

$^{48}\text{Ca}(\text{p},\text{n}\gamma)$ 1975As07,1971Ro27,1971Ca36

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 179, 1 (2022)	30-Nov-2021

1975As07: E=0.8-4.0 MeV proton beams were produced from the 4-MV Van de Graaff accelerator at the Tokyo Institute of Technology. Target was metallic 97.2% enriched ^{48}Ca on a gold backing. γ rays were detected with Ge(Li) detectors. Measured $E\gamma$, $I\gamma$, γ excitation functions, $\gamma\gamma$ -coin, $\gamma(\theta)$, $\gamma(\text{lin pol})$. Deduced levels, J, π , γ -ray multiplicities, mixing ratios.

1971Ca36: E=1.964, 1.975 MeV proton beams from the Laboratori Nazionali di Legnaro. γ rays and conversion electrons were detected with Si(Li) detectors. Measured electrons (at 90°). Deduced conversion coefficients, γ -ray multiplicities.

1971Ro27: E=2.6-3.9 MeV proton beams from the University of Alberta 6-MV van de Graaff generator. γ rays were detected with Ge(Li) detectors. Measured $E\gamma$, $I\gamma$, γ excitation function, $\gamma(\theta)$. Deduced levels, J, γ -ray branching ratios, mixing ratios. An upper limit of $\approx 2\%$ was placed on all unobserved γ transitions.

Other: 1968Vi04, 1967Sc39, 1966Du05, 1965Ch16.

All information is from 1975As07, except as noted. The level scheme was constructed based on $\gamma\gamma$ -coincidences, threshold, and branching ratio measurements.

 ^{48}Sc Levels

E(level) [†]	J π [‡]	Comments
0.0	6 ⁺ #	
130.62 20	5 ⁺ @	
251.8 3	4 ⁺ @	
622.1 3	3 ⁺ @	
1142.0 4	2 ⁺ @	
1401.2 4	2 ⁻ &	
1890.5 4	3 ⁻ &	
2063.8 5	5 ⁺	J π : from γ -excit and $\gamma(\theta)$.
2103.1 4	4 ⁻	J π : $\pi=-$ from L(d, ^3He)=0. J=4 from γ -excit and $\gamma(\theta)$.
2189.9 4	3 ⁺ &	
2275.0 4	2 ⁺ &	
2316? 2		Suggested by 1971Ro27. Existence considered extremely doubtful by 1975As07: see footnote on 2062 γ .
2390.2 7	3,4	
2516.8 5	1 ⁺	J π : J=1 from γ -excit and $\gamma(\theta)$. $\pi=+$ from strong excitation in ($^3\text{He},\text{t}$).
2559.7 6	3,4	
2619.1 6	(4,5) ^a	
2639.6 5	1,2 ⁻ &	
2669.8 4	1 ⁻ ,2 ⁻ &	
2728.5 9	(4,5) ^a	
2782.8 5	(2,3) ^a	
2810.6 5	1,2,3	
2890.8 5	2,3	
2923.5 6	(3)	Additional information 1.
2980.2 4	1,2,3	
3025.7 4	(2,3) ^a	
3056.0 4	1,2	
3149.4 5	1,2	
3215.6 7	(0,1,2,3 ⁺)#	
3295.1 6	(0 ⁺ to 4 ⁺)#	
3301.4 4	(0 to 3 ⁺)#	
3327.3 5	(4 ⁻)#	
6677.0 21	0 ⁺ #	T=4

Continued on next page (footnotes at end of table)

${}^{48}\text{Ca}(\text{p},\text{n}\gamma)$ [1975As07](#),[1971Ro27](#),[1971Ca36](#) (continued) ${}^{48}\text{Sc}$ Levels (continued)

<u>E(level)[†]</u>	<u>J^{π‡}</u>	<u>Comments</u>
		IAS(${}^{48}\text{Ca}$ g.s.). See 1997Jo08 for parameters of the isovector potential deduced from $\sigma(\theta)$ of ${}^{48}\text{Ca}(\text{p},\text{n})$ E=35 MeV.

[†] From a least-squares fit to γ -ray energies.

[‡] From γ excitation functions, $\gamma(\theta)$, and branching ratios, except as noted.

From Adopted Levels.

