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PREFERENTIAL POLAR EMISSION IN THE ALPHA DECAY OF DEFORMED Cf^{249} and E^{253} *

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In 1953 Hill and Wheeler predicted that prolately deformed alpha-emitting nuclei should exhibit enhanced emission from the polar regions, or "tips", because of the lower Coulomb barrier in these regions.[1] Dabbs and co-workers have observed anisotropic angular distributions of alpha particles from oriented uranium and neptunium nuclei.[2] For Np^{237} they determined the sign of the quadrupole coupling constant in neptunyl ion and showed that alpha particles are indeed emitted preferentially along the direction of the angular momentum vector, confirming the prediction of Hill and Wheeler. Pryce[3] has suggested that the quadrupole moment of Np^{237} is negative, which would require a different interpretation of the orientation experiments, but this seems unlikely on the basis of the collective nuclear model. In this letter we describe orientation experiments on Cf^{249} and E^{253} which provide independent confirmation of the predictions of Hill and Wheeler, that is to say, the L=2 component in the main alpha group is appreciable and is in phase ($\delta > 0$) with the dominant L=0 wave.

Neodymium ethylsulfate was chosen as the crystal most suitable for these experiments. The ions Cf^{+3} and E^{+3} are chemically analogous to Dy^{+3}

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and Ho^{+3}, nuclei of which have been aligned in this lattice.[4,5] This salt can easily be cooled to 0.02°K, where fairly complete alignment of these nuclei could be expected. The alpha counters used in this experiment were similar to those described by Walter, Dabbs, and Roberts.[6] In each experiment care was taken to grow the radioactive ions only in a thin surface layer on a small spot on the crystal. Low temperatures were obtained by standard adiabatic demagnetization techniques, and the temperature was measured with mutual inductance coils.

At the lowest temperatures the angular distributions of alpha particles from both isotopes were highly anisotropic. In E^{253}, as in Ho^{166},[5] it could be ascertained by the temperature dependence of the anisotropy that the alignment was nearly complete even at temperatures as high as 0.1°K. Every aspect of the sign, magnitude, and temperature dependence of the nuclear orientation parameters of these two isotopes is consistent with Cf^{+3} and E^{+3} having the same electronic ground states as Dy^{+3} and Ho^{+3}, respectively, in this lattice. For E^{253} the temperature dependence of the alpha particle intensity along the crystalline c axis is shown in Figure 1. Data were also taken at 90° to the c axis. These showed a change in counting rate on orientation of the E^{253} nuclei of opposite sign and approximately half the magnitude as that along the c axis, indicating an angular dependence proportional to $P_2(\cos\theta)$. Because of the large solid angle corrections (13% of the coefficient of the P_2 term), we cannot determine with any precision the contributions of higher-order terms in the angular distribution.

In the ethylsulfate lattice the dominant spin-Hamiltonian term affecting nuclear orientation is expected to be of the form $AS_z I_z$ for both E^{+3} and Cf^{+3}, and this alone would require "axial" nuclear alignment (states with $I_z = \pm I$

would lie lowest). Combining this with the observed enhancement of alpha particle intensity along the c axis on orientation, we find preferential alpha emission along the nuclear spin direction in both cases. Since the ground states of both Cf^{249} and E^{253} have spins greater than 1/2 and spin projections K equal to the spin, so that the nuclear spin is along the prolate axis,[7,8,9] alpha emission must take place preferentially from the tips of these prolately deformed nuclei. In both cases the direction of orientation can also be established completely unambiguously from experiment, for E^{253} from the magnitude and temperature dependence of the anisotropy, and in Cf^{249} from the sign of the anisotropy of the (following) 394-kev γ-ray and knowledge of its dipole character with $I \rightarrow I-1$ spin sequence.

The E^{253} decay scheme has been given by Asaro et al.[8] who estimate an L=2 to L=0 intensity ratio of 1:8 in the main alpha group. The estimate is based on the decay intensity to the first excited state together with the approximate branching relations of Bohr, Fröman, and Mottelson.[10] A 25% enhancement of the D-wave admixture has been predicted for U^{233} by taking into account effects due to the quadrupole moment and Coriolis forces.[11,12] A similar enhancement is expected for E^{253}. Using the 1:8 D- to S-wave ratio, assuming them to be in phase, ignoring the small L=4 components, and assuming an isotropic average contribution from the 4 percent alpha intensity to other groups we calculate a limiting ($T \rightarrow 0$) angular distribution for E^{253} of $1 + 0.98\,P_2(\cos\theta)$. There is also predicted a small negative $P_4(\cos\theta)$ term of magnitude more dependent on L=4 intensity assumptions. Our experimental limiting anisotropy is 25 percent less than theoretical, probably indicating that not all the E^{253} atoms have gone into crystalline sites equivalent to the Nd atoms of the bulk crystal. The Cf^{249} data are not yet accurate enough to permit a quantitative interpretation, although it is clear that the hyperfine splitting is considerably less than for E^{253}.

