^{96}Mo(α,2nγ) 2004Ca42,1971Le19

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Jun Chen, Balraj Singh	NDS 164, 1 (2020)	15-Feb-2020

2004Ca42: E=24-30 MeV alpha beams were produced from the ESTU tandem accelerator at WNSL at Yale University. Target was 4.51 mg/cm^2 ^{96}Mo. γ rays were detected with an array of six Compton-suppressed clover detectors from the YRAST Ball. Measured Eγ, Iγ, $\gamma\gamma$-coin. Deduced levels. Comparisons with theoretical calculations.

1971Le19: E=30 MeV alpha beam was produced from the Berkeley 88-inch cyclotron. Target was isotopically enriched ^{96}Mo. γ rays were detected with Ge(Li) detectors. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma(\theta)$ (90°−157°). Deduced levels, J, π. Comparisons with theoretical calculations. Authors state that estimated energy precision is ≈0.1-0.2 keV for strong γ rays but standard uncertainty is suggested as 1 keV due to additional systematic uncertainties from external calibrations. Deduced first high-spin level scheme of ^{98}Ru.

All data are from 2004Ca42, unless otherwise stated.

^{98}Ru Levels

2004Ca42 stressed that, since their objective was the study of low lying levels in ^{98}Ru, the portion of the scheme above the 2603-keV level might be incomplete for γ transitions above 2 MeV. Also, on account of this limitation, some levels based on a single γ-ray, must be viewed with caution.

E(level)[†]	J$^\pi$[‡]	Comments
0.0	0^+	
652.64 *18*	2^+	
1320.7 *9*	0^+	
1398.34 *22*	4^+	
1414.93 *20*	2^+	
1797.73 *22*	3^+	
1818.1 *4*	2^+	E(level): level from 2004Ca42 only. J$^\pi$: from Adopted Levels; 0^+,2^+ in 2004Ca42.
2013.65 *24*	3^+	
2223.5 *3*	6^+	
2245.7 *11*	0^+	
2267.43 *24*	4^+	
2278.0 *3*	2^+	
2374.0	0^+	E(level): not observed by 2004Ca42; included in level scheme for completeness.
2428.2 *4*	2^+	
2548.0 *3*	5^+,6^+	
2603.6 *4*	2^+,3^+	
2657.6 *3*	(5^-)	
2661.0 *4*	3^+,4	
2720.5 *5*		
2786.8 *5*		J$^\pi$: (3) in 2004Ca42 inconsistent with 563γ to 6^+.
2810.2 *4*	(2^+)	
2868.6 *4*	(6^+)	
3058.9 *5*		
3066.9 *4*	(3^+)	
3070.5 *5*		
3127.6 *3*	8^+	
3191.5 *3*	(8^+)	
3246.7 *3*	(6^+)	
3252.3 *3*		
3284.6 *3*	7^-	
3476.6 *4*		
3540.0 *4*	6^+,7^+,8^+	
3580.1 *4*	7^-,8^+	

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^{96}Mo(α,2nγ) 2004Ca42,1971Le19 (continued)

^{98}Ru Levels (continued)

E(level)[†]	J$^\pi$[‡]	Comments
3852.8 *4*		E(level),J$^\pi$: 9$^-$ in 2004Ca42 inconsistent with 312.7γ to 3540 level with J^π=6$^+$,7$^+$,8$^+$. In Adopted Levels, Gammas, two separate levels near this energy are adopted, where 272.8γ and 312.7γ are not adopted. See comments there for details.
3857.3 *5*		
3946.6 *5*		
4002.3 *4*	10$^+$	
4006.8 *5*		E(level): see comments for 4007.5 level.
4007.5 *4*		E(level),J$^\pi$: (8,9,10)$^+$ in 2004Ca42 inconsistent with 722.9γ to 7$^-$. Only one level near this energy is confirmed by 2016Gi05 in (^{3}He,2nγ) with J^π=(7$^+$), and not two at 4006.6 and 4007.4, as in 2004Ca42.
4136.0 *5*		
4216.3 *4*		
4221.9 *5*		
4224.9 *4*	(10$^+$)	
4258.8 *5*		
4416.9 *5*		
4564.0 *4*		
4635.1 *4*		
4674.1 *4*	11$^-$	
4824.4 *4*		
4848.3 *4*		
4915.8 *4*	12$^+$	
4989.9 *5*	(12$^+$)	
5219.4 *5*		
5349.7 *5*		
5522.1 *5*	(13$^-$)	
5614.5 *6*		
5626.2 *6*		
6591.4 *7*	15$^-$	

[†] From least-squares fit to γ-ray energies.
[‡] As given by 2004Ca42, based on previous assignments from $\gamma(\theta)$ in 1971Le19 where indicated and from other studies.

