^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 201,1 (2025)	31-Oct-2024

1977Ro07: E=1.4-3.8 MeV α beams were produced from NRC 4-MV Van de Graaff accelerator at the National Research Council, Canada. Target was a Si crystal. γ rays were detected with a NaI detector for thick target yields and a Ge detector for γ spectra. Measured Eγ, Iγ, $\gamma(\theta)$, γ-ray yields. Deduced levels, J, π, resonance strengths and widths, γ-ray branching ratios.

1971Ch52: E=4.2-6.0 MeV α beams were from the Van de Graaff accelerator at the Centre de Recherches Nucleaires, Strasbourg. Target was 98% enriched ^{28}Si. γ rays were detected with NaI detectors for angular distributions and Ge detector for intensities. Measured Eγ, Iγ, $\gamma(\theta)$, γ-ray yields. Deduced levels, J, π, resonance strengths and widths, γ-ray branching ratios, mixing ratios. See also 1969Ve01 and 1967Ve05 by the same group.

2002Ba81: E=2.91 MeV α beam was from the Van de Graaff of the University of Tubingen. Target was thick Si. γ rays were detected with a HPGe detector. Measured Eγ, Iγ. Deduced resonance strengths, branching ratios.

1985Ma32: E=1.76-3.82 MeV α beams from Chalk River accelerator. Targets were natural Si or SiO_2. γ rays were detected with Ge(Li) detectors. Measured Eγ, Iγ, $\gamma(\theta)$, γ yields, Doppler-shift attenuation. Deduced J, π, $T_{1/2}$, width, γ branching ratios for the 9065 resonance level.

1971To06: E=1.4-2.7 MeV α beams from the Caltech electrostatic generator. Target was 99.91% enriched ^{28}Si. γ rays were detected with NaI detectors. Measured γ-ray yields. Deduced resonance strengths.

1969Gr03: E=3-4 MeV α beams from the Freiburg Van de Graaff. γ rays were detected with a NaI and a Ge(Li) detectors. Measured Eγ, Doppler-shift attenuation. Deduced lifetimes, transition strengths, deformation parameters.

1964Sm03: E=2.0-3.3 α beams from the 3 MV Van de Graaff at Fysisch Laboratorium der Rijksuniversiteit, Utrecht. Target was natural Si. γ rays were detected with NaI detectors. Measured absolute yields, $\gamma(\theta)$, $\gamma\gamma(\theta)$. Deduced levels, J, resonance strengths, γ-ray mixing ratios.

1997Br07: E=3.473, 4.012 MeV α beams from 7 MV Van de Graaff accelerator of the University of Freiburg. Measured Eγ, Iγ, $\gamma(\theta)$. Deduced J, π, branching ratios for 9983 and 10434 levels. 1997Br07 report data primarily on (p,γ) and (α,nγ).

2016Mo35: measured isovector giant dipole resonance (IVGDR).

Others: 1993Il01, 1983La17, 1979Ku10, 1979Ku13, 1974Fo05, 1968Me04, 1965La13.

^{32}S Levels

Resonance strength $\omega\gamma=(2J+1)\Gamma_\alpha\Gamma_\gamma/\Gamma$.

Eα values under comments are from Eα(lab).

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$	Comments
0	0$^+$		
2232 *4*	2[&]	0.21 ps *6*	E(level): from 1969Gr03. $T_{1/2}$: from τ=0.31 ps *8*, weighted average of 0.30 ps *8* (line-shape) and 0.33 ps *12* (centroid-shift) in 1969Gr03 using DSAM. Deformation parameter β_2=0.25 *2* (1969Gr03).
3780			
4280			
4460	4[&]		
4700			
5010	3[&]		
5410			
5550			
5790			
6440[#]			
7003			E(level): from 1997Br07.
7120			
7500[#]			
7530[#]			

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^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 (continued)

^{32}S Levels (continued)

