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ELECTRONIC PROPERTIES OF Er\(^{3+}\) IN ErRh\(_4\)B\(_4\)

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Abstract.- The electronic state of Er\(^{3+}\) in the ternary superconductor ErRh\(_4\)B\(_4\) has been investigated using the Mossbauer effect in \(^{166}\)Er. The crystal field ground state is found to be a doublet, about 90 \% of which is the state \(|j = \pm 15/2\rangle\). The moment on the Er ion is 8.1 \(\pm 0.3 \mu_B\). Effects of the paramagnetic relaxation at low temperatures indicate the presence of obscure magnetic moments of which is electronic state is 4f. The relaxation frequency is small compared to the hyperfine frequencies. In the limit of slow relaxation, all but one of the doublets will give a five line spectrum with equal intensities in each line and with a splitting determined by the value of \(J_z\). The exception is the case of \(|\pm 1/2\rangle\) where the fact that the electronic \(g\) values are isotropic, \(g_x = g_y = g_z\), causes the spectrum to be two lines with unequal intensities.

Spectra shown in Figure 1, have been obtained at 4.2 K and 1.5 K. In both cases, these temperatures are below the superconducting transition but above the magnetic transition temperature. The five-line spectra observed identify the crystal field ground state to be doublet with a highly anisotropic \(g\) tensor. From the observed line positions we obtain a magnetic hyperfine constant \(A = (3639 \pm 80) \text{ MHz}\), and an electric quadrupole interaction \(e^2Qq : (773 \pm 15) \text{ MHz}\). Using known values for the nuclear moments of \(^{166}\)Er, the 4f radial integrals \(<r^{-2}\rangle\) and assuming the lattice contribution to the electric field gradient to be small, both of these hyperfine parameters are produced within experimental error by a ground state wave function

\[
\Psi = 0.942 |\pm 15/2\rangle + 0.335 |\pm 7/2\rangle
\]
Ryorfine spectra obtained using the $^{166}$Er Mössbauer resonances in ErRh$_4$B$_4$ at 4.2 and 1.5 K.

Here the predominant component $|\pm 15/2>$ arises from the $B_2^0$ term in Equation (1) when $B_2^0 < 0$, and the $|\pm 7/2>$ may be considered to be an admixture arising primarily from the highest order off-diagonal term, $B_4^0$. The magnetic moment for Er$^{3+}$ in the crystal field state of Equation (2) is 8.1 $\mu_B$, in comparison with a free-ion value of 9 $\mu_B$. This is in sharp contrast with the value of 5.6 $\mu_B$ obtained by neutron-diffraction in the ferromagnetic state.

Deviations from equal line intensities in the spectra of Figure 1 indicate the presence of effects due to paramagnetic relaxation of the Er magnetic moments. For an electronic state such as obtained here, with the $g$ value perpendicular to the $c$ axis being zero, one can show that relaxation effects from spin-spin interactions or from Korringa coupling with the conduction electrons are not effective. At these temperatures, phonon induced transitions are not expected to be large. The most likely mechanism for producing relaxation effects is then processes going through excited crystal field states. The fact that such phenomena are seen even at 1.5 K indicates that the first excited crystal field level is within a few degrees of the ground state. Additional experimental work and calculations are underway to clarify this point, as well as the nature of the Er ion in the magnetically ordered state.

References