γ(^{98}Ru)

A$_2$ and A$_4$ values are from $\gamma(\theta)$ measured by 1971Le19.
2004Ca42 list in Table III and Fig 11 spin allowed but unobserved transitions from levels up to 2608 keV, with upper limits of intensities. These are listed here as questionable, and not given in the Adopted dataset.

E$_\gamma$[†]	I$_\gamma$[@]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Comments
149.9[a]	<0.006	2428.2	2$^+$	2278.0	2$^+$	
160.7[a]	<0.006	2428.2	2$^+$	2267.43	4$^+$	
175.6[a]	<0.45	2603.6	2$^+$,3$^+$	2428.2	2$^+$	
182[a]	<0.01	2428.2	2$^+$	2245.7	0$^+$	
189.5[‡] *4*	0.12 *2*	4824.4		4635.1		
195.5[a]	<0.005	2013.65	3$^+$	1818.1	2$^+$	
214.3[‡] *4*	0.19 *3*	4216.3		4002.3	10$^+$	
215.8[a]	<0.83	2013.65	3$^+$	1797.73	3$^+$	
229.8[‡] *4*	0.23 *3*	3476.6		3246.7	(6$^+$)	
253.8 *3*	1.45 *6*	2267.43	4$^+$	2013.65	3$^+$	A$_2$=−0.37 *11*; A$_4$=+0.01 *9* Eγ=253.7 *10*, Iγ=1.4 *2* (1971Le19).

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^{96}Mo(α,2nγ) 2004Ca42,1971Le19 (continued)

γ(^{98}Ru) (continued)

