g factor of the 635.4 keV level in ^{171}Tm

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The g factor of the 635.4 keV level in ^{171}Tm, fed in the β^- decay of 7.5 h ^{171}Er, has been measured using perturbed angular correlation technique. The 277.4-210.5 keV γ-γ cascade through this level was employed for the measurements. The mean precession angle $\omega\tau$ for this level in an external field of 10 kG was measured to be $G_2\omega\tau = 0.232 \pm 0.031$ rad; G_2 was estimated to be $G_2 = 0.85 \pm 0.05$. Using the known value of the half-life for this level, $T_{1/2} = 1.26 \pm 0.06$ nsec, the g factor is found to be $g = +(0.62 \pm 0.09)$. The measured value of the g factor for this level is in agreement with the earlier assignment of this state to be the $[404]\frac{7}{2}^+$ Nilsson state.

[RADIOACTIVITY ^{171}Er from ^{170}Er(n,γ), measured $\gamma\gamma(\theta)$, $\gamma\gamma(\theta, H)$. ^{171}Tm levels, deduced g,μ. Enriched target.]

The energy levels of ^{171}Tm populated in the β^- decay of 7.5 h ^{171}Er were investigated earlier by several workers.[1] The electromagnetic properties of the excited states of this isotope have been studied recently by Gopinathan and Patel.[1] The half-life of the 635.4 keV level has been measured by them to be $T_{1/2} = 1.26 \pm 0.06$ nsec. Based on high resolution γ-ray and conversion electron measurements Graham, Geiger, and Johns[2] have proposed for the 635.4 keV level a spin $\frac{7}{2}^+$, though they do not rule out from their data the spin $\frac{5}{2}^+$ for this level. However, the γ-ray directional correlation measurements carried out by Gopinathan and Patel,[1] along with the high resolution conversion electron studies of Graham *et al.*,[2] uniquely assign the spin $\frac{7}{2}^+$, identifying it as the $\frac{7}{2}^+[404]$ Nilsson state.

We report here the measurement of the g factor for this state in order to understand more about the properties of this level. The perturbed angular correlation (PAC) technique was used for the measurement. The measurements were carried out using the 277.4-210.5 keV γ cascade through this level (see Fig. 1) in an externally applied magnetic field of 10 kG

Radioactive ^{171}Er, $T_{1/2} = 7.5$ h, was obtained by irradiating 97% enriched ^{170}Er in the pneumatic irradiation facility of the CIRUS reactor at Trombay for 30 min. The irradiated sample was dissolved in dil. HCl. A dilute solution of $ErCl_3$ in dil. HCl, contained in a small Perspex source holder, was used for the measurements. Since the source is short lived, several irradiations of ^{170}Er had to be made.

The levels fed in the β^- decay of ^{171}Er are shown in Fig. 1. Only levels which are somewhat strongly fed are shown (for complete details about the levels see Ref. 2). Most of the β^--decay feeding is to the 424.8 keV state. The 912.8 keV state, which feeds the 635.4 keV level through a γ ray of 277.4 keV, is fed in only 2.2% of all the β^- decays. The only γ cascade, which is available for measurements through the 635.4 keV level, is the 277.4-210.5 keV γ cascade. Figure 2 shows the γ-ray spectrum from a source of ^{171}Er with a 20 cm^{3}Ge(Li) detector. These two γ rays are very weakly seen. Because of counting rate problems we therefore decided to use the NaI(Tl) detectors for the measurements. Due to the poorer resolution of NaI(Tl) detectors and intense 308.2 and 295.8 keV γ rays, one does not see the photopeaks of 210.5 and 277.4 keV γ rays. Figure 3 shows a typical γ-ray spectrum of ^{171}Er taken on a 4.4 cm $\times$ 5 cm NaI(Tl) detector using suitable

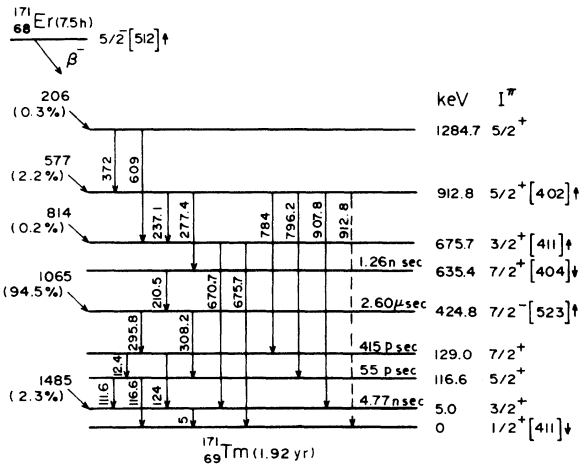

FIG. 1. Partial decay scheme of 7.5 h ^{171}Er (redrawn from Ref. 1).

