Estimate of the Nuclear Moment of Ni^{61} from Electron Spin Resonance*

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The electron spin resonance spectra of nickel and cobalt have been studied in single crystals of MgO. Hyperfine structure was detected from the Ni^{61} isotope in the spectrum of Ni^{+2} and the hyperfine splitting constant A^{61} found to be $(8.3\pm0.4)\times10^{-4}$ cm^{-1}. X irradiation of cobalt-containing crystals results in the formation of Co^{+1} (isoelectronic with Ni^{+2}). The hyperfine splitting constant A^{59} is $(54.0\pm0.2)\times10^{-4}$ cm^{-1}. Comparison between A^{59} and A^{61} yields a value of 0.30 ± 0.02 nm for the nuclear moment of Ni^{61}.

THE nuclear spin of Ni^{61} was recently determined by Ludwig *et al.*[1] from a study of the electron spin resonance spectrum of nickel as an impurity in germanium. They used nickel enriched in Ni^{61} and observed a clearly resolved hyperfine quartet, indicating a spin $I^{61}=\frac{3}{2}$. We have studied the electron spin resonance spectrum of Ni^{+2} ions in single crystals of MgO and have detected a weak structure which may be attributed to naturally occurring Ni^{61}. So far as we are aware, this is the first report of hyperfine structure from unenriched nickel.

At 77°K the spectrum of Ni^{+2} in MgO, as reported previously,[2] consists of a single, isotropic broad line (width $\sim$50 gauss) with, at high microwave power, a sharp double quantum line superposed at its center. The width of this central line is sufficiently small to permit observation of hyperfine structure even though there is no chance of doing so for the broad (single quantum) line. Figure 1 is a record of the spectrum, showing two weak lines, equally disposed about the central one and separated from one another by 23.9 ± 1.2 gauss. These lines have the same width as the central one and show a similar dependence of intensity on microwave power, i.e., this varies as the square of the power, rather than linearly. Their intensity, as a fraction of the main line, is found to be $(0.38\pm0.10)\%$, which may be compared with the expected value of 0.31% (the natural abundance of Ni^{61} being 1.25%).

We assume these weak lines to be the outer pair of a hyperfine quartet, the inner pair (shown dotted in Fig. 1) being lost in the central line. If this assumption is correct, it leads to a hyperfine splitting constant $A^{61}=(8.3\pm0.4)\times10^{-4}$ cm^{-1}.

To obtain an estimate of the nuclear moment of $Ni^{61}(\mu^{61})$, this hyperfine splitting may be compared with that from a nucleus of known magnetic moment and ideally the comparison should be made on an ion which is isoelectronic with $Ni^{+2}(3d^8)$. One possible choice is Co^{+1} and we have observed the spectrum of this ion in MgO at 77°K, following x irradiation of samples containing Co^{+2}. It consists of eight hyperfine lines ($I^{59}=\frac{7}{2}$) spaced approximately 55 gauss apart and, at large microwave powers, each hyperfine component is crowned by a sharp double quantum absorption as in the case of the Ni^{+2} line. A recording of the spectrum is shown in Fig. 2. The sharp line between the third and fourth hyperfine components is the double quantum absorption from Ni^{+2}: other lines present arise from Fe^{+3}, Mn^{+2}, and Cr^{+3}. It is of interest to note that, at low microwave powers, each Co^{+1} line shows a sharp dip at its center as we found earlier[2] for Ni^{+2}.

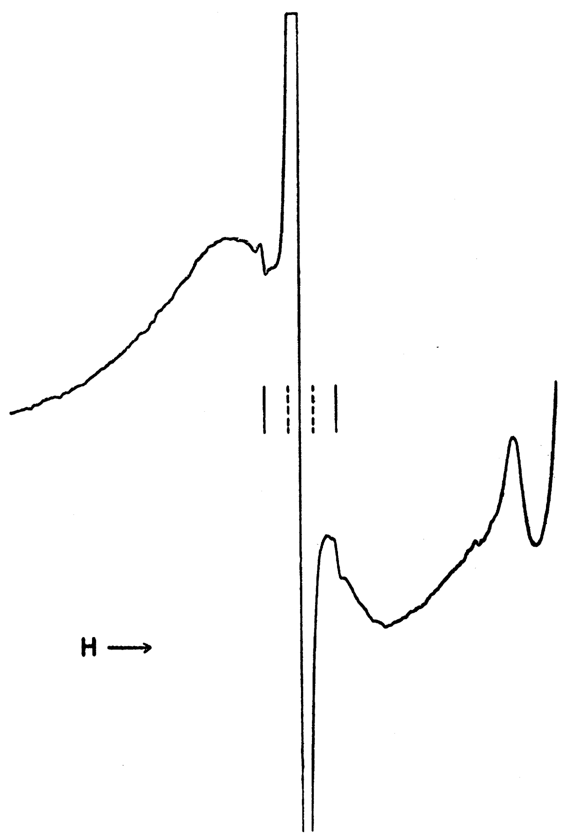

FIG. 1. Spectrum of Ni^{+2} in MgO showing a broad line with the sharp, double quantum line superimposed at its center. The position of the Ni^{61} hyperfine quartet is indicated at the center of the figure, the dotted pair of lines lying under the central one.