E_γ †	I_γ @	E_i(level)	J_i^π	E_f	J_f^π	Comments
260.3‡ *4*	0.14 *2*	4824.4		4564.0		
264.6[a]	<0.016	2278.0	2^+	2013.65	3^+	
272.8 *4*	0.22 *3*	3852.8		3580.1	7^-,8^+	
280.5‡ *4*	0.37 *6*	2548.0	5^+,6^+	2267.43	4^+	
295.5 *4*	0.26 *4*	3580.1	7^-,8^+	3284.6	7^-	
303.4‡ *4*	0.31 *5*	5219.4		4915.8	12^+	
312.7 *4*	0.19 *3*	3852.8		3540.0	6^+,7^+,8^+	
317.3‡ *3*	0.67 *10*	3857.3		3540.0	6^+,7^+,8^+	
320.6 *3*	1.46 *6*	2868.6	(6^+)	2548.0	5^+,6^+	
324.6 *3*	1.50 *6*	2548.0	5^+,6^+	2223.5	6^+	
325.5[a]	<0.15	2603.6	2^+,3^+	2278.0	2^+	
336.3[a]	<0.011	2603.6	2^+,3^+	2267.43	4^+	
339.0‡ *3*	1.50 *6*	4564.0		4224.9	(10^+)	
357[a]	<0.006	2603.6	2^+,3^+	2245.7	0^+	
380.2[a]	<0.40	2603.6	2^+,3^+	2223.5	6^+	
382.7 *3*	2.48 *10*	1797.73	3^+	1414.93	2^+	A_2=−0.12 *8*; A_4=−0.06 *13* Eγ=382.9 *10*, Iγ=1.9 *3* (1971Le19).
399.1 *3*	0.67 *10*	1797.73	3^+	1398.34	4^+	
403.0[a]	<0.055	1818.1	2^+	1414.93	2^+	
406.8‡ *4*	0.23 *3*	5626.2		5219.4		
410.7‡ *4*	0.32 *5*	4635.1		4224.9	(10^+)	
412.4 *3*	2.19 *9*	3540.0	6^+,7^+,8^+	3127.6	8^+	
414.5[a]	<0.066	2428.2	2^+	2013.65	3^+	
419.7[a]	<0.040	1818.1	2^+	1398.34	4^+	
449.3[a]	<0.022	2267.43	4^+	1818.1	2^+	
460.1[a]	<0.010	2278.0	2^+	1818.1	2^+	
469.6 *2*	5.50 *22*	2267.43	4^+	1797.73	3^+	A_2=+0.73 *14*; A_4=+0.06 *18* Eγ=469.9 *10*, Iγ=5.8 *4* (1971Le19).
480.4[a]	<0.030	2278.0	2^+	1797.73	3^+	
497.2[a]	<0.030	1818.1	2^+	1320.7	0^+	
522.5 *4*	0.24 *4*	3070.5		2548.0	5^+,6^+	
534.42[a]	<0.210	2548.0	5^+,6^+	2013.65	3^+	
542.8 *3*	0.66 *10*	2810.2	(2^+)	2267.43	4^+	
563.3‡ *4*	0.13 *2*	2786.8		2223.5	6^+	
589.6 *4*	0.24 *4*	2603.6	2^+,3^+	2013.65	3^+	
591.3‡ *4*	0.39 *6*	3252.3		2661.0	3^+,4	
594.7‡ *4*	0.47 *7*	3252.3		2657.6	(5^-)	
598.9 *3*	2.29 *9*	2013.65	3^+	1414.93	2^+	Eγ=598.9 *10*, Iγ=2.5 *4* (1971Le19).
599.4‡ *3*	0.55 *8*	4824.4		4224.9	(10^+)	
609.9 *4*	0.13 *2*	2428.2	2^+	1818.1	2^+	
615.0 *3*	2.58 *10*	2013.65	3^+	1398.34	4^+	Eγ=615.2 *10*, Iγ=2.6 *4* (1971Le19).
623.7‡ *4*	0.26 *4*	4848.3		4224.9	(10^+)	
627.1 *3*	1.40 *6*	3284.6	7^-	2657.6	(5^-)	
630.3 *4*	0.12 *2*	2428.2	2^+	1797.73	3^+	
632.6‡ *4*	0.34 *5*	4635.1		4002.3	10^+	
645.1 *4*	0.23 *3*	2868.6	(6^+)	2223.5	6^+	
652.6 *2*	100.0 *10*	652.64	2^+	0.0	0^+	A_2=+0.36 *3*; A_4=+0.04 *5* Eγ=652.7 *10*, Iγ=100 (1971Le19).
661.3 *4*	0.14 *2*	3852.8		3191.5	(8^+)	
668.1 *8*	0.13 *2*	1320.7	0^+	652.64	2^+	
676.3‡ *4*	0.17 *3*	4216.3		3540.0	6^+,7^+,8^+	

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^{96}Mo(α,2nγ) 2004Ca42,1971Le19 (continued)

$\gamma(^{98}Ru)$ (continued)

