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TRANSVERSE POLARIZATION OF K- AND L-CONVERSION ELECTRONS FOLLOWING THE BETA DECAY OF Hg^{203}

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Abstract: The degree of transverse polarization of internal K- and L-conversion electrons following the beta decay of Hg^{203} has been measured. In both cases the polarization vector was found to be antiparallel to the momentum of the preceding beta particle. Comparison of the experimental and theoretically calculated results indicates that the ground state spin of Hg^{203} will be $\frac{3}{2}$ or $\frac{5}{2}$.

It was predicted theoretically that as a consequence of parity non-conservation in weak interactions internal conversion electrons following a beta decay are partially polarized with the polarization vector parallel or antiparallel to the momentum of the preceding beta particle [1-6]. The degree of transverse polarization may be written in the form

$$P = K(v/c)\sin\theta,$$

where v/c is the beta particle velocity in units of light velocity and θ is the angle between the directions of emission of the beta particle and the conversion electron. The polarization coefficient K contains the characteristic constants of the γ-decay and the conversion process as well as the nuclear spins, coupling constants and matrix elements of the beta decay. It turns out that a determination of K will give the same information as a measurement of the beta-gamma circular polarization correlation. At low γ-transition energies where the detection of circular polarization is difficult the conversion coefficients are fortunately large especially for heavy nuclei. Thus, the measurement of conversion electron polarization supplements the investigations of the beta-gamma circular polarization correlation and is a very useful method in nuclear spectroscopy [7,8].

In our experiment we separately measured the transverse polarization of K- and L-shell conversion electrons following the beta decay of Hg^{203}. The goal of this experiment was to check the theory of the predicted effect, to determine the ground state spin of Hg^{203} and to get information about the mixture of the beta transition matrix elements.

Fig. 1 is a simplified illustration of our experimental set-up. In order to measure the transverse polarization we scattered the conversion electrons from a gold foil and observed the left-right asymmetry. The conversion electrons emitted by the source into a fixed solid angle and scattered at an angle φ were detected in the counter C. The beta particles were detected in the counter β whose position automatically was alternated at constant time intervals between L and R. Coincident events in both counters (about 2/10 min for L-conversion and about 15/10 min for K-conversion) were registered using a standard fast-slow coincidence circuit. The windows of the pulse-height analysers were adjusted for β to accept only the beta spectrum and for C to accept either the K- or the L-conversion peak (fig. 2). The recorded coincidence rates were corrected for accidental coincidences and for the background which was found by measuring without scattering foil. To be sure that no instrumental asymmetry simulates a polarization effect control measurements were made by replacing the gold scattering foil by an aluminium foil. No asymmetry effect was found in this case.

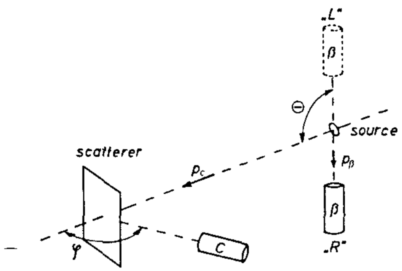

Fig. 1. Schematic illustration of the experimental arrangement.

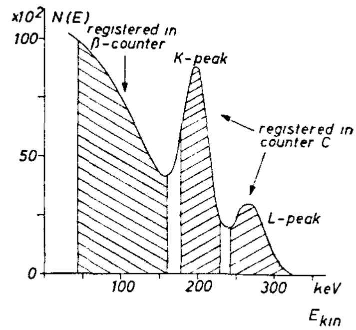

Fig. 2. Measured beta spectrum of Hg^{203}. The hatched areas indicate the windows of the pulse-height analysers. The β-particles were detected by a 1.5 mm thick anthrazenecrystal, 30 mm in diameter.