@ $\pi=+$ from L(d, ${}^3\text{He}$)=3. $J^\pi(131,252)=5^+$ and 4^+ , respectively, from cross section ratios and $\gamma(\theta)$. $J^\pi(622)=3^+$ from cross section ratios. J(1142)=2 from $\gamma(\theta)$.

& From γ excitation functions, $\gamma(\theta)$, and linear polarization.

^a From γ excitation functions and branching ratios.

$\gamma(^{48}\text{Sc})$

$\alpha(\text{exp})$ from 1971Ca36 as quoted under comments are from original values (normalized to $\alpha(\text{theory})=1.21\times 10^{-4}$ for 983.5 γ from ⁴⁵Sc β^- decay) re-normalized to $\alpha(\text{theory})=1.26\times 10^{-4}$ from BrIcc by the evaluator.

$E_i(\text{level})$	J_i^π	E_γ	I_γ &	E_f	J_f^π	Mult. ^a	δ^a	α^\dagger	Comments
130.62	5 ⁺	130.6 2	100	0.0	6 ⁺	M1(+E2)	0.04 5	0.0081 7	$\alpha(\text{exp})=0.0081 7$ $\alpha(\text{K})=0.0074 6$; $\alpha(\text{L})=0.00066 5$; $\alpha(\text{M})=8.2\times 10^{-5} 7$ $\alpha(\text{N})=4.53\times 10^{-6} 35$ Mult., δ : from $\alpha(\text{exp})$. $\alpha(\text{exp})=0.0140 13$
251.8	4 ⁺	121.2 2	100	130.62	5 ⁺	D(+Q)	-0.04 9		δ : <-6.7 and >+40 excluded from $\alpha(\text{exp})$ which gives $\delta(\text{E2/M1})<0.006$ or $\delta(\text{M2/E1})<0.010$.
622.1	3 ⁺	370.2 2	100	251.8	4 ⁺	D(+Q)	-0.02 2		$\alpha(\text{exp})=0.00065 6$ δ : +10 2 excluded from $\alpha(\text{exp})$ which gives $\delta(\text{E2/M1})<0.22$ or $\delta(\text{M2/E1})=0.30 +6-7$.
1142.0	2 ⁺	519.9 2	100	622.1	3 ⁺	M1+E2 ^b	-0.08 +2-6	0.000306 6	$\alpha(\text{exp})=0.00034 3$ $\alpha=0.000306 6$; $\alpha(\text{K})=0.000278 6$; $\alpha(\text{L})=2.45\times 10^{-5} 5$; $\alpha(\text{M})=3.04\times 10^{-6} 6$ $\alpha(\text{N})=1.702\times 10^{-7} 35$ δ : +11.3 +40-22 excluded from $\alpha(\text{exp})$ which gives $\delta(\text{E2/M1})=0.33 +14-20$.
1401.2	2 ⁻	259.1 2 779.0 2	4 I 96 I	1142.0 622.1	2 ⁺ 3 ⁺	D+Q E1+M2 ^b	-0.04 ^b 1	7.72 $\times 10^{-5}$ 11	δ : -0.08 6 or -1.8 3. $\alpha(\text{exp})=0.000078 6$ $\alpha=7.72\times 10^{-5} 11$; $\alpha(\text{K})=7.03\times 10^{-5} 10$; $\alpha(\text{L})=6.16\times 10^{-6} 9$; $\alpha(\text{M})=7.63\times 10^{-7} 11$ $\alpha(\text{N})=4.28\times 10^{-8} 6$
1890.5	3 ⁻	489.3 3	37 I	1401.2	2 ⁻	M1+E2 ^b		5.8 $\times 10^{-4}$ 24	$\alpha=5.8\times 10^{-4} 24$; $\alpha(\text{K})=5.3\times 10^{-4} 21$; $\alpha(\text{L})=4.7\times 10^{-5} 19$; $\alpha(\text{M})=5.8\times 10^{-6} 24$ $\alpha(\text{N})=3.2\times 10^{-7} 13$ δ : -0.08 3 or +8 2. δ : +0.02 11 or +3.7 +28-16.
		748.3 4 1268.3 [‡] 6 1638.8 3	7 I 6 I 51 I	1142.0 622.1 251.8	2 ⁺ 3 ⁺ 4 ⁺	D+Q E1+M2 ^b	+0.05 ^b 3	0.000392 6	$\alpha=0.000392 6$; $\alpha(\text{K})=1.787\times 10^{-5} 28$; $\alpha(\text{L})=1.561\times 10^{-6} 25$; $\alpha(\text{M})=1.936\times 10^{-7} 31$ $\alpha(\text{N})=1.089\times 10^{-8} 17$; $\alpha(\text{IPF})=0.000372 5$ δ : +6.0 10 considered unlikely.
2063.8	5 ⁺	1811.8 6 2063.9 [#] 6	24 I 76 I	251.8 0.0	4 ⁺ 6 ⁺	D(+Q)	-0.02 3		
2103.1	4 ⁻	1481.0 4 1851.1 5 1972.5 5	51 2 23 I 26 I	622.1 251.8 130.62	3 ⁺ 4 ⁺ 5 ⁺	D(+Q) D(+Q) D(+Q)	0.00 3 -0.12 +12-8 -0.02 4		δ : others: +0.02 2 or +4.3 4 (1971Ro27). δ : others: +0.02 15 or -0.90 +28-38 (1971Ro27).