E_γ[†]	I_γ[@]	E_i(level)	J_i^π	E_f	J_f^π	Comments
722.9 *3*	3.00 *12*	4007.5		3284.6	7^-	Eγ=722.6 *10*, Iγ=2.8 *5* (1971Le19).
725.2 *2*	5.44 *22*	3852.8		3127.6	8^+	A_2=−0.20 *8*; A_4=+0.12 *13* Eγ=724.9 *10*, Iγ=7.1 *4* (1971Le19).
745.6 *2*	83.1 *8*	1398.34	4^+	652.64	2^+	A_2=+0.35 *3*; A_4=−0.02 *4* Eγ=745.6 *10*, Iγ=81 *3* (1971Le19).
750.2[a]	<0.070	2548.0	5^+,6^+	1797.73	3^+	
754.5[‡] *3*	0.87 *13*	4006.8		3252.3		
762.3 *2*	3.99 *16*	1414.93	2^+	652.64	2^+	Eγ=762.0 *10*, Iγ=4.0 *4* (1971Le19).
785.6[a]	<0.03	2603.6	2^+,3^+	1818.1	2^+	
805.9[a]	<0.02	2603.6	2^+,3^+	1797.73	3^+	
810.7 *3*	2.45 *10*	4002.3	10^+	3191.5	(8^+)	Eγ=810.8 *10*, Iγ=3.1 *4* (1971Le19).
816.1[‡] *3*	1.37 *5*	4007.5		3191.5	(8^+)	
821.3 *2*	3.50 *14*	4674.1	11^-	3852.8		A_2=+0.37 *7*; A_4=−0.11 *9* Eγ=820.7 *10*, Iγ=4.7 *4* (1971Le19).
822.1[‡] *3*	1.08 *4*	4824.4		4002.3	10^+	
825.1 *2*	49.1 *5*	2223.5	6^+	1398.34	4^+	A_2=+0.30 *3*; A_4=−0.09 *5* Eγ=824.9 *10*, Iγ=57 *2* (1971Le19).
835.4[‡] *4*	0.32 *5*	3058.9		2223.5	6^+	
840.7 *3*	1.65 *7*	4848.3		4007.5		
848.0 *3*	2.04 *8*	5522.1	(13^-)	4674.1	11^-	
852.3[a]	<0.055	2267.43	4^+	1414.93	2^+	
863.1[a]	<0.100	2278.0	2^+	1414.93	2^+	
863.2 *3*	1.80 *7*	2661.0	3^+,4	1797.73	3^+	Eγ=862.9 *10*, Iγ=2.2 *4* (1971Le19), uncertain assignment and unplaced.
869.2 *3*	1.58 *6*	2267.43	4^+	1398.34	4^+	Eγ=868.6 *10*, Iγ=1.6 *3* (1971Le19).
874.7 *2*	5.76 *23*	4002.3	10^+	3127.6	8^+	A_2=+0.52 *8*; A_4=+0.01 *9* Eγ=874.5 *10*, Iγ=7.3 *4* (1971Le19).
879.6[&‡] *3*	0.68[&] *10*	2278.0	2^+	1398.34	4^+	
879.6[&‡] *3*	0.95[&] *14*	4007.5		3127.6	8^+	
889.3[‡] *4*	0.23 *3*	4136.0		3246.7	(6^+)	
904.1 *2*	21.6 *2*	3127.6	8^+	2223.5	6^+	A_2=+0.38 *4*; A_4=−0.02 *5* Eγ=904.0 *10*, Iγ=26 *1* (1971Le19).
913.4 *3*	1.63 *7*	4915.8	12^+	4002.3	10^+	
940.4[‡] *4*	0.18 *3*	5614.5		4674.1	11^-	
957.3[a]	<0.033	2278.0	2^+	1320.7	0^+	
968.0 *2*	12.1 *1*	3191.5	(8^+)	2223.5	6^+	A_2=+0.47 *6*; A_4=+0.04 *9* Eγ=967.8 *10*, Iγ=14.2 *6* (1971Le19).
979.2 *2*	3.79 *15*	3246.7	(6^+)	2267.43	4^+	
984.9 *3*	0.84 *13*	3252.3		2267.43	4^+	
987.6 *3*	1.13 *5*	4989.9	(12^+)	4002.3	10^+	
992.0 *3*	1.74 *7*	3540.0	6^+,7^+,8^+	2548.0	5^+,6^+	
1012.1[#] *3*	0.93 *14*	4258.8		3246.7	(6^+)	
1013.0[a]	<0.110	2428.2	2^+	1414.93	2^+	
1024.9[‡] *4*	0.43 *6*	4216.3		3191.5	(8^+)	
1029.7[a] *4*	<0.4	2428.2	2^+	1398.34	4^+	E_γ,I_γ: complex line. Intensity limit from comparison of singles and coincidence data.
1030.4[‡] *4*	0.41 *6*	4221.9		3191.5	(8^+)	
1032.1[#] *3*	0.99 *15*	3580.1	7^-,8^+	2548.0	5^+,6^+	
1033.3[#] *3*	2.69 *11*	4224.9	(10^+)	3191.5	(8^+)	A_2=+0.39 *13*; A_4=−0.19 *19* Eγ=1032.7 *10*, Iγ=4.3 *5* (1971Le19), placed tentatively between 3255 and 2223 levels.