E(level)[†]	J^{π}[‡]	$T_{1/2}$	Comments
8493 *2*	1^{-}[@]		Eα=1766 *2* (1985Ma32), 1767 *2* (1977Ro07). Others: 1770 (2002Ba81), 1776 *5* (1971To06). $\omega\gamma$=16 meV *3* (1977Ro07), 25 meV *7* (1971To06), 19.7 meV *20* (2002Ba81).
8690 *2*	2^{+}[@]		Eα=1990 *3* (1977Ro07), 1995 *5* (1971To06). $\omega\gamma$=12 meV 3 (1977Ro07), 20 meV *6* (1971To06).
8861 *2*	2^{+}[@]		Eα=2187 *3* (1977Ro07), 2187 *7* (1971To06). $\omega\gamma$=16 meV *3* (1977Ro07), 41 meV *14* (1971To06).
9023 *2*			Eα=2370 (2002Ba81), 2371 *3* (1977Ro07), 2370 *4* (1971To06). $\omega\gamma$=52 meV *10* (1977Ro07), 93 meV *23* (1971To06), 58 meV *6* (2002Ba81).
9065 *2*	4^{+}	<14 fs	J^{π}: spin=4 from $\gamma(\theta)$ in 1985Ma32; π=natural. $T_{1/2}$: from DSAM in 1985Ma32. Eα=2420 (2002Ba81), 2419 *2* (1977Ro07), 2415 *5* (1971To06). $\omega\gamma$=64 meV *13* (1977Ro07), 134 meV *34* (1971To06), 49 meV *11* (2002Ba81).
9236 *2*	1^{-}[*a*]		Eα=2610 (2002Ba81), 2614 *2* (1977Ro07), 2618 *4* (1971To06), 2618 *4* (1964Sm03). $\omega\gamma$=540 meV *100* (1977Ro07), 610 meV *150* (1971To06), 505 meV *34* (2002Ba81), 300 meV (1964Sm03).
9466.0 *15*	2^{+}[*a*]		Eα=2880 (2002Ba81), 2877.5 *16* (1977Ro07), 2878 *4* (1964Sm03). $\omega\gamma$=720 meV *150* (1977Ro07), 667 meV *85* (2002Ba81), 400 meV (1964Sm03). Average of the first two is 680 meV *85*.
9486 *2*	1^{-}[*a*]		Eα=2900 (2002Ba81), 2901 *2* (1977Ro07), 2904 *4* (1964Sm03). $\omega\gamma$=830 meV *170* (1977Ro07), 897 meV *78* (2002Ba81), 700 meV (1964Sm03). Average of the first two is 885 meV *78*.
9712 *2*	2^{+}[*a*]		Eα=3159 *2* (1977Ro07), 3162 *4* (1964Sm03). $\omega\gamma$=630 meV *130* (1977Ro07), 300 meV (1964Sm03).
9854? *6*			
9935 *6*			
9986			Eα=3474 (1997Br07). J^{π}: identified by 1997Br07 as the 0^{+} level seen in (p,p):resonances. $\omega\gamma\approx$20 meV (1997Br07).
9997? *6*			
10113 *6*			
10220 *2*	3^{-}[&]		Eα=3739 *2* (1977Ro07), 3753 (1969Ve01). $\omega\gamma$=8.1 eV *16* (1977Ro07), 11.4 eV *3* (1969Ve01).
10285 *2*	3^{-}[&]		3814 *2* (1977Ro07) and 3816 *2* (1985Ma32), 3820 (1969Ve01), $\omega\gamma$=2.3 eV *4* (1977Ro07), 3.0 eV *12* (1969Ve01).
10291 *2*			E(level): from Eα=3821 *2* (1985Ma32). Other: 3827 *8* (1967Ve05).
10340 *7*			Eα=3877 *8* (1967Ve05).
10433.3 *15*	3^{-}		E(level): from Eα=3983.4 *17* (1997Br07). Other: 3992 *8* (1967Ve05). J^{π}: from 1997Br07 based on γ-decay modes. $\omega\gamma$=0.5 eV *2* (1967Ve07).
10456			E(level): from Eα=4009 (1997Br07). $\omega\gamma$=46 meV *15* (1997Br07).
10532 *7*			E(level): from Eα=4096 *8* (1967Ve05). $\omega\gamma$=0.07 eV *3* (1967Ve07).
10632 *7*			E(level): from Eα=4210 *8* (1967Ve05). $\omega\gamma$=0.6 eV *2* (1967Ve07).
10709 *7*			E(level): from Eα=4299 *8* (1967Ve05). $\omega\gamma$=2.7 eV *9* (1967Ve07).
10790	1^{-}		E(level): from Eα=4391 (1971Ch52). $\omega\gamma$=6.0 eV *2* (1971Ch52).
10806	2^{+}		E(level): from Eα=4409 (1971Ch52). $\omega\gamma$=33 eV *11* (1971Ch52).
10832	1^{-}		E(level): from Eα=4439 (1971Ch52). $\omega\gamma$=1.0 eV *5* (1971Ch52).
10841	2^{+}		E(level): from Eα=4449 (1971Ch52). $\omega\gamma$=5.0 eV *18* (1971Ch52).

