^{28}Si(α,pγ),^{4}He(^{28}Si,pγ) 1974Tw01,1979Po01

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Jun Chen and Balraj Singh	NDS 184, 29 (2022)	24-Jun-2022

1974Tw01: (α,pγ) E=6.75-14 MeV from Oliver Lodge Laboratory. Enriched Si targets (99.6% ^{28}Si). Ge(Li)-NaI(T1) escape suppressed spectrometer for γ-ray detection. γ-ray polarization measured using a Compton polarimeter consisting of three GeLi detectors. Measured Eγ, Iγ, γγ, γ(θ), γ-p(θ), γ(lin pol), branching ratios and lifetimes using DSAM (line-shape analysis). Deduced levels, J, π, lifetimes, γ-ray multipolarities, mixing ratios, transition strengths. Additional 25% uncertainty in lifetime due to lack of full knowledge of the stopping power theory is not included by authors.

1979Po01: (^{28}Si,pγ) ^{28}Si beam at E=46.8 MeV from Oxford University tandem Van-de-Graaff accelerator. Target was ^{4}He-implanted nickel foil. Si detector for light ion products and GeLi detector for γ ray detection. Measured E(p), γp-coin, direct γ-line shape for lifetimes using DSAM (line-shape analysis). Uncertainty in lifetime arises from 5% and 12% uncertainties in the electronic and nuclear stopping powers, respectively.

Others:

1982Ho06: (α,pγ) E=7.8-8.5 MeV from Utrecht tandem Van de Graaff accelerator. IMPAC technique for measuring g-factor of levels. NaI detectors for γ-rays and Si surface barrier detector for protons.

1970Va12: (α,pγ) E=7-11 MeV from Utrecht tandem Van de Graaff. Enriched silicon oxide targets. Ge detectors for Eγ. Si detector for protons. DSAM (line-shape analysis) for lifetime measurements p-γ coin. The total 20% systematic uncertainty includes 8% uncertainty from experimental electronic stopping power data and 15% uncertainty in slowing-down theory where no experimental data exist.

1979Fo02: (^{28}Si,pγ) E=55 MeV ^{28}Si beam at Chalk River. Measured lifetimes using DSAM (line-shape analysis) with Ge(Li) detectors. Estimated 5% uncertainty due to experimental electric stopping power data is included.

1969Cu01: (α,pγ) E=9.5 MeV α beam from the Harwell 5-MV Van de Graaff at AERE. Measured lifetimes using DSAM (line-shape analysis) with a NaI(Tl) and a Ge(Li) detector.

All data are from 1974Tw01, unless otherwise stated.

^{31}P Levels

E(level)†	J$^{\pi}$‡	$T_{1/2}$@	Comments
0.0	1/2^{+}#		
1266.1 *4*	3/2^{+}#	521 fs *33*	$T_{1/2}$: weighted average of 527 fs *33* (1979Po01), 555 fs *152* (1974Tw01), 451 fs *153* (1970Va12), 555 fs *56* (1969Cu01), and 485 fs *49* (1979Fo02), all by DSAM. g-factor=+0.20 *5*, from precession angle (1982Ho06).
2233.6 *4*	5/2^{+}#	256 fs *17*	$T_{1/2}$: weighted average of 236 fs *21* (1974Tw01), 208 fs *79* (1970Va12), 263 fs *21* (1969Cu01), 252 fs *17* (1979Fo02), and 271 fs *18* (1979Po01), all by DSAM. g factor=+1.13 *18*, from precession angles (1982Ho06).
3133.7 *7*	1/2^{+}#	≤10 fs	
3294.8 *5*	5/2^{+}#	81 fs *25*	
3414.6 *6*	7/2^{+}	222 fs *59*	
3505.4 *7*	3/2^{+}#	≤7 fs	
4190.1 *5*	5/2^{+}#	≤10 fs	
4261 *1*	3/2^{+}#	≤10 fs	
4430.5 *5*	7/2^{-}#	0.41 ps *11*	
4594.2 *7*	3/2^{+}#	16 fs *10*	
4633.6 *6*	7/2^{+}	69 fs *20*	
4783.0 *6*	5/2^{+}#	≤10 fs	
5010	(3/2^{+})#	49 fs *16*	J$^{\pi}$: spin of doublet estimated to be 3/2 and 3/2^{+},(1/2) (1974Tw01).
5020	3/2^{-}#	≤7 fs	J$^{\pi}$: see comment for 5010 level.
5115.2 *7*	5/2^{+}	10.4 fs *44*	
5258 *2*	1/2^{+}	≤10 fs	
5343.1 *6*	9/2^{+}	33 fs *11*	
5529 *1*	7/2^{+},(5/2^{+})	≤10 fs	J$^{\pi}$: proposed by 1974Tw01 from γ(θ), with 5/2 being rejected only at the 1%

