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Publication Date

1968-01-31

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Submitted to The Physical Review

UCRL-17992
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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Sanford Stein and Alan T. Ramsey

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THE GROUND-STATE SPIN OF $^{163}\text{Er}^*$
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University of California
Berkeley, California

January 22, 1968

ABSTRACT

The ground-state nuclear spin of 75-min ^{163}Er has been measured and found to be $I = 5/2$, in agreement with the Nilsson state assignment for the 95th neutron.

INTRODUCTION

The rare earths have been subject to considerable study, both because of interest in the atomic properties of the f^n and $f^{n-1}d$ configuration, and because the region around $A = 150$ is characterized by large nuclear deformations which offer a good test for the Nilsson model of strongly deformed nuclei. In erbium, work has been done on ^{165}Er (Ref. 1), ^{167}Er (Ref. 2), ^{169}Er (Ref. 3), and ^{171}Er (Ref. 4). Erbium-169, which has spin $I = 1/2$, has been used to determine g_J to high accuracy.³ In this paper we report on a measurement of the spin of the ground state of ^{163}Er by the atomic beam magnetic resonance method.

EXPERIMENTAL METHOD

Erbium-163 has a half-life of 75 minutes, and decays by β^+ emission to ^{163}Ho (half-life $> 10^3$ years), which decays by electron capture to stable ^{163}Dy . ^{163}Er was made by bombarding stable ^{165}Ho (100% abundant) on the 88-inch Cyclotron at Berkeley with 37-Mev protons for about 2 hours at a current of 30 μA or greater, producing the reaction $\text{Ho}(p,3n)^{163}\text{Er}$.

The sample, which consisted of four disks, 0.230 in. diameter and 0.05 in. thick, was placed in a Ta oven and heated by electron bombardment until a satisfactory beam was obtained. The beam lasted about 4 hours. Sometimes the holmium melted and evaporated out of the oven; other times the erbium simply diffused out, and the holmium target after the run looked as if nothing had happened to it. Anywhere from 0.5 to 2 hours was occupied trying to obtain a satisfactory beam.

Frequently the initial radioactive beam from the oven was not thrown out well by the inhomogeneous fields. This indicated that erbium did not emerge as single atoms at first. The apparatus employed the conventional two inhomogeneous magnetic fields as a spin polarizer and analyzer. In between these, a third homogeneous field and a superimposed small oscillating magnetic field induce desired transitions between energy levels of the atom. The orientational arrangement of the polarizer and analyzer was of the flop-in type, in which a resonance is indicated by an enhancement of the signal at the detector. More detailed descriptions of the apparatus and of the experimental techniques are found in Ref. 5. The beam was collected on freshly flamed Pt foils, removed from the vacuum system, and counted in a methane-filled β counter. Counter background and machine background (for a 5-min resonance exposure with the rf off) were both 1 to 2 counts per minute. Resonance signals (5-min exposure) were from 10 to 30 cpm for a direct beam (stop wire out of the way, 1 min exposure) of about 100 cpm. Erbium has a ${}^3\text{H}_6$ ground state arising from a $4f^{12} 6s^2$ configuration. With a spin of $5/2$, there are 78 Zeeman sublevels in the beam, giving rise to six Zeeman flop-in resonances (see Fig. 1).

SPIN SEARCH

Radiofrequencies corresponding to spins from $I = 1/2$ to $I = 11/2$ in a magnetic field of 4 gauss were tried. The frequencies involved are given by the relation

$$\nu = \frac{F(F+1) + J(J+1) - I(I+1)}{2F(F+1)} \frac{g_J \mu_0}{h} H_{ext}$$

The results of this spin search are shown in Fig. 2. To eliminate any possible ambiguities the spin search was repeated at 6 gauss. All data indicates the spin of ^{163}Er is $I = 5/2$. As a further check, we looked at all six of the possible $\Delta F = 0$ transitions at 10 gauss. Five of the six transitions yielded large resonances ($> 25\%$ of the direct beam) while the sixth ($F = 7/2$, the lowest F value) was much smaller.

COMPARISON WITH THEORY

Since ^{163}Er is far removed from a closed shell, it is in a strongly deformed region, where the collective model of Nilsson applies.⁶ The measured spin $I = 5/2$ for the ground state of ^{163}Er agrees with the Nilsson model for the 95th neutron in a level characterized by the asymptotic orbital of $5/2^- [523]$.

ACKNOWLEDGMENTS

We thank Professor Richard Marrus for many helpful discussions during the course of this work.