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^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 (continued)

^{32}S Levels (continued)

E(level)[†]	J$^\pi$[‡]	Comments
10851	1$^-$	E(level): from Eα=4460 (1971Ch52). $\omega\gamma$=0.15 eV *10* (1971Ch52).
10941	1$^-$	E(level): from Eα=4563 (1971Ch52). $\omega\gamma$=1.8 eV *6* (1971Ch52).
10998	(3$^-$,4$^+$,5$^-$)	E(level): from Eα=4628 (1971Ch52). $\omega\gamma$=4.2 eV *14* (1971Ch52).
11052	(3$^-$,4$^+$,5$^-$)	E(level): from Eα=4690 (1971Ch52). $\omega\gamma$=2.2 eV *7* (1971Ch52).
11078	2$^+$	E(level): from Eα=4720 (1971Ch52). $\omega\gamma$=0.30 eV *15* (1971Ch52).
11110		E(level): from Eα=4757 (1971Ch52). $\omega\gamma$<0.10 eV (1971Ch52).
11746	(1$^-$)	E(level): from Eα=5483 (1971Ch52). $\omega\gamma$=3.7 eV *12* (1971Ch52).
11785	1$^-$	E(level): from Eα=5528 (1971Ch52). $\omega\gamma$=0.05 eV *3* (1971Ch52).
11803	1$^-$,2$^+$	E(level): from Eα=5549 (1971Ch52). This is an unresolved doublet. $\omega\gamma$=1.4 eV *5* (1971Ch52).
12021	1$^-$	E(level): from Eα=5798 (1971Ch52). $\omega\gamma$=3.2 eV *11* (1971Ch52).
12048	3$^-$	E(level): from Eα=5828 (1971Ch52). $\omega\gamma$=1.4 eV *5* (1971Ch52).

[†] From 1977Ro07 up to 10285 based on Eγ data and from Eα in 1971Ch52 above that, unless otherwise noted. Energy of resonance level above 10285 is deduced from E(level)=Eα(c.m.)+S(α)(^{32}S), where S(α)(^{32}S)=6947.6559 *14* (2021Wa16) and Eα(c.m.)=Eα(lab)×m(^{28}Si)/[m(^{28}Si)+m(α)], from Eα(lab) value given under comments; for those cases, average Eα(lab) is taken where available, as noted under comments.
[‡] Spins of resonance levels are from $\gamma(\theta)$ in 1971Ch52, unless otherwise noted; only natural-parity resonance populated in this reaction.
[#] From 1971Ch52.
[@] Spin from $\gamma(\theta)$ in 1977Ro07.
[&] Spin from $\gamma\gamma(\theta)$ in 1969Ve01.
[a] Spin from $\gamma(\theta)$ or $\gamma\gamma(\theta)$ in 1964Sm03.

