LETTERS TO THE EDITOR

V. B. BERESTETSKII

Submitted to JETP editor May 19, 1958

(August, 1958)

As is well known, the nucleus becomes oriented as a consequence of parity nonconservation in beta decay. For the case of an allowed beta-transition of a nonoriented nucleus, the average value \( \langle J \rangle \) of the angular momentum of the daughter nucleus is given by

\[
\langle J \rangle = \frac{i}{\hbar} (j + 1) c v,
\]

where \( j \) is the angular momentum of the daughter nucleus, \( c v \) is the velocity of the \( \beta \) electron (the neutrino direction is not observed), and \( \xi \) is the coefficient in the formula

\[
w = 1 + \xi \langle J \rangle / j,
\]

which describes the electron angular distribution for decays of oriented nuclei. 1-3 This orientation is responsible for effects in the electromagnetic transitions of the daughter nucleus such as the circular polarization of photons, 3 and the polarization of conversion electrons. 4

An analogous orientation of the nucleus also takes place in radiative orbital electron capture \( e + p \rightarrow n + \nu + \gamma \) (see reference 5). The nuclear orientation is given in this case by Eq. (1), in which \( c v \) is the photon velocity and \( \xi \) is the coefficient that appears in positron emission.

To prove this premise, let us consider the matrix element \( V_{m,m} \) for radiative K capture with the nucleus going from the state \( j m_1 \) into \( j m \). Accurate to within an overall multiplicative factor, we have

\[
V_{m,m} = (jm | O_i | j m_1) (\bar{u}_e(q) O_i (\hat{p} - \hat{k} + im) \hat{e} u_e(p)),
\]

where \( (jm | O_i | j m_1) \) is the nuclear matrix element, \( u_e(q) \) is the amplitude of a neutrino with four-momentum \( q \), \( u_e(p) \) is the electron amplitude, \( \hat{e} \) is the polarization vector of the photon, and \( \hat{k} \) is its four-momentum. The polarization density matrix of the daughter nucleus is of the following form (accurate up to an overall multiplicative factor):

\[
\rho_{mm'} = \sum_{m} (jm | O_i | j m_1)(jm' | O_i | j m_1)^* Sp Q,
\]

\[
Sp Q = Sp [(\hat{p} + im) \hat{e} (\hat{p} - \hat{k} + im) \hat{O}_i \hat{O}_i (\hat{p} - \hat{k} + im) \hat{e}],
\]

where \( \hat{O}_i \) is the nuclear matrix element. Since for K capture \( \hat{p} = \gamma q \hat{p}_e \), hence

\[
Sp Q = Sp (\hat{p}_e + im) \hat{O}_i \hat{O}_i,
\]

In the case of positron emission \( \rho_{mm'} \) is also of the form (2) and

\[
\rho_{mm'} = Sp (\hat{p}_e + im) \hat{O}_i \hat{O}_i,
\]

where \( \hat{p}_e \) is the positron four-momentum. For an extremely relativistic positron \( m = 0, p_e^2 = k^2 + \gamma^2 = 0 \) Eq. (4) goes over into (3), thus proving Eq. (1) with \( \gamma \) equal to the photon velocity. (We have here the same relationship as in the formulas for photon polarization.)

At first sight it may seem peculiar that the pseudovector \( \langle \gamma J \rangle \) is proportional to the vector representing the photon momentum since photon emission proceeds through a parity conserving mechanism. In actuality, the nucleus becomes polarized because the virtual electron can be absorbed by the nucleus only in a state with a definite polarization, namely in the direction of its momentum, which in turn is opposite to the direction of the momentum of the emitted photon.

I express gratitude to A. I. Alikhanov, V. A. Liubimov, and L. B. Okun' for discussions.


Translated by R. Krotkov

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3 Alder, Stech and Winther, Phys. Rev. 107, 728 (1957).

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