# Observation of parity violation and a left-right asymmetry in the reaction $^{35}Cl\ (n, p)\ ^{35}S$

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The *P*-odd and left-right asymmetry in the emission of protons by the compound nucleus in the reaction $^{35}Cl\ (n, p)\ ^{35}S$ have been measured for the first time. The coefficients are $a_p = -(1.51 \pm 0.34)\times 10^{-4}$ and $a_p^{LR} = -(2.40 \pm 0.43)\times 10^{-4}$. A limitation is found on the dependence of the total cross section on the neutron helicity: $|\alpha_n| < 2\times 10^{-6}$ (at a 90% confidence level).

The observation of parity violation in the reaction $^{35}Cl\ (n, \gamma)\ ^{36}Cl$ in the integrated spectrum of $\gamma$ rays[1] and the indications of an effect for the isolated $\gamma$ transition[2] are evidence of a comparatively extensive mixing of states of different parities in the compound nucleus formed during the neutron capture. This circumstance suggests that it may be possible to observe parity violation in the reaction channel involving the emission of a proton. Since a comprehensive study of parity-violating effects in each individual case yields important information about the mechanisms for the enhancement of parity-violating effects and about highly excited nuclear states, we have undertaken a study of the reaction $^{35}Cl\ (n, p)\ ^{35}S$, which includes a *P*-even and a *P*-odd asymmetry in the emission of protons with respect to the polarization direction of the neutron.

The experiments were carried out in a polarized neutron beam with a wavelength $\lambda_{av} = 2.7$ Å at the VVR-M reactor of the B. P. Konstantinov Leningrad Institute of Nuclear Physics. The basic parameters of the apparatus and the measurement proce-

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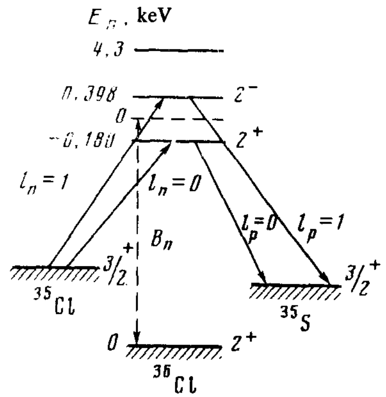


FIG. 1. Level scheme for the reaction $^{35}$Cl $(n, p)$ $^{35}$S.

dure are described in Ref. 3. In the present experiments we used a counting method to detect the secondary emission. Protons from the reaction $^{35}$Cl $(n, p)$ $^{35}$S (Fig. 1) with an energy $E_p = 0.6$ MeV were detected by a double proportional chamber with a grid which made it possible to set up an insensitive gas-filled gap (Fig. 2) for proton collimation. The dimensions of each of the two single-sided targets, each working with its own chamber, were $60 \times 11$ mm. These targets completely covered the exit aperture of the neutron collimator, with dimensions of $60 \times 8$ mm. The targets were filled with salt $BaCl_2$. An rf adiabatic flipper reversed the direction of the neutron spin each 2.8 s.

Three experiments were carried out. In the first we sought a $P$-odd asymmetry $W(\theta) \sim 1 + a_p \vec{\sigma}_n \mathbf{k}_p$ in the proton emission; in the second we sought $W(\theta) \sim 1 + a_p^{\mathrm{LR}} \vec{\sigma}_n [\mathbf{k}_n, \mathbf{k}_p]$ (a left-right asymmetry), and in the third we sought $W(\theta) \sim 1 + \alpha_{p,n} \vec{\sigma}_n \mathbf{k}_n$; a dependence of the cross section on the neutron helicity in the channel of the $(n, p)$ reaction and the same dependence in the total reaction cross section, by analogy with Ref. 3. Here $\vec{\sigma}_n$, $\mathbf{k}_p$, $\mathbf{k}_n$, and $\mathbf{k}_\gamma$ are unit vectors along the spin of the neutron and along the momenta of the proton, the neutron, and the $\gamma$ ray, respectively.

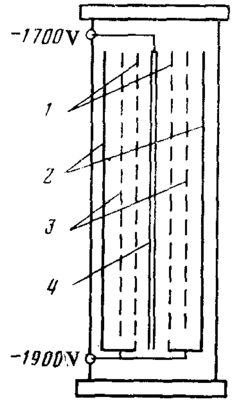


FIG. 2. The chamber. 1,2—Wire and solid high-voltage electrodes; 3—signal grids; 4—target.

