On the observation of the $3/2^+[411]$ and $½^+[420]$ rotational bands in the decay spectroscopic studies on ^{153}Sm

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Introduction

The decays of ^{153}Sm and ^{153}Gd into ^{153}Eu were known to populate three clearly identified intrinsic configurations with rotational structures built on them - the $5/2^+[413]$ ground state, the $5/2^-[532]$ intrinsic level at 97·4 keV and the $3/2^+[411]$ state at 103.2 keV. However, in the recent single-proton-transfer studies of ^{153}Eu levels by Burke [1], several band assignments were proposed for most of the known low lying ^{153}Eu levels and new levels were identified. Since many of these levels were not interpreted with such band assignments in earlier beta decay studies and also since some spin parity assignments were tentative, we felt that it would be interesting to study this nucleus by gamma and conversion electron spectroscopy following beta decay of ^{153}Sm. Our main aim was to study and confirm the low lying level structure of ^{153}Eu accessible through the said beta decay.

Experiment:

Radioactive sources of ^{153}Sm were produced by thermal neutron irradiation of ^{152}Sm at Bhabha Atomic Research Centre, Mumbai and shipped as Samarium Chloride in HCl. Sources were prepared with the required count rate (500-1000 counts per second) for the gamma spectroscopy experiments. These were used with the HPGe detector based gamma spectroscopy system. The gamma spectra were acquired with a coaxial HPGe detector which was coupled to an 8K Multi Channel Analyzer. The detector has an active volume of 60 cc and FWHM of 1.8 keV at 1.33 MeV. The unshielded detector's energy calibration and efficiency calibration were performed with IAEA standard sources of point geometry, placed at distance of 25 cm. Spectral acquisition and analysis was performed with MCA emulator and spectrum analysis software GammaVision-32 and the interactive computer program FIT. The typical counting periods were about 5 x 10^5 seconds. The spectra were normalized with respect to the intense 103.2 keV transition taken as 10,000. An indigenously developed Mini-Orange [2] electron transporter coupled to a cooled Si(Li) detector, that was optimized for best transmission characteristics was used for electron spectroscopy.

Results and discussion:

The $1/2^+[420]$ band and the 634.6 keV level

The 634.6 keV level in ^{153}Eu was first identified by Suter et al [3] who suggested that it could be the $1/2^+$ member of the $1/2^+[420]$ rotational brand, which is expected to appear in this region of excitation both by the Nilsson model and the calculations of Soloviev and Vogel [4]. The $1/2^+[420]$ band is seen in the neighboring nuclides, ^{151}Pm and ^{155}Eu in gamma studies and in ^{151}Pm, ^{153}Pm, ^{155}Eu, ^{157}Eu and ^{159}Eu in (t, α) measurements. Burke [4] proposed that the levels at 634.8, 694.3 and 718.4 keV are the spin $1/2^+$, $5/2^+$ and spin $3/2^+$ members of the $1/2^+[420]$ band respectively. In the present study, conclusive evidence in terms of gamma transitions and conversion coefficients were found. A direct transition to the $5/2^+$ ground state is observed from the 634.6 keV level. Two more transitions with energies 462.0 and 531.4 keV were found and could be fitted following the sum rule:

531.4 keV + 103.2 keV = 634.6 keV
462.0 keV + 172.8 keV = 634.8 keV

The gamma energies and intensities used in the GTOL program has resulted in an energy of 634.6 keV for this level. Also the tentative α_K of the 531.4 keV transition determined in the present work as 0.0148 (14) suggests an M1+E2 character for this transition. As this transition connects the 634.6 keV level to the $3/2^+$, 103.2 keV level, its M1+E2 character fixes the $1/2^+$ assignment for this state, thus confirming it as the $1/2^+$ band head of the $1/2^+$[420] band as observed in the particle transfer reaction studies.

