^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	C. W. Reich	NDS 112,2497 (2011)	1-Jun-2011

Additional information 1.

Includes data from ^{161}Dy(p,nγ), ^{154}Sm(^{11}B,4nγ) and ^{159}Tb(α,2nγ) reactions.

Data presented are primarily from 1971Fu08 and secondarily from 1970Re12, 1974Gr01, and 1976Sc19. Others: 1971Al02 and notes in annual reports by 1969JoZY, 1972Sh36, and 1974GrZI.

Reactions include ^{159}Tb(α,2nγ) with E(α)=21-27 MeV, ^{161}Dy(d,2nγ) with E(d)=13.5 MeV, and ^{161}Dy(p,nγ) with E(p)=6.7 MeV by 1971Fu08; ^{159}Tb(α,2nγ) with E(α)=20-43 MeV by 1970Re12; ^{154}Sm(^{11}B,4nγ) with E(^{11}B)=51 MeV; and ^{161}Dy(p,nγ) with E(p)=8.5 MeV.

^{161}Ho Levels

Additional information 2.

E(level)[†]	J$^{\pi}$[‡]	T$_{1/2}$[#]
0.[@]	7/2$^-$	
99.59[&] 7	9/2$^-$	
211.10[a] 9	1/2$^+$	
221.94[@] 7	11/2$^-$	
222.44[b] 11	3/2$^+$	
252.77[c] 9	7/2$^+$	≤0.2 ns
298.61[e] 14	3/2$^+$	
316.55[a] 14	5/2$^+$	
353.25[b] 14	7/2$^+$	0.52 ns 15
368.09[&] 8	13/2$^-$	
370.80[d] 7	9/2$^+$	
373.21[f] 14	5/2$^+$	
423.94[g] 23	1/2$^-$	
463.30[e] 14	7/2$^+$	
511.73[c] 9	11/2$^+$	
519.55[a] 24	9/2$^+$	
525.90[h] 22	3/2$^-$	
534.44[@] 9	15/2$^-$	
579.48[g] 17	9/2$^-$	≤0.2 ns
583.83[b] 17	11/2$^+$	
598.84[f] 17	9/2$^+$	
674.54[d] 10	13/2$^+$	
726.40[&] 10	17/2$^-$	
733.00[e] 17	11/2$^+$	
788.10[g] 17	13/2$^-$	
821.1[a] 3	13/2$^+$	
857.27[c] 10	15/2$^+$	
906.83[b] 18	15/2$^+$	
920.72[f] 18	(13/2$^+$)	
931.63[@] 11	19/2$^-$	
1059.55[d] 11	17/2$^+$	
1084.39[g] 18	17/2$^-$	

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^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01 (continued)

^{161}Ho Levels (continued)

E(level)[†]	J$^{\pi}$[‡]	Comments
1096.06[e] 22	(15/2$^+$)	
1167.28[&] 12	21/2$^-$	
1210.9[a] 3	17/2$^+$	
1278.29[c] 11	19/2$^+$	
1311.78[b] 20	19/2$^+$	
1404.21[@] 13	23/2$^-$	
1465.59[g] 21	21/2$^-$	
1514.07[d] 14	21/2$^+$	
1674.4[a] 3	(21/2$^+$)	
1678.37[&] 14	25/2$^-$	
1762.19[c] 23	23/2$^+$	
1786.38[b] 22	23/2$^+$	
1926.90[g] 23	(25/2$^-$)	
1938.66[@] 15	27/2$^-$	
2032.77[d] 24	(25/2$^+$)	E(level): 2004Es01, in ^{160}Gd(^{7}Li,6nγ), report a different γ decay pattern from that given here and place the 25/2$^+$ band member elsewhere in the level scheme.
2250.77[&] 24	29/2$^-$	E(level): 2004Es01, in ^{160}Gd(^{7}Li,6nγ), report a different γ decay pattern from that given here and place the 29/2$^-$ band member elsewhere in the level scheme.
2316.7[b] 3	(27/2$^+$)	E(level): 2004Es01, in ^{160}Gd(^{7}Li,6nγ), report a different γ decay pattern from that given here and place the 27/2$^+$ band member elsewhere in the level scheme.
2512.0[@] 7	31/2$^-$	E(level): 2004Es01, in ^{160}Gd(^{7}Li,6nγ), report a γ-decay pattern different from that given here. The data for this level and for the higher-spin levels in this band that are included in the adopted values are those from the study of 2004Es01.
3080.9[@] 11	35/2$^-$	
3625.7[@] 15	(39/2$^-$)	

[†] From least-squares fit to γ energies.
[‡] Authors' (1971Fu08,1974Gr01, etc.) assignments are given. These are based on γ multipolarities and expected band structure above 230 keV and other studies below 230 keV. Assignments agree with those in Adopted Levels. Supporting arguments are given there.
[#] Measured (1976Sc19) in (p,nγ) from $\gamma\gamma$(t) and centroid shift method. See Adopted Levels for half-lives measured following other modes of excitation.
[@] Band(A): 7/2[523] band; signature= −1/2.
[&] Band(B): 7/2[523] band; signature= +1/2.
[a] Band(C): 1/2[411] band; signature= +1/2.
[b] Band(D): 1/2[411] band; signature= −1/2.
[c] Band(E): 7/2[404] band; signature= −1/2.
[d] Band(F): 7/2[404] band; signature= +1/2.
[e] Band(G): 3/2[411] band; signature= −1/2.
[f] Band(H): 3/2[411] band; signature= +1/2.
[g] Band(I): 1/2[541] band; signature= +1/2.
[h] Band(J): 1/2[541] band; signature= −1/2.