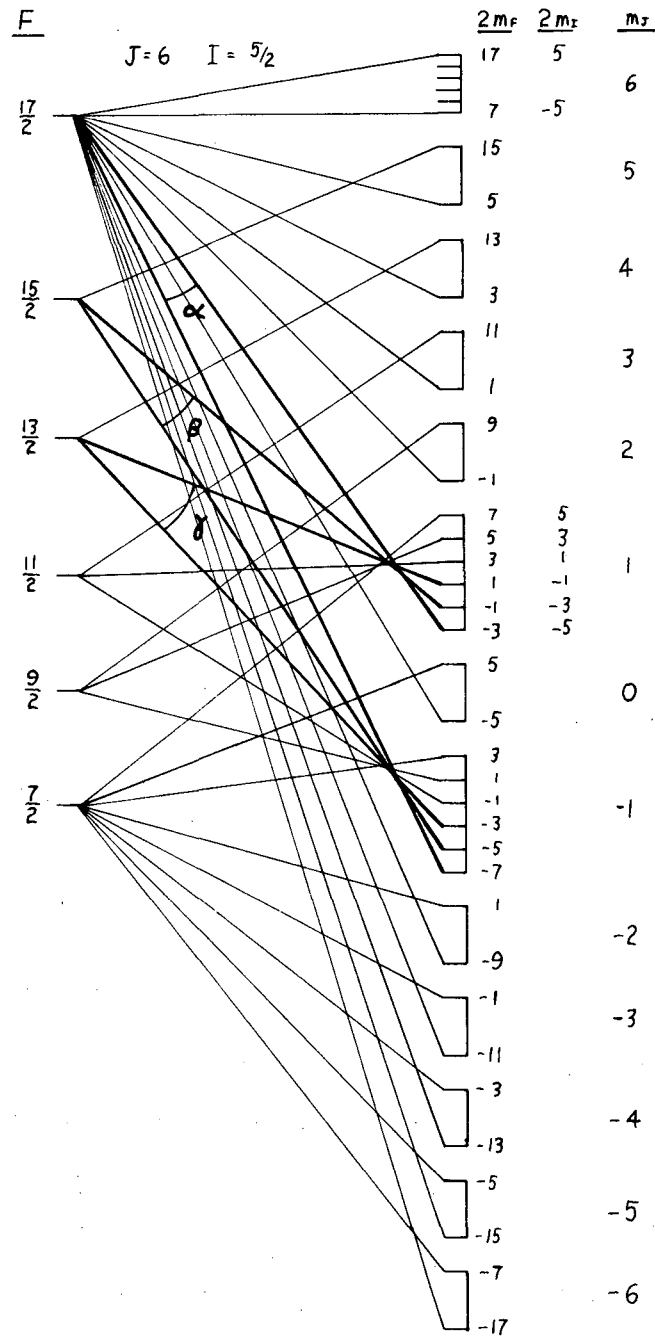
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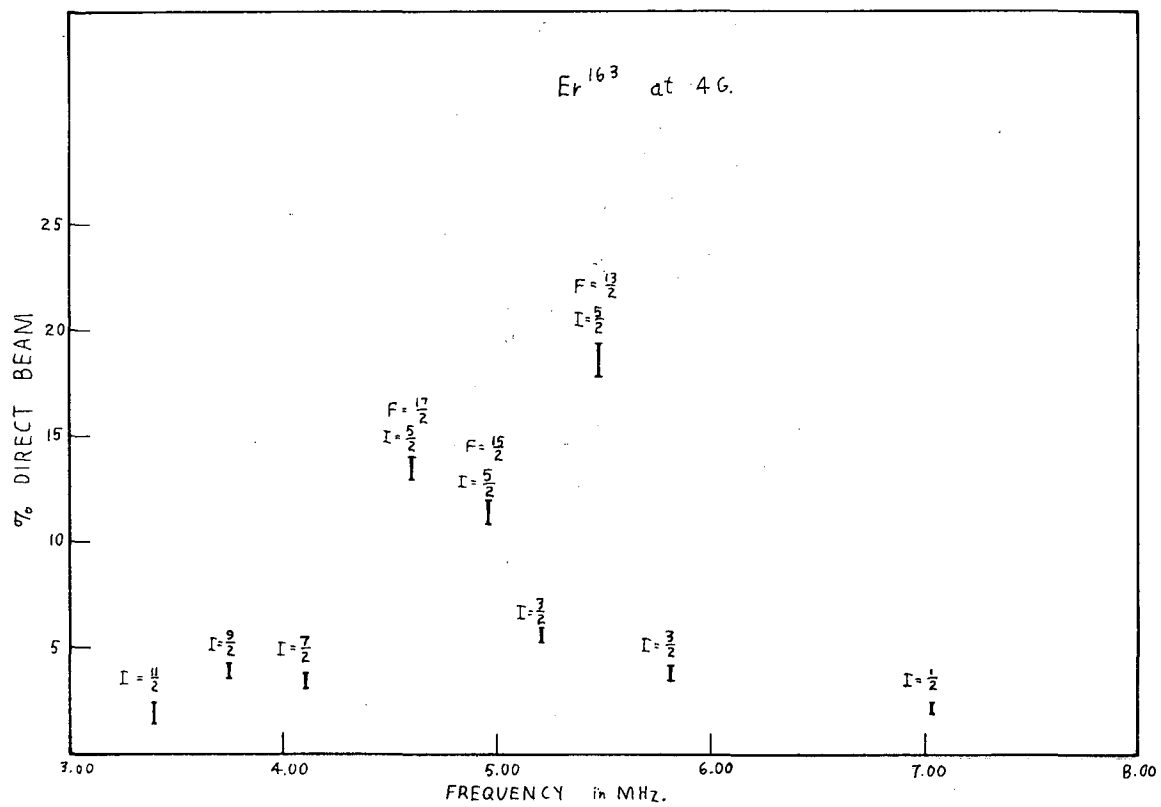
FIGURE LEGENDS

- Fig. 1. Hyperfine structure diagram (partially schematic) for ¹⁶³Er.
- Fig. 2. ¹⁶³Er spin search at 4 gauss. The error bars indicate 1 standard deviation.



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Fig. 1



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Fig. 2

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