Long-Lived Isomers in the Z=71 (Lu) isotopic sequence

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Experimental data related to the deformed (N≥90) nuclides in the Z=71(Lu) isotopic sequence provide a rich ground for studying various facets of structures observed/expected in this region. In particular, this sequence includes the maximum number (18) of long-lived ($t_{1/2} \geq$ 1ms) isomers (LLI) reported so far for any such set. We discuss a few of the distinctive features of these LLI. The presently available data, listed in the current data files [1,2], for these LLI are summarized in Table 1 for odd-A nuclei, and in Table 2 for odd-odd nuclei.

Examination of odd-A data [2] reveals some interesting facts. We notice that the ground state (gs) $J^{\pi}=1/2^{+}$ for ^{161,163,165}Lu, whereas it is $J^{\pi}=7/2^{+}$ for all heavier isotopes, presumably up to ^{183}Lu. Further, it is seen that the Isomeric Transition (IT) connects ($9/2^{-} \rightarrow 1/2^{+}$) levels in the N=90 ^{161}Lu isomer-pair. The corresponding IT is ($1/2 \rightarrow 7/2$) in all such pairs in N>95 isotopes. The respective IT connects ($1/2^{+} \rightarrow 7/2^{+}$) levels in ^{167}Lu and also in ^{179}Lu, whereas it connects ($1/2^{-} \rightarrow 7/2^{+}$) levels in ^{169,171}Lu. To understand these features, we look at the Nilsson level diagram wherein crossing of respective orbitals with increasing deformation is witnessed. Specifically we find the sharply down-sloping $1/2^{-}[541]_{p}$ orbital crossing over the $1/2^{+}[411]_{p}$ orbital. These observations lead us to conclude that, at least for this isotopic sequence, onset of deformation is not sudden around N=90, but it gradually increases over the N=90-95 domain and then it stabilizes over the N=96-110 region. Another unique feature of odd-A LLI herein is the occurrence of a 160 day ^{177}Lu^{m} 3qp (970 keV; $J^{\pi}=23/2^{-}$) isomer, in sharp contrast to $t_{1/2}$(^{177}Lu gs) = 6.67 days only. Further, a 5qp LLI ^{177}Lu^{n} ($J^{\pi}=39/2^{-}$; E_x = 3530 keV), not listed in Table 1, has also been identified with reported $t_{1/2}$ varying from >6.9 μs (IT) to 7(2) m (β-decaying)[2].

Table 2 for odd-odd nuclei includes 2 sets of isomer triplets [3] in lighter Lu isotopes wherein each one of the 3 LLI (including gs) has comparable half-life within 1-3 m range. In particular, presently each LLI for ^{162}Lu (N=91) has only a β-decay mode and their relative energy placement and 2qp assignments are uncertain. A preliminary analysis leads us to assign $6^{+}\{p:9/2^{-} \otimes n:3/2^{-}\}$ configuration to the 1.9m ^{162}Lu isomer. On the other hand, energy and decay mode as well as the 2qp character of each of the 3 LLI in N=95 ^{166}Lu isotope are well defined [4]. Likewise, the isomer pairs in isotopes with A=168(2)178 have been satisfactorily characterized in the Two-Quasiparticle Rotor Model (TQRM) formulation

Table 1: Long Lived Isomers of Odd Mass Isotopes of Lu

^{A}X	$t_{1/2}$	E_x(keV)	J^{π}	p:Ω[Nn$_3$Λ]
^{161}Lu	77s	0	$1/2^{+}$	1/2[411]
^{161}Lu^{m}	7.3ms	167	$(9/2)^{-}$	9/2[514]
^{167}Lu	51.5m	0	$7/2^{+}$	7/2[404]
^{167}Lu^{m}	≥1m	0+X	$1/2^{+}$	1/2[411]
^{169}Lu	34.1h	0	$7/2^{+}$	7/2[404]
^{169}Lu^{m}	160s	29	$(1/2^{-})$	1/2[541]
^{171}Lu	8.2d	0	$7/2^{+}$	7/2[404]
^{171}Lu^{m}	79s	71	$1/2^{-}$	1/2[541]
^{177}Lu	6.7d	0	$7/2^{+}$	7/2[404]
^{177}Lu^{p}	160.4d	970	$23/2^{-}$	7^{-} (^{176}Lu/gs) +n:9/2[624]
^{179}Lu	4.6h	0	$7/2^{+}$	7/2[404]
^{179}Lu^{m}	3.1ms	592	$1/2^{+}$	1/2[411]