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01 (continued)

$\gamma(^{161}Ho)$

E_γ[†‡]	I_γ[#@]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	Comments
(11.4 *1*)		222.44	$3/2^+$	211.10	$1/2^+$		
74.6 *2*	1.6	373.21	$5/2^+$	298.61	$3/2^+$		
76.2 *2*	1.8	298.61	$3/2^+$	222.44	$3/2^+$		
87.6 *2*	2.3[c]	298.61	$3/2^+$	211.10	$1/2^+$	M1	Mult.: $\gamma(\theta)$ indicates D, but line is doublet (1971Fu08). From ^{161}Er decay, γ is M1.
90.1 *2*	4.3	463.30	$7/2^+$	373.21	$5/2^+$	M1(+E2)	Mult.: $\gamma(\theta)$ gives D. M1(+E2) is from ^{161}Er decay.
94.1 *1*	8.1	316.55	$5/2^+$	222.44	$3/2^+$	M1(+E2)	Mult.: $\gamma(\theta)$ gives D. M1(+E2) is from ^{161}Er decay.
99.6 *1*	95.7	99.59	$9/2^-$	0.	$7/2^-$	M1(+E2)	Mult.: $\gamma(\theta)$ indicates D. M1(+E2) is from ^{161}Er decay studies.
105.5 *2*	0.6	316.55	$5/2^+$	211.10	$1/2^+$		
[x]107.3 *2*	1.4						
110.0 *2*	7.5	463.30	$7/2^+$	353.25	$7/2^+$		
114.9[f] *2*	1.0	1210.9	$17/2^+$	1096.06	$(15/2^+)$		
118.5[d] *5*	2.3[d]	370.80	$9/2^+$	252.77	$7/2^+$		
118.5[d] *5*	2.3[d]	906.83	$15/2^+$	788.10	$13/2^-$		
122.3 *1*	105.	221.94	$11/2^-$	99.59	$9/2^-$	(M1)	Mult.: D from in-beam study. (M1) is from ^{161}Er decay studies.
130.8 *1*	47.6	353.25	$7/2^+$	222.44	$3/2^+$	E2	Mult.: $\gamma(\theta)$ indicates Q. E2 is from ^{161}Er decay.
134.1 *2*	4.1	733.00	$11/2^+$	598.84	$9/2^+$	D	A_2=−0.05 *15* (1971Fu08).
135.7 *2*	4.3	598.84	$9/2^+$	463.30	$7/2^+$	Q	A_2=0.30 *15* (1971Fu08).
141.1 *2*	1.7[c]	511.73	$11/2^+$	370.80	$9/2^+$		
146.1 *1*	95.7	368.09	$13/2^-$	221.94	$11/2^-$	D	A_2=0.06 *2* (1970Re12).
148.6 *2*	3.0[c]	370.80	$9/2^+$	221.94	$11/2^-$		
151.1 *2*	0.8	373.21	$5/2^+$	222.44	$3/2^+$		
153.9[e] *6*	1.7[e]	252.77	$7/2^+$	99.59	$9/2^-$		I_γ: reported Iγ=3.4 for doublet. Intensity divided by evaluator on basis of ^{161}Er ε decay data. Mult.: $\gamma(\theta)$ indicates D, but γ is multiply placed (1971Fu08).
153.9[e] *6*	1.7[e]	1465.59	$21/2^-$	1311.78	$19/2^+$		I_γ: reported Iγ=3.4 for doublet. Intensity divided by evaluator on basis of ^{161}Er ε decay data for the other placement. Mult.: $\gamma(\theta)$ indicates D, but γ is multiply placed (1971Fu08).
162.3[d] *4*	1.1[d]	373.21	$5/2^+$	211.10	$1/2^+$		
162.3[d] *4*	1.1[d]	674.54	$13/2^+$	511.73	$11/2^+$		
164.8 *2*	2.8	463.30	$7/2^+$	298.61	$3/2^+$		
166.3 *1*	76.9	534.44	$15/2^-$	368.09	$13/2^-$	D	A_2=0.03 *2* (1970Re12).
[x]172.7 *2*	2.0						
175.4 *2*	3.5[c]	1096.06	$(15/2^+)$	920.72	$(13/2^+)$		Mult.: $\gamma(\theta)$ indicates D, but γ is doublet (1971Fu08).
177.5 *1*	5.3	1084.39	$17/2^-$	906.83	$15/2^+$	D	A_2=−0.35 *9* (1971Fu08).
187.7 *2*	2.2	920.72	$(13/2^+)$	733.00	$11/2^+$		
191.9 *1*	54.5	726.40	$17/2^-$	534.44	$15/2^-$	D	A_2=0.06 *2* (1970Re12).
201.5 *2*	1.7	423.94	$1/2^-$	222.44	$3/2^+$		
203.0 *2*	4.4	519.55	$9/2^+$	316.55	$5/2^+$		
204.2 *1*	19.1	788.10	$13/2^-$	583.83	$11/2^+$	D	A_2=0.04 *14* (1970Re12).
205.2 *1*	34.4	931.63	$19/2^-$	726.40	$17/2^-$	D	A_2=0.01 *8* (1971Fu08).
208.7 *1*	6.6	788.10	$13/2^-$	579.48	$9/2^-$	Q	A_2=0.25 *3* (1970Re12).
211.2 *1*	100.	211.10	$1/2^+$	0.	$7/2^-$	E3	Mult.: from ^{161}Er decay studies.
[x]213.1 *2*	2.6						
221.9 *1*	18.0	221.94	$11/2^-$	0.	$7/2^-$	Q	A_2=0.22 *3* (1970Re12).
225.5 *2*	4.4	598.84	$9/2^+$	373.21	$5/2^+$		
226.3 *1*	11.8	579.48	$9/2^-$	353.25	$7/2^+$	D	A_2=−0.11 *2* (1970Re12).
227.2 *2*	2.0	1311.78	$19/2^+$	1084.39	$17/2^-$		