γ(^{32}S)

E$_i$(level)	J$_i^\pi$	E$_\gamma$[†]	I$_\gamma$[†]	E$_f$	J$_f^\pi$	Comments
8493	1$^-$	4214[@]	<8[#]	4280		
		4714[@]	<3[#]	3780		
		6261	40[#] *4*	2232	2	I$_\gamma$: other: 38 *5* (1977Ro07).
		8493	60[#] *4*	0	0$^+$	I$_\gamma$: other: 62 *5* (1977Ro07).
8690	2$^+$	4910	12 *4*	3780		
		6457	56 *5*	2232	2	
		8689	32 *4*	0	0$^+$	
8861	2$^+$	5081	14 *4*	3780		
		6628	34 *4*	2232	2	
		8860	52 *5*	0	0$^+$	
9023		4013	19 *2*	5010	3	
		4743	20 *2*	4280		
		6790	61 *2*	2232	2	
9065	4$^+$	3655	58 *4*	5410		I$_\gamma$: from 1985Ma32. Other: 43 *2* (1977Ro07).

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^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 (continued)

$\gamma(^{32}S)$ (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	δ[‡]	Comments
9065	4^+	4605	30 *3*	4460	4			I_γ: from 1985Ma32. Other: 41 *2* (1977Ro07).
		4785	12 *1*	4280				I_γ: from 1985Ma32. Other: 17 *3* (1977Ro07).
		6835[@]	<1	2232	2			I_γ: from 1985Ma32.
9236	1^-	4536	8.8[#] *4*	4700				I_γ: other: 11 *2* (1977Ro07).
		5456	29.5[#] *11*	3780				I_γ: other: 30 *2* (1977Ro07).
		7003	58.7[#] *12*	2232	2			I_γ: other: 58 *2* (1977Ro07).
		9235	3.0[#] *2*	0	0^+			I_γ: other: 1.9 *6* (1977Ro07).
9466.0	2^+	3676	4 *1*	5790				
		3916	4 *1*	5550				
		4456	4 *1*	5010	3			
		4766	20 *2*	4700				
		5006	4 *1*	4460	4			
		5686	5 *1*	3780				
		7233	26 *2*	2232	2			
		9464.5	34 *2*	0	0^+			
9486	1^-	2366	2.5[#] *3*	7120				I_γ: other: 2 *1* (1977Ro07).
		4476	1.5[#] *1*	5010	3			I_γ: other: 5 *1* (1977Ro07).
		5206	10.9[#] *6*	4280				I_γ: other: 10 *1* (1977Ro07).
		5706[@]	<0.5[#]	3780				I_γ: other: 2 *1* (1977Ro07).
		7253[@]	<0.3[#]	2232	2			I_γ: other: <4 (1977Ro07).
		9485	85.1[#] *7*	0	0^+			I_γ: other: 81 *2* (1977Ro07).
9712	2^+	5012	34 *9*	4700				
		7479	57 *6*	2232	2			
		9710	9 *3*	0	0^+			
9986		2983		7003				E_γ: weak transition seen in 1997Br07.
10220	3^-	3100	<2	7120				
		5210	68 *2*	5010	3	D(+Q)	−0.06 *6*	I_γ: other: 60 *5* (1969Ve01). Mult.,δ: from 1969Ve01.
		5520	<2	4700				
		5759	21 *2*	4460	4	D+Q	−0.09 *2*	I_γ: other: 26 4 (1969Ve01). Mult.,δ: from $\gamma\gamma(\theta)$ 1969Ve01.
		7987	11 *1*	2232	2	D+Q	+0.11 *5*	Mult.,δ: from $\gamma\gamma(\theta)$ 1969Ve01. I_γ: other: 14 *3* (1969Ve01).
10285	3^-	5275	79 *2*	5010	3			I_γ: other: 75 *5* (1969Ve01).
		5824	15 *2*	4460	4			I_γ: other: 15 *4* (1969Ve01).
		8052	6 *1*	2232	2			I_γ: other: 10 *3* (1969Ve01).
		10283[@]	<1	0	0^+			
10433.3	3^-	5424	18	5010	3			E_γ,I_γ: from 1997Br07.
		5974	23	4460	4			E_γ,I_γ: from 1997Br07.
		8202	59	2232	2			E_γ,I_γ: from 1997Br07.
10456		3454		7003				E_γ: weak transition seen in 1997Br07.
10790	1^-	3260	<10	7530				
		5779	11	5010	3			
		6089	12	4700				
		6509	7	4280				
		8557	33	2232	2	D+Q		A_2=+0.3 *2* (1971Ch52). Mult.,δ: −0.3 *2* or −1.4 *12* (1971Ch52).
		10788	37	0	0^+			A_2=−0.92 *4* (1971Ch52).
10806	2^+	5396	4	5410				
		5795	10	5010	3			
		6105	2	4700				
		6525	9	4280				
		8573	46	2232	2	D+Q	−0.19 *6*	A_2=+0.25 *10*, A_4=−0.40 *18* (1971Ch52).