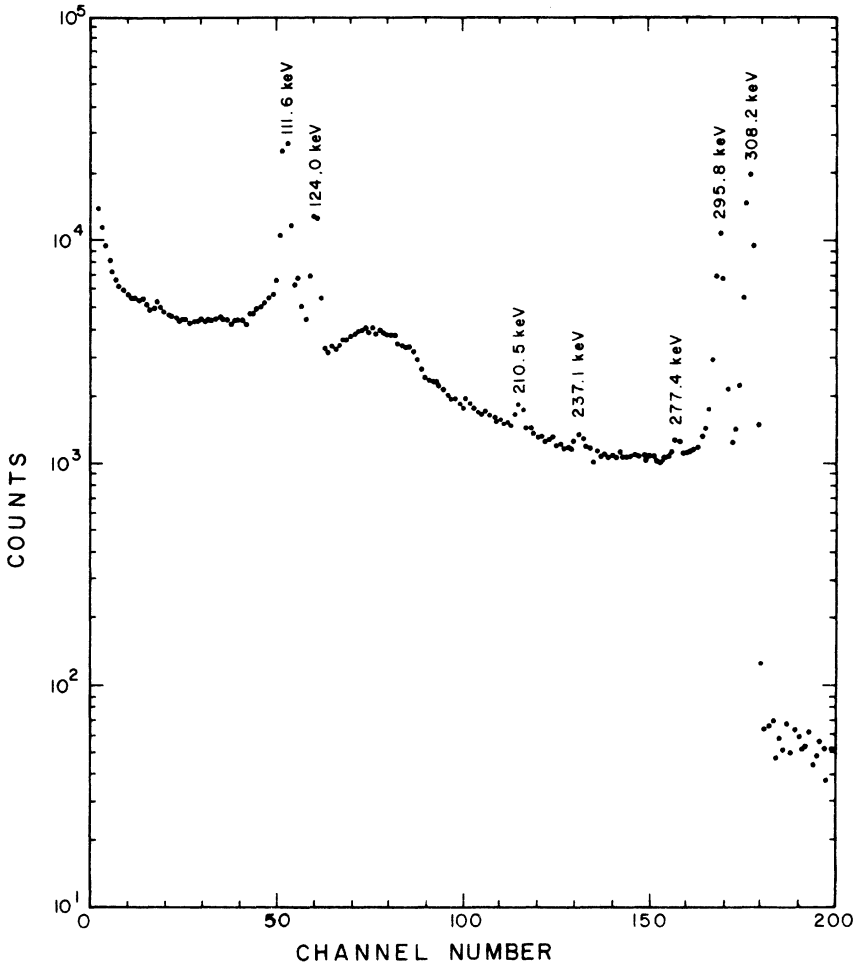

FIG. 2. γ-ray spectrum of 7.5 h ^{171}Er using a 20 cm^3 Ge(Li) detector.

absorbers of Cd and Cu to avoid piling up effects. The energy gates selected for the 210.5 and 277.4 keV γ rays are also shown. They were selected from the coincidence spectra recorded with 210.5 and 277.4 keV regions of the γ-ray spectrum as gates. A typical coincidence spectrum with 277.4 keV γ ray in the gate is also shown in Fig. 3. Care was also taken to avoid contribution of one γ energy in the gate fixed for the other (see discussion below). The directional correlation studies were made using two NaI(Tl) counters. The coincidence counts were collected at four angles: 90, 120, 150, and 180°. After applying the usual corrections for chance coincidences, decay of the source, etc., the data was least squares fitted to the expression

$$W(\theta) = 1 + G_2 A_2 P_2(\cos\theta).$$

Higher terms were not included as the 210.5 keV transition is almost pure $E1$. The value of the fitted coefficients $G_2 A_2'(0.102 \pm 0.005)$ corrected for finite geometry is found to be $G_2 A_2 = 0.119 \pm 0.006$. This is in good agreement with the earlier measurement of Gopinathan and Patel,[1] viz., $A_2 = 0.124 \pm 0.005$.

The 635.4 keV level being long-lived ($T_{1/2} = 1.26$ nsec), the directional correlation of the 277.4-210.5 keV γ-ray cascade could be attenuated even in a dilute liquid source. In fact, Kaufmann, Bowman, and Bhattacherjee,[3] who have studied the electromagnetic properties of ^{169}Tm and ^{171}Tm, do find attenuations in the directional correlations in liquid sources of ^{169}Yb. They have experimentally measured the attenuation coefficient G_2 for the $\frac{7}{2}^+$(177 keV)$\frac{7}{2}^+$(130 keV)$\frac{3}{2}^+$ cascade in ^{169}Tm, the intermediate state lifetime being $\tau = 0.452 \pm 0.018$ nsec,[3] to be $G_2 = 0.956 \pm 0.012$. From their data we estimate the attenuation coefficient for our case to be $G_2 = 0.85 \pm 0.05$, assuming the perturbing interaction to be similar and by scaling according to the ratio of the lifetimes of the two states.