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^{28}Si(α,pγ),^{4}He(^{28}Si,pγ) 1974Tw01,1979Po01 (continued)

^{31}P Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$@	Comments
			confidence limit; however, 7/2+ is in disagreement with adopted (5/2)+.
5562 *2*			
5672			
5773 *1*			
5892.4 *7*	9/2+	21 fs *8*	
5988			
6048 *1*	7/2+	22 fs *12*	
6081 *1*	9/2+	22 fs *12*	
6398 *1*	7/2(−)	22 fs *12*	
6452 *1*	11/2+	22 fs *12*	
6500 *1*	9/2−	38 fs *14*	
6793 *1*	9/2−	139 fs *41*	Jπ: (5/2,9/2) from pγ(θ) in 1974Tw01.
6825 *1*	11/2−	62 fs *26*	
6932	5/2+	≤28 fs	
7080			
7118 *1*	9/2+	≤17 fs	
7441 *1*	11/2+	≤10 fs	
7466 *2*			

† From 1974Tw01.
‡ From 1974Tw01 based on measured pγ(θ), γ(lin pol), γ-ray multipolarity character deduced based on measured lifetime and RUL where available and adopted assignments for certain levels as indicated, unless otherwise noted.
# From the Adopted Levels.
@ From Doppler-shift attenuation (line-shape analysis) method (DSAM) in 1974Tw01, unless otherwise stated. For values from 1974Tw01, an additional 25% uncertainty due to lack of full knowledge of the stopping theory as stated by authors has been added in quadrature by evaluators.

γ(^{31}P)

E_i(level)	$J_i^π$	$E_γ$	$I_γ$	E_f	$J_f^π$	Mult.†	δ†	Comments
1266.1	3/2+	1266	100	0.0	1/2+			M1+E2, δ=0.28 2 assumed by (1974Tw01), which is taken from 1968Wo01.
2233.6	5/2+	968	<0.1	1266.1	3/2+			
		2234	100	0.0	1/2+			E2 assumed by 1974Tw01. A_2=+0.38 *4* and +0.41 *6*, A_4=−0.28 *5* and −0.26 *7*; mult not assigned. γ(θ) data are given for a 2234γ with both the 5892 and 6081 levels, however these levels do not de-excite via a 2234γ. The evaluator tentatively assigns these angular distributions here.
3133.7	1/2+	3134	100	0.0	1/2+			M1 assumed by 1974Tw01.
3294.8	5/2+	1061	19 *5*	2233.6	5/2+	M1+E2	+0.38 *9*	A_2=+0.61 *2*, A_4=+0.05 *2*.
		2029	81 *5*	1266.1	3/2+	M1+E2	+0.37 *3*	A_2=+0.26 *1*, A_4=+0.04 *2*.
3414.6	7/2+	1181	4 *1*	2233.6	5/2+	M1+E2	−0.35 *7*	A_2=+0.90 *5*, A_4=+0.05 *5*.
		2149	96 *1*	1266.1	3/2+			E2 assumed by 1974Tw01. 2149γ shown with 6452, 7118 and 7441 levels, however this γ must belong to this transition. A_2=+0.50 *5*, +0.51 *2*, +0.43 *3*, A_4=−0.17 *3*, −0.21 *2*, −0.15 *4*.
3505.4	3/2+	2239	36 *4*	1266.1	3/2+			
		3505	64 *4*	0.0	1/2+	M1+E2	+0.40 *3*	A_2=+0.27 *2*, A_4=−0.03 *10*.
4190.1	5/2+	1956	24 *3*	2233.6	5/2+	M1(+E2)	+0.09 *14*	A_2=+0.47 *7*, A_4=+0.18 *5*.