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^{96}Mo(α,2nγ) 2004Ca42,1971Le19 (continued)

$\gamma(^{98}Ru)$ (continued)

E_γ †	I_γ @	E_i(level)	J_i^π	E_f	J_f^π	Comments
1061.2 *2*	5.49 *22*	3284.6	7^-	2223.5	6^+	A_2=−0.01 *15*; A_4=−0.05 *23* Eγ=1061.1 *10*, Iγ=6.1 *5* (1971Le19).
1069.3 *4*	0.08 *1*	6591.4	15^-	5522.1	(13^-)	
1088.5‡ *4*	0.26 *4*	4216.3		3127.6	8^+	
1097.5 *3*	1.33 *5*	4224.9	(10^+)	3127.6	8^+	
1107.2[a]	<0.066	2428.2	2^+	1320.7	0^+	
1124.8‡ *3*	0.50 *8*	5349.7		4224.9	(10^+)	
1145.1 *2*	9.6 *4*	1797.73	3^+	652.64	2^+	Eγ=1143.9 *10*, Iγ=8.1 *6* (1971Le19).
1149.7 *2*	6.91 *28*	2548.0	5^+,6^+	1398.34	4^+	Eγ=1148.5 *10*, Iγ=7.3 *6* (1971Le19).
1165.3 *3*	0.64 *10*	1818.1	2^+	652.64	2^+	
1188.6[a]	<0.06	2603.6	2^+,3^+	1414.93	2^+	
1205.7 *4*	0.46 *7*	2603.6	2^+,3^+	1398.34	4^+	
1217.3‡ *4*	0.43 *6*	5219.4		4002.3	10^+	
1225.4‡ *4*	0.31 *5*	4416.9		3191.5	(8^+)	
1253.2‡ *4*	0.35 *5*	3476.6		2223.5	6^+	
1259.3 *2*	4.66 *19*	2657.6	(5^-)	1398.34	4^+	Eγ=1257.9 *10*, Iγ=4.9 *5* (1971Le19).
1322.2 *4*	0.29 *4*	2720.5		1398.34	4^+	
1360.9 *4*	0.26 *4*	2013.65	3^+	652.64	2^+	
1415.0 *3*	1.94 *8*	1414.93	2^+	0.0	0^+	Eγ=1414.0 *10*, Iγ=2.2 *5* (1971Le19).
1436.6‡ *4*	0.44 *7*	4564.0		3127.6	8^+	
1593[a]	<0.15	2245.7	0^+	652.64	2^+	E_γ,I_γ: this γ was not observed by 2004Ca42, only an upper limit of intensity given, as shown in authors′ Fig. 4.
1614.6[a]	<0.030	2267.43	4^+	652.64	2^+	
1625.4 *3*	0.74 *11*	2278.0	2^+	652.64	2^+	
1668.5 *3*	0.67 *10*	3066.9	(3^+)	1398.34	4^+	
1723.1# *4*	0.31 *5*	3946.6		2223.5	6^+	
1776.4 *6*	1.99 *8*	2428.2	2^+	652.64	2^+	E_γ: transition identified as a doublet in 2004Ca42, only one of the γ-rays belongs to ^{98}Ru.
1818.4[a] *4*	0.09 *1*	1818.1	2^+	0.0	0^+	E_γ: tentatively assigned to ^{98}Ru as it only appears at some beam energies. The summing contribution to this line is estimated at <0.03 units of intensity.
1950.9[a]	<0.006	2603.6	2^+,3^+	652.64	2^+	

† 2004Ca42 quote uncertainty of 0.2 keV for the strong and intermediate intensity transitions, and up to 0.4 keV for the weakest ones. Evaluators have assigned uncertainties in the following manner: 0.2 keV for Iγ>3, 0.3 keV for Iγ=0.5-3, and 0.4 keV for Iγ<0.5.

‡ New γ ray from 2004Ca42.

Placement of this γ is different in 2004Ca42 as compared to the previous assignment in literature.

@ In 2004Ca42 the uncertainties on relative intensities are quoted as 1% for Iγ≥10, 2-4% for Iγ=1-10%, 5-15% for Iγ<1. The evaluators have assigned uncertainties based upon the following criterion: 1% for Iγ≥10, 4% for Iγ=1-10% and 15% for Iγ<1. Quoted Iγ values are the original values in 2004Ca42 divided by 10.