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^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01 (continued)

γ(^{161}Ho) (continued)

E_γ[†‡]	I_γ[#@]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	Comments
230.5 *1*	57.0	583.83	11/2$^+$	353.25	7/2$^+$	Q	A_2=0.28 *1* (1970Re12).
235.5 *1*	21.5	1167.28	21/2$^-$	931.63	19/2$^-$	D	A_2=0.07 *6* (1971Fu08).
236.9 *1*	14.1[c]	1404.21	23/2$^-$	1167.28	21/2$^-$		Mult.: $\gamma(\theta)$ indicates D, but γ is doublet (1971Fu08).
240.9 *2*	2.0	463.30	7/2$^+$	222.44	3/2$^+$		
245.0[f] *2*	1.6	598.84	9/2$^+$	353.25	7/2$^+$		
252.7 *1*	15.7	252.77	7/2$^+$	0.	7/2$^-$		Mult.: $\gamma(\theta)$ indicates Q (1970Re12,1971Fu08), but ^{161}Er decay data indicate E1, which agrees with J^π's.
258.7 *2*	1.6	511.73	11/2$^+$	252.77	7/2$^+$		
260.1 *2*	2.8	1938.66	27/2$^-$	1678.37	25/2$^-$		Mult.: $\gamma(\theta)$ indicates D, but γ is doublet (1971Fu08).
268.5 *1*	32.4	368.09	13/2$^-$	99.59	9/2$^-$	Q	A_2=0.38 *7* (1970Re12).
269.7 *1*	6.8	733.00	11/2$^+$	463.30	7/2$^+$		Mult.: $\gamma(\theta)$ indicates D (1970Re12), but placement suggests E2.
271.2 *1*	7.3	370.80	9/2$^+$	99.59	9/2$^-$		Mult.: $\gamma(\theta)$ gives Q (1970Re12) and (D) (1971Fu08); placement requires E1.
274.2 *1*	6.0	1678.37	25/2$^-$	1404.21	23/2$^-$	D	A_2=−0.04 *8* (1971Fu08).
289.8 *2*	4.6	511.73	11/2$^+$	221.94	11/2$^-$		Mult.: $\gamma(\theta)$ indicates Q, but placement suggests E1.
296.3 *1*	15.1	1084.39	17/2$^-$	788.10	13/2$^-$	Q	A_2=0.32 *4* (1971Fu08).
301.5 *1*	12.7	821.1	13/2$^+$	519.55	9/2$^+$	Q	A_2=0.24 *3* (1970Re12).
303.8 *2*	4.2	674.54	13/2$^+$	370.80	9/2$^+$	Q	A_2=0.32 *13* (1971Fu08).
306.5 *2*	2.2	674.54	13/2$^+$	368.09	13/2$^-$		Mult.: $\gamma(\theta)$ indicates Q, but placement suggests E1.
312.5 *1*	40.6	534.44	15/2$^-$	221.94	11/2$^-$	Q	A_2=0.31 *2* (1970Re12).
314.8 *2*	1.3	525.90	3/2$^-$	211.10	1/2$^+$		
320.2[f] *2*	1.3	1786.38	23/2$^+$	1465.59	21/2$^-$		
321.9 *1*	8.0	920.72	(13/2$^+$)	598.84	9/2$^+$		
323.0 *1*	25.7	906.83	15/2$^+$	583.83	11/2$^+$	Q	A_2=0.35 *3* (1971Fu08).
[x]327.0 *2*	1.7						
[x]331.8 *2*	2.2						
345.6 *1*	5.6	857.27	15/2$^+$	511.73	11/2$^+$	Q	A_2=0.30 *8* (1970Re12).
358.3 *1*	39.8	726.40	17/2$^-$	368.09	13/2$^-$	Q	A_2=0.32 *1* (1970Re12).
363.0 *2*	6.7[c]	1096.06	(15/2$^+$)	733.00	11/2$^+$		
370.8 *1*	8.1	370.80	9/2$^+$	0.	7/2$^-$	D	A_2=−0.25 *7* (1970Re12).
[x]376.6 *2*	3.0						
381.2 *1*	10.5	1465.59	21/2$^-$	1084.39	17/2$^-$	Q	A_2=0.42 *7* (1971Fu08).
385.0 *1*	6.2	1059.55	17/2$^+$	674.54	13/2$^+$	Q	A_2=0.34 *9* (1971Fu08).
389.8 *1*	9.5	1210.9	17/2$^+$	821.1	13/2$^+$	Q	A_2=0.27 *6* (1971Fu08).
397.2 *1*	34.3	931.63	19/2$^-$	534.44	15/2$^-$	Q	A_2=0.32 *3* (1971Fu08).
[x]403.2 *2*	2.5					Q	
405.0 *1*	13.3	1311.78	19/2$^+$	906.83	15/2$^+$	Q	A_2=0.40 *8* (1971Fu08).
412.2 *1*	12.5	511.73	11/2$^+$	99.59	9/2$^-$	D	A_2=−0.19 *2* (1970Re12).
[x]414.7 *2*	2.5						
421.1 *1*	7.5	1278.29	19/2$^+$	857.27	15/2$^+$		Mult.: $\gamma(\theta)$ indicates D (1970Re12) and Q (1971Fu08); J^π's require E2.
[x]425.5 *2*	2.0						E_γ,I_γ: doublet (1971Fu08); neither placement known.
[x]431.8 *2*	2.2						
[x]433.6 *2*	1.7						
440.9 *1*	28.3	1167.28	21/2$^-$	726.40	17/2$^-$	Q	A_2=0.34 *3* (1971Fu08).
[x]446.8 *2*	2.7					D	
452.6 *1*	13.9	674.54	13/2$^+$	221.94	11/2$^-$	D	A_2=−0.14 *2* (1970Re12).
454.5 *1*	9.9[c]	1514.07	21/2$^+$	1059.55	17/2$^+$		Mult.: $\gamma(\theta)$ indicates Q, but γ is doublet (1971Fu08).
461.3 *1*	5.3[c]	1926.90	(25/2$^-$)	1465.59	21/2$^-$		Mult.: $\gamma(\theta)$ indicates Q, but γ is doublet (1971Fu08).
463.5 *1*	6.0	1674.4	(21/2$^+$)	1210.9	17/2$^+$	Q	A_2=0.60 *20* (1971Fu08).
472.7 *1*	21.9	1404.21	23/2$^-$	931.63	19/2$^-$	Q	A_2=0.38 *4* (1971Fu08).
474.6 *1*	5.2	1786.38	23/2$^+$	1311.78	19/2$^+$		
483.9 *2*	3.9	1762.19	23/2$^+$	1278.29	19/2$^+$		
489.2 *1*	12.4	857.27	15/2$^+$	368.09	13/2$^-$	D	A_2=−0.18 *5* (1970Re12).

