

¹⁶⁷Er(α,2nγ) **1970Se15**

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Coral M. Baglin	NDS 109, 2033 (2008)	15-Jun-2008

1970Se15: E(α)=26 MeV; θ=90°, 110°, 130°, 150°; metallic erbium targets enriched to 87.2% in ¹⁶⁷Er; measured E_γ, I_γ (Ge(Li), FWHM=1.5 keV at 100 keV), excit (Eα=20-43 MeV), γ-ray angular distributions; used decay of γ spectrum between beam pulses to look for delayed transitions (10-100 ns range); used Nilsson model (with Coriolis coupling) to interpret level structure.

¹⁶⁹Yb Levels

E(level) [†]	J ^π [‡]	E(level) [†]	J ^π [‡]	E(level) [†]	J ^π [‡]	E(level) [†]	J ^π [‡]
0.0 [#]	7/2 ⁺	269.4 [#] 6	13/2 ⁺	735.5 [#] 7	19/2 ⁺	1249.8? ^{&} 11	19/2 ⁻
24.20 [@] 2	1/2 ⁻	278.6 ^{&} 7	7/2 ⁻	807.3 [@] 8	15/2 ⁻	1334.5 [#] 9	25/2 ⁺
70.8 [#] 4	9/2 ⁺	388.9 ^{&} 9	9/2 ⁻	833.6 [@] 9	17/2 ⁻	1650.2 [@] 11	23/2 ⁻
86.92 [@] 2	3/2 ⁻	404.6 [#] 6	15/2 ⁺	850.7 ^{&} 10	15/2 ⁻	1654.7 [@] 12	25/2 ⁻
99.4 [@] 4	5/2 ⁻	486.6 [@] 6	11/2 ⁻	902.2 [#] 7	21/2 ⁺	1664.3? [#] 9	(27/2 ⁺)
161.5 [#] 4	11/2 ⁺	511.9 [@] 8	13/2 ⁻	1042.2 ^{&} 11	17/2 ⁻	1843.2? [#] 10	(29/2 ⁺)
191.0 ^{&} 5	5/2 ⁻	522.2 ^{&} 10	11/2 ⁻	1155.6 [#] 8	23/2 ⁺		
243.7 [@] 4	7/2 ⁻	546.5 [#] 7	17/2 ⁺	1198.4 [@] 9	19/2 ⁻		
264.2 [@] 6	9/2 ⁻	676.5 ^{&} 10	13/2 ⁻	1217.5 [@] 11	21/2 ⁻		

[†] From least-squares fit to E_γ.

[‡] Authors' values, based on coincidence data, rotational structure, and γ-ray multiplicities. Values In Adopted Levels agree, apart from the possible introduction of parentheses for some of the adopted values.

[#] Band(A): 7/2[633] band. Band is strongly perturbed, but authors could describe it well within the non-adiabatic unified model by reducing the single-particle Coriolis matrix elements for orbitals near the Fermi surface.

[@] Band(B): 1/2[521] band.

[&] Band(C): 5/2[512] band.

γ(¹⁶⁹Yb)

