Observation of the $7/2^+[404]$ rotational band in the decay spectroscopy of ^{153}Eu

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Introduction

In the A ≈ 150 region, the nuclear deformation changes rather abruptly between the N = 88 nuclei, which are often classified as spherical, and the N = 90 nuclei, which usually exhibit characteristics of an ellipsoidal deformation. In several other odd mass deformed nuclei, evidence has been found for beta and gamma vibrational bands. The Eu isotopes have Z = 63, so they are good candidates to study the development of deformation from N = 82 onwards. Between the spherical ^{145}Eu and the well deformed ^{155}Eu there is a transitional region which has been extensively studied from both experimental and theoretical points of view.

The properties of the ^{153}Eu nucleus in this region are of particular interest because of the location of this nucleus at the border of strongly deformed nuclei. The decay of ^{153}Sm into ^{153}Eu is known to involve three clearly indentified intrinsic configurations. These are the K = $5/2^+[413]$ ground state band, the K= $5/2^-[532]$ intrinsic level at 97.4 keV and the K = $3/2^+[411]$ band at 103.2 keV. Out of the various 3/2 Nilsson orbits available in this region, only the $3/2^+[411]$ state with well developed rotational bands built on it has been observed in several nuclei. This state appears as an excited (particle) state in the Eu isotopes, as the ground state in Tb isotopes and a hole state in Ho and Tm isotopes. The apparent change of eccentricity between the [413] and [411] bands on the one hand, and the [532] band on the other, renders interesting information concerning transitions between these bands. These orbitals originate from the $1g_{7/2}$, $1h_{11/2}$ and $2d_{5/2}$ shell model states and therefore have large single-nucleon transfer strengths for only their respective spins: 7/2, 11/2 and 5/2. A level at 568.9 keV has been reported in the $^{153}Sm(^3He, d)^{153}Eu$ reaction [1] with the angular distribution consistent with l = 4 or l = 5. This level has not yet been confirmed by any experiment. However, a level has been observed at 569.3 keV in coulomb excitation studies [2]. If this is the same state as that found in the particle transfer reaction studies, the observed gamma transitions to the spin $5/2^+$ and $7/2^+$ members of the ground state rotational band would rule out a 11/2 $7/2^+[523]$ assignment. However, it is quite unlikely that different states are observed in the two experiments, because it would be difficult to explain a strong coulomb excitation probability either to the 7/2 $7/2^+[404]$ or the 11/2 $7/2^-[523]$ states.

Experiment

Radioactive sources of ^{153}Sm were produced by thermal neutron irradiation of ^{152}Sm at Bhabha Atomic Research Centre, Mumbai and shipped to Prasanthinilayam 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 (EG & G ORTEC -GMX series) 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 and 665 eV at 5.9 keV. 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. As this

103.2 keV transition in ^{153}Sm decay is very intense, the high energy (>400 keV) portion of the gamma ray spectrum was obtained separately with a stronger source and a 7.2 mm Pb absorber to attenuate this gamma, while having a negligible effect on the high energy gamma rays.

Results and discussion

Seaman et al [2] have reported the observation of a level at 568.9 keV in ^{153}Eu in Coulomb excitation studies. Ungrin et al. [2] also observed a level at 569 keV strongly populated in their (^{3}He, d) reaction with an angular distribution consistent with l = 4 or l = 5. Later experiments showed that this level decays most strongly to the 5/2$^+$ ground state. This level was not reported in any of the decay studies. This level is not likely to be fed directly by the beta decay of ^{153}Sm 3/2$^+$ ground state, since $\Delta J = 2$ and $\Delta\boldsymbol{\pi}$ = no. Likely $\Delta J = 0, 1, 2$ feeds are 124.9, 137.9, 163.2 and 191.1 keV gammas. Also the two decay gammas 472.2 and 485.8 keV from this state, were not observed yet in the beta decay studies of ^{153}Sm. However, the 485.8 and 472.2 keV gammas were observed in (n, n'γ) and (d, 3nγ) reaction studies.

Table 1 and 2 list the present gamma energies and intensities of a few relevant gamma transitions in the decay of ^{153}Sm. A careful and focused search in the present work, for the possible weak transitions from/to the 569.3 keV level has resulted in the observation of two weak transitions with energies 124.9 keV and 137.5 keV satisfying the sum rule:

694.29(30) keV – 124.94(30) keV = 569.3 keV
706.99(20) keV – 137.46(13) keV = 569.5 keV

While these transitions are found to populate the 569.4 keV level, two other transitions of energies 471.8 keV and 485.9 keV were observed to depopulate from 569.5 keV level following the sum rule:

83.363 (6) keV + 485.9(2) keV = 569.3 keV
97.430(2) keV + 472.0(2) keV = 569.4 keV

These four transitions were incorporated into GTOL resulting in a level energy of 569.4 keV, as the evidence for the existence of the 569 keV level discussed earlier even in the decay spectroscopy. Thus the band head of the 7/2$^+$[404] band at 569.4 keV has been observed in the present study. This level has been tentatively incorporated into the revised decay scheme of ^{153}Sm. The 9/2$^+$ member of this band at approximately 711.1 keV is beyond the scope of the present decay because of spin hindrance.

Table 1: Gamma (partial) energies in keV

E_γ (keV)	Abdel-Malak [3]	Blichert-Toft [4]	Present work
83.36	83.57(42)	83.37	83.363(6)
97.43	97.30(25)	97.45	97.430(1)
103.18	103.52(50)	103.175	103.179(1)
124.9	124.91(40)	--	124.94(30)
--	--	--	137.46 13
--	--	--	472.0(2)
485.9	--	485	485.9(2)
694.1	694.02(25)	--	694.15(30)
706.8	707.29(28	--	706.48(20)

Table 2: Relative gamma intensities

E_γ (keV)	NDS 2006[5]	Abdel-Malak [3]	Chand [6]	Present work
83.4	65.5(25)	54.805	63(2)	68.0(5)
97.4	264(6)	221.78	255(4)	256.2(18)
103.2	10000	10000	10000	10000(54)
124.9	3.1	3.069	--	0.038(4)
137.5	--	--	--	0.012(2)
472.0	--	--	--	0.0086(8)
485.9	--	--	--	0.160(12)
694.2	0.007(2)	0.028	0.007(2)	0.010(2)
706.5	0.0053(5)	0.012	--	0.005(1)

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