Nonconservation of *P* parity in the Mössbauer transition of a ^{119}Sn nucleus

A. V. Baluev,[2] L. V. Inzhechik,[1] E. V. Mel'nikov,[1] B. I. Rogozev,[2]
A. S. Khlebnikov,[1] V. G. Tsinoev,[1] and V. M. Cherepanov[1]
I. V. Kurchatov Institute of Atomic Energy

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The asymmetry of the emission of Mössbauer photons relative to the direction of the spin of a ^{119}Sn nucleus has been studied. The quantity $2R$, a measure of the P-parity violation in nuclei, equal to twice the ratio of the reduced matrix elements of the impurity $E1$ transition and regular $M1$ transition, has the value $2R = (0.94 \pm 0.08) \times 10^{-3}$.

A wide variety of P-odd effects associated with the existence of a weak nucleon-nucleon interaction, including the asymmetry of the emission of photons due to the decay of a polarized radioactive nucleus, have now been detected by the nuclear-spectroscopy methods (see, e.g., Refs. 1–3).

In the present letter we report the results of a measurement of an analogous effect in the Mössbauer $M1$ transition of an ^{119}Sn nucleus, making use of the various applications of nuclear γ-resonance spectroscopy.

The use of resonance scintillation detectors and nuclear γ-resonance methods make it possible to single out the transitions between individual Zeeman components of the excited state m_e and the ground state m_g, thus selectively isolating the nuclei in a particular polarized state, without appealing to the conventional technology of extremely low temperatures. Furthermore, there is another way of achieving a resonance by varying the chemical shift between the source and the absorber and by thermally varying the hyperfine splitting by nuclei of the source.

The information on the odd P effect is contained only in the transitions with $\Delta M = m_e - m_g = \pm 1$. The contribution of this effect to the intensity $I(\Delta M)$ of the dipole radiation for the transitions with any values of ΔM is

$$\Delta I/I = -\ 2R \cdot \Delta M \cdot \xi_c ,^{3)}$$

where $\xi_c = 2\cos\theta/1 + \cos^2\theta$ is the degree of circular polarization of the emitted line.

We used the following experimental arrangement. The ^{119m}Sn isomer, a γ-ray source, was one of the components of the ferromagnetic compound Mn$_4$Sn, whose Curie point was found to be $T_C = 435$ K. The radioactive compound in the form of a solution which we obtained was poured into a matrix with dimensions $6 \times 12 \times 0.3$ mm. The ~600-Oe external magnetic field was applied along the longer side of the rectangle. The angle between the direction of the field and the direction of radiation incident on the detector was either 45° or 135°, depending on the sign of the orienting magnetic field.

Figure 1 shows the emission spectra measured at several temperatures with use of

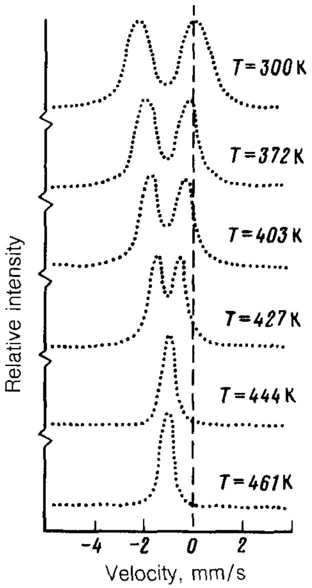

FIG. 1. Temperature-induced emission spectra of the Mn_4 ^{119m}Sn source.

tin phosphate resonance scintillation detectors. The spectra were measured in a working geometry in an external orienting field. We see that a resonant absorption of photons at zero relative velocity of the source and the detector (dashed line) can be accomplished over a broad temperature interval through an isomeric shift selected beforehand. As a result, we were able to carry out the experiment with a source and a detector which were stationary with respect to each other and to measure the asymmetry only when the sign of the external field changed. In the experiment we used an integrated photon detection method and a synchronous method of detecting the sought-for periodic signal which is produced as a result of reversal of the sign of the magnetic field every four seconds.

