Hyperfine-Structure Measurements on Dy$^{161}$ and Dy$^{163}$

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In an atomic beam magnetic resonance experiment the hyperfine interaction constants $A$ and $B$ of the $^5I_8$ groundstate of Dy$^{161}$ and Dy$^{163}$ were found to be

Dy$^{161}$: $A = -(115.8 \pm 1)$ MHz, $B = (1102 \pm 15)$ MHz,

Dy$^{163}$: $A = (162.9 \pm 0.6)$ MHz, $B = (1150 \pm 20)$ MHz.

Using an effective value for $\langle r^{-3} \rangle$, the magnetic moments and electric quadrupole moments of the Dy$^{161}$ and Dy$^{163}$ nuclei were calculated to be

Dy$^{161}$: $\mu_I = -(0.47 \pm 0.09)$ n.m.,

Dy$^{163}$: $\mu_I = (0.66 \pm 0.13)$ n.m.,

$Q = (2.36 \pm 0.4)$ barns, $Q = (2.46 \pm 0.4)$ barns.

A. Introduction

The electronic $g$-factor of the ground state of the Dy I-spectrum was determined by CABEZAS et al. to be $g_J = 1.2414 (3)$ and by SMITH and SPALDING to be $g_J = 1.24166 (17)$ on the assumption that the ground state configuration is $4f^{10} 6s^2$ with the HUND'S-rule ground state $^5I_8$. By taking into account SCHWINGR, spin-orbit, relativistic and diamagnetic corrections JUDD and LINDGREN arrived at a theoretical value of $g_J = 1.2414$ for the same state. From the good agreement between the experimental and theoretical value one deduces a $^5I_8$-ground state.

By the method of optical spectroscopy MURAKAWA made the first measurement of the nuclear spins of the two odd-A Dysprosium isotopes Dy$^{161}$ and Dy$^{163}$ (natural abundances 18.9% and 25% respectively) and found them both to be $7/2$. But paramagnetic resonance measurements by COOKE and PARK yielded a nuclear spin of $I = 5/2$ for the two isotopes. This result was verified by subsequent measurements of PARK and later...
by SMITH and SPALDING\textsuperscript{7}, who determined the nuclear spins via the method of atomic beams. From his results Park ascertains the hyperfine-structure constants \( A \) and \( B \) of the \( \text{Dy}^{3+} \)-ions in a crystal-field and the nuclear moments. He obtains

\[
\text{Dy}^{161}: \quad \mu_I = -(0.37 \pm 0.04) \text{ n.m.,} \quad \text{Dy}^{163}: \quad \mu_I = (0.51 \pm 0.06) \text{ n.m.,}
\]

\[
Q = (1.1 \pm 0.4) \text{ barns,} \quad Q = (1.3 \pm 0.4) \text{ barns}
\]

using BLEANEY'S value\textsuperscript{8} for \( \langle r^{-3} \rangle (\text{Dy}^{3+}) \).

For the nuclear quadrupole moment of \( \text{Dy}^{161} \) there are measurements by HEYDENBURG and PIPER\textsuperscript{9} with Coulomb-excitation. They obtain \( Q(\text{Dy}^{161}) = 3 \) barns. Measurements with Mössbauer-effect by BAUMINGER et al.\textsuperscript{10} yielded a quadrupole moment \( Q(\text{Dy}^{161}) = 2.0 \) barns. No similar measurements exist for \( \text{Dy}^{163} \).

Since the magnetic moments had been determined only from measurements on ions in crystal-fields, fields which by their very nature give rise to complications not present for measurements on free atoms, it appeared worthwhile to undertake a new determination of these moments with the help of the atomic beam method. Because of the large discrepancies between the measured quadrupole moments of \( \text{Dy}^{161} \) a new investigation of these moments for both isotopes was deemed to be very desirable.

\section*{B. Relevant Hyperfine Structure Theory}

The atomic groundstate term of Dysprosium is a \( 4f^{10} 6s^{2} 5I \)-multiplet and the state with the lowest energy within the multiplet has the quantum number \( J = 8 \). Fig. 1 and 2 show the hfs-splittings of the \( 5I_8 \)-groundstates in dependence on the external magnetic field.

Neglecting the external magnetic field, the energy of the hfs-states is given in first order of perturbation theory by the diagonal matrix elements\textsuperscript{11,12}

\[
W^0_F = \sum_k (-1)^{I+J+F+k} \langle I \parallel T^{(k)} \parallel I \rangle \langle J \parallel T^{(k)} \parallel J \rangle \bar{W} \begin{pmatrix} I \\ J \\ F \end{pmatrix}.
\]

\( T^{(k)} \) is a tensor operator of rank \( k \) which operates in the space of the electronic coordinates only. \( T^{(k)} \) operates on the coordinates of the nucleons in the same manner.