^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 191,1 (2023)	22-Aug-2023

1977Ba40 (also 1974Fo19): E(^{3}He)=42-57 MeV, E(α)=72 MeV; metallic foil targets. Some data are from ^{170}Yb(p,4nγ),E=40 MeV, using targets enriched to 67% in ^{170}Yb at Grenoble. Measured Eγ, Iγ, $\gamma\gamma$-coin, and $\alpha\gamma$(t) using Ge(Li) detectors. No delayed γ rays were reported. The (α,6nγ) reaction was used for $\gamma\gamma$-coin data.

See also ^{170}Yb(p,4nγ) dataset from 1977Ba40.

Other:

1976RoYE (thesis, also 1974SiZT): ^{169}Tm(α,6nγ),E=70 MeV. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma(\theta)$ at Naval Research Laboratory cyclotron facility. Extensive data are reported in this work, but these are not considered by evaluators as agreement with results in 1977Ba40 is poor, and many transitions of similar energies are reported, making it difficult to combine data with those from 1977Ba40 for specific transitions. In 1974SiZT, following bands and γ-cascades were reported: π1/2[541], ΔJ=2 band from 5/2$^-$ to 29/2$^-$ with a γ-cascade of 573.2→496.7→410.8→314.2→212.4→106.5; π7/2[404], ΔJ=2 band from 35/2$^+$ to 9/2$^+$ with γ cascade of 583.7→552.6→511→455.3→383.4→298.3→198.3; and π1/2[411] band with two groups of ΔJ=2 transitions with the first group of γ cascade of (598.2)→575.1→551.3→579.6→564.2→539.9→476.7→398.6→303.2, and the second group with γ cascade of (561)→439.6→353.6.

Additional information 1.

^{167}Lu Levels

Band assignments from 1977Ba40 (also 1974Fo19).

E(level)[†]	J$^\pi$[‡]	Comments
0.0[#]	7/2$^+$	
0.0+x[&]	1/2$^+$	Additional information 2. E(level): x=33.7 keV, as in the Adopted Levels, taken from 2015Ro27.
0.0+y[b]	5/2$^+$	Additional information 3. E(level): y=67.1 keV, as in the Adopted Levels, taken from 2015Ro27.
14.9+x[&] *5*	3/2$^+$	E(level): 1977Ba40 propose E=19.6+X from the difference between 107.3γ and 87.7γ placed by 1977Ba40 from the 1/2$^-$ level, while it is adopted from 2015Ro27 that it is 102.6γ and 87.7γ that deexcite the 1/2$^-$ level and the 107.3γ deexcites the 5/2$^-$ level instead.
102.6+x[a] *5*	1/2$^-$	E(level): 1977Ba40 propose E=107.3+x based on the placement of 107.3γ from this level; however, it has be adopted from the level scheme in 2015Ro27 that it is 102.6γ that deexcites this level.
116.69+y[b] *10*	7/2$^+$	
122.2+x[a] *7*	5/2$^-$	
140.02[#] *7*	9/2$^+$	
234.1+x[a] *8*	9/2$^-$	
243.9+x?[a] *7*	3/2$^-$	Additional information 4. E(level): this level corresponds to the 258.7, (3/2$^-$) level in Adopted Levels.
261.84+y[b] *16*	9/2$^+$	
305.27[#] *8*	11/2$^+$	
331.82[@] *8*	9/2$^-$	
400.7+x[a] *7*	7/2$^-$	
431.57+y[b] *14*	11/2$^+$	
433.6[@] *3*	11/2$^-$	
446.6+x[a] *9*	13/2$^-$	
494.20[#] *11*	13/2$^+$	
577.0[@] *4*	13/2$^-$	
624.5+y[b] *4*	13/2$^+$	

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^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40 (continued)

^{167}Lu Levels (continued)

E(level)†	Jπ‡	E(level)†	Jπ‡	E(level)†	Jπ‡	E(level)†	Jπ‡
659.0+x[a] 8	11/2−	1000.6+x[a] 8	15/2−	1656.4[@] 5	23/2−	2300.12[#] 19	27/2+
704.38[#] 11	15/2+	1159.5[@] 4	19/2−	1671.1+x[a] 11	25/2−	2532.0[@] 4	29/2−
744.2[@] 4	15/2−	1172.7+x[a] 10	21/2−	1720.72[#] 16	23/2+	2581.5[#] 6	29/2+
761.5+x[a] 9	17/2−	1181.30[#] 13	19/2+	1947.7[@] 4	25/2−	2884.9+x[a] 13	33/2−
846.88+y[b] 17	15/2+	1411.8[@] 4	21/2−	2008.75[#] 20	25/2+		
934.29[#] 13	17/2+	1425.4+x[a] 8	19/2−	2216.4[@] 7	27/2−		
948.0[@] 4	17/2−	1444.75[#] 18	21/2+	2243.9+x[a] 12	29/2−		