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^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 (continued)

$\gamma(^{32}S)$ (continued)

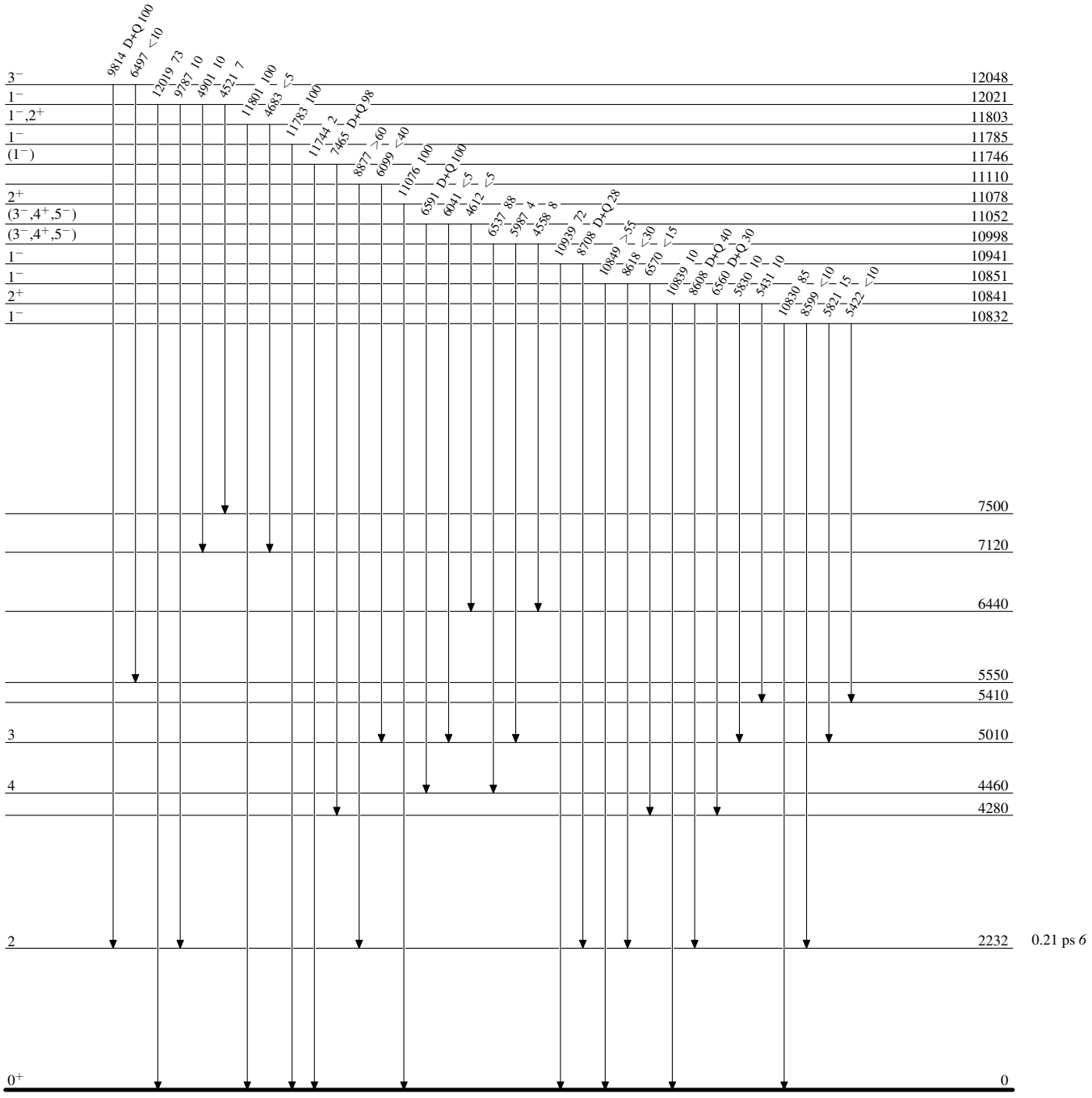
E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	δ[‡]	Comments
10806	2^+	10804	29	0	0^+			A_2=+0.4 *1*, A_4=−1.2 *2* (1971Ch52).
10832	1^-	5422	<10	5410				
		5821	15	5010	3			
		8599	<10	2232	2			
		10830	85	0	0^+			A_2=−1.0 *1* (1971Ch52).
10841	2^+	5431	10	5410				
		5830	10	5010	3			
		6560	30	4280		D+Q	+0.60 *12*	A_2=+1.1 *1*, A_4=−0.08 *15* (1971Ch52).
		8608	40	2232	2	D+Q	+0.54 *15*	A_2=+1.1 *1*, A_4=+0.05 *10* (1971Ch52).
		10839	10	0	0^+			A_2=−0.30 *4*, A_4=−0.64 *5* (1971Ch52).
10851	1^-	6570	<15	4280				
		8618	<30	2232	2			
		10849	>55	0	0^+			A_2=−1.1 *1* (1971Ch52).
10941	1^-	8708	28	2232	2	D+Q		A_2=−0.1 *2* (1971Ch52). δ: 0.00 *18* or 3.0 *15* (1971Ch52).
		10939	72	0	0^+			A_2=−1.10 *5* (1971Ch52).
10998	$(3^-,4^+,5^-)$	4558	8	6440				
		5987	4	5010	3			
		6537	88	4460	4			δ: −0.24 *6* for J=3, −0.30 *6* for J=4, +0.26 *4* for J=5 (1971Ch52). A_2=+0.21 *7*, A_4=+0.14 *10* (1971Ch52).
11052	$(3^-,4^+,5^-)$	4612	<5	6440				