From the corrected coincidence rates L and R we evaluated the transverse polarization of the conversion electrons

$$P = \frac{1}{S(\bar{\varphi})}\,\frac{L-R}{L+R}, \tag{2}$$

using values of the Mott asymmetry function S which were calculated by Sherman without screening corrections [9]). This is justified at our energies (> 193 keV) by the experimental results of Bienlein *et al.* [10]). The reduction of the asymmetry effect due to plural scattering in the gold foil (0.18 mg/cm²) was taken into account according to Wegener's data [11]). In eq. (2) the quantity $\bar{\varphi}$ is the weighted scattering angle regarding the finite sizes of gold foil and counter C and the φ-dependence of S. In our case: $\bar{\varphi} = 112.5°$. Depolarization in the sources (0.05 mg/cm² and 0.1 mg/cm²) was estimated to be [12]) less than 1 %. The average v/c in our experiments was 0.49 determined by the window of the β-analyser. Because of the finite geometrical size of the apparatus the angle θ entering in eq. (1) had to be averaged and we obtained $\bar{\theta} = 109°$.

Our experimental results for the polarization of K- and L-conversion electrons are listed in table 1 together with the results of other authors.

TABLE 1

Experimental results for the polarization of K- and L-conversion electrons

Author	Polarization coefficient	
	K_K	K_L
Alberghini and Steffen [13])	$+0.35 \pm 0.07$	
Vishnevskii *et al.* [14])	-0.32 ± 0.09	
Frauenfelder *et al.* [15])	$+0.30 \pm 0.08$	
Schneider *et al.* [16])	-0.42 ± 0.18	
Buhl [17])	negative sign	
present work	-0.31 ± 0.04	-0.16 ± 0.06

All results of K-conversion agree as far as the absolute value is concerned but they differ in sign. No explanation for this discrepancy has been found until now. To facilitate comparison we remark that negative K means $L > R$ with the definition of L and R as given in fig. 1. This is equivalent with the statement that a polarization vector with a direction antiparallel to the momentum of the preceding beta particle yields a negative K-value.

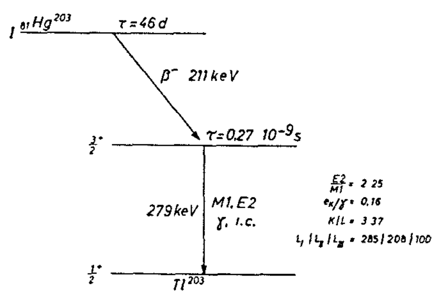

Fig. 3. Decay scheme of Hg^{203}. The insert gives the constants of γ-decay and conversion process as they were used in the theoretical calculations [19]).

The decay scheme of Hg^{203} is given in fig. 3. All characteristic constants of the γ-transition are known, whereas the ground state spin I has not yet been determined. Therefore, the polarization coefficients K_K for pure K-conversion and K_L for the mixture of L_I-L_{II}-L_{III} conversion were calculated for each of the possible spins $I = \frac{1}{2}, \frac{3}{2}$ and $\frac{5}{2}$ by means of the formulae and numerical data † of refs. [2,4,5]).

† It should be noted that in Geshkenbein's work [4]) the sign of his polarization formula is wrong. In our calculations we used his formula inverting the sign.

For beta transitions with $\Delta I = \pm 1$ the polarization coefficients K_K and K_L turned out to be independent from the beta matrix elements and in these cases ($I = \frac{1}{2}$ and $I = \frac{5}{2}$) we got

$$K_K(\tfrac{1}{2}) = +0.53, \quad K_K(\tfrac{5}{2}) = -0.32,$$
$$K_L(\tfrac{1}{2}) = +0.26, \quad K_L(\tfrac{5}{2}) = -0.15.$$

In the case $\Delta I = 0$, i.e. $I = \frac{3}{2}$, the polarization coefficients depend on a combination z of beta transition matrix elements which for the considered Coulomb transition of Hg^{203} has the form [8, 18])

$$z = \frac{-c_V \int \alpha + \xi(c_V \int i\boldsymbol{r} + c_A \int \boldsymbol{\sigma}\times\boldsymbol{r})}{c_A \int \gamma_5 - \xi c_A \int i\boldsymbol{\sigma}\cdot\boldsymbol{r}}. \tag{3}$$

The results are

$$K_K(\tfrac{3}{2}) = \frac{0.21z^2+0.82z}{1+z^2}; \qquad K_L(\tfrac{3}{2}) = \frac{0.1z^2+0.4z}{1+z^2}.$$

Fig. 4 shows a plot of the calculated $K(\frac{3}{2})$ values versus $z^2/(1+z^2)$.