& Multiply placed with intensity suitably divided.

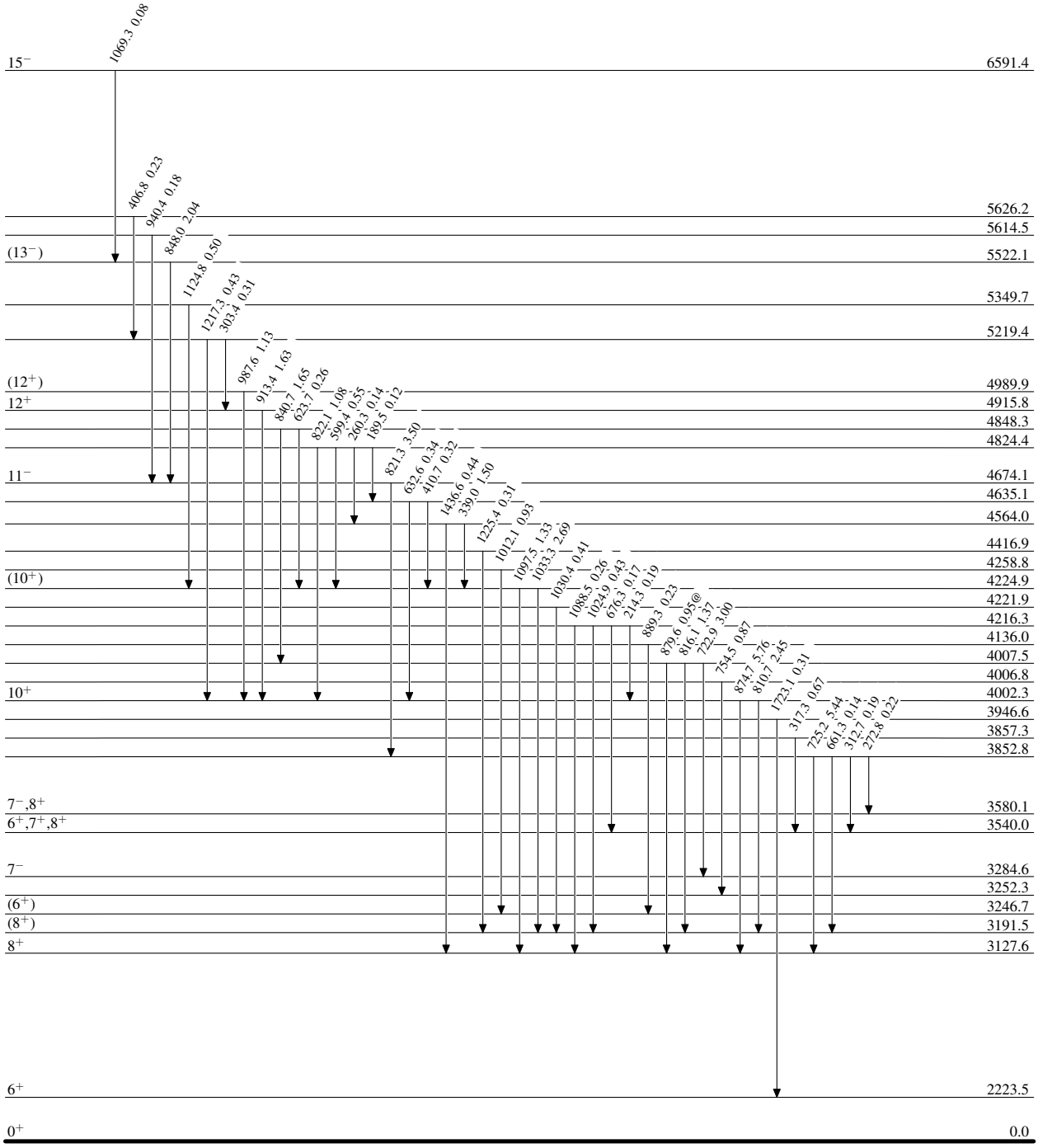
a Placement of transition in the level scheme is uncertain.