⁴⁸Ca(p,n) γ 1975As07,1971Ro27,1971Ca36 (continued)

$\gamma(^{48}\text{Sc})$ (continued)

$E_i(\text{level})$	J_i^π	E_γ	I_γ &	E_f	J_f^π	Mult. ^a	δ^a	α^\dagger	Comments
2189.9	3 ⁺	1567.7 3	22 1	622.1	3 ⁺	M1+E2 ^b	+0.09 ^b 4	0.0001203 17	$\alpha=0.0001203$ 17; $\alpha(\text{K})=3.13\times 10^{-5}$ 4; $\alpha(\text{L})=2.74\times 10^{-6}$ 4; $\alpha(\text{M})=3.40\times 10^{-7}$ 5 $\alpha(\text{N})=1.912\times 10^{-8}$ 27; $\alpha(\text{IPF})=8.59\times 10^{-5}$ 12 δ : others: 0.00 2 or -1.20 16 (1971Ro27).
		1938.1 3	78 1	251.8	4 ⁺	M1(+E2) ^b	+0.01 ^b 1	0.0002477 35	$\alpha=0.0002477$ 35; $\alpha(\text{K})=2.166\times 10^{-5}$ 30; $\alpha(\text{L})=1.893\times 10^{-6}$ 27; $\alpha(\text{M})=2.348\times 10^{-7}$ 33 $\alpha(\text{N})=1.323\times 10^{-8}$ 19; $\alpha(\text{IPF})=0.0002239$ 31 δ : other: +0.03 2 (1971Ro27).
2275.0	2 ⁺	1132.8 3	70 1	1142.0	2 ⁺	M1+E2 ^b	+0.03 ^b 2	6.39 $\times 10^{-5}$ 9	$\alpha=6.39\times 10^{-5}$ 9; $\alpha(\text{K})=5.67\times 10^{-5}$ 8; $\alpha(\text{L})=4.97\times 10^{-6}$ 7; $\alpha(\text{M})=6.16\times 10^{-7}$ 9 $\alpha(\text{N})=3.47\times 10^{-8}$ 5; $\alpha(\text{IPF})=1.560\times 10^{-6}$ 25 δ : others: -0.28 4 or -1.10 10 (1971Ro27).
		1652.9 3	30 1	622.1	3 ⁺	M1+E2 ^b		0.000167 21	$\alpha=0.000167$ 21; $\alpha(\text{K})=3.02\times 10^{-5}$ 18; $\alpha(\text{L})=2.65\times 10^{-6}$ 16; $\alpha(\text{M})=3.28\times 10^{-7}$ 20 $\alpha(\text{N})=1.85\times 10^{-8}$ 11; $\alpha(\text{IPF})=0.000133$ 19 δ : -0.03 2 or +7.7 12 (1975As09). Others: -0.07 3, or <-6.8 or >4.7 (1971Ro27).
2316?		2062 ^{#c}	100	251.8	4 ⁺				
