ELECTRON POLARIZATION IN THE β-DECAY OF RaE†

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The β-decay of RaE(Bi^{210}) is a first-forbidden transition ($1^- \rightarrow 0^+$). The energy spectrum of a nonunique first-forbidden transition usually has the statistical shape and the electron polarization is $P=-v/c$, as in allowed transitions.[1] It is well known,[2] however, that the spectrum of RaE departs from the statistical shape substantially. Due to a particular relation between the nuclear matrix elements, the normally dominating energy-independent Coulomb terms are small and the energy-dependent terms come into play. Consequently one expects in this case the electron polarization to deviate from the normal value $P=-v/c$. Indeed, Geiger et al.[3] have found in a Moeller scattering experiment a smaller effect for RaE than for some other β-emitters investigated.

We have measured the polarization of RaE electrons using a method described in detail in previous publications,[4] which is suitable for accurate relative measurements of the electron polarization of two β emitters having similar energy distributions. The instrument is sensitive for electrons in an energy range from ~250 kev to ~600 kev. In this method the electrons are first deflected by multiple scattering with a thick Cu scatterer and then by single scattering at a thin Pt or Au foil. The scattering angles are 90° and 135°, respectively. The multiple scattering turns the original longitudinal polarization of the electrons into a polarization having a well defined transversal component, which in turn is measured by the azimuthal asymmetry of the single scattering. The asymmetry x is obtained from the ratio of the counting rates L (left) and R (right) of two β counters mounted at 135° with respect to the beam incident on the single-scattering foil: $L/R = \alpha(1-x)/(1+x)$. The factor α, arising from the difference in counter efficiencies, can be eliminated by interchanging the counters, a procedure easily possible in our arrangement. The relationship between x and the polarization can be written in the following form[5]:

$$x = -f_N \frac{\int (Pc/v) N(E)\, w(E)\, dE}{\int N(E)\, w(E)\, dE} = -f_N \left\langle \frac{P}{v/c} \right\rangle_{\text{Av}} \qquad (1)$$

$N(E)$ being the β spectrum and $w(E)$ the total efficiency of the apparatus for electrons of energy E. The factor f_N depends on the energy distribution of the β particles. The essential point is that this dependence is small in our experimental arrangement. This is the case even for comparatively thick single-scattering foils. A foil of 2.03-mg/cm² Pt has turned out to be suitable.

We have compared the experimental asymmetry x of RaE ($E_{max} = 1.15$ Mev) with that of Tl^{204} ($E_{max} = 0.76$ Mev) and Y^{91} ($E_{max} = 1.54$ Mev). Tl^{204} and Y^{91} are unique first-forbidden transitions and therefore have the polarization $P=-v/c$.[1] The results are as follows:

$$x(Tl^{204}) = f_N(Tl^{204}) = (6.42 \pm 0.05)\%,$$

$$\frac{x(Y^{91})}{x(Tl^{204})} = \frac{f_N(Y^{91})}{f_N(Tl^{204})} = 1.016 \pm 0.014,$$

$$\frac{x(\text{RaE})}{x(Tl^{204})} = \frac{f_N(\text{RaE})}{f_N(Tl^{204})} \left\langle \left(-\frac{P}{v/c} \right)_{\text{RaE}} \right\rangle_{\text{Av}} = 0.832 \pm 0.018.$$

These data are mean values of two independent statistically consistent sets of measurements with two RaE sources differing in their effective thickness by a factor of 3. The following corrections have been applied:

(1) Corrections for the instrumental asymmetry. This asymmetry has been measured and the correction shifts the final result by 2%.

(2) Corrections for the depolarization in the source, based on experimental and theoretical results. In the most unfavorable case, this correction amounts to $(3 \pm 1.5)\%$.

