Parity violation in gamma decay of ^{118}Sn

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We measured the P-odd asymmetry of the emission of γ quanta in the reaction $^{117}\mathrm{Sn}(n,\gamma)^{118}\mathrm{Sn}$ on polarized neutrons, and found it to equal $a = (8.1 \pm 1.3) \times 10^{-4}$. For comparison, measurements were also made of the asymmetry in the reaction $^{113}\mathrm{Cd}(n,\gamma)^{114}\mathrm{Cd}$. The obtained value $a = (-5.0 \pm 1.2) \times 10^{-4}$ agrees with the known data.

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The theory of universal weak interaction predicts the existence of a spatial-partity-violating weak internucleon potential. It follows therefore that the

TABLE I.

№	Purpose of measurement	Reaction	E_γ MeV	Measured asymmetry × 10^4	
				Polarized beam	Depolarized beam
1	Apparatus asymmetry	$^{113}Cd(n,\gamma)^{114}Cd$	> 2.5	−0,10 ±0.06	−0.05 ±0.06
2	Imitated asymmetry	$^{113}Cd(n,\gamma)^{114}Cd$	> 2.5	0.60 ±0.06	0.06 ±0.07
3	*P*-odd asymmetry	$^{117}Sn(n,\gamma)^{118}Sn$	9.3	6.1 ±0.7	0.4 ± 0.7
4	Apparatus asymmetry	$^{117}Sn(n,\gamma)^{118}Sn$	> 5.5	−0.3 ±0.4	0.8 ± 0.4
5	*P*-odd asymmetry	$^{113}Cd(n,\gamma)^{114}Cd$	9.04	−3.8 ±0.6	−0.1 ±0.7
6	Contribution of *p*-neutrons	$^{117}Sn(n,\gamma)^{118}Sn$	9.3	−2.6 ±2.1	−0.7 ±2.0

nuclear states contain a small admixture of states with opposite parity, and the transitions between them constitute an admixture of transitions with different parity—regular and irregular transitions. The interference between them leads to an angular anisotropy of the radiation, in the form

$$W(\theta) \sim 1 + a \cos \theta, \tag{1}$$

where θ is the angle between the direction of emission of the quantum and the spin of the nucleus. The asymmetry parameter a depends both on the characteristics of the states and the transitions between them, and on the amplitude of the admixture of the state with opposite parity. In the general case we have $a \sim 10^{-7}$, but, as shown in[1,2], there can exist in the nuclei various mechanisms that enhance the effect and can lead in the aggregate to experimentally observable asymmetries on the order of 10^{-4}.

We have undertaken an experiment aimed at measuring the *P*-odd angular correlation of the γ quanta in the reaction $^{117}Sn(n,\gamma)^{118}Sn$ on polarized thermal neutrons of the heavy-water reactor of the Institute of Theoretical and Experimental Physics. The measurements were performed with the modified and approved installation used in[6]. A beam of polarized neutrons with 90% polarization was incident on a target of metallic tin enriched to 90% of ^{117}Sn. The target was viewed with four scintillation blocks (NaI(Tl)) and an FEU-52 photomultiplier with a resolution 8—9% relative to the 660-keV γ line of ^{137}Cs, located on both sides of the target at an angle 22.5°. The pulses from the detectors were passed through shaping amplifiers to discriminators that separated the required sections of the spectrum. From the discriminators the pulses went to a distributing unit that sent them through two groups of scaler systems, depending on the direction of the neutron polarization during the time of the measurements. The direction of a neutron beam polarization could be reversed every second, but whether a reversal occurred or not depended on a random factor. In equally random fashion, the electronic registration circuits were switched over after each exposure. The measurements with the polarized beam were alternated with measurements with the depolarized beam every 16 min. Information from the scalar systems was analyzed with a computer operating "in line" with the installation. The following measurements were made: 1) measurement of the apparatus asymmetry, when γ quanta with energy $E_\gamma > 2.5$ MeV from a cadmium target were registered; 2) measurement of the imitated small asymmetry effect, when the intensity of the beam of polarized neutrons was modulated by passage through a thin strip of magnetized iron and γ quanta with energy $E_\gamma > 2.5$ MeV from a cadmium target were registered; 3) measurements of the asymmetry of the emission of γ quanta with $E_\gamma > 9.3$ MeV (the discrimination threshold was set at the level $E_\gamma > 8.0$ MeV) from a ^{117}Sn target.

The measurement results are gathered in Table I. It is seen that the apparatus had no intrinsic asymmetry and its operation was stable enough not to mask a specially imitated small effect. On the other hand, comparison of the results of measurements with tin at $E_\gamma = 9.3$ MeV and $E_\gamma > 5.5$ MeV shows that an asymmetry appears in the counting of the γ quanta with $E_\gamma = 9.3$ MeV (principal approach), correlated with the polarization of the neutron beam. This asymmetry can be due to three causes: violation of P parity, circular polarization of the registered γ quanta, which pass through a layer of weakly magnetized iron 1 mm thick prior to entering the detector, and finally, the interference of the s and p resonances, which leads to a correlation of the form $\mathbf{S}_n[\mathbf{K}_n \times \mathbf{K}_\gamma]$, where $\mathbf{S}_n$ is the neutron spin and $\mathbf{K}_n$ and $\mathbf{K}_\gamma$ are respectively the momenta of the neutron and of the γ quantum. This correlation is maximal for a geometry in which the neutron spin and the γ-quantum momentum are perpendicular, and should vanish in our geometry, when the detectors are located in a plane determined by the beam axis and the direction of the neutron spin. An estimate that takes into account the maximum possible deviations of our apparatus from ideal shows that this effect is smaller by a factor of at least 30 than the maximum effect. To measure the maximum possible effect due to the interference of the s and p resonances, we placed one of the γ-quantum detectors perpendicular to the direction of the neutron-beam polarization. The results of these measurements are also given in Table I. It is seen that the effect observed in tin cannot due to the contribution of p-neutrons.

To verify the sensitivity of the installation to circular polarization of the registered γ quanta, we measured the asymmetry of the γ-quantum emission of the principal transition in the reaction $^{113}\mathrm{Cd}(n,\gamma)^{114}\mathrm{Cd}$. The thresholds of the discriminators were set such that γ quanta with $E_\gamma > 8.5$ MeV were registered. As seen from the table, the asymmetry observed by us in the emission of the γ quanta of the principal transition of ^{118}Sn is opposite in sign to the asymmetry of the emission of γ quanta of the principal transition of ^{114}Cd, measured in[3,5]. If the observed effect were due to circular polarization, then the effect of Cd should be of the same sign as that of Sn. Consequently it was sufficient to determine only the sign of the asymmetry for Cd. The results of these measurements are also given in Table I. It is seen that the signs of the effects due to

Sn and Cd are different, and consequently the sensitivity of the installation to circular polarization of the γ quanta is negligibly small. Taking into account the corrections for the degree of polarization of the neutron beam and the finite solid angle spanned by the γ-quantum detector, and also the errors in the measurements of the asymmetry with the depolarized beam, we obtain

for $^{118}\mathrm{Sn}$ $a = (8.1 \pm 1.3) \cdot 10^{-4}$,

for $^{114}\mathrm{Cd}$ $a = (-5.0 \pm 1.2) \cdot 10^{-4}$.

The results for $^{114}\mathrm{Cd}$ agree well within the limits of the measurement errors with the data of[3-5]. However, it is surprising that the values of the effect for different nuclei are the same within a factor of two, although the theoretically predicted enhancements of the effect should fluctuate strongly. It is not excluded that the "working" enhancement mechanism is in fact different.

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