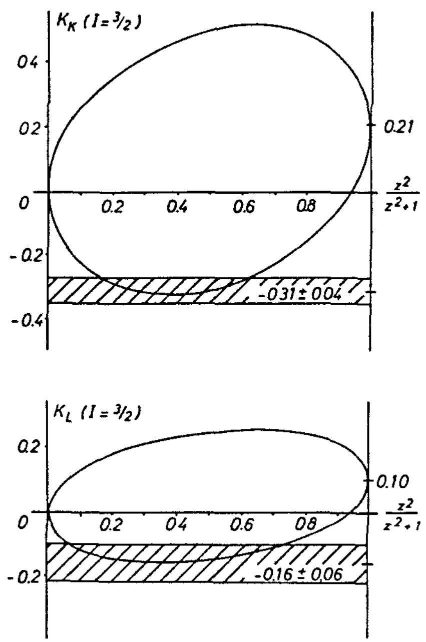

Fig. 4. The polarization coefficients for K- and L-conversion as a function of the matrix element mixture $z^2/(1+z^2)$ in the case of a $\frac{3}{2} \to \frac{1}{2}$ beta transition.

Obviously the ground state spin $I = \frac{1}{2}$ is excluded by our measurements whereas the assumption of $I = \frac{5}{2}$ gives excellent agreement between theoretical and experimental results. The ground state spin $I = \frac{3}{2}$ is consistent with our measurements, too. In this case the experimental values of $K_K(\frac{3}{2})$ and $K_L(\frac{3}{2})$ both would indicate a strong mixture between the beta matrix elements associated with a spin-flip and those without spin-flip.

A decision which of the ground state spins, $\frac{3}{2}$ or $\frac{5}{2}$, is the real one cannot be given by means of this experiment. The agreement of the results inferred from the measurements of the K- and L- conversion electron polarization confirms the validity of the theoretical calculations.

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References

1) H. Frauenfelder *et al.*, Phys. Rev. **110** (1958) 451
2) M. E. Rose and R. L. Becker, Phys. Rev. Lett. **1** (1958) 116, Nuovo Cim. **13** (1959) 1182
3) V. B. Berestetskii and A. P. Rudik, JETP (Soviet Physics) **8** (1958) 111
4) B. V. Geshkenbein, JETP (Soviet Physics) **8** (1958) 865; Bull. USSR Acad. Sc. **23** (1959) 1464
5) I. S. Baikov, JETP (Soviet Physics) **12** (1961) 439
6) H. R. Lewis and I. R. Albers, Z. Phys. **158** (1960) 155
7) H. Schopper, Nucl. Instr. **3** (1958) 158
8) H. Schopper, Fortschr. Phys. **8** (1960) 327
9) N. Sherman, Phys. Rev. **103** (1956) 1601
10) H. Bienlein *et al.*, Z. Phys. **154** (1959) 376
11) H. Wegener, Z. Phys. **151** (1958) 252
12) B. Blake and B. Mühlschlegel, Z. Phys. **167** (1962) 584
13) I. E. Alberghini and R. M. Steffen, Nuclear Physics **14** (1959) 199
14) M. E. Vishnevskii *et al.*, Nuclear Physics **18** (1960) 122
15) B. Blake, R. Bobone, H. Frauenfelder and H. J. Lipkin, preprint
16) H. Schneider *et al.*, Phys. Verhandlungen **3** (1962) 135
17) S. Buhl, Thesis, Heidelberg (1962)
18) H. A. Weidenmüller, Revs. Mod. Phys. **33** (1961) 574
19) Nuclear Data Sheets, National Academy of Sciences, Washington, D.C.