2390.2	3,4	1767.8 8	53 3	622.1	3 ⁺	D+Q			δ : -0.0 2 or -1.6 6 if J=3 or +0.06 2 or -4 +1-2 if J=4. Others: +0.03 7 or -1.35 +40-30 if J=3, or -0.36 50 or -5.4 +9-11 if J=4 (1971Ro27).
		2138.5 8	47 2	251.8	4 ⁺	D+Q			δ : +0.06 7 or -6 +3-2 if J=3 or -0.35 10 if J=4.
2516.8	1 ⁺	1374.7 3	100	1142.0	2 ⁺	M1(+E2) ^b		8.8 $\times 10^{-5}$ 11	$\alpha=8.8\times 10^{-5}$ 11; $\alpha(\text{K})=4.3\times 10^{-5}$ 4; $\alpha(\text{L})=3.77\times 10^{-6}$ 32; $\alpha(\text{M})=4.7\times 10^{-7}$ 4 $\alpha(\text{N})=2.63\times 10^{-8}$ 22; $\alpha(\text{IPF})=4.1\times 10^{-5}$ 7 δ : -0.06 20 or +4.3 +51-70. Others: +0.10 17 or 1.9 +24-8 (1971Ro27).
2559.7	3,4	1417.5 6 2307.9 8	58 5 42 6	1142.0 251.8	2 ⁺ 4 ⁺	D+Q			δ : 0.00 4 or +8 2 if J=3 or +0.74 10 or -6.0 20 if J=4.
2619.1	(4,5)	2367.2 [@] 8 2488.5 8	44 2 56 2	251.8 130.62	4 ⁺ 5 ⁺				
2639.6	1,2 ⁻	1238.4 3	100	1401.2	2 ⁻	D+Q ^b			δ : +0.36 2 or -14 3 if $J^\pi=2^-$, -0.05< δ <+0.2 if $J^\pi=1^-$, or -0.27 $\leq\delta$ <+ ∞ if $J^\pi=1^+$. Other: +0.75 +44-33 if J=1 or +0.29 3 if J=2 (1971Ro27).
2669.8	1 ⁻ ,2 ⁻	1268.5 [‡] 3	100	1401.2	2 ⁻	M1+E2 ^b		7.4 $\times 10^{-5}$ 9	$\alpha=7.4\times 10^{-5}$ 9; $\alpha(\text{K})=5.1\times 10^{-5}$ 5; $\alpha(\text{L})=4.4\times 10^{-6}$ 4; $\alpha(\text{M})=5.5\times 10^{-7}$ 5 $\alpha(\text{N})=3.09\times 10^{-8}$ 29; $\alpha(\text{IPF})=1.86\times 10^{-5}$ 34 δ : -0.50 10 or -5.5 +20-30 if $J^\pi=1^-$ or +14 2 if $J^\pi=2^-$. Other: +0.40 3 if J=2 (1971Ro27).
2728.5	(4,5)	2476.6 8	100	251.8	4 ⁺				
2782.8	(2,3)	892.0 5	59 1	1890.5	3 ⁻				

4

⁴⁸Ca(p,n γ) 1975As07,1971Ro27,1971Ca36 (continued) $\gamma(^{48}\text{Sc})$ (continued)