The 694.3 keV level as the $5/2^+$ member of the $1/2^+$[420] band:

This level was originally attributed as the $5/2^+$[402] orbital, expected in this energy region, in the lighter deformed rare earths. This spin and parity of $5/2^+$ was suggested based on the L = 0 transfer strengths from a $5/2^+$ target in (t, p) reaction studies of Burke et al [5]. However, in the recent (t, α) experiment, the large strength observed by Burke [1] supports its assignment as the $5/2^+$ member of the $1/2^+$[420] rotational band. In the present study, gammas of energy 424.4, 521.3, 542.7, 591.0, 596.7 and 694.1 keV are found to de-excite this state which is fed significantly in the beta decay of ^{153}Sm. The values of α_K of the 424.4, 521.3 and 596.7 keV transitions prove that these are of M1, M1+E2 and E1(+M2) multipolarity respectively, thereby confirming the $5/2^+$ nature of this level.

The 718.4 keV level as the $3/2^+$ member of $1/2^+$[420] band:

The level at 718.4 keV was first identified by Suter et al [3]. Burke, from (t, α) and (^{3}He,d) reaction studies [1], has proposed the 718.4 keV as spin $3/2^+$ member of the $1/2^+$[420] band. In the present work, two gammas with energies 615.8 keV and depopulating this level were identified. These satisfy the sum rules:

545.5 keV + 172.8 keV = 718.3 keV

615.6 keV + 103.2 keV = 718.8 keV

The energies and intensities when fitted by GTOL, establishes the connections and the energy of this level as 718.4 keV. The α_K of the 545.5 keV transition is tentatively determined in the present experiment as 0.017(5). This value very well agrees with the M1 value of the BRICC. Thus a $3/2^+$ assignment can be made for the 718.4 keV level. This identifies this level as the $3/2^+$ member of the $1/2^+$[420] band as seen in the particle transfer reaction studies.

The excited members of the $3/2^+$[411] rotational band at 172.8 and 269.6 keV:

Based on the K, L and M ICC measurements of the 103.2 keV transition, the 103.2 keV level is identified as the 3/2 band head of the $3/2^+$[411] band. A number of inter-band transitions with energies 531.4, 533.4, 578.8, 590.96, 598.3, 603.6 and 615.8 keV were observed and could be fitted in the present work by GTOL as populating the 103.2 keV level. Similarly, the ICCs of the 172.8 and 69.7 keV transitions confirm the $5/2^+$ nature of the 172.8 keV level and α_K of the 96.8 keV transition establishes the $7/2^+$ character of the 269.6 keV level.

Table 1: Partial list of gamma energies and intensities in the decay of ^{153}Sm

Gamma energy (keV)	Gamma Intensity	Gamma Energy (keV)	Gamma Intensity
69.68 *1*	1673 *12*	531.44 *1*	23.4 *3*
96.79 *15*	2.52 *25*	542.71 *17*	0.75 *21*
118.12 *9*	0.12 *2*	545.54 *8*	0.51 *2*
166.55 *2*	0.27 *3*	579.05 *48*	1.16 *3*
172.85 *2*	0.14 *2*	590.83 *26*	0.507 *23*
411.88 *14*	0.658 *14*	596.89 *5*	3.662 *62*
424.62 *18*	0.662 *15*	603.65 *30*	1.394 *39*
437.09 *13*	0.684 *51*	615.63 *24*	0.25 *5*
463.78 *4*	4.72 *13*	694.15 *30*	0.010 *2*
485.03 *2*	0.117 *10*	103.179 *2*	10000 *54*

Table 2: Experimental ICCs for select transitions in ^{153}Eu.

E_γ (keV)	Expt. ICC	Multipolarity
69.67	α_K = 4.37 *25* α_L = 0.0874 *55* α_M = 0.167 *6*	M1+E2
96.79	α_K = 1.29 *20*	E2
172.85	α_K = 0.299 *16* α_L = 0.057 *5* α_M = 0.0157 *31*	M1+E2
424.62	α_K = 0.034 *6*	M1
437.09	α_K = 0.031 *6*	M1
531.44	α_K = 0.0146 *14*	M1+E2
545.54	α_K = 0.017 *5*	M1
596.89	α_K = 0.0202 *21*	E1(+M2)

References

[1] D. G. Burke Nucl. Phys., **A747** (2005) 131.
[2] M. Sainath, Ph.D. Thesis, SSSIHL, 1996.
[3] T. Suter *et al*., Nucl. Phys., **A29** (1962) 33.
[4] V. G. Soloviev, P. Vogel, Nucl. Phys., **A92** (1967) 449.
[5] D.G.Burke *et al*, Nucl.Phys.**A258** (1976)118.