E _γ	I _γ [†]	E _i (level)	J _i ^π	E _f	J _f ^π	Mult. [‡]	δ [‡]	Comments
(24.20 [#] 2)		24.20	1/2 ⁻	0.0	7/2 ⁺			
(62.719 [#] 1)		86.92	3/2 ⁻	24.20	1/2 ⁻			
70.9 5	18.5 19	70.8	9/2 ⁺	0.0	7/2 ⁺	D+Q		Mult.: A ₂ =-1.0 5.
^x 72.7 5	1.5 3					D(+Q)		Mult.: A ₂ =-0.4 4.
75.1 5	3.5 7	99.4	5/2 ⁻	24.20	1/2 ⁻			Mult.: A ₂ =-0.5 7.
87.6 ^d 5	<15.4	278.6	7/2 ⁻	191.0	5/2 ⁻			I _γ : includes component from ¹⁶⁸ Yb.
90.7 5	25.5 26	161.5	11/2 ⁺	70.8	9/2 ⁺	D+Q	-0.40 ^a 9	Mult.: A ₂ =+0.11 18.
^x 93.1 5	1.2 3							Mult.: A ₂ =-0.49 3, A ₄ =+0.03 4.
^x 106.1 5	4.0 8							Mult.: A ₂ =+0.07 20.
108.0 5	18.0 18	269.4	13/2 ⁺	161.5	11/2 ⁺	D+Q	-0.32 ^a 12	Mult.: A ₂ =-0.51 10, A ₄ =-0.15 13.
^x 108.9 5	6.0 12							
110.3 5	7.0 14	388.9	9/2 ⁻	278.6	7/2 ⁻	D(+Q)	-0.11 +16-25	Mult.: A ₂ =-0.34 24.
^x 111.4 5	3.5 7					D(+Q)		Mult.: A ₂ =-0.35 23.
133.3 5	3.7 8	522.2	11/2 ⁻	388.9	9/2 ⁻	D+Q	-0.20 +10-12	Mult.: A ₂ =-0.45 13, A ₄ =+0.08 17.
135.3 5	20.0 20	404.6	15/2 ⁺	269.4	13/2 ⁺	D+Q	-0.32 ^a 8	Mult.: A ₂ =-0.58 4, A ₄ =+0.05 5.
141.9 5	14.1 14	546.5	17/2 ⁺	404.6	15/2 ⁺	D+Q	-0.23 ^a 9	Mult.: A ₂ =-0.53 10, A ₄ =+0.27 12.
144.3 5	5.0 10	243.7	7/2 ⁻	99.4	5/2 ⁻	D+Q	>+0.5	Mult.: A ₂ =+0.26 10, A ₄ =+0.09 15.

δ: positive, with 0.5 ≤ δ ≤ 5.0.

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$^{167}\text{Er}(\alpha, 2n\gamma)$ **1970Se15 (continued)** $\gamma(^{169}\text{Yb})$ (continued)

