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Non-adiabatic Effect on the Collective g-Factor and the K-Forbidden M1 Transition in ^{166}Er

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The I-dependence of the reduced spin rotation g/Q_{00}^2 was observed for the ground-state rotational band of ^{166}Er. The M1-admixture in the interband $K=2\rightarrow K=0$ transition was found to be three order of magnitude larger than that expected from the direct band-mixing theory. These facts show that the role of the mixing of states with $K=1$ (the core polarization) and/or the Coriolis anti-pairing are of particular importance in the magnetic properties of the collective states.

Magnetic properties of the collective states have been studied both theoretically and experimentally. As a result of these efforts it appears that differences may exist in g-factors between different excited states even in the same vibrational or rotational band. However, the quoted experimental errors are usually so large that one can't make a final assessment of the problem.[1)]

The principal aim of the present study is to settle the experimental situation for the rotational levels of the ground state in ^{166}Er by making an accurate precession measurement for the 4^+ excited state. Another aim is to measure the Ml-admixture in the interband transition to this 4^+ state and to examine what kind of K-impurities are responsible for the K-forbidden Ml-transition.

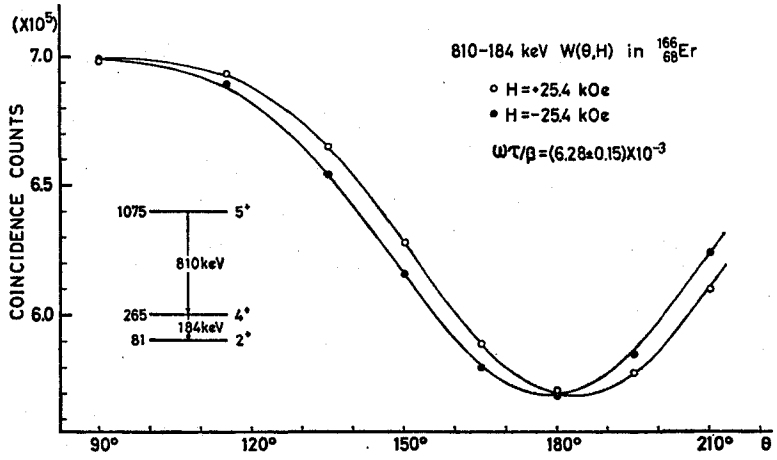

Fig. 1. Perturbed angular correlation of the 810γ–184γ cascade.

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Active samples of 1200 y ^{166}Ho were prepared by neutron irradiation of Ho-metal targets, which were then converted into the form of $HoCl_3$ after some chemical purifications. The γ-ray source used was an aqueous solution of these samples. The precession measurements were performed by the time-integral method applied to the angular correlation of the cascade, $5^+(K=2) \xrightarrow{810\gamma} 4^+(K=0) \xrightarrow{184\gamma} 2^+(K=0)$. A 7.6cm × 7.6cm NaI (Tl) crystal and a 27cm^3 Ge(Li) detectors were used for the 184 and the 810 keV γ-rays, respectively. The coincidence spectra at eight angles of the NaI detector were recorded in the 128-channel sub-memories of a 4096-channel pulse height analyzer. The measuring time interval was 10 min and the field direction was reversed after every 48 hour measurement. Five independent runs were carried out for slightly different settings of the apparatus. The data was accumulated for 5500 hours and the total number of coincidence counts was about 18 million.

