SOVIET PHYSICS JETP VOLUME 11, NUMBER 6 DECEMBER, 1960

CONNECTION BETWEEN THE POLARIZATION OF β ELECTRONS AND THE SHAPE OF THE β SPECTRUM

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Submitted to JETP editor February 15, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 1894-1895 (June, 1960)

The connection between the longitudinal polarization of the β electrons and the shape of the β spectrum is established.

As is known,[1] the shape factor of the β spectrum $C(W)$ and the longitudinal polarization of the β electrons $\langle\sigma\rangle$ are given by the following expressions:

$$C(W)=\sum_i M_i(Z,\ W)f_i(W,\ X), \tag{1}$$

$$\langle\sigma\rangle=\frac{v}{c}\sum_i M_i(Z,\ W)f_i(W,\ X)a_i(Z,\ W)\Big/\sum_i M_i(Z,\ W)\times f_i(W,\ X). \tag{2}$$

Here Z is the charge of the nucleus, W and v are the energy and the velocity of the β electrons, respectively, X are the nuclear matrix elements, M_i and a_i are certain complicated functions which take account of the motion of the electron in the Coulomb field of the daughter nucleus, and the functions f_i depend on the energy of the electron and on the matrix elements.

From formulas (1) and (2) we can obtain the qualitative dependence of the polarization of the β electrons on the shape of the β spectrum for first-forbidden transitions in heavy nuclei. It appears, firstly, that, if there are no accidental relations between the matrix elements (due to some particular feature in the structure of the given nucleus), the Coulomb terms play the most important role in the expression (1) for $C(W)$, and $C(W)$ is constant, i.e., we have a pure Fermi spectrum. Secondly, the function $a_i(Z, W)$ is always very close to unity, deviating only by 2 to 4%. For a spectrum with Fermi shape the polarization of the β electrons therefore practically coincides with $-v/c$. This last result is well known from experiment.[2]

However, cases of first-forbidden decay are known for which the longitudinal polarization of the β electrons differs appreciably from the value $-v/c$. Here the β spectrum is not of the Fermi type.

The classic example of this type is the β decay of RaE (transition $1^- \rightarrow 0^+$). In this transition the polarization of the β electrons is appreciably different from the value $-v/c$,[3] and $C(W)$ is definitely not a constant.[4] Both these experimental facts can be explained by assuming that the relation between the matrix elements is such that the main, energy independent terms cancel each other for the most part, so that energy dependent terms start to play the most important role.[5]

An interesting example is also the β decay of Au^{198} (transition $2^- \rightarrow 2^+$). According to the data of the group of Alikhanov et al. (private communication and reference 6) the longitudinal polarization of the β electrons is appreciably different from $-v/c$ in the region of small energies [$\langle\sigma\rangle = (-0.83 \pm 0.05)\ v/c$ for $W = 100$ kev] and is equal to $-v/c$ in the region of large energies [$\langle\sigma\rangle = (-0.97 \pm 0.06)\ v/c$ for $W = 400$ kev]. The work of reference 7 contains similar data on the polarization of the β electrons of Au^{198} in the region of small energies.

It is interesting to compare these data with the data on the shape of the β spectrum of Au^{198}. It appears[8] that $C(W)$ is constant for $W > 300$ kev and increases sharply with decreasing energy in the region $W < 300$ kev. Thus we see again that the deviation of the polarization from $-v/c$ is intimately related to the deviation of the shape of the spectrum from the Fermi shape. In the case of unique transitions, $\Delta_j = 2$ (yes), the polarization is equal to $-v/c$, since there is only one matrix element and a cancelling out is impossible. Quantitative calculations for the case of the β decay of Au^{198} are of little interest, since the number of unknown matrix elements (six) is too large.

We note finally that the deviation of the polarization from the value $-v/c$ is due to the deviation of the shape of the spectrum from the Fermi shape also in the case of P^{32} and In^{114} (the data on the polarization are taken from Mikaélyan and Spivak,[10] the data on the spectra from reference 9).

The authors express their deep appreciation to Acad. A. I. Alikhanov and V. A. Lyubimov, who directed their attention to the anomalies in the polarization of the β electrons of Au^{198}, for their interest in this work.

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Translated by R. Lipperheide
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