E_γ	I_γ^\dagger	$E_i(\text{level})$	J_i^π	E_f	J_f^π	Mult. [‡]	δ^\ddagger	Comments
154.2 5	2.9 6	676.5	13/2 ⁻	522.2	11/2 ⁻	D+Q	-0.29 +9-7	Mult.: $A_2=-0.56$ 4, $A_4=0.00$ 5.
156.8 5	12.1 12	243.7	7/2 ⁻	86.92	3/2 ⁻			Mult.: $A_2=+0.14$ 9.
^x 158.7 5	2.2 5					D+Q		Mult.: $A_2=0.00$ 7.
161.4 5	8.7 18	161.5	11/2 ⁺	0.0	7/2 ⁺	Q		Mult.: $A_2=+0.38$ 5, $A_4=-0.08$ 8.
164.8 5	26.9 27	264.2	9/2 ⁻	99.4	5/2 ⁻	Q		Mult.: $A_2=+0.29$ 3, $A_4=-0.01$ 5.
166.8 5	6.0 12	902.2	21/2 ⁺	735.5	19/2 ⁺	D+Q	-0.14 ^a 8	Mult.: $A_2=-0.48$ 10, $A_4=-0.05$ 5.
174.5 5	2.4 5	850.7	15/2 ⁻	676.5	13/2 ⁻	D+Q	-0.6 +5-3	Mult.: $A_2=-0.6$ 5.
177.9 ^d 5	<2.3	1334.5	25/2 ⁺	1155.6	23/2 ⁺			I_γ : includes component from $^{167}\text{Er}(\alpha, \alpha')$.
^x 180.9 5	2.5 5							Mult.: $A_2=-0.3$ 6.
189.1 5	12.3 13	735.5	19/2 ⁺	546.5	17/2 ⁺	D+Q	-0.32 ^a 8	Mult.: $A_2=-0.67$ 3, $A_4=-0.04$ 3.
191.0 ^c 5	28.5 ^c 29	191.0	5/2 ⁻	0.0	7/2 ⁺			Mult.: $A_2=-0.01$ 6.
191.0 ^{cd} 5	^c	1042.2	17/2 ⁻	850.7	15/2 ⁻			1970Se15 indicate this placement as questionable; evaluator assigns all intensity to 191.0 level placement.
198.5 ^{cd} 5	25 ^{c@} 3	269.4	13/2 ⁺	70.8	9/2 ⁺			Mult.: $A_2=+0.25$ 2, $A_4=-0.15$ 3 for doublet.
								I_γ : 1970Se15 attribute remaining portion ($I_\gamma=55$) of total $I_\gamma (=81.5)$ to ^{168}Yb .
								Mult.: angular distribution data are consistent with Q, but no assignment is made because of complexity of peak.
198.5 ^{cd} 5	1.5 ^{c@} 3	388.9	9/2 ⁻	191.0	5/2 ⁻			Mult.: $A_2=+0.25$ 2, $A_4=-0.15$ 3 for doublet.
207.4 ^d 5	2.2 5	1249.8?	19/2 ⁻	1042.2	17/2 ⁻			Mult.: $A_2=-0.02$ 25.
222.4 5	3.5 7	486.6	11/2 ⁻	264.2	9/2 ⁻			Mult.: $A_2=+0.14$ 13; $\delta=+0.15$ to $+0.40$ or $+4.0$ to $+\infty$.
^x 227.8 5	2.3 5							Mult.: $A_2=+0.2$ 9.
243.0 ^c 5	40 ^{c@} 4	404.6	15/2 ⁺	161.5	11/2 ⁺			Mult.: $\gamma(\theta)$ data are consistent with Q, but no assignment is made because of complexity of peak. $A_2=+0.29$ 3, $A_4=-0.04$ 5 for triplet.
243.0 ^c 5	20 ^{c@} 2	486.6	11/2 ⁻	243.7	7/2 ⁻			see comment on 243.0 γ from 405 level.
243.0 ^{cd} 5	2.9 ^{c@} 6	522.2	11/2 ⁻	278.6	7/2 ⁻			see comment on 243.0 γ from 405 level.
247.7 5	37 4	511.9	13/2 ⁻	264.2	9/2 ⁻	Q		Mult.: $A_2=+0.30$ 2, $A_4=-0.01$ 4.
253.3 5	4.7 10	1155.6	23/2 ⁺	902.2	21/2 ⁺	D+Q	-0.33 ^a 9	Mult.: $A_2=-0.74$ 3, $A_4=+0.16$ 3.
277.1 5	49 5	546.5	17/2 ⁺	269.4	13/2 ⁺	Q		Mult.: $A_2=+0.34$ 1, $A_4=-0.05$ 1.
287.6 5	5.5 11	676.5	13/2 ⁻	388.9	9/2 ⁻	(Q)		Mult.: $A_2=+0.27$ 16.
320.7 5	15 2	807.3	15/2 ⁻	486.6	11/2 ⁻			Mult.: $A_2=+0.30$ 1, $A_4=-0.06$ 1 for 320.7 γ +321.7 γ .
321.7 5	27 3	833.6	17/2 ⁻	511.9	13/2 ⁻	(Q)		Mult.: $A_2=+0.30$ 1, $A_4=-0.06$ 1 for 320.7 γ +321.7 γ .
328.4 5	7.2 15	850.7	15/2 ⁻	522.2	11/2 ⁻	(Q)		Mult.: $A_2=+0.12$ 4.
330.9 5	39 4	735.5	19/2 ⁺	404.6	15/2 ⁺	Q		Mult.: $A_2=+0.31$ 1, $A_4=-0.11$ 2.
355.6 5	37 4	902.2	21/2 ⁺	546.5	17/2 ⁺	Q		Mult.: $A_2=+0.35$ 1, $A_4=-0.11$ 2.
365.5 5	4.3 9	1042.2	17/2 ⁻	676.5	13/2 ⁻	(Q)		Mult.: $A_2=+0.3$ 3, $A_4=-0.1$ 5.
383.9 5	15 2	1217.5	21/2 ⁻	833.6	17/2 ⁻			I_γ : estimated from level intensity balances; 1970Se15 attribute remaining portion ($I_\gamma=30$) of total $I_\gamma (=44.8)$ to ^{168}Yb .
								Mult.: $A_2=+0.32$ 2, $A_4=-0.20$ 4 for contaminated line.
391.1 5	8.8 18	1198.4	19/2 ⁻	807.3	15/2 ⁻	Q		Mult.: $A_2=+0.21$ 4, $A_4=-0.01$ 6.
399.4 ^d 5	3.5 7	1249.8?	19/2 ⁻	850.7	15/2 ⁻			Mult.: $A_2=-0.13$ 14 for possibly complex line.