By varying the temperature of the source without changing the resonance conditions we were able to control the reliability of the results and to identify the case in which a false asymmetry is superimposed on the effect which we are seeking. The value $2R$ which is determined must be a constant and there must be no emission asymmetry in the paramagnetic region.

Because of the poor resolution of the Zeeman-splitting lines in that part of the spectrum in which the resonance conditions hold, the detector also recorded transitions with other values of ΔM, in addition to the intensity of the line corresponding to the transition $+3/2 \to +1/2$ $(\Delta M = \pm 1)$.

The working formula for determining the value of $2R$ therefore has the form

$$\Delta I_{\uparrow\downarrow}/I_{\text{res}} = -2R\cdot 2\overline{\Delta M}|\overline{\xi_c}|,$$

where $\Delta I_{\uparrow\downarrow}$ denotes change in the radiation intensity when the internal magnetic field at the nucleus is oriented in the direction of the emitted photons and when it is oriented in the opposite direction, $\overline{\xi_c}$ is the value of ξ_c which is averaged over the aperture of the source-detector, and $\overline{\Delta M}$ is the effective value of ΔM equal to $\overline{\Delta M}$

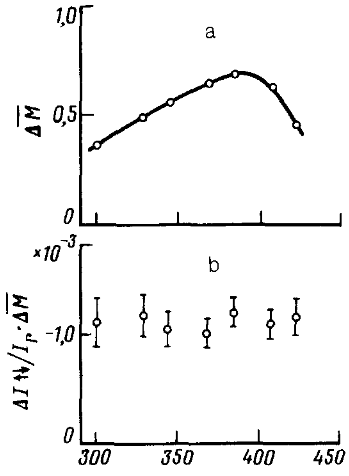

FIG. 2. (a) The normalized total contribution to the asymmetry of all the lines of the spectrum, $\overline{\Delta M}$, as a function of the temperature; (b) the normalized asymmetry of the emission of photons, $\Delta I_{\uparrow\downarrow}/I_{\text{res}}\,\overline{\Delta M}$, at various temperatures of the source.

$= \Sigma(\Delta M)_i a_i/\Sigma a_i$ (a_i is the contribution of each transition to the intensity of the resonance radiation detected by a resonance scintillation detector).

The value of $\overline{\Delta M}$ found from the interpretation of the emission spectra is shown in Fig. 2a, from which we see that the $+3/2 \to +1/2$ transition is the principal contribution to the effect which we are investigating. The relative value of the partial contribution of the resonance radiation to the total photomultiplier current at $T > T_c$ was determined by the standard SnO_2 "black-absorber" method. At $T < T_c$ we were able to reconstruct $I_{\text{res}}(T)$ from the area of the corresponding Mössbauer spectrum. The results of the measurement of $\Delta I_{\uparrow\downarrow}/I_{\text{res}}\,\overline{\Delta M}$, with allowance for the fact that the sign of the effective magnetic field of the ^{119}Sn nucleus in the Mn_4Sn compound is opposite to that of the applied external field,[5] are shown in Fig. 2b. The errors given here are determined primarily by the statistical base of the measurements, since I_{res} and $\overline{\Delta M}$ were determined to within ~1%.

We have thus measured the asymmetry of the photon emission as a function of the free parameter—the temperature. As expected, there is no energy dependence of the normalized asymmetry, and all the points in Fig. 2b can be combined in order to find $2R$. Since the measurement accuracy of the geometric factor $\overline{\xi}_c$ common to all the points amounts to ~7%, the resultant value of $2R$ is $(0.94 \pm 0.08) \times 10^{-3}$.

This result is in good agreement with the preliminary calculations of Platonov.[6]

[1)] I. V. Kurchatov Institute of Atomic Energy.

[2)] V. G. Khlopin Radium Institute.

[3)] From the equations[4] we used we found the relation $P_c = -2R$ for the circular polarization of an unpolarized source.

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