UCRL 9569

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

For publication in Physical Review Letter

UCRL-9569

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

NUCLEAR ORIENTATION OF PARAMAGNETIC IMPURITY IONS

Morton Kaplan and D. A. Shirley

February 10, 1961

NUCLEAR ORIENTATION OF PARAMAGNETIC IMPURITY IONS*

Morton Kaplan and D. A. Shirley

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

February 10, 1961

The well-known Gorter-Rose method of nuclear orientation has been used with considerable success in recent years.[1-4] The method as used consists in cooling, by adiabatic demagnetization, a paramagnetic salt into which ions containing radioactive nuclei have been incorporated in lattice positions. These ions are polarized by a small applied magnetic field, and they in turn polarize their nuclei. A limitation of the method is that only nuclei of elements which form paramagnetic ions isomorphous with those of certain "good" cooling salts can be studied.

A substantial extension of this technique would result if nuclei of all elements that form paramagnetic ions could be oriented in this way. The purpose of this letter is to point out that this extension is made possible by incorporating the ions of interest as impurities into single crystals of cerium magnesium nitrate (CMN). The impurity ions may be interstitial or they may be trapped in tiny "brine holes". At any rate, they should be in thermal equilibrium with the lattice after demagnetization and can be polarized in fields of several hundred oersteds at temperatures below 0.01 $^{\circ}$K. To test this hypothesis, we have carried out nuclear-orientation experiments with Cr^{51} in CMN and have detected nuclear orientation by measuring the anisotropy of the 325-kev gamma rays.

The specimen consisted of a 5-gm single crystal of CMN grown from a solution containing small amounts of Cr^{51} along with about 1 mg of Cr^{+++} carrier. It was mounted in a demagnetization cryostat described elsewhere,[5] and cooled by adiabatic demagnetization to ~ 0.003 $^{\circ}$K. A polarizing field was applied along the trigonal axis of the crystal, and the gamma-ray counting rates were measured along and perpendicular to the field direction. The magnetic temperature of

the crystal was monitored continuously during the counting period. The results for two polarizing fields are shown in Fig. 1. The experiments were repeated with a second, independently grown crystal, and the data were found to be reproducible. Nuclear-orientation experiments in zero applied magnetic field show that the gamma-ray emission from Cr^{51} is still anisotropic, the normalized intensities being about 1.03 along the axis and 0.98 perpendicular to the axis, at the lowest temperatures reached.

Although the main object of this experiment was to test the above-mentioned nuclear-orientation mechanism, some nuclear information was obtained from a preliminary analysis of the results. Using our data for a polarizing field of 400 oersteds, where nondiagonal interactions should be least important, together with the measured partial E2 and total lifetimes[6,7] of the 325-kev state in V^{51}, we find: (1) the E2-M1 mixing ratio of the 325-kev gamma ray of V^{51} has the value $\delta(E2/M1) = +0.37 \pm 0.04$; (2) a spin assignment of 7/2- is absolutely ruled out for this state; and (3) a lower limit of $|\mu| \geq 0.8$ nm can be set for the magnetic moment of Cr^{51}.

The evidence which shows that Cr^{+++} does not go into lattice sites in CMN is derived from experiments in which we attempted to grow several percent chromium into cerium magnesium nitrate and lanthanum magnesium nitrate. In these experiments, the double nitrate crystals were grown from solutions containing relatively high concentrations of Cr^{+++}. The crystals obtained were analyzed spectroscopically for chromium with the result that portions of crystals that were cloudy and slightly blue contained small amounts($\sim$ 0.1%) of chromium. However, those portions of crystals which were optically clear and colorless contained no detectable traces of chromium. We conclude that Cr^{+++} does not substitute in lattice positions, but is probably incorporated into the crystal in "brine holes" as growth proceeds.

Considerable development may be necessary before this technique can be used to obtain reliable values of nuclear moments. It should be immediately useful, however, for investigating other nuclear properties. In particular, nuclei of elements in the 4d, 5d, and 5f transition series should be within the scope of the method.

We thank George Shalimoff for performing the analyses of the double nitrate crystals.

REFERENCES

*Supported by the U. S. Atomic Energy Commission.