$E_i(\text{level})$	J_i^π	E_γ	I_γ ^{&}	E_f	J_f^π	Mult. ^a	δ^a	Comments
2782.8	(2,3)	1381.9 [@] 5 2160.4 8	34 2 7 4	1401.2 622.1	2 ⁻ 3 ⁺			
2810.6	1,2,3	1409.4 3	100	1401.2	2 ⁻	D+Q		δ : -0.45 10 if J=1, +0.47 2 or -15 5 if J=2, or -0.09 1 if J=3. Others: +0.78 +70-46 if J=1, +0.25 4 or -6.0 +15-35 if J=2, -0.14 8 if J=3 (1971Ro27).
2890.8	2,3	1748.7 5 2268.6 5	55 2 45 2	1142.0 622.1	2 ⁺ 3 ⁺	D+Q D+Q		δ : +0.04 12 or -2.5 1 if J=2 or -0.36 8 or -10 +4-10 if J=3. Others: -0.18 6 or -1.39 17 if J=2, -0.52 4 or -4.0 +11-16 if J=3 (1971Ro27). δ : -0.03 6 or +7 +4-2 if J=2 or +0.6 1 if J=3. Others: -0.01 6 or <-9.5, or 6.3 +31-16 if J=2, +0.55 7 or >10 or <-10 if J=3 (1971Ro27).
2923.5	(3)	2301.2 6 2671.8 8	63 1 37 1	622.1 251.8	3 ⁺ 4 ⁺	D+Q ^b D+Q ^b	-0.17 2	δ : +0.38 5 or +1.7 2 if J=2 or +0.20 4 if J=3. δ : others: -0.18 2 or <-6 for J=3 (1971Ro27). Additional information 2.
2980.2	1,2,3	1838.3 3	100	1142.0	2 ⁺	D+Q		δ : +0.34 8 or +1.5 3 if J=1, +0.27 3 if J=2, -0.21 3 if J=3. Others: +1.0 +19-6 if J=1, +0.29 4 if J=2, -0.17 2 if J=3 (1971Ro27).
3025.7	(2,3)	835.6 [@] 5 1624.4 [@] 5 1883.8 [@] 6 2403.7 6	46 3 8 2 10 2 36 2	2189.9 1401.2 1142.0 622.1	3 ⁺ 2 ⁻ 2 ⁺ 3 ⁺			
3056.0	1,2	1913.9 3	100	1142.0	2 ⁺	D+Q		δ : +0.15 +2-1 or +2 1 if J=1 or +0.30 5 if J=2. Others: +0.21 5 or -4.10 8 if J=2 (1971Ro27).
3149.4	1,2	2007.3 3	100	1142.0	2 ⁺	D+Q		δ : +0.08 $\leq\delta<2.6$ 1 if J=1 or +0.30 5 if J=2.
3215.6	(0,1,2,3 ⁺)	698.8 5	100	2516.8	1 ⁺			
3295.1	(0 ⁺ to 4 ⁺)	2153.0 5	100	1142.0	2 ⁺			
3301.4	(0 to 3 ⁺)	245.4 4 321.4 4 490.5 6 631.4 4	23 2 28 2 49 2	3056.0 2980.2 2810.6 2669.8	1,2 1,2,3 1 ⁻ ,2 ⁻			
3327.3	(4 ⁻)	2185.1 6 2705.5 8 3075.2 8 3196.4 8	22 2 35 2 28 2 15 1	1142.0 622.1 251.8 130.62	2 ⁺ 3 ⁺ 4 ⁺ 5 ⁺			
6677.0	0 ⁺	4160 2		2516.8	1 ⁺			E_γ : from difference spectrum (1975Fo12. E=7.7-14.2 MeV. Measured γ 's and $\gamma\gamma$ -coincidences).

† Additional information 3.

‡ Assigned to a 2673 state by 1971Ro27. However, from the 1268 γ -excit and those of the γ 's deexciting the 1890 state the 1268 γ consists of two components: one deexciting the 1890 state which is overlapped for E(p) \geq 3.30 MeV by the other strong component from the 2669 state.# Assigned to a 2316 state by 1971Ro27 who estimated a branching of <2% for a component deexciting the 2191 state. However, 1975As07 note that the similarity of the 1812 γ and 2064 γ excit indicates that at least the dominate component of the 2064 γ deexcites the 2064 state. This is confirmed by the absence of any other ⁴⁸Sc γ 's in coincidence with the 2064 γ (within experimental limits).

$\gamma(^{48}\text{Sc})$ (continued)

@ Not reported by 1971Ro27.

& %photon branching ratio from each level (1975As07). Values are also available but less complete in 1971Ro27 and they are in good agreement with values from 1975As07.

^a From $\gamma(\theta)$ in 1975As07, except as noted. δ values from 1971Ro27 are given under comments. δ values from $\alpha(\text{exp})$ in 1971Ca36 are deduced using the BrIccMixing code by the evaluator.

^b From $\gamma(\theta)$ and linear polarization.