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^{28}Si(α,pγ),^{4}He(^{28}Si,pγ) 1974Tw01,1979Po01 (continued)

γ(^{31}P) (continued)

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.†	δ†	Comments
4190.1	5/2+	2924	76 *4*	1266.1	3/2+	M1+E2	−0.12 *5*	A_2=−0.64 *5*, A_4=+0.05 *6*.
4261	3/2+	2995	36 *4*	1266.1	3/2+			M1+E2,δ=+0.25 5 assumed by 1974Tw01, taken from (p,γ).
		4261	64 *4*	0.0	1/2+	M1+E2	+0.40 *6*	A_2=+0.23 *4*, A_4=+0.05 *5*.
4430.5	7/2−	1016	6 *2*	3414.6	7/2+			E1 assumed by 1974Tw01.
		1136	49 *4*	3294.8	5/2+			E1 assumed by 1974Tw01.
		2197	45 *4*	2233.6	5/2+			E1 assumed by 1974Tw01.
4594.2	3/2+	2360	19 *3*	2233.6	5/2+			
		3328	62 *4*	1266.1	3/2+	M1+E2	−0.8 *4*	A_2=+0.41 *4*, A_4=+0.03 *5* for doubly-placed γ.
		4594	19 *3*	0.0	1/2+			
4633.6	7/2+	1219	39 *2*	3414.6	7/2+	M1+E2	+0.33 *6*	A_2=+0.64 *2*, A_4=−0.02 *2*, POL=+0.69 *15*.
		1339	36 *3*	3294.8	5/2+	M1+E2	+0.38 *4*	A_2=+0.42 *3*, A_4=+0.09 *3*, POL=+0.81 *10*.
		2400	22 *4*	2233.6	5/2+	M1+E2	+0.45 *6*	A_2=+0.47 *4*, A_4=+0.09 *5*.
		3368	3 *1*	1266.1	3/2+			E2 assumed by 1974Tw01.
4783.0	5/2+	1488	35 *4*	3294.8	5/2+	M1(+E2)	+0.04 *10*	A_2=+0.50 *5*, A_4=−0.02 *6*.
		2549	19 *3*	2233.6	5/2+			
		3517	≤8	1266.1	3/2+			
		4783	46 *4*	0.0	1/2+			
5010	(3/2+)	3749‡	25‡ *5*	1266.1	3/2+			A_2=+0.21 *4*, A_4=0.00 *4* and A_2=+0.12 *6*, A_4=+0.05 *7*. Mult=E1 estimated by 1974Tw01 but not adopted by evaluator.
		5015‡	75‡ *5*	0.0	1/2+			A_2=−0.31 *3*, A_4=+0.01 *4* and A_2=−0.22 *17*, A_4=+0.33 *20*. Mult=E1 estimated by 1974Tw01 but not adopted by evaluators.