† From a least-squares fit to Eγ data. From a comparison to level structure in 2015Ro27 and in the Adopted Levels, x=33.7 keV, and y=67.1 keV.
‡ From 1977Ba40, based on energy and intensity fits of coincident transitions into rotational bands based on expected Nilsson states.
# Band(A): π7/2[404] band.
@ Band(B): π9/2[514] band.
& Band(C): π1/2[411] band.
a Band(D): π1/2[541] band.
b Band(E): π5/2[402] band (?). Tentative assignment.

γ(^{167}Lu)

Eγ†	Iγ†	Ei(level)	Jiπ	Ef	Jfπ	Comments
(14.9[#])		14.9+x	3/2+	0.0+x	1/2+	
(19.6[#])		122.2+x	5/2−	102.6+x	1/2−	
x71.0 5	&					
x75.2 5	1.0 5					
x78.7 1	20.4 21					
x80.7 5	10.8‡ 11					
x82.5 5	3.8‡ 19					
87.7 1	129‡ 13	102.6+x	1/2−	14.9+x	3/2+	
x90.9 5	13.3 13					Possibly a ^{169}Yb transition (1977Ba40).
x91.5 5	5.6 28					
x99.8 5	4.2 21					
101.7 5	27.3 27	433.6	11/2−	331.82	9/2−	
102.6 5	38.8‡ 39	102.6+x	1/2−	0.0+x	1/2+	Eγ: placement from Adopted Gammas; 1977Ba40 place this γ from the 5/2− level to feed the 3/2+ level.
107.3 5	43.0 43	122.2+x	5/2−	14.9+x	3/2+	Eγ: placement from Adopted Gammas; 1977Ba40 place this γ from the 1/2− level to feed the 1/2+ level.
111.7 5	95 10	234.1+x	9/2−	122.2+x	5/2−	
116.7 1	44.4‡ 45	116.69+y	7/2+	0.0+y	5/2+	
122.1[c] 5	25 4	243.9+x?	3/2−	122.2+x	5/2−	Eγ: not seen in other studies (1990Yu01,2015Ro27). Iγ: deduced from I(243γ):I(122γ)=28.7:17.1 in ^{170}Yb(p,4nγ) and I(243γ) in (^{3}He,5nγ).
x127.5 5	5.6 28					
x129.2 5	8.9 45					
x133.5 5	3.6 18					
x135.2 5	8.9 45					
139.9 1	100 10	140.02	9/2+	0.0	7/2+	
x142.2 5	12.8 13					
143.4 5	74.2‡ 74	577.0	13/2−	433.6	11/2−	

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^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40 (continued)

$\gamma(^{167}Lu)$ (continued)

