UCRL-9960

University of California

Ernest O. Lawrence Radiation Laboratory

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

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

Q. O. Navarro, J. O. Rasmussen, and D. A. Shirley

February 6, 1962

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

Q. O. Navarro, J. O. Rasmussen,** and D. A. Shirley

Lawrence Radiation Laboratory and Department of Chemistry,
University of California, Berkeley.

February 6, 1962

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}

---

* This work was supported under contract with U. S. Atomic Energy Commission.

** Presently on leave at the Institute for Theoretical Physics, Copenhagen, Denmark.

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}.

It is a pleasure to thank Dr. S. G. Thompson, who participated in early stages of this research, Ray Gatti and Llad Phillips, for providing carrier-free E^{253}, and Professor B. B. Cunningham and Dr. J. C. Wallmann, who lent us their entire supply of Cf^{249}.

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).

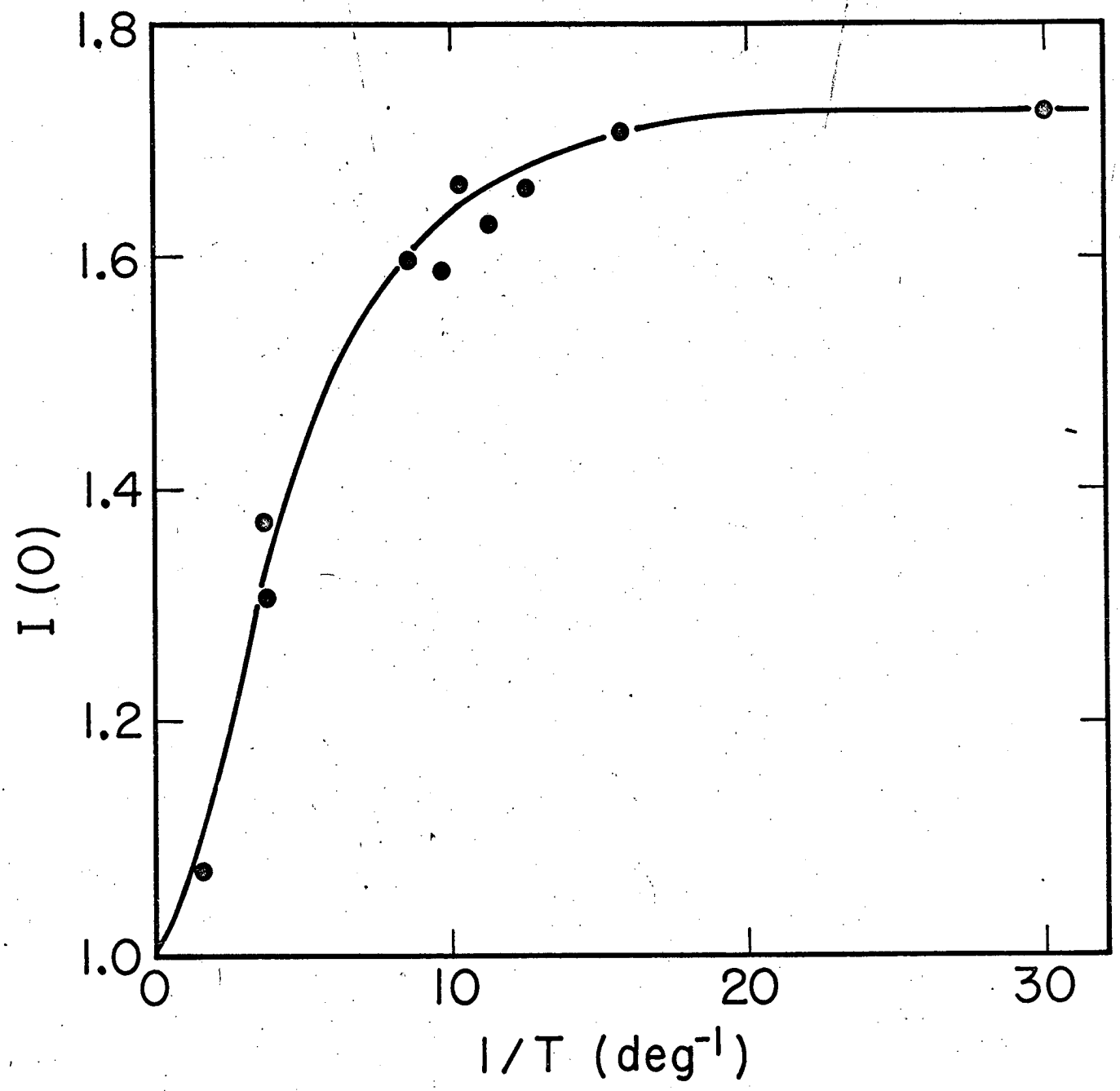
10. A. Bohr, P. O. Fröman, and B. R. Mottelson, Dan. Mat. Fys. Medd. 29, No. 10 (1955).

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_ZI_Z, with both A and the low temperature limiting asymptote adjustable.



MU-25384

Fig. 1

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of he Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.