5020	3/2−	3749‡	80‡ *10*	1266.1	3/2+			
		5015‡	20‡ *10*	0.0	1/2+			
5115.2	5/2+	1700	13 *3*	3414.6	7/2+	M1+E2	+1.6 *11*	A_2=−1.01 *26*, A_4=+0.13 *33* at 10 MeV; A_2=−0.24 *5*, A_4=+0.06 *6* at 17 MeV. δ: from +0.6<δ<+2.7.
		2881	25 *4*	2233.6	5/2+	M1+E2	+0.65 *55*	A_2=+0.55 *6*, A_4=−0.02 *7*. δ: from +0.1<δ<+1.2.
		3849	62 *4*	1266.1	3/2+	M1+E2	+0.30 *6*	A_2=+0.20 *30*, A_4=−0.06 *4*.
5258	1/2+	5258	100	0.0	1/2+	M1		A_2=+0.11 *4*, A_4=+0.01 *5*.
5343.1	9/2+	1928	82 *4*	3414.6	7/2+	M1(+E2)	+0.04 *6*	A_2=−0.42 *2*, A_4=+0.07 *3*.
		2048	8 *2*	3294.8	5/2+	E2		A_2=−0.24 *5*, A_4=+0.06 *6*.
		3109	10 *2*	2233.6	5/2+	E2		A_2=+0.47 *5*, A_4=−0.29 *5*.
5529	7/2+,(5/2+)	2114	54 *6*	3414.6	7/2+	M1+E2	+1.0 *5*	A_2=+0.53 *1*, A_4=−0.35 *12*.
		3295	46 *6*	2233.6	5/2+	M1+E2	+0.12 *5*	A_2=−0.09 *9*, A_4=+0.01 *12*.
5562		3328		2233.6	5/2+			
		5562	100	0.0	1/2+			
5672		1241	<10	4430.5	7/2−			I_γ: if I(4406γ) is negligible.
		2257	50	3414.6	7/2+			I_γ: if I(4406γ) is negligible.
		3438	50	2233.6	5/2+			I_γ: if I(4406γ) is negligible.
		4406		1266.1	3/2+			I_γ: intensity was masked by an impurity.
5773		1139	10 *5*	4633.6	7/2+			
		1583	15 *5*	4190.1	5/2+			
		2358	50 *10*	3414.6	7/2+			
		3539	25 *8*	2233.6	5/2+			
5892.4	9/2+	2477	10 *2*	3414.6	7/2+	M1+E2	+0.23 *6*	A_2=+0.15 *12*, A_4=+0.03 *14*.
		3658	90 *2*	2233.6	5/2+	E2		A_2=+0.42 *3*, A_4=−0.29 *3*.
5988		4722	100	1266.1	3/2+			
6048	7/2+	1414	27 *6*	4633.6	7/2+			
		2633	51 *4*	3414.6	7/2+	M1+E2	−0.4 *6*	A_2=+0.47 *9*, A_4=−0.03 *12*. δ: from +0.2>δ>−1.0.