It remains to consider the influence of the β spectra on f_N. Experimentally we have obtained $f_N(Tl^{204}) = f_N(Y^{91})$. We have investigated in detail the energy dependence of f_N. It turns out that within an error of <1%, we have $f_N(\text{RaE})/f_N(Tl^{204}) = 1$. The electron distributions, $N(E) \times w(E)$, of Tl^{204} and RaE are much more alike than those of Tl^{204} and Y^{91}, as can be seen from Fig. 1. We obtain, for the average electron polariza-

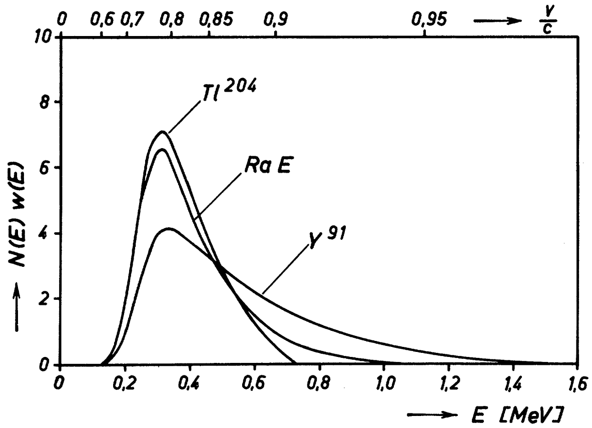

FIG. 1. The electron distributions $N(E)w(E)$ are plotted in arbitrary units. $N(E)$ is the β spectrum, $w(E)$ the total efficiency of the apparatus for electrons of energy E. $w(E)$ has been calculated approximately.[4]

tion defined in Eq. (1) for RaE,[6]

$$\left\langle -\left(\frac{P}{v/c}\right)_{\mathrm{RaE}}\right\rangle_{\mathrm{Av}} = 0.83 \pm 0.02.$$

RaE is the first example of a β emitter which has an electron polarization clearly deviating from $P = -v/c$. Curtis and Lewis[7] have calculated formulas for the polarization and the spectrum shape factor of RaE using STP coupling. For VA coupling[8] the formulas are easily obtained by changing the nuclear matrix elements and coupling constants and reversing the sign of the neutrino momentum,[5] if the two-component theory of the neutrino is valid. The β decay of RaE is governed by three nuclear matrix elements, $\int \vec{\sigma} \times \vec{r}$, $\int \vec{r}$, $\int \vec{\alpha}$. It is convenient to introduce two real[9, 10] parameters ξ_1 and η_1 by the relations

$$\xi_1 C_A \int \vec{\sigma} \times \vec{r} = i C_V \int \vec{r},$$
$$\eta_1 C_A \int \vec{\sigma} \times \vec{r} = \left(\frac{\alpha Z}{2\rho}\right)^{-1} C_V \int \vec{\alpha}, \qquad (2)$$

since both the spectrum shape and the polarization are dependent on these two parameters only (the unexplained symbols are defined by Konopinski[11]). For a quantitative discussion of the polarization measurement one has to determine ξ_1 and η_1 by fitting the experimental (2) spectrum shape factor to the theoretical one and to calculate the polarization using these values. To get a rough idea we can use the approximation $\alpha Z \ll 1$, $p\rho \ll 1$, which really is not well satisfied by RaE. Then the polarization can be written conveniently as

$$P = -\frac{v}{c}\,\frac{X(W,\xi_1,\eta_1) - Y(W,\xi_1,\eta_1)}{X(W,\xi_1,\eta_1) - (\frac{v}{c})^2 Y(W,\xi_1,\eta_1)}. \qquad (3)$$

(W is the electron energy, the functions X and Y can be obtained with the help of reference 7.) It can be seen that a deviation of $-P/(v/c)$ from 1 must occur for $v/c \neq 1$.

A more detailed description of this experiment can be found in reference 5.

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DETERMINATION OF THE PARITIES OF STRANGE PARTICLES FROM DISPERSION RELATIONS*

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Several authors [1-3] have recently suggested that the parities of the K-Λ and K-Σ systems relative to the nucleon might be determined