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$^{167}\text{Er}(\alpha, 2n\gamma)$ **1970Se15** (continued) $\gamma(^{169}\text{Yb})$ (continued)

E_γ	I_γ^\dagger	$E_i(\text{level})$	J_i^π	E_f	J_f^π	Mult. [‡]	Comments
^x 400.4 5	4.6 9						
^x 416.4 5	1.9 4						
420.2 5	19.5 20	1155.6	23/2 ⁺	735.5	19/2 ⁺	Q	Mult.: $A_2=+0.29$ 4, $A_4=-0.15$ 6.
432.3 5	16.2 16	1334.5	25/2 ⁺	902.2	21/2 ⁺	Q	Mult.: $A_2=+0.27$ 1, $A_4=-0.16$ 2.
437.2 5	7.8 16	1654.7	25/2 ⁻	1217.5	21/2 ⁻	Q	Mult.: $A_2=+0.29$ 1, $A_4=-0.18$ 11.
451.8 5	5.6 12	1650.2	23/2 ⁻	1198.4	19/2 ⁻	Q	Mult.: $A_2=+0.38$ 2, $A_4=-0.14$ 4.
^x 463.8 5	2.5 5						
^x 483.3 5	4.8 10					Q	Mult.: $A_2=+0.36$ 13.
508.7 ^{b&d} 5	30 ^b 3	1664.3?	(27/2 ⁺)	1155.6	23/2 ⁺		
508.7 ^{b&d} 5	30 ^b 3	1843.2?	(29/2 ⁺)	1334.5	25/2 ⁺		
^x 584.2 5	2.8 6						
^x 590.3 5	7.4 15						

[†] Arbitrary units for $E(\alpha)=26$ MeV, $\theta=130^\circ$. $\Delta I_\gamma=10\%$ for strong transitions (taken by evaluator to be those with $I_\gamma \geq 10$); $\Delta I_\gamma=20\%$ assumed for others.

[‡] From γ -ray angular distributions. Stretched Q assignments were based on large positive A_2 , and intraband D(+Q) assignments, on negative A_2 and placement relative to cascading Q γ 's, except As noted. additionally, In Adopted Gammas, $\Delta\pi=(\text{No})$ is assigned for intraband transitions.

Adopted values (rounded).

@ Deduced from combined I_γ for both placements and analysis of level intensity balances.

& **1970Se15** suggest possible placements of a 508.7 γ in the 7/2[633] band, from a 27/2⁺ level at 1664 keV and/or a 29/2⁺ level at 1843 keV; both options are consistent with Adopted Levels, Gammas, so the 508.7 γ is presumed to Be a doublet here, consistent with its I_γ .

^a Read by evaluator from plot of measured and calculated mixing ratios A_s as a function of spin I in fig. 8 of **1970Se15**.

^b Multiply placed with undivided intensity.

^c Multiply placed with intensity suitably divided.

^d Placement of transition in the level scheme is uncertain.

^x γ ray not placed in level scheme.