E_γ †	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Comments
144.7 *5*	72.6‡ *73*	261.84+y	9/2$^+$	116.69+y	7/2$^+$	
x147.0 *5*	14.7 *15*					
x148.5 *5*	4.8 *24*					
x154.3 *1*	10.8 *11*					
156.5c *1*	25.0‡ *25*	400.7+x	7/2$^-$	243.9+x?	3/2$^-$	Shown in Fig. 3 of 1977Ba40, but attributed to ^{168}Lu ε decay in authors′ Table 1.
x160.6 *5*	13.1 *13*					
x161.5 *5*	5.1 *26*					
165.2 *1*	60.7 *61*	305.27	11/2$^+$	140.02	9/2$^+$	
167.2bc *1*	46.6b *47*	400.7+x	7/2$^-$	234.1+x	9/2$^-$	
167.2b *1*	46.6b *47*	744.2	15/2$^-$	577.0	13/2$^-$	
169.7 *1*	50.5 *51*	431.57+y	11/2$^+$	261.84+y	9/2$^+$	
x179.0 *5*	24.1‡ *24*					
188.8 *5*	54.9‡ *55*	494.20	13/2$^+$	305.27	11/2$^+$	
191.7 *1*	66.9‡ *67*	331.82	9/2$^-$	140.02	9/2$^+$	
193.1 *5*	40.6 *41*	624.5+y	13/2$^+$	431.57+y	11/2$^+$	
x197.3 *5*	73.5 *74*					
203.5 *5*	42.1 *42*	948.0	17/2$^-$	744.2	15/2$^-$	
x204.6 *5*	16.0 *16*					
210.1 *5*	20.9 *21*	704.38	15/2$^+$	494.20	13/2$^+$	
211.6 *5*	29.1 *29*	1159.5	19/2$^-$	948.0	17/2$^-$	
212.3b *5*	138b‡ *14*	446.6+x	13/2$^-$	234.1+x	9/2$^-$	E_γ: 212.8 in Table 1 of 1977Ba40, but 212.3 in authors′ Fig. 3 and text; also in Table 1 and Fig. 1 of 1974Fo19.
212.3b *5*	138b‡ *14*	659.0+x	11/2$^-$	446.6+x	13/2$^-$	
x217.9 *1*	17.3 *17*					
222.6 *5*	49.0‡ *49*	846.88+y	15/2$^+$	624.5+y	13/2$^+$	
224.2c *5*	34 *6*	243.9+x?	3/2$^-$	14.9+x	3/2$^+$	E_γ: placed from the 258.7 level to 1/2$^+$ level in Adopted Levels; 1977Ba40 place it to 3/2$^+$ level. I_γ: deduced from I(243γ):I(224γ)=28.7:23.3 in ^{170}Yb(p,3nγ) and I(243γ) in (^{3}He,5nγ).
x225.0 *5*	17.6 *18*					
x228.6 *5*	70.0 *70*					
230.1 *5*	10.8 *11*	934.29	17/2$^+$	704.38	15/2$^+$	
x236.1 *5*	7.0 *35*					
243.3c *5*	42.4 *43*	243.9+x?	3/2$^-$	0.0+x	1/2$^+$	
244.8b *5*	19.2b *19*	577.0	13/2$^-$	331.82	9/2$^-$	
244.8b *5*	19.2b *19*	1656.4	23/2$^-$	1411.8	21/2$^-$	
247.0 *1*	21.9‡ *22*	1181.30	19/2$^+$	934.29	17/2$^+$	
252.3 *1*	17.3 *17*	1411.8	21/2$^-$	1159.5	19/2$^-$	
x254.5 *1*	11.8 *12*					
x256.7 *5*	<19.3					I_γ: 19.3 *19* for 256.7γ+258.5γ doublet.
258.5 *5*	<19.3	659.0+x	11/2$^-$	400.7+x	7/2$^-$	I_γ: see comment with 256.7γ.
261.7 *5*	13.4 *13*	261.84+y	9/2$^+$	0.0+y	5/2$^+$	
263.5 *5*	7.1 *36*	1444.75	21/2$^+$	1181.30	19/2$^+$	
267.9c *5*	9.2 *46*	2216.4	27/2$^-$	1947.7	25/2$^-$	
x270.5 *5*	<14.1					I_γ: 14.1 *14* for 270.5γ+271.6γ doublet.
x271.6 *5*	<14.1					I_γ: see comment with 270.5γ.
276.0 *1*	12.7 *13*	1720.72	23/2$^+$	1444.75	21/2$^+$	
278.5 *1*	34.3‡ *34*	400.7+x	7/2$^-$	122.2+x	5/2$^-$	
x280.6 *5*	8.4 *42*					
x284.3 *5*	7.9 *40*					

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^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40 (continued)

$\gamma(^{167}Lu)$ (continued)