^{96}Mo(α,2nγ) 2004Ca42,1971Le19

Level Scheme

Intensities: Relative I_γ
@ Multiply placed: intensity suitably divided

Legend
$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$



$^{98}_{44}Ru_{54}$

^{96}Mo(α,2nγ) 2004Ca42,1971Le19

Level Scheme (continued)

Intensities: Relative I_γ

@ Multiply placed: intensity suitably divided

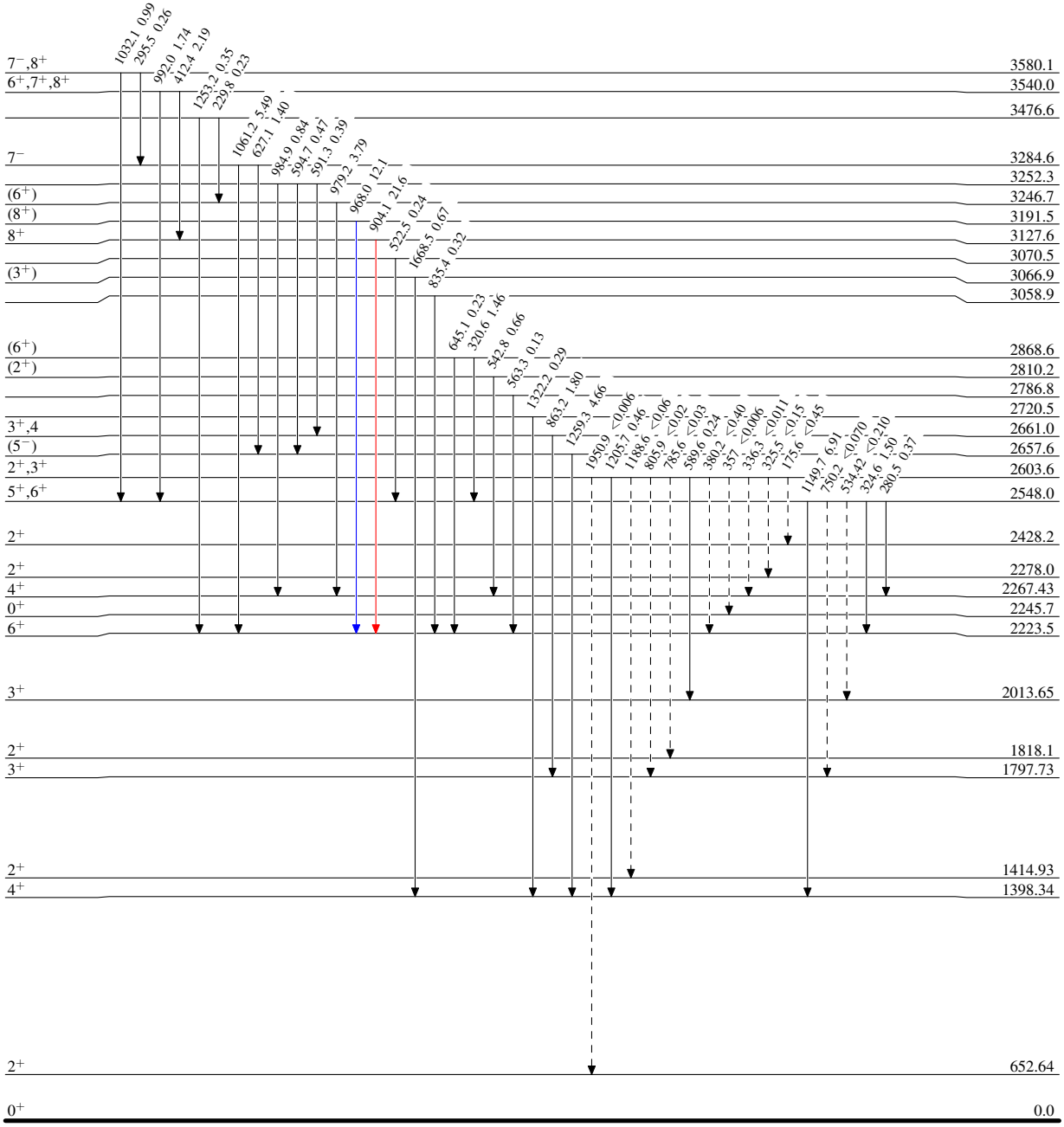
Legend

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

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

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

γ Decay (Uncertain)