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^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01 (continued)

γ(^{161}Ho) (continued)

E_γ[†‡]	I_γ[#@]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	Comments
[x]503.1 *2*	3.7						
511.0 *1*	13.0	1678.37	25/2$^-$	1167.28	21/2$^-$		
518.7 *2*	1.4	2032.77	(25/2$^+$)	1514.07	21/2$^+$		
525.1 *1*	10.9	1059.55	17/2$^+$	534.44	15/2$^-$	D	A_2=−0.26 *8* (1971Fu08).
530.3 *2*	1.3	2316.7	(27/2$^+$)	1786.38	23/2$^+$		
534.5 *1*	6.8	1938.66	27/2$^-$	1404.21	23/2$^-$	Q	A_2=0.40 *12* (1971Fu08).
544.8[a] *10*		3625.7	(39/2$^-$)	3080.9	35/2$^-$	(Q)[b]	A_2=0.20 *20* (1974Gr01).
551.8 *1*	9.0	1278.29	19/2$^+$	726.40	17/2$^-$	D	A_2=−0.21 *8* (1971Fu08).
568.9[a] *8*		3080.9	35/2$^-$	2512.0	31/2$^-$	(Q)[b]	A_2=0.21 *13* (1974Gr01).
572.4 *2*	2.6	2250.77	29/2$^-$	1678.37	25/2$^-$		
573.3[a] *6*		2512.0	31/2$^-$	1938.66	27/2$^-$	Q[b]	A_2=0.26 *7* (1974Gr01).
582.5 *2*	4.9	1514.07	21/2$^+$	931.63	19/2$^-$	D	A_2=−0.13 *12* (1971Fu08).

[†] Values are from 1971Fu08, except three as noted from 1974Gr01. The general statement (1971Fu08) that the uncertainties are 0.1-0.3 keV, depending on Iγ has been interpreted by the evaluator to give specific values.

[‡] Unplaced γ's are from 1971Fu08; very weak lines noted in a footnote (1971Fu08) are: 116.5, 137.5, 157.4, 169.5, 183.0, 238.3, 262.8, 275.0, 285.0, 366.2, 387.2, 508, 522.2, 537.1, 546.1, 549.0, 554.2, 562.9, 568.4, 585.2, and 607.0 keV.

[#] Values are for the (α,2nγ) reaction with E(α)=27 MeV at 125° (1971Fu08). The uncertainties are stated to be 5% to 20%, but specific values are not given by the evaluator.

[@] Values available for other reactions and beam energies are as follows: (α,2nγ) at 23 MeV by 1971Fu08 and at 30 MeV by 1970Re12; (d,2nγ) at 13 MeV by 1971Fu08; (p,nγ) at 6.7 MeV by 1971Fu08; (^{11}B,4nγ) at 52 MeV by 1971Al02 and at 58 MeV by 1974Gr01.