E_γ [†]	I_γ [†]	E_i(level)	J_i^π	E_f	J_f^π	Comments
288.1 *5*	4.1 *21*	2008.75	25/2$^+$	1720.72	23/2$^+$	
291.3[ac] *5*	&	1947.7	25/2$^-$	1656.4	23/2$^-$	
291.3[ac] *5*	&	2300.12	27/2$^+$	2008.75	25/2$^+$	
294.0 *5*	19.1 *19*	433.6	11/2$^-$	140.02	9/2$^+$	
[x]296.7 *5*	30 *3*					
305.3 *1*	56.9 *57*	305.27	11/2$^+$	0.0	7/2$^+$	
310.9 *5*	27.0 *27*	744.2	15/2$^-$	433.6	11/2$^-$	
314.9[b] *1*	163[b@] *16*	431.57+y	11/2$^+$	116.69+y	7/2$^+$	
314.9[b] *1*	163[b@] *16*	761.5+x	17/2$^-$	446.6+x	13/2$^-$	
314.9[c] *5*	<10[‡]	2532.0	29/2$^-$	2216.4	27/2$^-$	Negligible intensity is expected for placement from 2532 level for the triply placed 314.9γ.
[x]321.5 *1*	14.0 *14*					
[x]324.4 *1*	17.0 *17*					
331.9 *1*	94.7 *95*	331.82	9/2$^-$	0.0	7/2$^+$	
341.7 *1*	22.8 *23*	1000.6+x	15/2$^-$	659.0+x	11/2$^-$	
[x]348.4 *1*	29.9 *30*					
[x]351.6 *1*	23.5 *24*					
354.2 *1*	71.8 *72*	494.20	13/2$^+$	140.02	9/2$^+$	
[x]357.9 *1*	11.4 *11*					
363 *1*		624.5+y	13/2$^+$	261.84+y	9/2$^+$	E_γ: from Fig. 3 of 1977Ba40; presumably different from the unplaced 364.5γ.
[x]364.5 *5*	22.5 *23*					
[x]367.3 *1*	14.0 *14*					
371.0 *1*	27.2 *27*	948.0	17/2$^-$	577.0	13/2$^-$	
[x]379.8 *5*	24.6 *25*					
[x]388.3 *5*	24.0 *24*					
[x]391.2 *5*	11.9 *12*					
[x]393.5 *1*	12.3 *12*					
399.1 *1*	73.7 *74*	704.38	15/2$^+$	305.27	11/2$^+$	
[x]401.1 *1*	42 *4*					
[x]408.6 *5*	21.7 *22*					
411.2 *5*	77.6 *78*	1172.7+x	21/2$^-$	761.5+x	17/2$^-$	
415.3[b] *1*	36.5[b] *37*	846.88+y	15/2$^+$	431.57+y	11/2$^+$	
415.3[b] *1*	36.5[b] *37*	1159.5	19/2$^-$	744.2	15/2$^-$	
[x]417.6 *1*	14.5 *15*					
[x]421.0 *5*	9.1 *46*					
424.8[b] *1*	25.8[b] *26*	659.0+x	11/2$^-$	234.1+x	9/2$^-$	
424.8[b] *1*	25.8[b] *26*	1425.4+x	19/2$^-$	1000.6+x	15/2$^-$	
[x]431.3 *5*	5.9 *30*					
[x]433.6 *5*	15.2 *15*					
440.1 *1*	73.7 *74*	934.29	17/2$^+$	494.20	13/2$^+$	
[x]448.0 *5*	24.0 *24*					
[x]459.5 *1*	31.3 *31*					
463.8 *5*	25.7 *26*	1411.8	21/2$^-$	948.0	17/2$^-$	
[x]467.9 *5*	7.3 *37*					
476.9 *1*	51.4 *52*	1181.30	19/2$^+$	704.38	15/2$^+$	
[x]479.1 *5*	7.0 *35*					
[x]482.5 *5*	4.4 *22*					
[x]486.8 *5*	6.2 *31*					
[x]490.2 *1*	11.1 *11*					
496.7 *5*	23.2 *23*	1656.4	23/2$^-$	1159.5	19/2$^-$	
498.4 *5*	32.3 *32*	1671.1+x	25/2$^-$	1172.7+x	21/2$^-$	

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^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40 (continued)