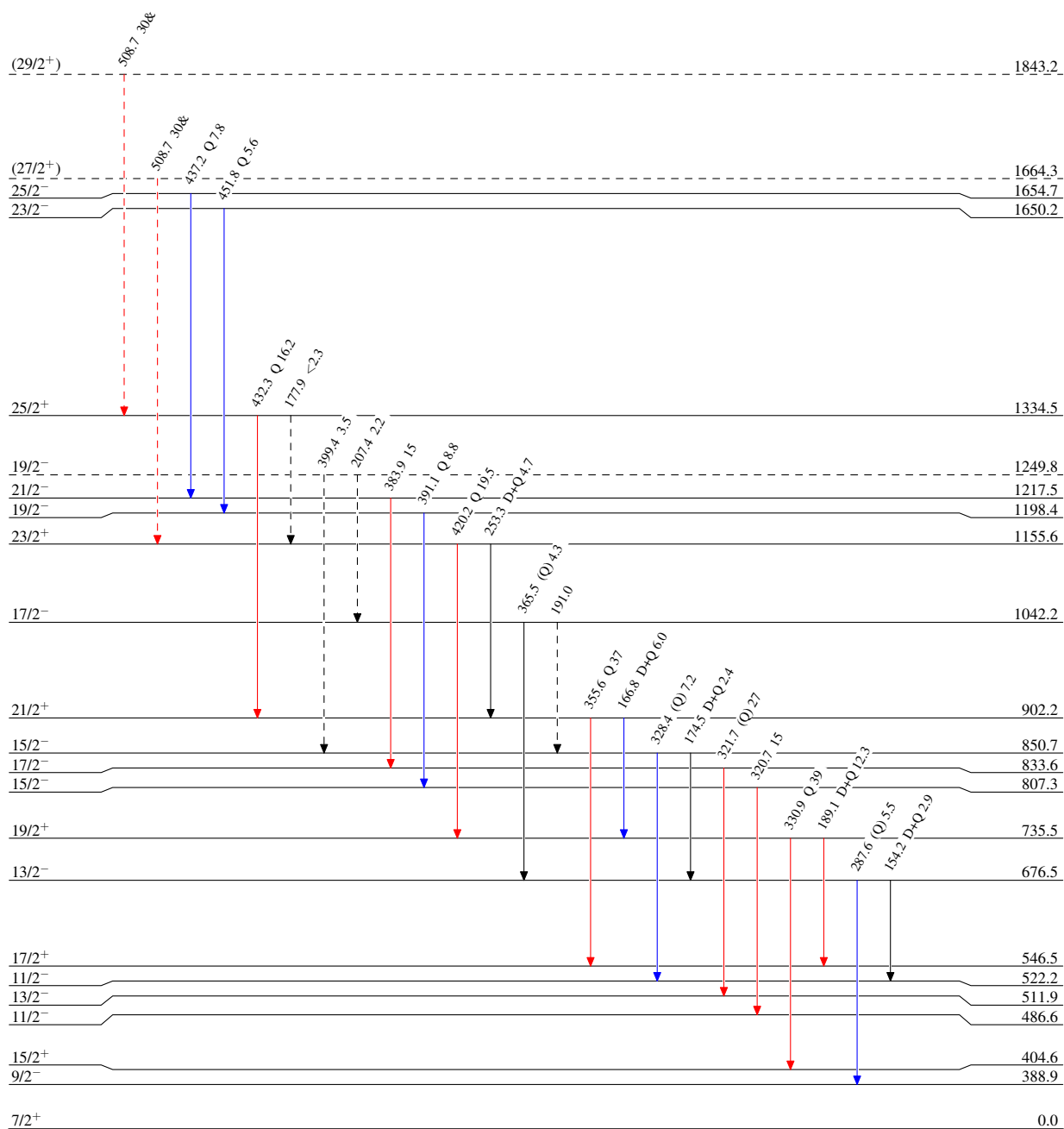
$^{167}\text{Er}(\alpha,2n\gamma)$ 1970Se15

Level Scheme

Intensities: Relative I_γ for $E(\alpha)=26$ MeV, $\theta=130^\circ$
& 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)



