Parity violation at the 0.75-eV neutron resonance of lanthanum-139

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A parity violation at the 0.75-eV neutron resonance of lanthanum-139 has been observed in an experiment on the transmission of polarized resonance neutrons. The change in the cross section upon a change in the neutron helicity is $P(E_p) = (\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) = (7.3 \pm 0.5) \times 10^{-2}$.

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A recent experimental study[1] of parity violation at the 1.33-eV neutron resonance of tin-117 confirmed the theoretical predictions of Refs. 2 and 3 of an important enhancement of this effect near compound states of nuclei. If new experimental capabilities are exploited to study this effect in various nuclei, it will become possible to obtain more specific information about the resonance contribution to the nonconserved parity of the amplitudes for neutron-induced reactions. In the present letter we are reporting measurements of the difference between the resonance part of the cross section of the lanthanum-139 nucleus for neutrons polarized in the directions parallel and antiparallel to their momentum.

The measurements were carried out in an IBR-30 pulsed reactor under conditions similar to those described in Ref. 1. We measured the transmission of longitudinally polarized neutrons by a sample of natural lanthanum with a thickness of 4.7 cm ($n = 1.25 \times 10^{23}$ nuclei/cm^2). A neutron beam with a cross section of 5×6 cm was polarized by a method involving transmission through a dynamically polarized proton target. The polarization f_n was 0.55; reversal occurred in 40 s. Neutron time-of-flight spectra were recorded by a detector 58 m from the reactor core and by a measurement system using a small computer. The statistical base was acquired over a useful time of 7 days.

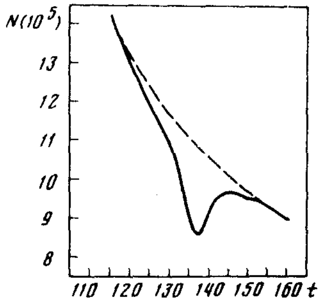

FIG. 1. Instrumental neutron spectrum after transmission through a 4.7-cm-thick lanthanum target, obtained by a time-of-flight method.

Figure 1 shows a part of the spectrum with the 0.75-eV resonance, obtained in 40 h for one of the beam polarization directions. The dashed curve is the spectrum in the absence of the resonance, found from measurements without lanthanum, with allowance for the known energy dependence of the total cross section of the resonance. The elongated left-hand wing is caused by the impurity resonance of ^{149}Sm with an energy of 0.87 eV. Figure 2 shows the experimental parity-violation effect

$$\epsilon = \frac{N^+ - N^-}{f_n (N^+ + N^-)} ,$$

where N^+ and N^- are the numbers of counts over the given part of the spectrum for neutrons of positive and negative helicity. The effect reaches a maximum value of 2% and is clearly of a resonance nature. We measured the parameters of the p-wave resonance of lanthanum and found $E_p = 0.75 \pm 0.01$ eV, $g\Gamma_p^n = (3.6 \pm 0.3)\cdot 10^{-8}$ eV, and $\Gamma_p = 0.045 \pm 0.005$ eV, in good agreement with the data of Ref. 4. The energy width of the resolution function of the neutron spectrometer is $R = 25$ meV in our case, and the Doppler level width is $\Delta = 23$ meV. Obviously, such parameters should lead to an experimental resonance curve in Fig. 2 which is slightly broader than that when R and Δ are ignored. In the present case, therefore, we will use the relative change in the area A above the resonance dip upon a change in the sign of the polarization:

$$\epsilon_A = \frac{A^+ - A^-}{f_n (A^+ + A^-)} . \tag{1}$$

Using the expression of Ref. 2 for the resonance part of the p-wave cross section, σ_p,

$$\sigma_p^{\pm} = \sigma_p(E) [1 \pm \mathscr{P}] , \tag{2}$$

we find, for thin sample

$$\epsilon_A = \mathscr{P}$$

$$\mathscr{P} = (7.3 \pm 0.5) \cdot 10^{-2} . \tag{3}$$

A conversion of ϵ to ϵ_A yields $\mathscr{P} = (7.3 \pm 0.5)\cdot 10^{-2}$. Since there is no significant effect away from the 0.75-eV resonance, we may assume that the observed parity-violation effect occurs exclusively in the resonance part of the cross section.

It is interesting to compare this result with the parity-violation effect in the total cross section of lanthanum at thermal energies, $\mathscr{P}(E) = (5.6 \pm 0.8)\cdot 10^{-6}$, found in

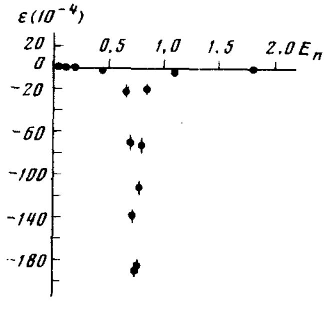

FIG. 2. Dependence of the parity-violation effect on the neutron energy (in electron volts) near the p-wave resonance of lanthanum at 0.75 eV. Where error bars are not shown, the corresponding errors do not exceed the size of the circle.

TABLE I.

Compound nucleus	$\lvert E_s \rvert$, eV	a	$\langle s \lvert H_W \rvert p \rangle$, eV
Tin-118	10	$4 \cdot 10^{-5}$	$0{,}4 \cdot 10^{-3}$
Lanthanum-140	37	$3 \cdot 10^{-5}$	$1{,}1 \cdot 10^{-3}$

Ref. 5. If the effect in the thermal region is primarily a consequence of radiative capture, we can base the comparison on the equation

$$\frac{\mathcal{P}(E)}{\mathcal{P}} \simeq \frac{\sigma_p(E_p)}{\sigma_t(E)} \left(\frac{\Gamma_p}{2E_p} \right)^2 \tag{4}$$

(see Ref. 1, for example), where $\sigma_t(E)$ is the total cross section in the thermal region, and $\sigma_p(E_p)$ is the resonance part of the cross section at the maximum of the p resonance. The experimental value of $\mathcal{P}(E)/\mathcal{P}$ agrees with that calculated from Eq. (4) within a factor1) of 1.5–2, and this agreement should be judged extremely satisfactory, since $\mathcal{P}(E)$ and $\mathcal{P}$ differ by four orders of magnitude.

According to theoretical arguments, the parity-nonconserving weak nucleon-nucleon interaction leads to an admixture of compound states of the opposite parity in the p level. The mixing ratio a was calculated from $\mathcal{P} = 2a(\Gamma_s^n/\Gamma_p^n)^{1/2}$ with a neutron width $\Gamma_s^n = 0.1$ eV for the nearest strong s-wave resonance at $E_s = -37$ eV (Ref. 4). The matrix element of the parity-violating interaction was evaluated from the equation[2] $\langle s|H_W|p\rangle = a|E_s|$. The results for the cases studied by us, lanthanum and tin,[1] are listed in Table I.

Because of the uncertainties in the parameters of the negative resonances and the several assumptions which have been used, the values of a and $\langle s|H_W|p\rangle$ are no more than estimates. In this sense, the results demonstrate that the weak nucleon-nucleon interactions are of roughly equal importance in the compound states of tin-118 and lanthanum-140. The very high experimental value of ϵ for lanthanum is attributed primarily to the anomalously high reduced neutron width of the s level.

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1)This agreement is improved by refined data from a Leningrad group[6]: $\mathcal{P}(E) = (9 \pm 1.4) \cdot 10^{-6}$, $\mathcal{P}_\gamma(E) = (16.1 \pm 2.0) \cdot 10^{-6}$, $\sigma_t(E) = 19.6\ b$, and $\mathcal{P}(E) = 9.4\ b$.

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