γ(^{167}Lu) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J_i^π	E_f	J_f^π	Comments
[x]500.8 *5*	9.3 *47*					
511.0 *5*	[‡]	1444.75	21/2$^+$	934.29	17/2$^+$	
535.9 *1*	21.3 *21*	1947.7	25/2$^-$	1411.8	21/2$^-$	
539.4 *1*	75.2[‡] *75*	1720.72	23/2$^+$	1181.30	19/2$^+$	
[x]544.8 *1*	12.9 *13*					
[x]548.3 *1*	15.0 *15*					
553.8 *5*	8 *4*	1000.6+x	15/2$^-$	446.6+x	13/2$^-$	I_γ: deduced from I(342γ):I(554γ)=16.0:5.9 in ^{170}Yb(p,4nγ) and I(342γ) in (^{3}He,5nγ).
560.0 *5*	9.9 *50*	2216.4	27/2$^-$	1656.4	23/2$^-$	
564.0 *1*	27.3 *27*	2008.75	25/2$^+$	1444.75	21/2$^+$	
572.7[a] *5*		2243.9+x	29/2$^-$	1671.1+x	25/2$^-$	E_γ: from Fig. 3 of 1977Ba40, absent in authors′ Table 1, but present in $\gamma\gamma$-coin.
572.7[a] *5*		2581.5	29/2$^+$	2008.75	25/2$^+$	
579.4 *1*	10.6 *11*	2300.12	27/2$^+$	1720.72	23/2$^+$	
584.3 *1*	38.4[‡] *39*	2532.0	29/2$^-$	1947.7	25/2$^-$	E_γ: attributed to ^{168}Yb in Table 1 of 1977Ba40, but included in authors′ level scheme Fig. 3.
[x]610.1 *1*	11.3 *11*					
[x]634.4 *1*	10.1 *10*					
641.0 *5*	9.2 *46*	2884.9+x	33/2$^-$	2243.9+x	29/2$^-$	E_γ: from Figs. 1 and 3 of 1977Ba40; misprinted as 614.0 in authors′ Table 1.
[x]657.6 *5*	[&]					
[x]718.8 *1*	28.3 *28*					
[x]729.3 *5*	9.8 *49*					
[x]780.8 *1*	22.0 *22*					
[x]820.1 *5*	[&]					
[x]823.7 *5*	[&]					
[x]835.1 *1*	23.1 *23*					
[x]844.5 *1*	44.7 *45*					
[x]846.6 *1*	34.8 *35*					
[x]853.3 *1*	25.5 *26*					
[x]860.0 *1*	27.4 *28*					

[†] From ^{169}Tm(^{3}He,5nγ) at 45 MeV and/or ^{170}Yb(p,4nγ),E=40 MeV, except where noted. $\Delta E\gamma$=0.1 keV and $\Delta I\gamma$=10% for strong, well-resolved peaks, $\Delta E\gamma$=0.5 keV for weak or barely-resolved peaks, $\Delta I\gamma$=50% for weak peaks. Evaluators estimate weak peaks to be those with $I\gamma \leq 10$.

[‡] Includes component from contaminant line.

[#] From energy difference between initial and final levels. Note that 1977Ba40 place 87.7γ and 107.3γ from the same level, while place 87.7γ and 102.6γ from the same level, with the latter placement adopted in the Adopted Levels, Gammas.

[@] Triplet γ with $I\gamma$=163 *16*. Based on I(267.9γ)=9.2 *46* and I(291.3γ)=weak for the two transitions immediately below the 314.9γ in the ΔJ=1 cascade of 9/2[514] band, $I\gamma$(315γ) from 2532 level can reasonably be assumed to be <10, leaving essentially all the triplet intensity to be assigned from the 761+x level and the 431+y level.

[&] Weak γ.

[a] Multiply placed.

[b] Multiply placed with undivided intensity.

[c] Placement of transition in the level scheme is uncertain.