TABLE I.

| | $a_p \times 10^4$ | $a_p^{LR} \cdot 10^4$ | $\alpha_{p,n} \cdot 10^4$ |
|---|---|---|---|
| (n, p) reaction | $-1{,}51 \pm 0{,}34$ | $-2{,}40 \pm 0{,}43$ | $-0{,}31 \pm 0{,}36$ |
| (n, γ) reaction integral over the spectrum | $-(0{,}28 \pm 0{,}05)$ 1 | – | $< 0{,}02$ |

To eliminate false effects, the guiding magnetic field in the chamber was reversed every 12 h. This reversal changed the sign of the effect but not the sign of the stray electromagnetic pickup. By using this procedure we were able to work without a beam depolarizer and to reduce the time required for the experiments.

We measured the quantity $\delta = (I^+ - I^-)/(I^+ + I^-)$, where $I^\pm$ are the intensities of the protons or neutrons detected for opposite directions of the neutron spin.

We also carried out several control experiments, which showed that the apparatus could reliably measure effects at the level of $10^{-4}$–$10^{-6}$.

As a result of these measurements, we have detected a $P$-odd asymmetry in the proton emission, $a_p$, and a left-right asymmetry, $a_p^{LR}$, for the first time.

The experimental results are listed in Table I. The data in this table have been corrected for the beam polarization $P = 0.95$ and for the background; in addition, $a_p$ and $a_p^{LR}$ have been corrected for the average cosine of the proton emission angle with respect to the neutron spin, $\overline{\cos\theta} = 0.8$.

Working from these results on the even and odd asymmetries, we can calculate the matrix element of the weak interaction. Simplifying the expressions in Ref. 4 for thermal energies, and assuming $\Gamma^n_{p1/2} = \Gamma^n_p$, $\Gamma^p_{p1/2} = \Gamma^p_p$, we find

$$a_p^{LR} = S\sqrt{\frac{\Gamma^n_{p1/2}\Gamma^p_{p1/2}}{\Gamma^n_s \Gamma^p_s}}\left(\frac{E_p\Gamma_s - E_s\Gamma_p}{E_p^2}\cos\Delta\varphi + \frac{2E_s}{E_p}\sin\Delta\varphi\right), \tag{1}$$

$$a_p = \frac{2VS}{E_p}\sqrt{\frac{\Gamma^p_{p1/2}}{\Gamma^p_s}}\left(\cos\Delta\varphi + \frac{\Gamma_p}{2E_p}\sin\Delta\varphi\right), \tag{2}$$

where $V$ is the matrix element of the weak interaction, $\Delta\varphi$ is the difference between the phase shifts for the $s$- and $p$-neutron resonances, $S$ is a spin factor on the order of unity, and the other symbols are the parameters of the $s$ and $p$ resonances.

In the case of $^{35}Cl$ $(n, p)$ we have $\Delta\varphi = 72.7°$ because of the phase shifts of the Coulomb interaction. In the corresponding calculations we used the neutron resonance parameters $E_p = 398$ eV and $E_s = -180$ eV from Ref. 6, and we took the proton widths from Ref. 7. The validity of the two-level approximation can be drawn from the fact that the cross section at the thermal point is determined within 20% by the resonance $E_s = -180$ eV (Ref. 7). Since only the total proton and neutron widths of the $p$ resonance in the 1/2 and 3/2 channels are known, the calculations give us only an upper estimate of the $P$-odd and the left-right asymmetry because of the high values of $\Gamma^{p}_{p1/2}$ and $\Gamma^{n}_{p1/2}$: $a_p$ (calc) $= -0.72\times10^{-2}$ (eV) and $a_p^{\rm LR}$ (calc) $= 11\times10^{-4}$.

Using expression (2) and the experimental value of $a_p$ we can estimate a lower limit on the matrix element of the weak interaction.

Our measurements yield $|V| > 3\times10^{-2}$ eV (90% confidence level). Because of the uncertainty of a factor of two or three due to the ratio of widths and the spin factor, this result is consistent with the estimate $|V| = 11.5\times10^{-2}$ eV ($\pm$ 50%) of Ref. 8 and with the estimate $|V| \sim (9-12)\times10^{-2}$ eV from the data of Ref. 1; here we are using a suppression factor $\sim$(3–4) for the $P$-odd integral asymmetry in accordance with Refs. 4 and 5. Calculations of the magnitude of the effect in the total cross section yields $\sim10^{-7}$ consistent with the experimental estimate obtained by us.

The overall agreement of the values found for the various correlations can be described satisfactorily in the model of Refs. 4 and 5.

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