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

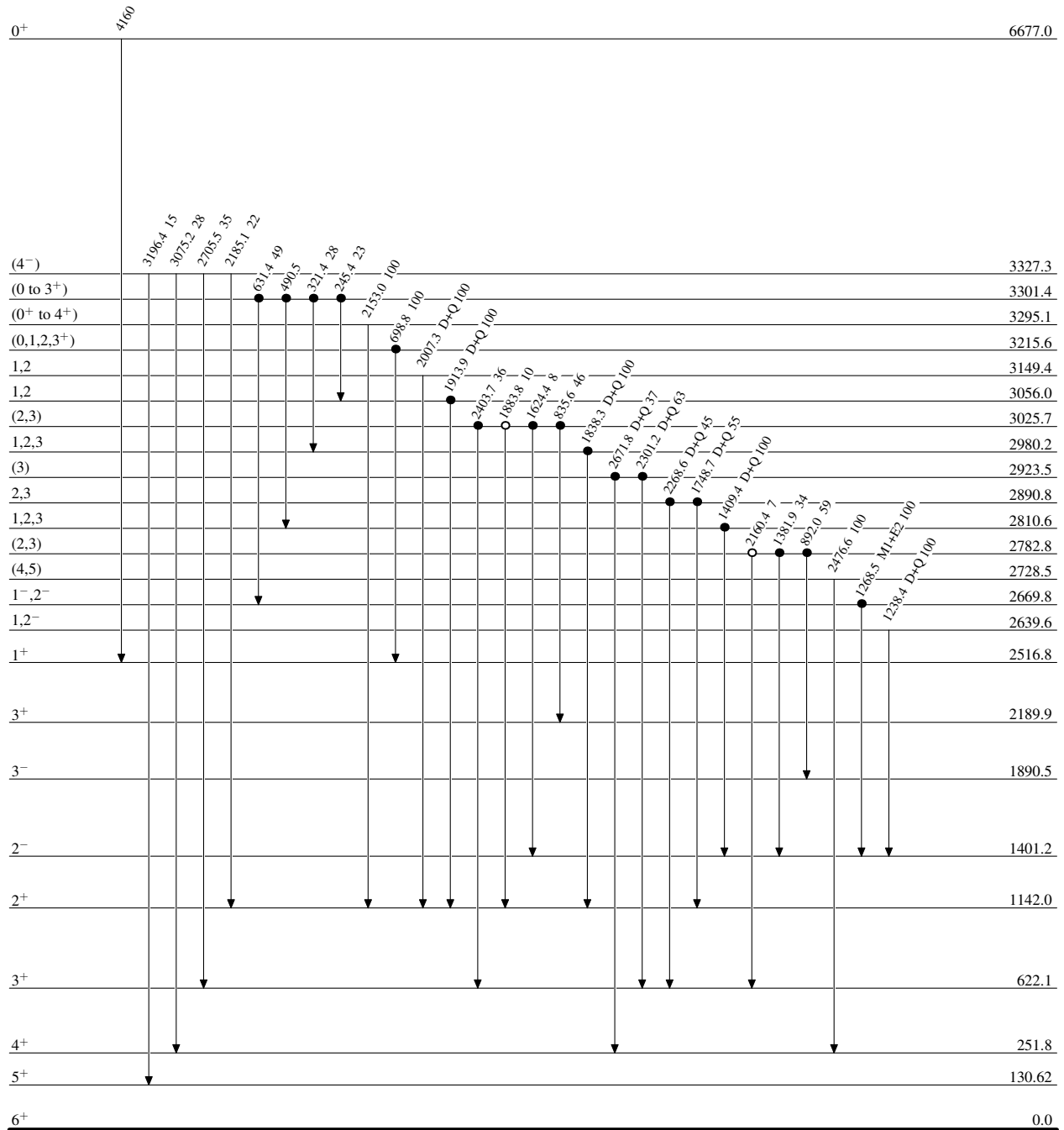
$^{48}\text{Ca}(p,n\gamma)$ 1975As07,1971Ro27,1971Ca36

Legend

Level Scheme

Intensities: % photon branching from each level

● Coincidence
○ Coincidence (Uncertain)

 $^{48}_{21}\text{Sc}_{27}$

Legend

 $^{48}\text{Ca}(p,n\gamma)$ 1975As07,1971Ro27,1971Ca36

Level Scheme (continued)

Intensities: % photon branching from each level

- ▶ γ Decay (Uncertain)
 ● Coincidence
 ○ Coincidence (Uncertain)