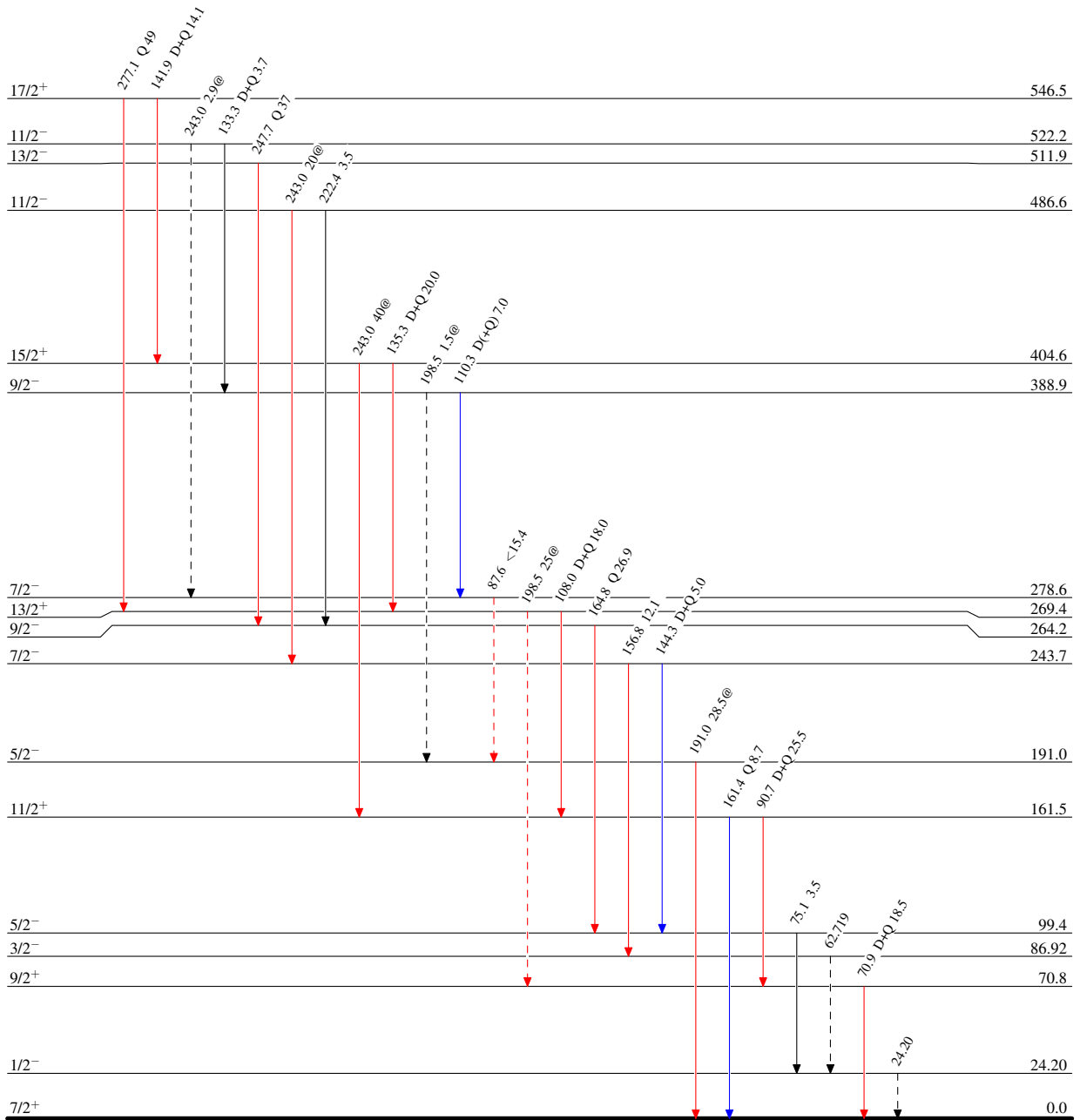
$^{167}\text{Er}(\alpha,2n\gamma)$ 1970Se15