		6041	<5	5010	3			
		6591	100	4460	4	D+Q		δ: −0.20 *7* for J=3, −0.34 *8* for J=4, +0.23 *4* for J=5 (1971Ch52). A_2=+0.14 *7*, A_4=+0.15 *8* (1971Ch52).
11078	2^+	11076	100	0	0^+			A_2=+0.6 *3*, A_4=−1.8 *4* (1971Ch52).
11110		6099	<40	5010	3			
		8877	>60	2232	2			
11746	(1^-)	7465	98	4280		D+Q		A_2=+0.15 *2* (1971Ch52). δ: −0.21 *2* or −1.8 *1* (1971Ch52).
		11744	2	0	0^+			A_2=−1.0 *1* (1971Ch52).
11785	1^-	11783	100	0	0^+			A_2=−0.95 *6* (1971Ch52).
11803	$1^-,2^+$	4683	<5	7120				I_γ: intensity seen in only one part of the doublet.
		11801	100	0	0^+			A_2=+0.40 *15*, A_4=−1.4 *2* (1971Ch52).
12021	1^-	4521	7	7500				
		4901	10	7120				
		9787	10	2232	2			
		12019	73	0	0^+			A_2=−1.1 *1* (1971Ch52).
12048	3^-	6497	<10	5550				
		9814	100	2232	2	D+Q	+0.03 *2*	Mult.,δ: D+Q with δ=−0.03 2. A_2=−0.40 *4*, A_4=+0.08 *6* (1971Ch52).

[†] Transitions from 1977Ro07 for levels up to 10285 and from 1971Ch52 for levels above that, unless otherwise noted. Quoted values of Eγ are from level-energy differences.
[‡] From $\gamma(\theta)$ in 1971Ch52.
[#] From 2002Ba81.
[@] Placement of transition in the level scheme is uncertain.