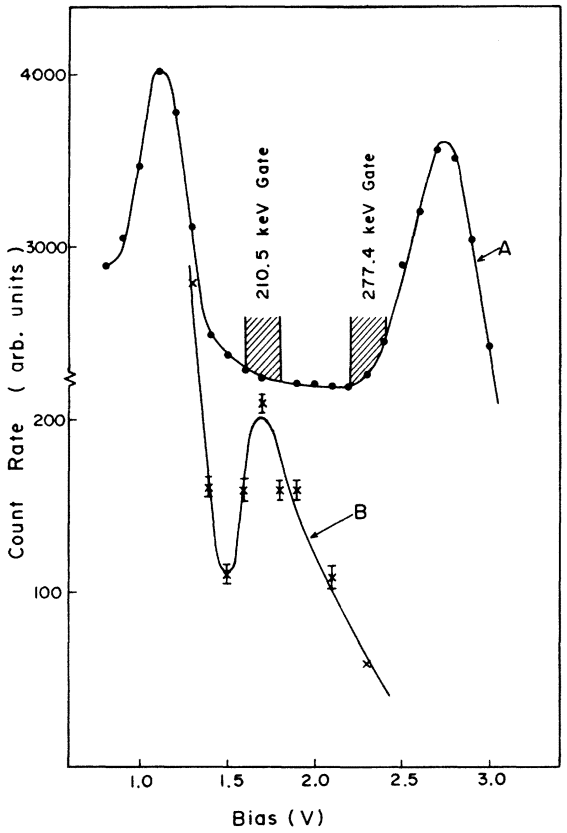

FIG. 3. (a) γ-ray spectrum of 7.5 h ^{171}Er using a 5 cm×5 cm NaI(Tl) counter with absorbers of Perspex, cadmium, and copper. The hatched areas show the energy gates chosen. (b) Coincidence spectrum with 277.4 keV in gate.

The spin precession of the 635.4 keV state was measured in an external field of 10 kG. Two well-shielded NaI(Tl) counters 5 cm × 5 cm each were kept at a distance of 8 cm from the pole tips of the magnet. No light guides were required at this distance from the pole tips of the magnet, which was specially designed to have small fringing fields. Measurements were done in an externally applied magnetic field of 10 kG. Since the directional correlation has terms essentially only up to the A_2 term, the fractional change in coincidence counting rate R, defined below, was measured with counters at 135°. Each counter was sensitive to both the γ rays of interest but the γ-ray gates were separately selected by using two single channel analyzers for each counter, thereby getting simultaneously the value of R at +135° and −135°. R is defined as $R = 2(\text{Coinc}\uparrow - \text{Coinc}\downarrow)/(\text{Coinc}\uparrow + \text{Coinc}\downarrow)$. The values of R measured at −135° and +135°, after correcting for chance count rate and decay, are found to be $R = 0.052 \pm 0.010$ and -0.061 ± 0.009, respectively. The average of these gives R as 0.057 ± 0.007. From the measured value of R, the spin precession $G_2\omega\tau$ was obtained using the relations

$$R_{\pm 135} = \mp \frac{4C_2 G_2 \omega\tau}{1 + (2G_2\omega\tau)^2} ,$$

where $C_2 = 3A_2/(4 + A_2)$ and $\omega = -g\mu_N H_{\text{eff}}/\hbar$. Here G_2 is the integrated attenuation coefficient due to time dependent interactions and H_{eff} is the effective magnetic field seen at the nucleus. In the present case $H_{\text{eff}} = \beta H_{\text{applied}}$, where β is the paramagnetic correction factor. The value of $\omega\tau$ (using $G_2 = 0.85 \pm 0.05$, see above) was obtained as $\omega\tau = 0.273 \pm 0.036$. Using $T_{1/2} = 1.26 \pm 0.06$ nsec, $H_{\text{app}} = 10$ kG, and $\beta = 5.08$ from Gunther and Lindgren[4] for Tm at room temperature (300°K) the value of the g factor is found to be $g = +(0.62 \pm 0.09)$; the sign is inferred from the sense of the rotation. The spin of the 635.4 keV level being $\frac{7}{2}$, its magnetic moment therefore is found to be $\mu = (2.16 \pm 0.30)\mu_N$.

The $\frac{7}{2}^+[404]$ Nilsson state has been identified in a large number of odd proton nuclei (see Ref. 5). However, only in a few cases, where this state is a ground state, has its magnetic moment been measured. The measured values of μ for this state in ^{175}Lu and ^{177}Lu are $2.237\,99\mu_N$ and $2.245\mu_N$, respectively, and that in ^{181}Ta is $2.370\mu_N$ (see Ref. 6). The measured value (present work) for the 635.4 keV level in ^{171}Tm, $\mu = (2.16 \pm 0.30)\mu_N$, agrees very well with these values. This supports the earlier assignment of Nilsson quantum number for this level as the $\frac{7}{2}^+[404]$ Nilsson state.[7]

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