1. C. J. Gorter, Physica 14, 504 (1948).

2. M. E. Rose, Phys. Rev. 75, 213 (1949).

3. R. J. Blin-Stoyle and M. A. Grace, Handbuch der Physik, Vol. 42 (Springer Verlag, Berlin, 1957), p. 555.

4. E. Ambler, Progress in Cryogenics, Vol. 2 (Heywood and Company, Ltd., London, 1960), p. 235.

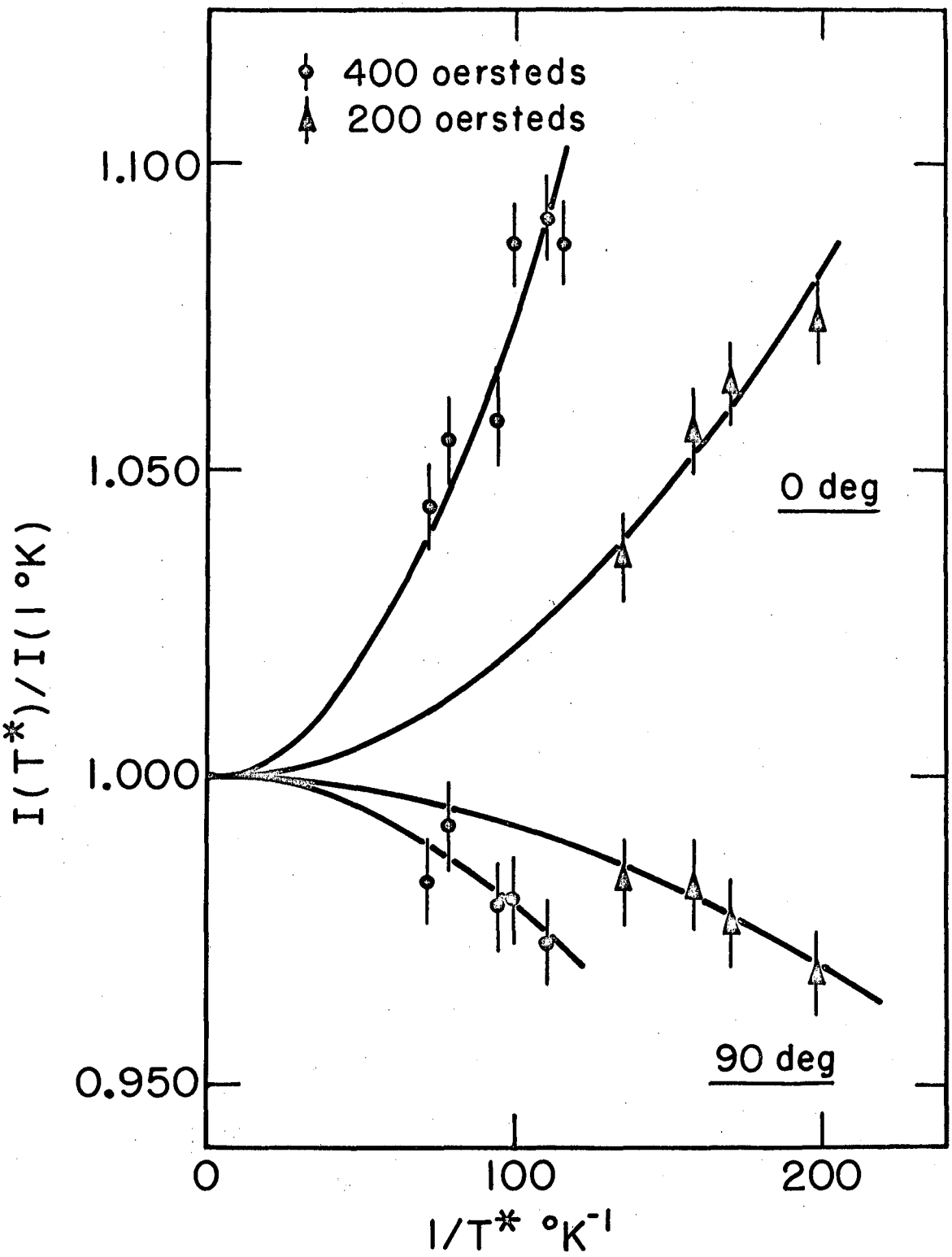
5. C. E. Johnson, J. F. Schooley, and D. A. Shirley, Phys. Rev. 120, 2108 (1960).

6. G. M. Temmer and N. P. Heydenburg, Phys. Rev. 104, 967 (1956).

7. A. W. Sunyar and M. Deutsch, private communication quoted by D. Strominger, J. M. Hollander, and G. T. Seaborg, Rev. Mod. Phys. 30, 585 (1958).

Figure Legend

Fig. 1. Experimental results for nuclear orientation of Cr^{51} in cerium magnesium nitrate as a function of the reciprocal magnetic temperature, $1/T^*$. The ordinate is the ratio of the intensity of 325-kev gamma rays at temperature T^* to the intensity at 1 ^oK. Data shown are from measurements at 0 and 90 deg to the crystal trigonal axis, for two values of the magnetic field applied along the axis. The uncertainties indicated are statistical standard deviations. The curves drawn through the points are proportional to $(1/T^*)^2$.



UCRL-9569

Fig. 1

59045-1