[&] Assignments are based on $\gamma(\theta)$ results from these in-beam measurements, except as otherwise noted. These authors (1970Re12,1971Fu08,1974Gr01) give only angular distributions, so the specific multipolarity assignments have been made by the evaluator using the following rules: D if A_2<+0.10 and Q if A_2≥+0.15. Conflicts between measurements or with J^π assignments are noted. For multipolarity assignments for other γ's, see Adopted Gammas.

[a] From 1974Gr01.

[b] From 1974Gr01.

[c] γ is doublet (1971Fu08) with intensity not divided and other component is not placed.

[d] Multiply placed with undivided intensity.

[e] Multiply placed with intensity suitably divided.

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

[x] γ ray not placed in level scheme.

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01

Legend

Level Scheme

Intensities: Relative I_γ

@ Multiply placed: intensity suitably divided

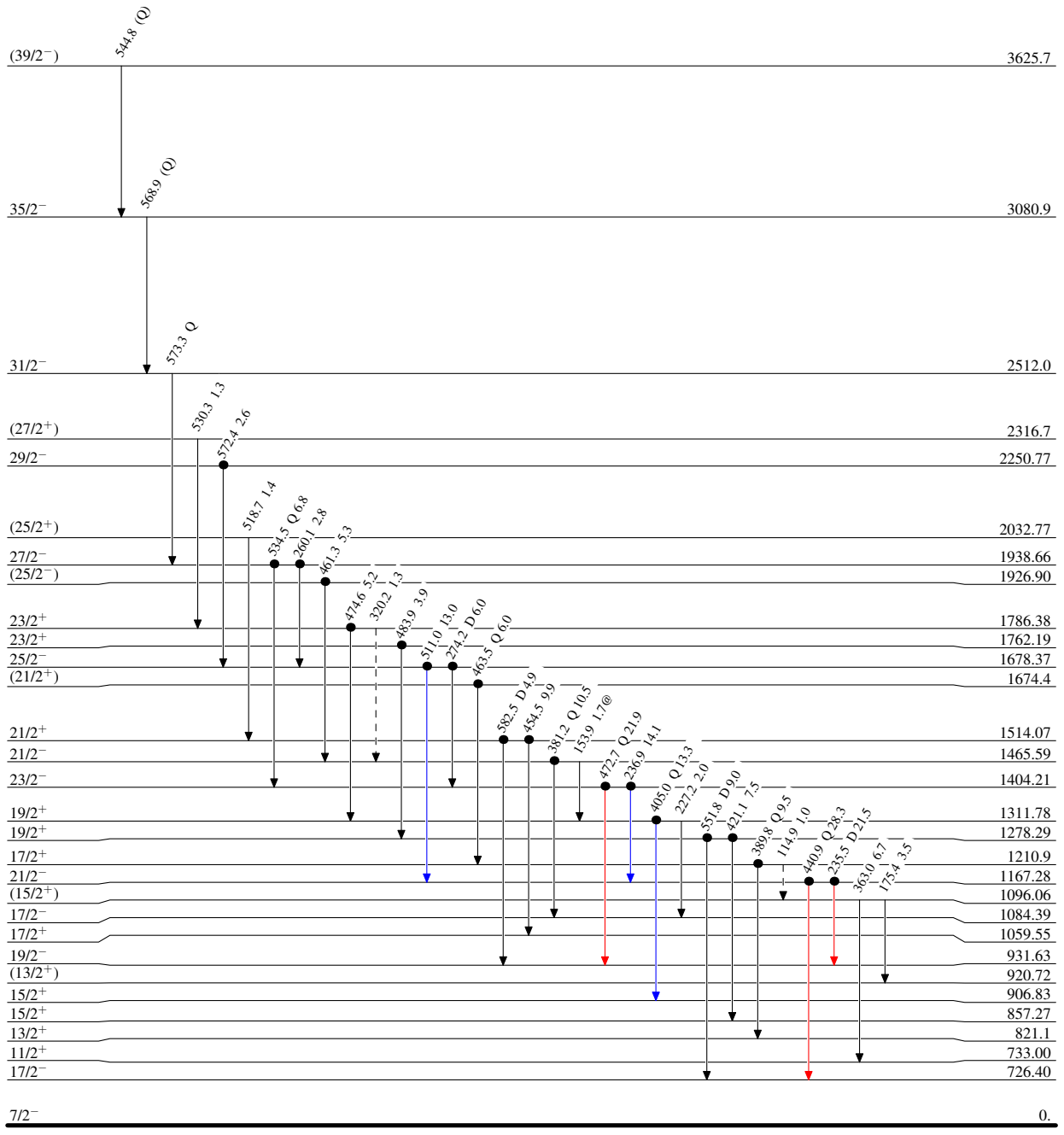
$I_\gamma < 2\% \times I_\gamma^{max}$

$I_\gamma < 10\% \times I_\gamma^{max}$

$I_\gamma > 10\% \times I_\gamma^{max}$

γ Decay (Uncertain)