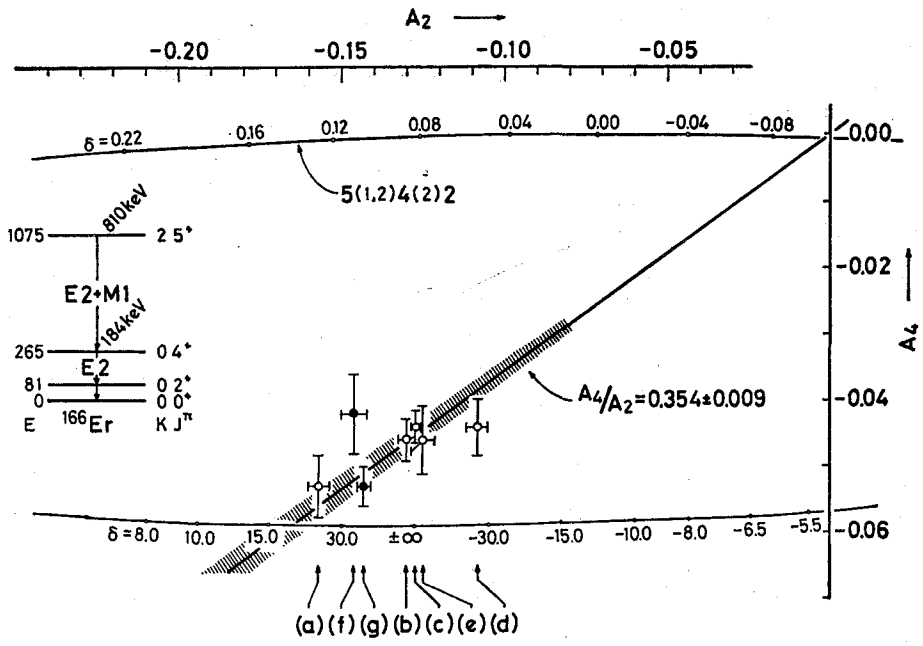

Fig. 2. The 810γ–184γ angular correlation coefficients obtained for the different settings of apparatus: (a)~(d), with a magnet (present results); (e), without the magnet (Present result); (f); without a magnet (Ref. 5); (g), with a magnet (Ref. 1). Though observed coefficients A_2 and A_4 scatter sometimes beyond their experimental errors, the A_4/A_2 ratios showed a good constancy irrespective to the geometries. The fact suggests that the observed angular correlations include isotropic components due to the scattering of γ-rays from the pole pieces of the magnet and/or from the surrounding materials.

After some geometrical corrections[2] and a small correction for the time dependent attenuation effect[1,3] were made, the results from the measurements were averaged (see Figs. 1 and 2). We obtained finally,

$$\omega\tau/\beta = (6.28 \pm 0.15) \cdot 10^{-3}$$

for $H_{ext}=25.4\pm0.3$ KOe and $T=299°$
and

$$A_4/A_2=0.354\pm0.009, \qquad \delta^{-1}=+0.057\pm0.007.$$

Here δ is the multipole mixing parameter and β is the paramagnetic correction factor for the Er^{+++} ion.[4] These values are in agreement with results by Reich and Cline, and by Bodenstedt group.[5,1] Now, we obtain the quantity g/Q_{00}^2, hereafter called the "reduced spin rotation", as[6]

$$(g/Q_{00}^2)_4{}^+=(5.12\pm0.14)\cdot10^{-3} \qquad b^{-2}$$

where Q_{00} is the intrinsic quadrupole moment of the ground-state rotational band.

The value for the 2^+ state is obtained from Mössbauer measurements[7] and lifetime data as,[8]

$$(g/Q_{00}^2)_2{}^+=(5.43\pm0.07)\cdot10^{-3} \qquad b^{-2}.$$

Thus it is found that the reduced spin rotation for the 4^+ state is smaller by $(5.8\pm2.8)\%$ than the value for the 2^+ state.[9]

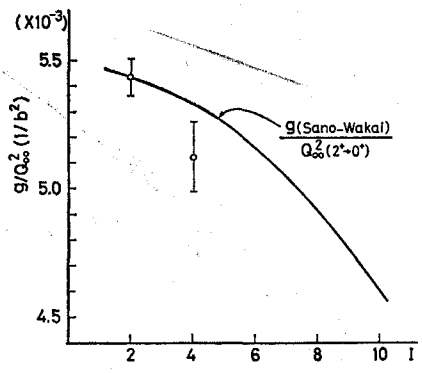

Fig. 3. I-dependence of the reduced spin rotation g/Q_{00}^2. The dependence of the curve might be more remarkable if Q_{00} increases with I.

Under the assumption that the direct mixing between bands with $K=2$ and 0 is the only important one, we expect

$$\Delta=\left|\frac{(g/Q_{00}^2)_I{}^+}{(g/Q_{00}^2)_2{}^+}-1\right|=8[I(I+2)-8]\varepsilon_2^2\cdot\left|\frac{g_K-g_R}{g_R}\right|$$

and

$$\delta^{-2}(I+1,\ K=2\to I,\ K=0)=27.7E\gamma^{-2}(\text{in MeV})\,(I-1)^2I(I+2)\varepsilon_2^2\cdot\left(\frac{g_K-g_R}{Q_{20}}\right)^2.$$

With the following values of the I-independent parameters: $\varepsilon_2=1.2\cdot10^{-3}$, $Q_{00}=1.6Q_{20}=7.6b$ and $|g_K-g_R|=0.11$,[5,8] we find $\Delta=0.006\%$ and $\delta^{-2}(810\gamma)=7.2\cdot10^{-6}$. These are three order of magnitude smaller than the present experimental results. A similar estimate shows that the $\Delta K=0$ admixture also doesn't explain the experimental results.

The I-dependence of the collective g-factors has been predicted by Sano and Wakai[10] using the cranking model with the Coriolis anti-pairing effect. In Fig. 3, the present results are compared with their values. The I-dependence of the curve in the figure might be more remarkable if Q_{00} increases with I.[11]

A microscopic calculation has also been carried out by Bés *et al.* for the K-forbidden M1-transition.[12] They assume that the mixing with $K=1$ states to be responsible for the M1-admixture and, in an RPA calculation, obtain matrix elements which predict $\delta^{-2}(810\gamma)=0.09$. The result is comparable with the present data and is of the right sign.

In the light of the present study, it is concluded that the role of the mixing with $K=1$ states (the core polarization) and/or the Coriolis anti-pairing are of particular importance in the magnetic properties of the collective states.[13]

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