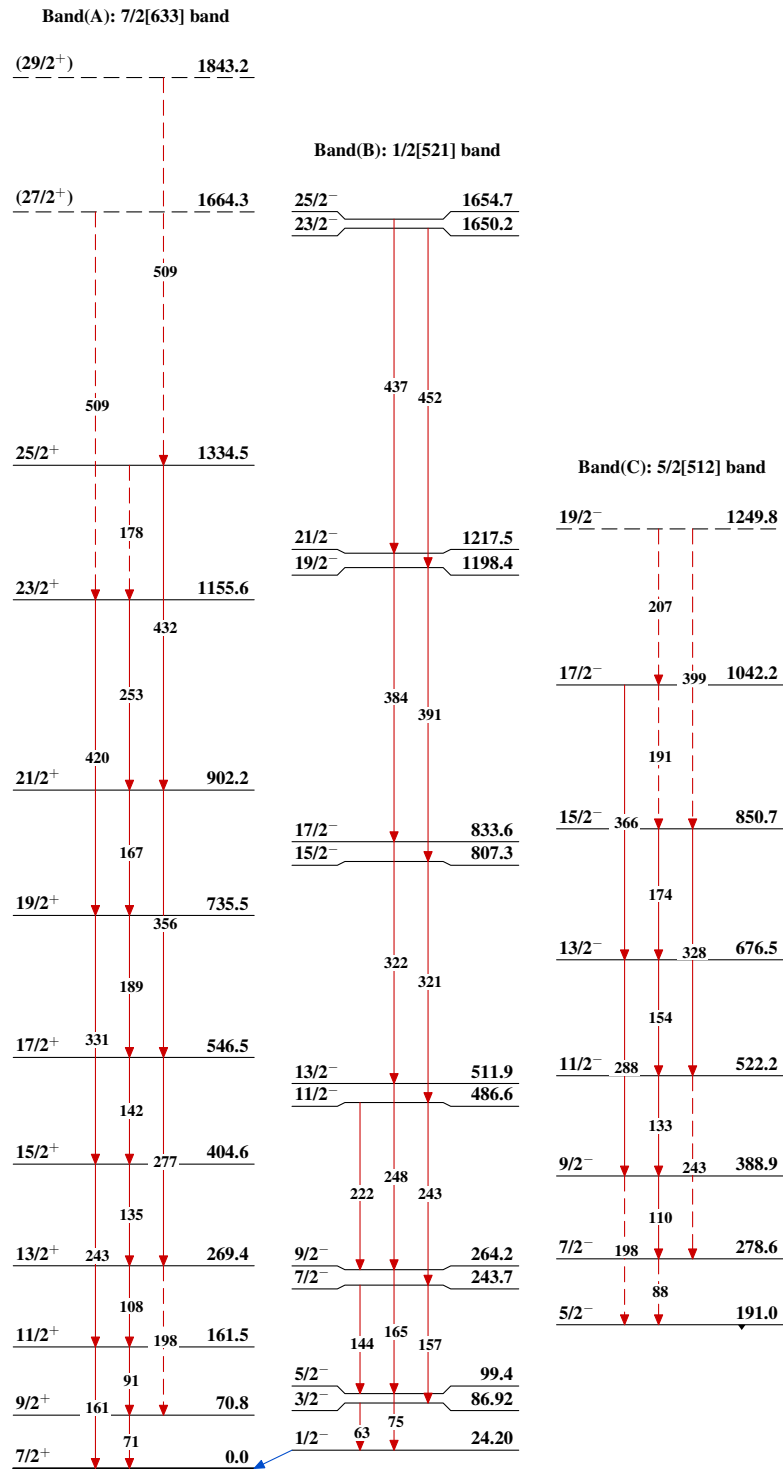
Level Scheme (continued)

Intensities: Relative I_γ for $E(\alpha)=26$ MeV, $\theta=130^\circ$
 & Multiply placed: undivided intensity given
 @ Multiply placed: intensity suitably divided

Legend

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

 $^{169}_{70}\text{Yb}_{99}$

$^{167}\text{Er}(\alpha,2n\gamma)$ 1970Se15 $^{169}_{70}\text{Yb}_{99}$