^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81

Level Scheme

Intensities: % photon branching from each level



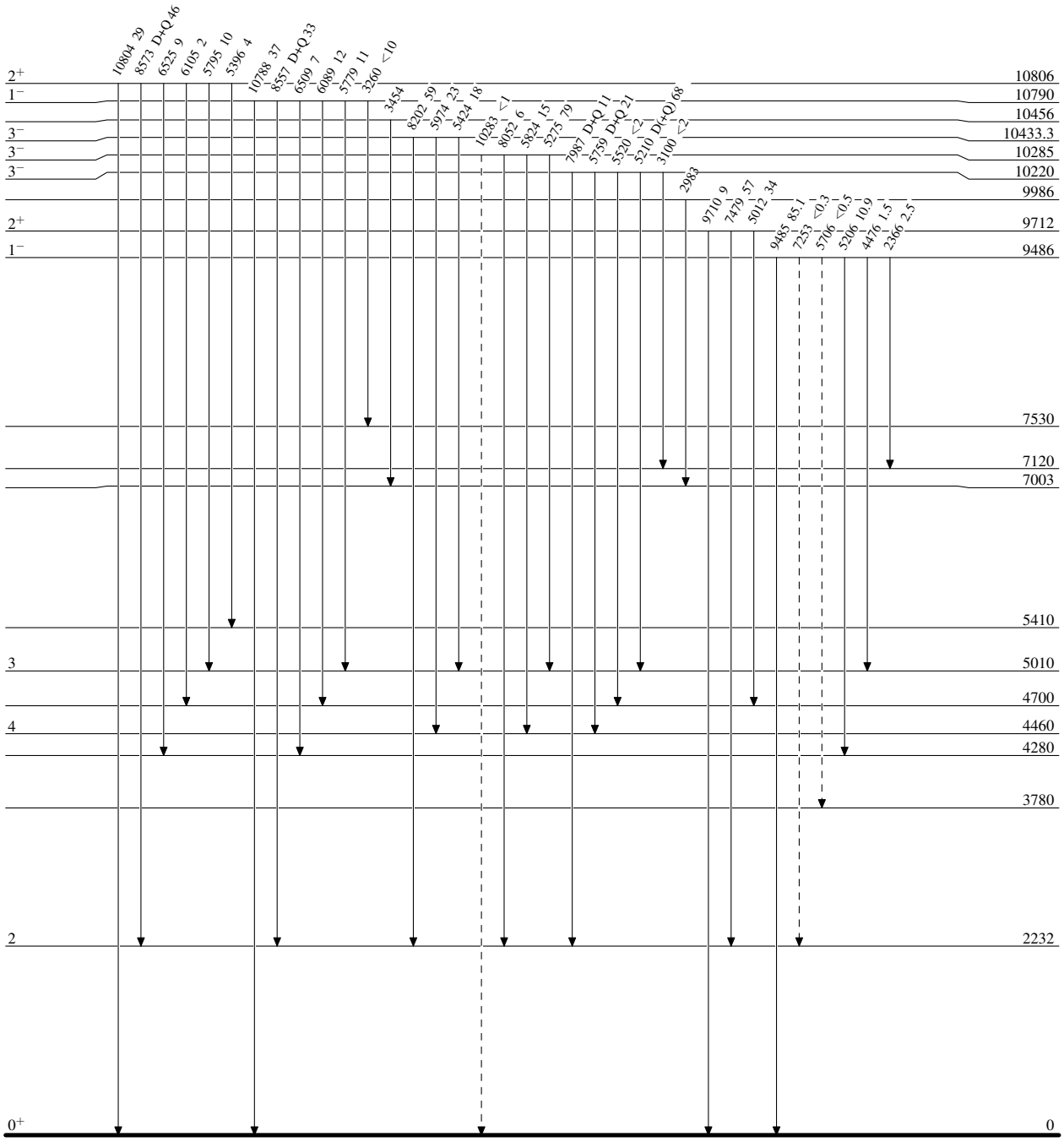
$^{32}_{16}S_{16}$

^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 Legend

Level Scheme (continued)

Intensities: % photon branching from each level

γ Decay (Uncertain)