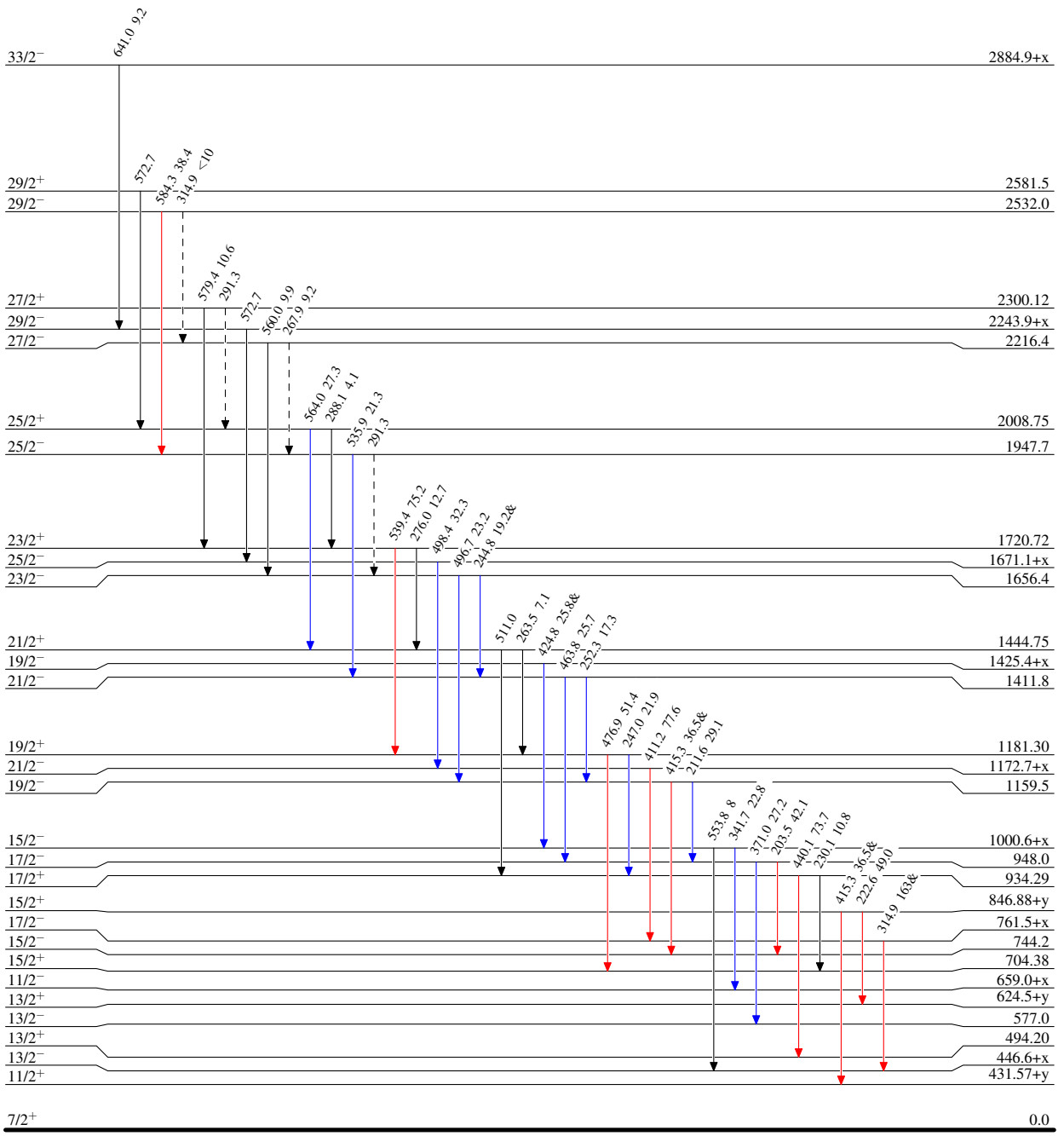
[x] γ ray not placed in level scheme.