Coincidence



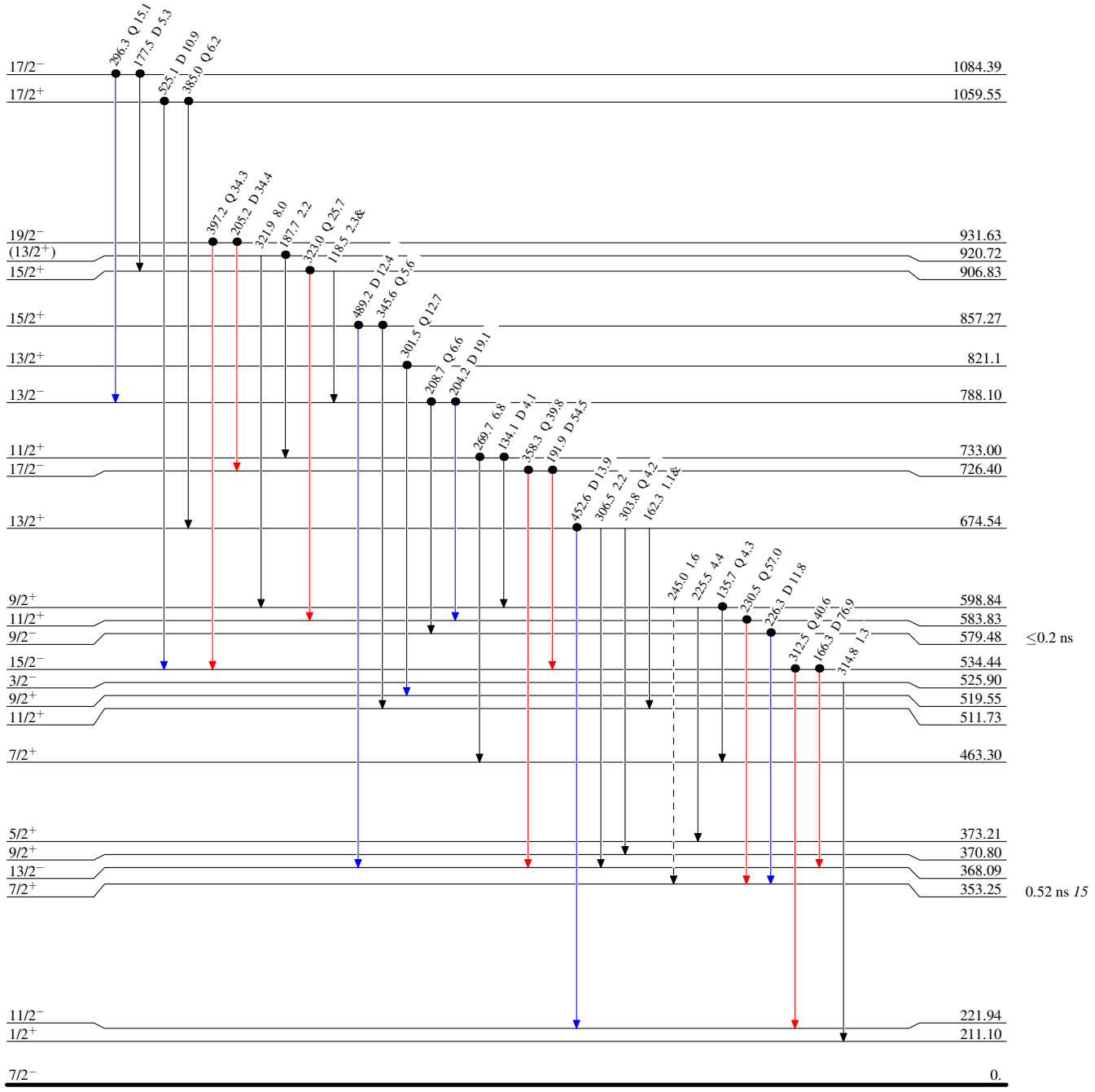
$^{161}_{67}Ho_{94}$

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01

Level Scheme (continued)

Intensities: Relative I_γ
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided