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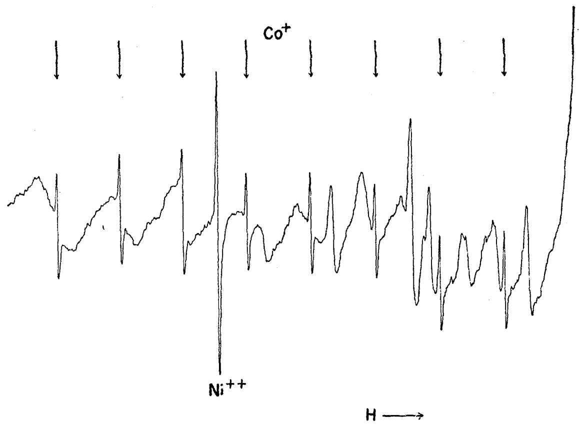

FIG. 2. Spectrum of Co^{+1} in MgO. The eight sharp lines are double quantum transitions, i.e., $\Delta M=2$, $\Delta m=0$. The double quantum line from Ni^{+2} lies between the third and fourth Co^{+1} line. Other lines are due to Fe^{+3}, Mn^{+2}, and Cr^{+3}.

The sharpness of the double quantum lines makes it possible to measure the g value and hyperfine splitting with considerable accuracy. The results are: $g=2.1728\pm0.0005$, $A^{59}=(54.0\pm0.2)\times10^{-4}$ cm^{-1}.

Using the usual formula $A=\gamma\beta\beta_N\langle 1/r^3\rangle_{av}$, and writing $\gamma=\mu/I$, we calculate the value of μ^{61} from

$$\mu^{61}=\frac{A^{61}}{A^{59}}\frac{I^{61}}{I^{59}}\mu^{59}R, \qquad (1)$$

where $I^{61}=\frac{3}{2}$, $I^{59}=\frac{7}{2}$ and R is the ratio $\langle 1/r^3\rangle_{av}(\text{Co})/\langle 1/r^3\rangle_{av}(\text{Ni})$. From the measured values of A, we find $\mu^{61}=0.31R$ nm.

To estimate a possible value for R we may calculate it for the case of V^{+2} and Cr^{+3} in MgO using the known values of the nuclear moments of V^{51} and Cr^{53}. The values of A are 74.3 and 16.2 ($\times10^{-4}$ cm^{-1}), respectively,[3] giving $R\approx0.98$, i.e., very close to unity. Thus, we estimate the nuclear moment of Ni^{61} to be (0.30 ± 0.02) nuclear magneton. The probable error is somewhat arbitrary.

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Decays of Rh^{106} and Ag^{106}

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The gamma-ray spectra of 30-sec Rh^{106} and 8.3-day Ag^{106}, which both decay to Pd^{106}, have been studied with scintillation spectrometers. Three gamma-gamma angular correlations have also been measured. The results are consistent with the following level scheme for Pd^{106}: 0.513(2+), 1.131(2+), 1.137(0+), 1.360 or 1.213, 1.563(2+), 1.73(2 or 3), 1.84, 1.88, 1.94(3− or 4+), 2.01, 2.052(4+), 2.09(3), 2.28, 2.305 (3 or 4), 2.352(4+), 2.46, 2.62, 2.764(5−), 2.87, and 3.08 Mev. The transition between the first and second 2+ levels was found to consist primarily of $E2$ radiation. The branching ratio obtained for the cascade to crossover gamma rays from the second 2+ level is 2.1 ± 0.3. This ratio combined with Coulomb excitation data of Stelson and McGowan gives a value of 1.0 ± 0.3 for the ratio $B(E2, 2'\rightarrow2)/B(E2, 2\rightarrow0)$.

I. INTRODUCTION

THIRTY-SECOND Rh^{106} decays by beta-ray emission to Pd^{106}, and 8.3-day Ag^{106} decays by orbital electron capture also to Pd^{106}. The spin and parity of Rh^{106} have been deduced as 1+ from the comparative half-lives of the beta-ray transitions to the 2+, 0.513-Mev level and 0+ ground state in Pd^{106}.[1] The spin of Ag^{106} has been measured by Ewbank *et al.*[2] as 6. Alburger and Toppel[3] from their investigation of the decays of Rh^{106} and Ag^{106} have proposed the energy level diagram given in Fig. 1. Most of the levels are shown as being populated by both Rh^{106} and Ag^{106}. This is rather surprising in view of the large difference in the spins of the two isotopes. Because of this unsatisfactory situation it was felt desirable to re-examine the decays of Rh^{106} and Ag^{106}.

The gamma rays of Rh^{106} given in Fig. 1 include all previously reported gamma rays[1,4,5] with the exception of a 2.28-Mev gamma ray observed by Kahn and Lyon.[5]

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