Features of Isomer Triplets in Transitional (A=152-162) Odd-Odd Nuclei

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As a part of our ongoing programme to elucidate level structures of odd-odd deformed nuclei, we have lately focused on nuclei of transitional region, with particular attention to characterization of their long-lived ($t_{1/2} \geq 1$s) isomers [1]. In this context, we have updated the earlier reported [2,3] survey of such isomers observed in medium-heavy (A=144-194) region using current data listings [4,5]. This exercise has revealed an interesting fact that, while isomer pairs are observed all over the region, isomer triplets are rarely seen. Presently only 9 instances of isomer triplets have been identified, as listed in our Table 1. In our present analysis, we exclude ^{166}Lu triplet which has been unambiguously characterized earlier [6] on the basis of unique 'allowed unhindered (au)' β-decay from each of the 3 isomers thereof. These data have certain distinctive features, briefly mentioned here.

(a) These triplets are observed only in lighter rare earths overlapping the transitional region. Presently identified triplets include only nuclei with N=89/91/93.

(b) Almost in all cases, the three isomers in each triplet have comparable half-life.

(c) In case of isomer neighbors with ΔI=3, the E3/M3 transition is greatly hindered, or even absent.

(d) More significantly, from structure point of view, 11 (out of 16) excited isomers have E_x and/or J^π entries with a question mark and hence uncertain 2qp configuration assignments. In this report, we attempt to predict the level structures giving rise to these triplets in each instance using our 3-step procedure [1] to deduce the level energies and configurations of odd-odd deformed nuclei.

First, we map the available Nilsson model 1qp configuration space for the region under consideration. In Fig. 1 we plot the level ordering of proton orbitals (on the right) based on the observed ground state (gs) spin-parity I^π of the respective odd-Z nucleus, and that for the neutron orbitals (on the left) corresponding to the

Table 1: Experimental [4, 5] data on presently known isomer triplets in medium-heavy Odd-Odd Nuclei. The data includes half-life and excitation energy (E_x in keV).

^{A}X	$t_{1/2}$	E_x(keV)	J^π	%β	%IT
^{152}Pm	4m	0	1+		
	8m	1.5x10^{+2}	4-	100	--
	14m	150+x	(8)	≤100	≥0
^{152}Eu	13y	0	3-		
	9h	46	0-	100	
	96m	148	8-	-	100
^{154}Tb	21h	0	0		
	9h	0+x	3-	78	22
	23h	0+y	7-	98	2
^{156}Tb	5d	0	3-		
	24h	50+x	(7-)	-	(100)
	5h	88	(0+)	>0	<100
^{156}Ho	56m	0	4-		
	9s	52	1-	?	(100)
	8m	52+x	9+	75	25
^{158}Ho	11m	0	5+		
	28m	67	2-	<19	>81
	21m	180(CA)	(9+)	≥93	<7
^{160}Ho	26m	0	5+		
	5h	60	2-	27	73
	3s	170+x	(9+)	--	100
^{162}Lu	1.4m	0	1-		
	1.5m	X	(4-)	≤100	-
	1.9m	Y		≤100	-
^{166}Lu	2.65m	0	6-	58	42
	1.41m	34	(3-)	>80	<20
	2.12m	43	0-	100	--

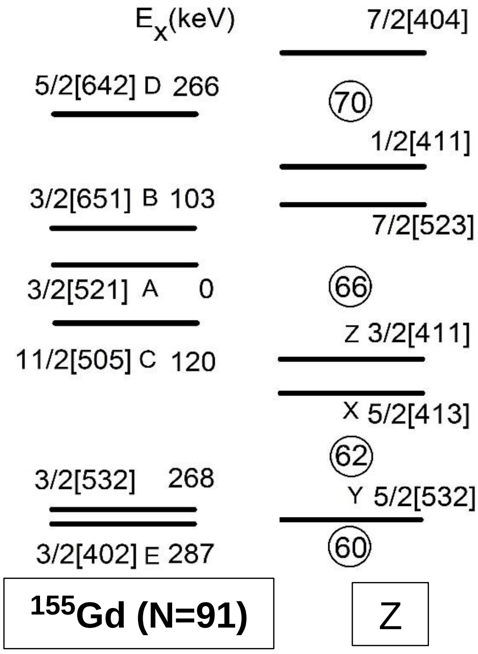

Fig. 1: Plot (not to scale) of Nilsson model 1qp configurations of interest for deducing 2qp configurations in odd-odd nuclei.

experimental assignments [7] for the respective levels in the N=91 nucleus ^{155}Gd. A striking feature of the n-spectra in N=89/91/93 odd-mass nuclei is the appearance of a low-lying deformation-driving high-spin $11/2^-$[505] orbital as an isomeric state. Evidently coupling of this n-orbital with the respective I=3/2, 5/2 or 7/2 p-orbital gives rise to a high-spin (I=7-9) long-lived isomer as a member of respective triplet in the neighboring odd-odd nucleus.

Our detailed model calculations for each odd-odd nucleus follow the procedure adopted in the earlier reported [8] description of the ^{158}Ho triplet and of isomers in Z=61Pm isotopes [1]. Using this procedure we evaluate the band head energies of each admissible 2qp configuration state and examine their correspondence with available experiments to seek acceptable characterization of each member of the listed isomer triplets.

To illustrate our procedure we present in Table 2 the 2qp bands expected in $^{156}_{65}Tb_{91}$. The presently available NDS (2012) data on ^{156}Tb is essentially a patch-up of three non-overlapping experiments. For instance, the postulated 24 h isomer, having no direct experimental inputs, is assigned $K^\pi=7^-$(ZC) 2qp configuration [in terms of our Table 2 notation] and is assumed to possibly decay (by unobserved E3 transition) to the 49.6 keV 4^+ level which is said to have 4^+(ZD) configuration. Our analysis places the 4^+(ZD) band-head at around 250 keV and concludes the 49.6 keV 4^+ level to have a complex $i_{13/2}$ Coriolis mixed structure. It may be of interest to look for a direct E4 decay from 24h 7^- isomer to 3^- gs. Further our analysis places 0^+(ZE) configuration (suggested for 88.4 keV (0^+) level in NDS-2012) around 250 keV; we assign the 0^+(ZB) configuration to the 88 keV 5.3h isomer.

Table 2: Low lying 2qp bands in ^{156}Tb.

Z=65 / N=91	Z: $3/2^+$		Y: $5/2^-$		X: $5/2^+$	
A: $3/2^-$	3^-	0^-	4^+	1^+	1^-	4^-
B: $3/2^+$	3^+	0^+	4^-	1^-	1^+	4^+
C: $11/2^-$	7^-	4^-	8^+	3^+	3^-	8^-
D: $5/2^+$	4^+	1^+	5^-	0^-	0^+	5^+
E: $3/2^+$	0^+	3^+	1^-	4^-	4^+	1^+

Another serious anomaly is revealed for ^{154}Tb data through this analysis. The NDS-2009 listing assigns I=0 for ^{154}Tb gs with configurations $K^\pi = 0^-$(ZA) or $K^\pi = 0^+$(ZB). But both these configurations necessarily have a lower-lying K=3 GM partner, which would correspond to ^{154}Tb gs and another isomer. Alternative structures for ^{154}Tb gs are being investigated.

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