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REFERENCES

1. D. L. Hill and J. A. Wheeler, Phys. Rev. 89, 1102 (1953).
2. J. W. T. Dabbs, L. D. Roberts, and G. W. Parker, Bull. Am. Phys. Soc. II, 2, 31 (1957); Physica 24, 69 (1958); F. J. Walter, J. W. T. Dabbs, L. D. Roberts, and H. W. Wright, Bull. Am. Phys. Soc. II, 3, 304 (1958); S. H. Hanauer, J. W. T. Dabbs, L. D. Roberts, and G. W. Parker, Phys. Rev. 124, 1512 (1961).
3. M. H. L. Pryce, Phys. Rev. Letters 3, 375 (1959).
4. Q. O. Navarro and D. A. Shirley, Phys. Rev. 123, 186 (1961).
5. H. Postma, A. R. Miedema, and Miss M. C. Eversdijk Smulders, Physica 25, 671 (1959).
6. F. J. Walter, J. W. T. Dabbs, and L. D. Roberts, Rev. Sci. Instr. 31, 756 (1960).
7. F. S. Stephens, F. Asaro, S. G. Thompson, and I. Perlman, Bull. Am. Phys. Soc. Series II, 2, 394 (1957).
8. F. Asaro, S. G. Thompson, F. S. Stephens, and I. Perlman, Proceedings of the Kingston Conference on Nuclear Structure, University of Toronto Press (1960), p. 581.
9. S. G. Nilsson, Mat. Fys. Medd. Dan. Vid. Selsk. 29, No. 16 (1955).
10. A. Bohr, P. O. Fröman, and B. R. Mottelson, Dan. Mat. Fys. Medd. 29, No. 10 (1955).
11. R. R. Chasman and J. O. Rasmussen, Phys. Rev. 115, 1257 (1959).
12. J. O. Rasmussen, Bull. Am. Phys. Soc. II, 6, 232 (1961).

FIGURE LEGEND

Fig. 1. Normalized total alpha-particle intensity along the c axis from E^{253} oriented in neodymium ethylsulfate at low temperatures. The upper curve is the best fit using the theoretical temperature dependence for the spin Hamiltonian $AS_Z I_Z$, with both A and the low temperature limiting asymptote adjustable.

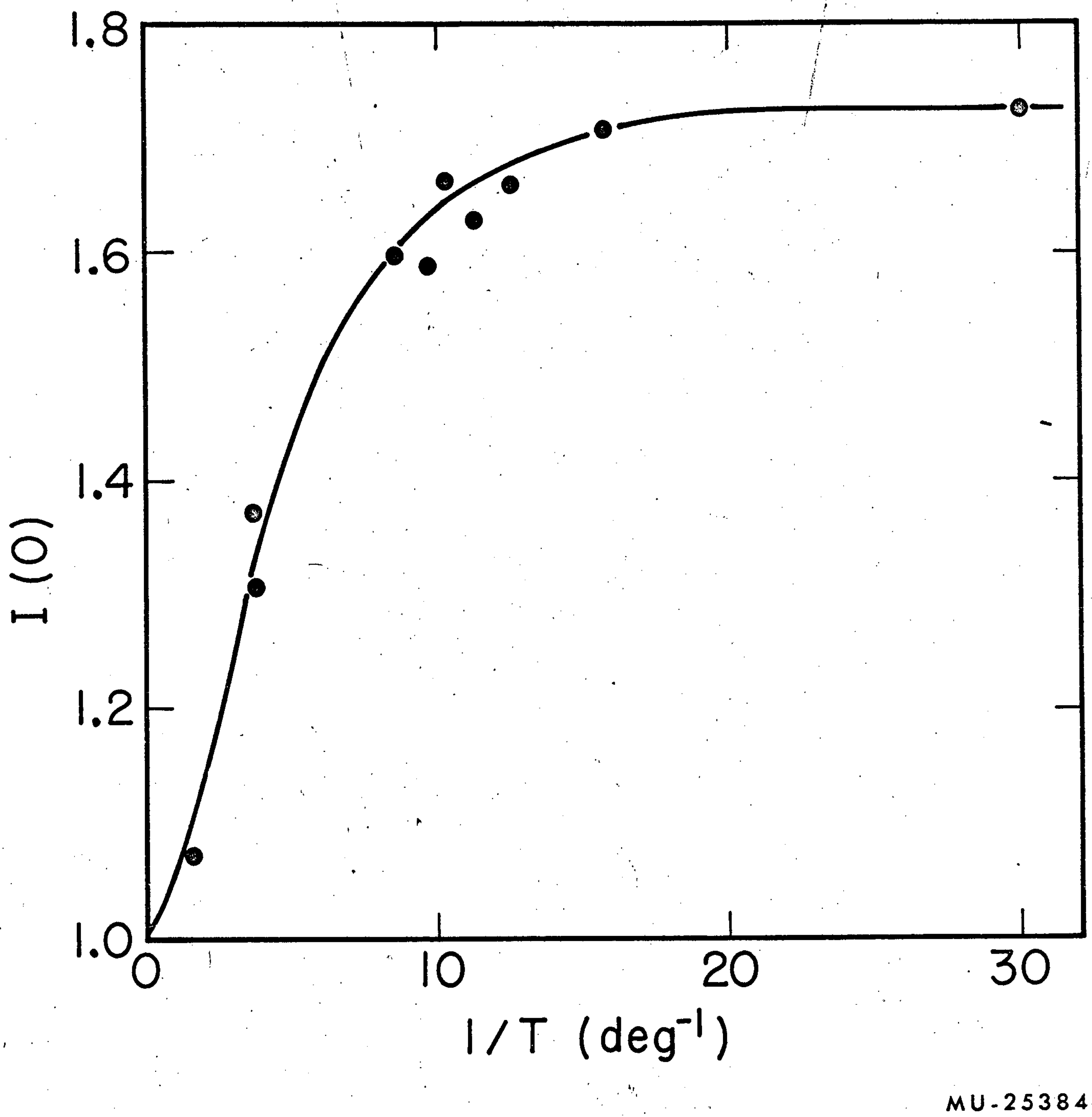

Fig. 1