Table 2: Long Lived Isomers of Even Mass Isotopes of Lu.

^{A}X	$t_{1/2}$	E_x (keV)	J^{π}	p:Ω[Nn$_3$Λ] n:Ω[Nn$_3$Λ]
^{162}Lu	1.4m	0	1^-	1/2[411] 3/2[521]
^{162}Lu^m	1.5m	X	(4^-)	5/2[402] 3/2[521]
^{162}Lu^n	1.9m	Y	?	?
^{166}Lu	2.7m	0	6^-	7/2[404] 5/2[523]
^{166}Lu^m	1.4m	34	$3^{(-)}$	1/2[411] 5/2[523]
^{166}Lu^n	2.1m	43	0^-	5/2[402] 5/2[523]
^{168}Lu	5.5m	0	$6^{(-)}$	7/2[404] 5/2[523]
^{168}Lu^m	6.7m	203	3^+	1/2[541] 5/2[523]
^{170}Lu	2.0d	0	0^+	7/2[404] 7/2[633]
^{170}Lu^m	670ms	93	$(4)^-$	7/2[404] 1/2[521]
^{172}Lu	6.7d	0	4^-	7/2[404] 1/2[521]
^{172}Lu^m	3.7m	42	1^-	7/2[404] 5/2[512]
^{174}Lu	3.3yrs	0	$(1)^-$	7/2[404] 5/2[512]
^{174}Lu^m	142d	171	$(6)^-$	7/2[404] 5/2[512]
^{176}Lu	37.6Gy	0	7^-	7/2[404] 7/2[514]
^{176}Lu^m	3.7h	123	1^-	7/2[404] 7/2[514]
^{178}Lu	28.4m	0	$1^{(+)}$	7/2[404] 9/2[624]
^{178}Lu^m	23.1m	124	$9^{(-)}$	9/2[514] 9/2[624]
^{180}Lu	5.7m	0	5^+	9/2[514] 1/2[510]
^{180}Lu^m	(280ms)	14	3^-	7/2[404] 1/2[510]
^{180}Lu^n	>1ms	624	(9^-)	9/2[514] 9/2[624]

[5-7]. The model evaluation also predicts defining properties of certain as yet un-observed isomers in this domain. The even-A listing also includes ^{176}Lu data; it is the only heavy odd-odd nuclide to have a natural abundance [1], other than ^{180}Ta^m wherein the stable species is the 75 keV $J^{\pi}=9^-$ isomer. Another unusual characteristic of ^{176}Lu level scheme related to ΔK=0 admixed bands is reported by us elsewhere in this symposium. Special mention herein may be made of ^{180}Lu data. In Table 2, we list an isomer triplet for this nucleus. The latest NDS evaluation [8] does not include $t_{1/2}$ for the 14 keV 3^- level, since it has not been directly determined so far. However, in the isotonic ^{182}Ta spectrum, 3^- is gs and 5^+ (16 keV) level is shown [2] to have $t_{1/2}$=283 ms. With 15(1) keV M2 transition connecting the $5^+ \rightarrow 3^-$ pair of levels of specified 2qp configuration in each case, it is reasonable to infer the LLI character of ^{180}Lu^m (14 keV) level with a comparable half-life of ~280 ms, as entered in Table 2.

Detailed and critical examination of the available data and model evaluation of open questions in respect of this isotopic chain are being pursued.

References

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