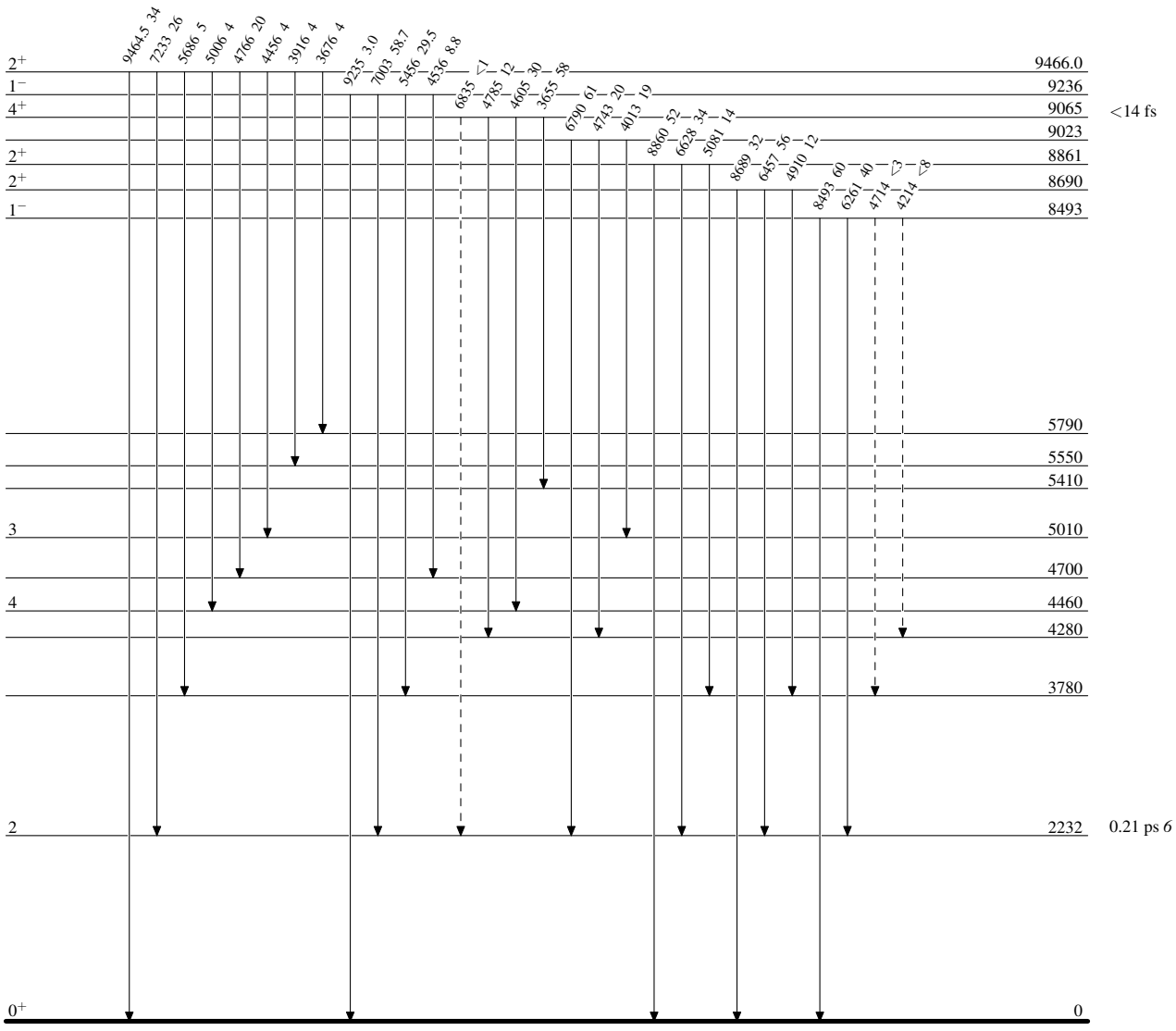
$^{32}_{16}S_{16}$

^{28}Si(α,γ) E=res 1977Ro07,1971Ch52,2002Ba81 Legend

Level Scheme (continued)

Intensities: % photon branching from each level

γ Decay (Uncertain)



$^{32}_{16}S_{16}$