^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40

Level Scheme

Intensities: Relative I_γ

& Multiply placed: undivided intensity given



$^{167}_{71}Lu_{96}$

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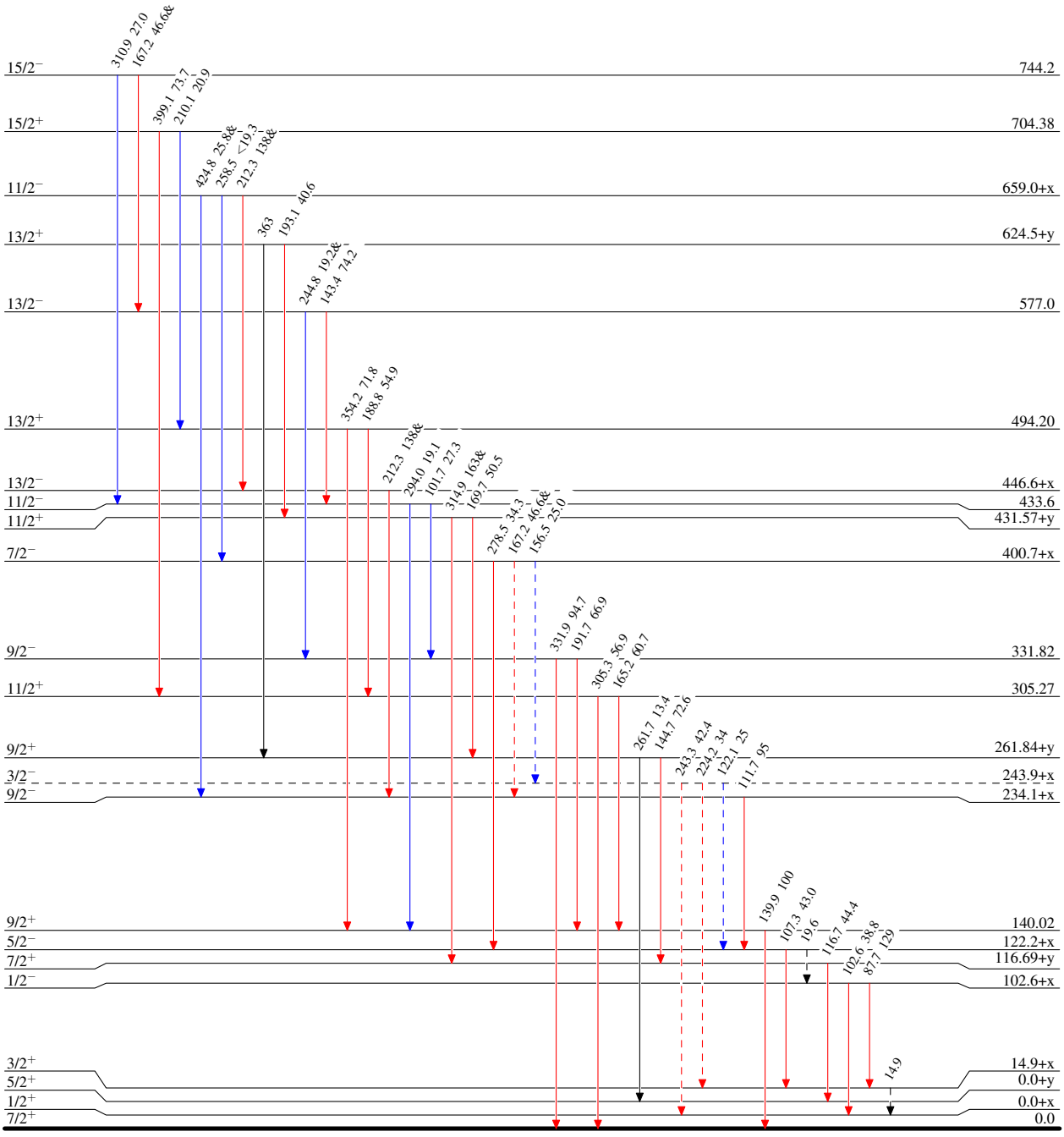
Level Scheme (continued)

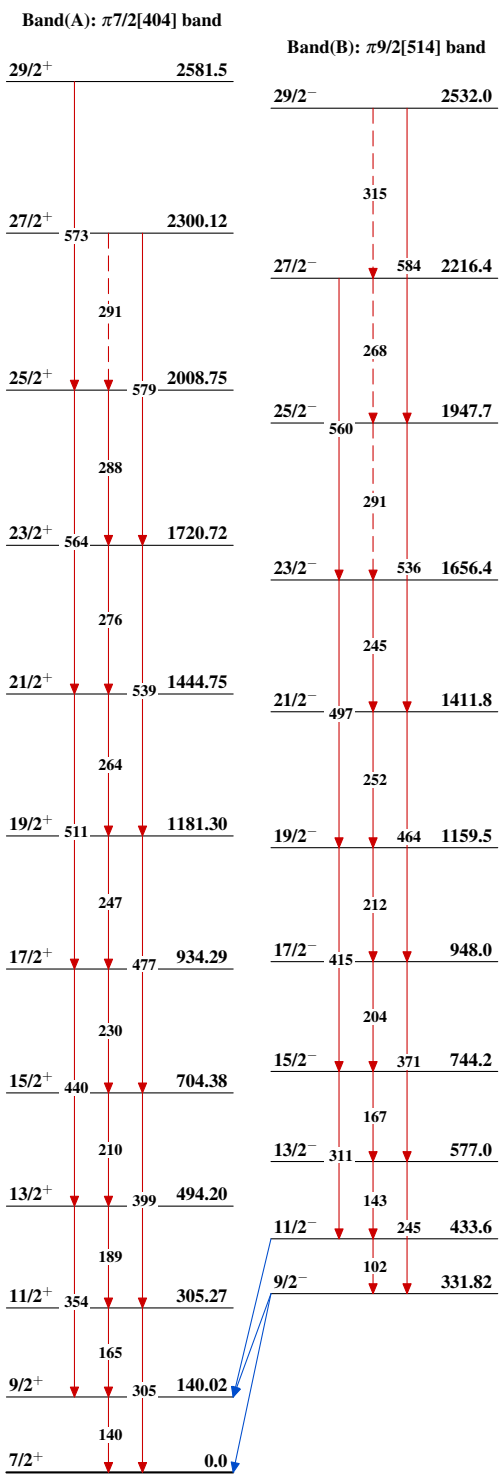
Intensities: Relative I_γ
& Multiply placed: undivided intensity given