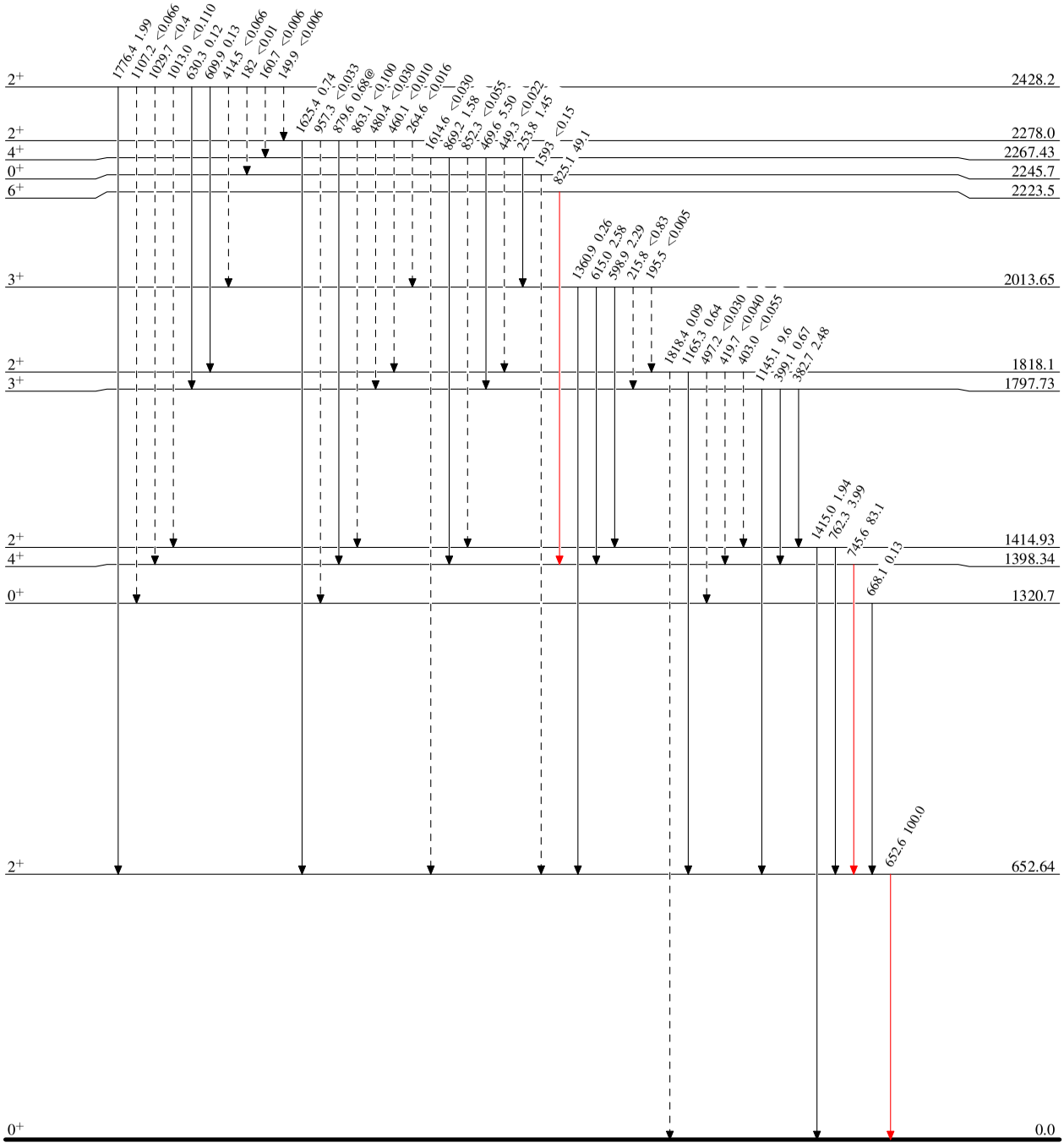
$^{98}_{44}Ru_{54}$

^{96}Mo(α,2nγ) 2004Ca42,1971Le19

Level Scheme (continued)

Intensities: Relative I_γ
@ 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)



$^{98}_{44}Ru_{54}$