Properties of the 635.4 keV Level in $^{171}$Tm

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The properties of some high excited states of $^{171}$Tm have been studied using Ge(Li) detectors. The directional angular correlation measurements for 277.4–210.5 keV cascade are in agreement with the spins of the 635.4 keV ($\frac{5}{2}^-$) and 912.8 keV ($\frac{3}{2}^-$) levels. The magnetic moment $\mu = (1.15 \pm 0.21) \mu_N$ of the 635.4 keV level was determined by integral perturbed angular correlation (IPAC) in external magnetic field.

1. Introduction

The $^{171}$Tm nucleus is situated in the region of deformed nuclei. The levels scheme of $^{171}$Tm has been investigated in recent years [1–6] (Fig. 1). The ground state rotational band is built on the $\frac{1}{2}^+$ [411] Nilsson orbital. The spectroscopic properties of this band have been studied in detail [3, 7, 8]. The 424.8 keV and 635.4 keV levels have been identified as $\frac{7}{2}^-$ [523] and $\frac{7}{2}^+$ [404] intrinsic states, respectively [3–8].

2. Experimental Technique and Results

The angular correlation coefficients and the magnetic moment of 635.4 keV level have been determined by measuring the unperturbed and perturbed angular correlation in external magnetic field using semiconductor detectors.

Erbium activities have been obtained after 9 hours thermal neutron irradiation of the natural Er$_2$O$_3$. The radioactive material was dissolved in HCl and afterwards diluted with distilled water. The sources thus prepared contain $^{163, 165}$Ho, $^{165}$Er decay by electron capture on the ground state of the $^{163, 165}$Ho. $^{169}$Er feeds, by $\beta^+$-emission the 8.4 keV excited (42 %) and ground (58 %) states in $^{169}$Tm. The $^{172}$Er activity induced by double neutron capture was negligibly because of the small irradiation time. Thus, the $\gamma$-spectrum of such a source should contain only a 8.4 keV gamma line beside the gamma spectrum of the $^{171}$Er. The gamma spectrum taken by a Ge(Li) detector (Fig. 2a) confirms this situation.

We used an automatic correlation turn-table with three Ge(Li) detectors, two fast-slow coincidence equipments ($2 \tau = 30$ ns) and a 4,096 channels analyser. The active volumes of the detectors were 32, 40 and
Fig. 2. Gamma spectrum of $^{171}$Tm. a single spectrum; b coincidences with 277.4 keV line

55 cm$^3$ with 3.5, 3.6 and 3 keV FWHM at 661 keV, respectively. During both the directional angular correlation and the magnetic moment measurements, the detectors were protected by lead collimators. Depending on the kind of the measurement, either the position of the movable detector or the magnetic field direction was changed every 3 minutes. The coincidence counts were corrected for random coincidences and for decay of the source. Random coincidences were directly measured and subtracted.

2.1. Angular Correlation Measurement

Gopinathan and Patel [6] performed the 277.4-210.5 keV and 371.9-277.4 keV gamma-gamma angular correlation measurements using two scintillation detectors. The gamma transitions involved in this study are rather weakly and NaI(Tl) detectors did not resolve them. That is why we remeasured the same angular correlations taking into advantage of the high resolution of the Ge(Li) detectors.

The directional angular correlation measurements have been carried out by recording coincidence spectra for 90°, 135° and 180° angles, with two detectors fixed at 90° and a movable one, gated by a certain gamma line. First, in order to check our set-up we measured the angular correlation of the intense 295.9-124.0 keV cascade in the same $^{171}$Tm. Kaufmann et al. [3] studied this correlation using a Ge(Li) and a NaI(Tl) detectors. Their $A_2$ coefficient is in a good agreement with ours (Table 1) if one takes into account that the first is not corrected for the attenuation due to the finite solid angle of the detectors.

The angular correlation coefficients for 277.4-210.5 keV cascade were measured by storing coincidence spectra gated with the window set on the 277.4 keV peak (Fig. 2b). The values of the angular correlation coefficients corrected for the finite solid angle are given in Table 1. The value of the $A_2$ coefficient is statistically in agreement with the one measured by Gopinathan and Patel [6]. Taking into account the $M1+E2$ character of the 277.4 keV gamma transition with $\delta = 0.37 \pm 0.07$ [4] and the 5/2, 7/2 and 7/2 spin values for the 912.8 keV [5], 635.4 keV [6] and 424.8 keV [5] levels respectively, the $A_2$ coefficient for angular correlation 277.4-210.5 keV leads to the $M1+(1.5 \pm 0.07)E2$ multipolarity for the 210.5 keV transitions, in good agreement with Ref. 5.

2.2. Magnetic Moment Measurement

Patel et al. [9] have studied the IPAC of the 277.4-210.5 keV gamma cascade in an external magnetic field (10 kG) using two NaI(Tl) detectors and reported the $g$ factor of the 635.4 keV level in $^{171}$Tm as $g = 0.42 \pm 0.07$. Later on, while performing the present work, the same authors carried out the similar measurements in the same experimental conditions and found a larger value: $g = 0.62 \pm 0.09$, [10].

Here, we determined the magnetic moment of the 635.4 keV level by IPAC measurements of the same gamma cascade in better experimental conditions: using Ge(Li) detectors and a stronger external magnetic field. The magnetic field of 19.5 kG, perpendicular to the detectors plane and uniform within the source volume up to 1% of its strength, was produced by an electromagnet with cylindrical yoke. We recorded coincident spectra, successively for the two opposite field directions, and simultaneously for the 135° and 225° (−135°) angles between the detector gated for 277.4 keV $\gamma$ rays and the two other ones, respectively.

<table>
<thead>
<tr>
<th>Cascade (keV)</th>
<th>$A_2$</th>
<th>$A_4$</th>
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<tr>
<td>277.4–210.5</td>
<td>0.102 ± 0.013</td>
<td>0.124 ± 0.005</td>
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<tr>
<td>295.9–124.0</td>
<td>0.177 ± 0.005</td>
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