Legend
- $I_\gamma < 2\% \times I_\gamma^{max}$
- $I_\gamma < 10\% \times I_\gamma^{max}$
- $I_\gamma > 10\% \times I_\gamma^{max}$
- γ Decay (Uncertain)



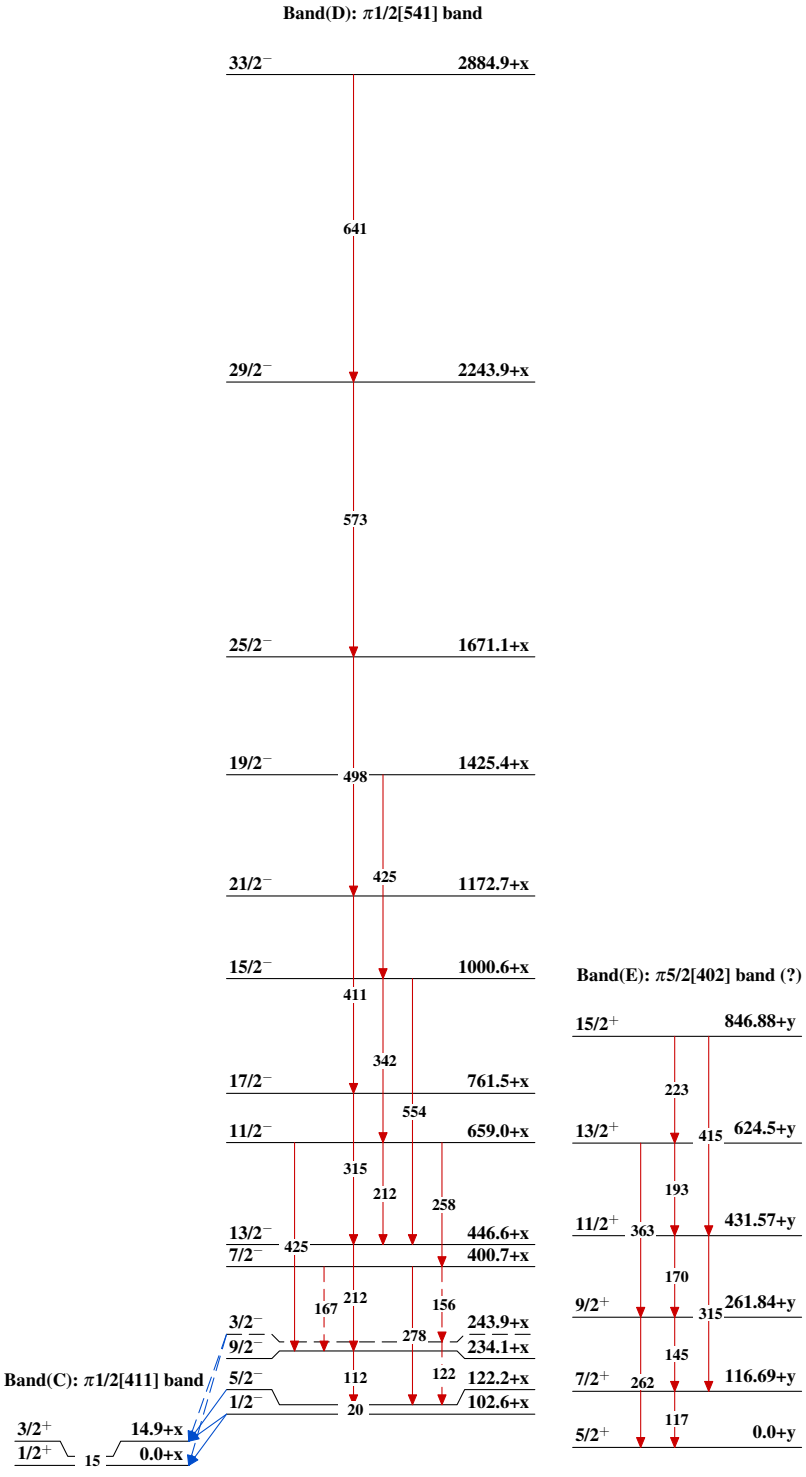
$^{167}_{71}Lu_{96}$

^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40



$^{167}_{71}Lu_{96}$

^{169}Tm(^{3}He,5nγ),(α,6nγ) 1977Ba40 (continued)



$^{167}_{71}Lu_{96}$