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)
Coincidence



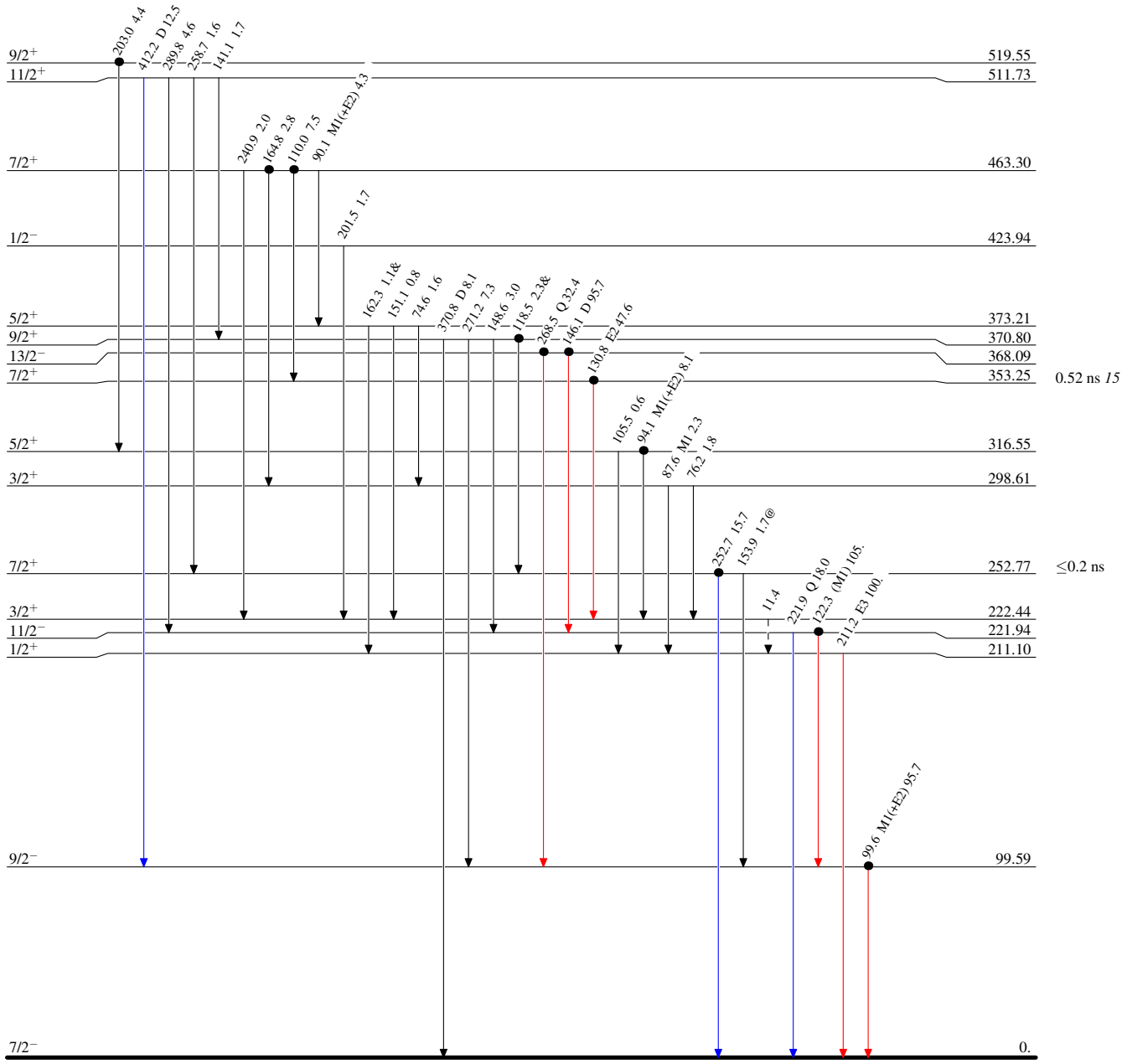
$^{161}_{67}Ho_{94}$

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01

Level Scheme (continued)

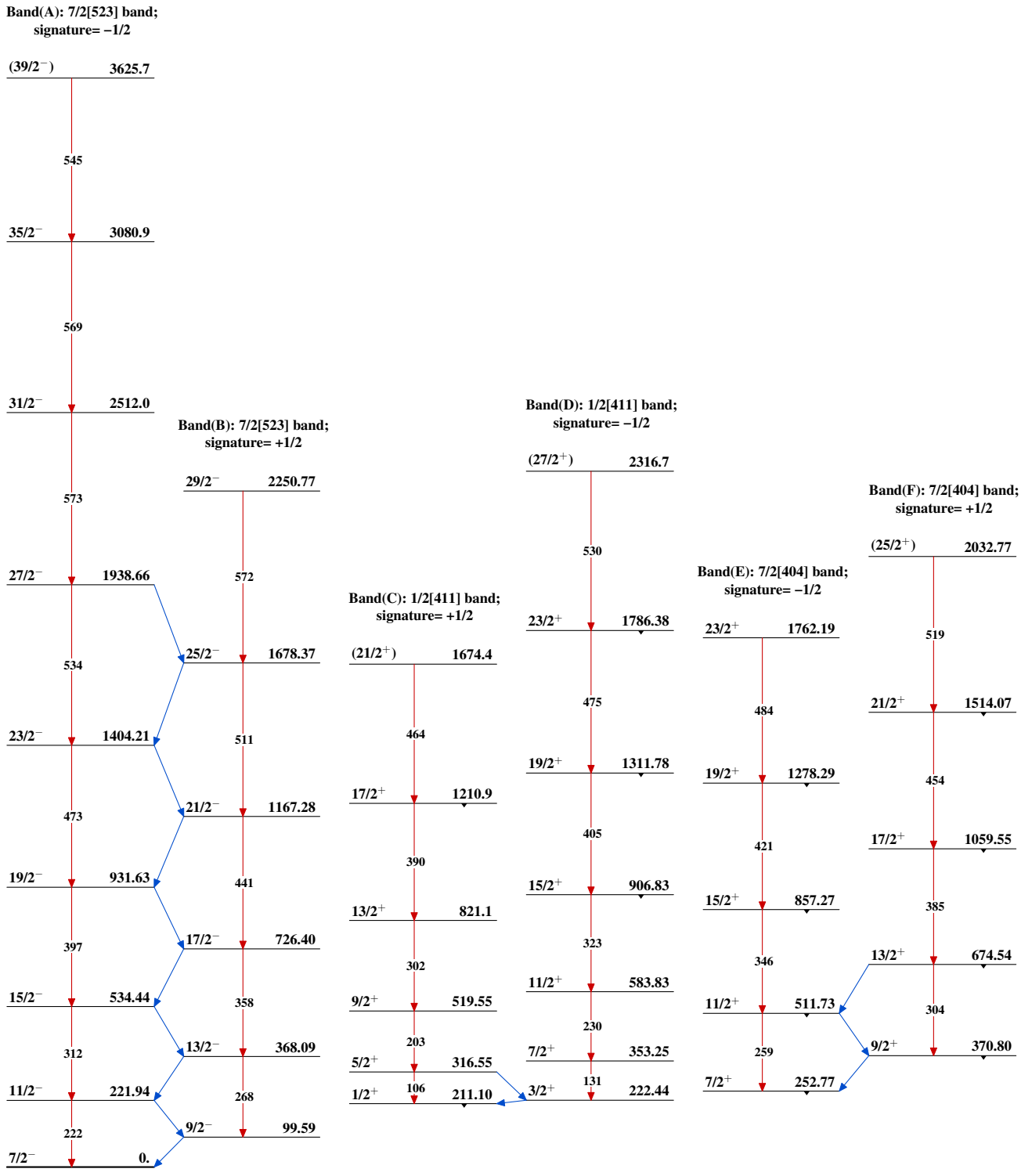
Intensities: Relative I_γ
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided

