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ANGULAR DISTRIBUTIONS OF CONVERSION ELECTRONS FROM ORIENTED Ce^{137m} NUCLEI*

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Measurement of the energy dependence of charged-particle anisotropies from oriented nuclei would be valuable for many problems in nuclear physics. This report will describe special experimental techniques which have been developed to make such measurements possible, and their application to obtain the angular distribution of conversion electrons from oriented Ce^{137m}. The simultaneous measurement of gamma and conversion electron angular distributions gives a most direct determination for the "particle parameter." The general expression for the observed angular distribution of conversion electrons following the decay of oriented nuclei is

$$W(\theta) = 1 + \sum_{\nu \text{ even}} B_\nu U_\nu Q_\nu g_\nu b_\nu F_\nu P_\nu(\cos\theta) \quad . \tag{1}$$

Here B_ν are orientation functions, P_ν are Legendre polynomials, and F_ν are the angular correlation coefficients. The g_ν are attenuation coefficients which account for finite counter solid angles. The parameters Q_ν and U_ν describe, respectively, the reorientation in intermediate states, and the reorientation due to unobserved transitions between the original states in which the nuclei are oriented, and the state from which the observed radiations are emitted. b_ν are "particle parameters" which modify F_ν for the observed transition.

The Ce^{137m} isomeric transition is a very favorable case for study by nuclear orientation. The decay scheme is shown in slide 1.[2] The decay

sequence is $11/2 \rightarrow M4 \rightarrow 3/2$ and the M4 transition should be very pure. Ce^{137m} aligned in neodymium ethyl sulphate (N.E.S.) shows large gamma-ray anisotropies, and the 255-keV transition is highly converted ($e_K/\gamma \approx 6$).[3] There are no intermediate states in this experiment, so the $U_\nu Q_\nu$ factors in Eq. (1) can be replaced by unity. The B_ν are identical for conversion electron and γ-ray emission, and all B_ν for $\nu > 4$ are negligible. The relationship between B_2 and B_4 is accurately known from γ-ray studies,[4] and their values are known for any measured $W(0)_\gamma$. The g_2 corrections may be calculated, thus, along the axis of orientation ($P_\nu = 1$) we have

$$\begin{aligned} W(0)_e &= 1 + B_2 g_2(e) b_2 F_2 + B_4 g_4(e) b_4 F_4 \\ W(0)_\gamma &= 1 + B_2 g_2(\gamma) F_2 + B_4 g_4(\gamma) F_4 \end{aligned} \qquad (2)$$

where all except b_2 and b_4 are known. The b_ν are related by[5]

$$b_\nu = 1 + (b_2 - 1)\, \frac{\nu(\nu+1)[L(L+1)-3]}{3[2L(L+1)-\nu(\nu+1)]} \qquad (3)$$

$$\text{i.e.,} \quad b_4 = 17/3\, b_2 - 14/3$$

so that from the ratio

$$\frac{1-W(0)_e}{1-W(0)_\gamma} = \frac{F_2 g_2(e) B_2 b_2 + F_4 g_4(e) B_4 b_4}{F_2 g_2(\gamma) B_2 + F_4 g_4(\gamma) B_4} \qquad (4)$$

we have, for any value of $1-W(0)_\gamma$, an equation with b_2 as the only unknown.

The experimental cryostat is shown schematically in slide 2. The NES crystal is mounted with its c axis (the axis of orientation) horizontal, and electron detectors are placed inside the cryostat along and normal to this

axis. The gamma-ray detectors are outside the cryostat. The source was a small spot on the crystal onto which a small drop of aqueous solution containing the radioactive Ce^{3+} ions had been placed. The drop was deposited and removed several times, without evaporation, and some Ce^{3+} ions replaced Nd^{3+} in the lattice. This gave a 'thin' electron source, and the large anisotropies obtained showed that the Ce^{3+} was in lattice sites. The electron detectors were surface-barrier counters with up to 30v bias applied across an evaporated gold layer on a 1 m × 0.8 cm × 0.8 cm Ge crystal.

Upon demagnetization, simultaneous gamma and conversion electron counts were taken for about 1-1/2 hours as the source warmed up. Then exchange gas was admitted to the cryostat, warming the source to 1° K where normalizing 'warm' counts were taken. Typical 'cold' and 'warm' electron and gamma-ray spectra are shown in slide 3.

The results are shown in the final two slides where we have compared the data with values of the ratio $[1-W(0)_e]/[1-W(0)_\gamma]$ for several values of b_2. The final results are

$$b_2(K) = 1.061\ (18)$$

$$b_2(L+M) = 1.059\ (20).$$

The quoted uncertainties include estimated systematic errors in background and solid-angle corrections.

The theoretical value for this transition, for K electrons, based on a point nucleus model, is $b_2(K) = 1.055$[5] which is in excellent agreement with our result. No theoretical values are available for the L and M shells. For such a high multipolarity, point nucleus calculations are expected to be satisfactory.

The techniques reported here would be applicable for measuring particle parameters in any nuclear orientation experiments in which intensities permit and for which sufficiently thin sources can be prepared. In these cases this type of measurement can be especially valuable for the following reasons:

(1) Nuclear orientation, employing singles rather than coincidence counting, is the most direct method for measuring particle parameters. This leads to higher accuracy as is shown by comparison of the present result (±2%) with typical results of angular-correlation experiments (±10%).[6,7,8]

(2) The b_ν are parity sensitive, thus for an unknown transition an internal parity determination, which is absent in directional correlation of γ-rays alone, is provided.

(3) The ratio $F_2(e)/F_2(\gamma)$ for mixed transitions is in some multipolarity regions extremely sensitive to the multipole mixing ratio and can give this ratio with high accuracy than any other method.

FOOTNOTES AND REFERENCES

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