fluctuations were cancelled out during the data processing.

TABLE I.

Sample	Length of sample, in mean free paths	$\frac{I^+ - I^-}{P(I^+ + I^-)} \cdot 10^6$	$\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \cdot 10^6$
$^{79,81}Br$ Transmission $\sigma_{tot} = 15,5$ b	1,27	− (12,5 ± 1,2)	9,8 ± 1,0
$^{79,81}Br\ (n\ \gamma)$ $\sigma_\gamma = 9,8$ b	1,27	10,5 ± 1,4	15,5 ± 1,5[1)]

[1)] A correction has been made for the transmission effect.

The bromine sample was liquid bromine filling a quartz cell 35 X 70 X20 mm in size. The length of the sample along the beam path was 35 mm.

We measured the radiative-capture cross section and the total cross section for the loss of neutrons from the beam. The total cross section was determined from the attenuation of a collimated neutron beam. The error in the measurement of σ_{tot} was ~3%. The radiative-capture cross section was determined by simultaneously detecting the attenuation of neutrons transmitted through the sample and measuring the intensity of scattered neutrons, by detecting the γ rays produced in the capture of neutrons scattered by the sample in a cadmium layer on the γ detector.

The cadmium scattered-neutron detector was calibrated with the help of a graphite sample, for which there is essentially no radiative capture. The error in the measurement of σ_γ by this method is ~10%.

The background was measured by replacing the bromine sample with a graphite sample in which the intensity of transmitted neutrons was equal to the intensity of neutrons transmitted through the bromine. The background amounted to ~4%.

The measurable quantity is $\delta = (I^+ - I^-)/(I^+ + I^-)$, where I^+ and I^- are the intensities of the detected neutrons or γ rays corresponding to the different neutron helicities. The experimental results are presented in Table I.

Using the results of Ref. 8, Table I we can compare our results with those of Ref. 5, where the *p* resonance at 0.88 eV was suggested as the source of the effect at the thermal point. Within the errors there is a good agreement.

In summary, effects associated with the helicity dependence in the total cross section have now been studied at the thermal point and at the *p* resonance for ^{117}Sn, ^{139}La, and a natural isotopic mixture of bromine.

In all three cases the agreement of the experimental data obtained at the thermal point with the data obtained at the *p* resonance can be judged completely satisfactory. The one dissonant note is the sign found for the neutron spin rotation by ^{117}Sn by Forte *et al.*[1]; this sign does not agree with the sign of the effect in the total and radiative cross section if it is assumed that the effects at the thermal point are caused exclusively by the known 1.3-eV *p* resonance. The effect at the resonance for ^{117}Sn has not been determined accurately enough to permit definite conclusions regarding the possible existence of a subthreshold *p* resonance. Otherwise, it may be said that the theory which has been derived gives a good description of the experimental data.

We wish to thank A. I. Egorov for assistance in preparing the sample.

[1)]Institute of Nuclear Research, Academy of Sciences of the USSR, Moscow.

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Translated by Dave Parsons
Edited by S. J. Amoretty