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)
Coincidence



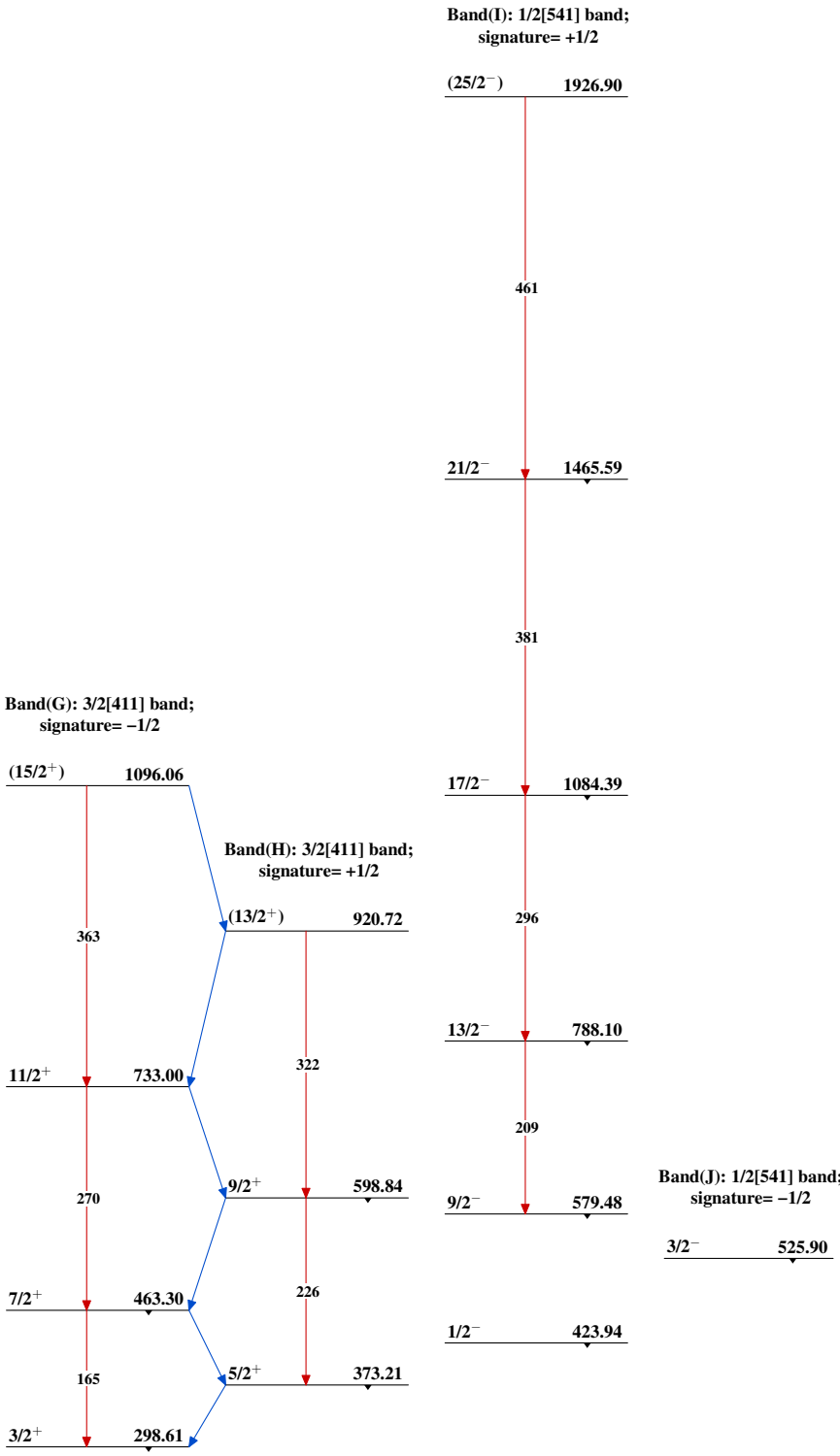
$^{161}_{67}Ho_{94}$

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01



$^{161}_{67}Ho_{94}$

^{159}Tb(α,2nγ),^{161}Dy(d,2nγ) 1971Fu08,1970Re12,1974Gr01 (continued)



$^{161}_{67}Ho_{94}$