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^{28}Si(α,pγ),^{4}He(^{28}Si,pγ) 1974Tw01,1979Po01 (continued)

γ(^{31}P) (continued)

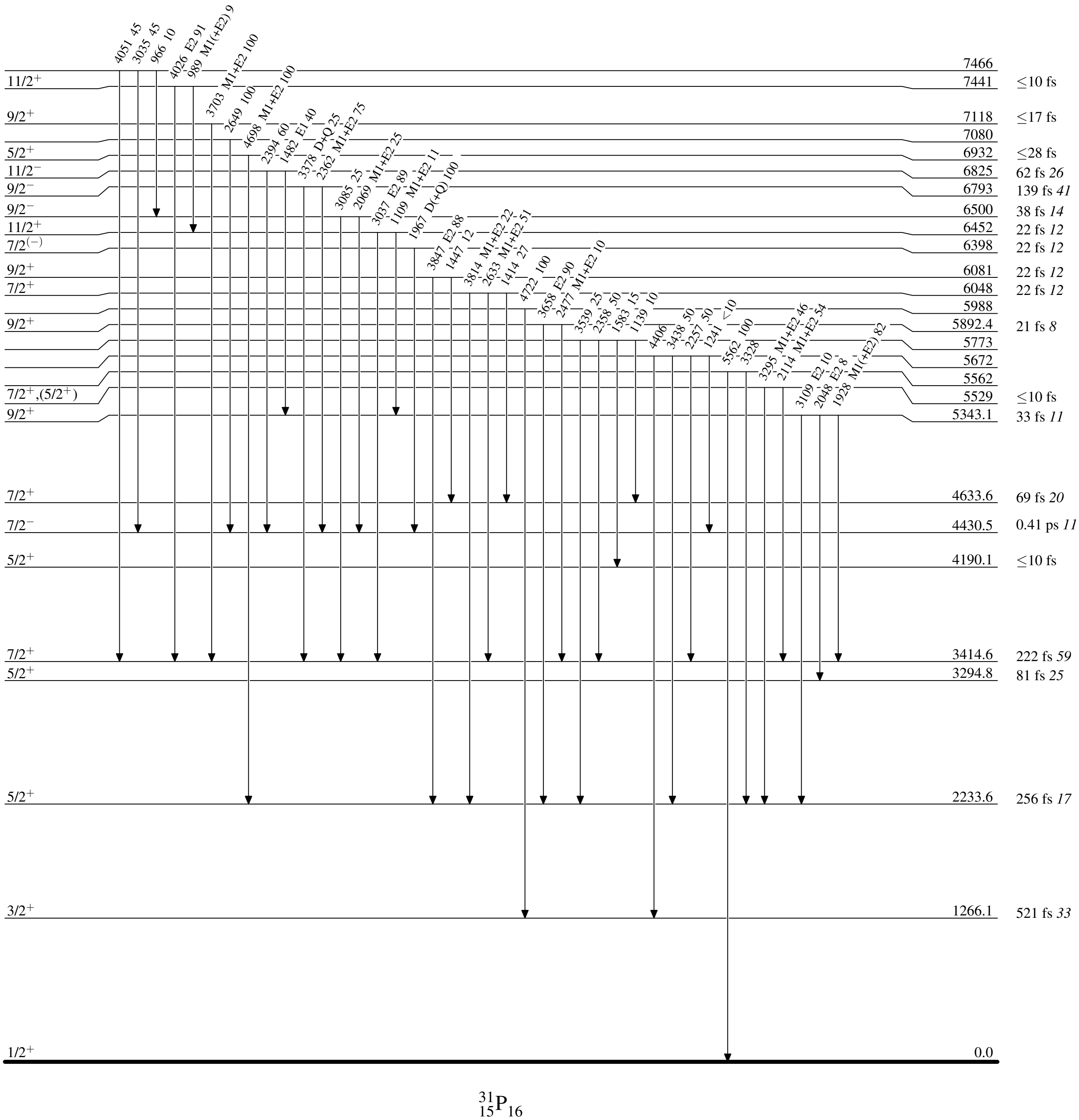
E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.†	δ†	Comments
6048	7/2$^+$	3814	22 *4*	2233.6	5/2$^+$	M1+E2	+1.2 *6*	A_2=−1.03 *17*, A_4=+0.36 *20*. δ: from +1.7>δ>+0.6.
6081	9/2$^+$	1447	12 *3*	4633.6	7/2$^+$			
		3847	88 *3*	2233.6	5/2$^+$	E2		A_2=+0.46 *2*, A_4=−0.30 *2*.
6398	7/2$^{(-)}$	1967	100	4430.5	7/2$^-$	D(+Q)	−0.03 *8*	A_2=+0.42 *4*, A_4=+0.01 *5*.
6452	11/2$^+$	1109	11 *4*	5343.1	9/2$^+$	M1+E2	+0.27 *3*	A_2=+0.21 *4*, A_4=+0.04 *4*.
		3037	89 *4*	3414.6	7/2$^+$	E2		A_2=+0.42 *2*, A_4=−0.23 *2*.
6500	9/2$^-$	2069	25 *5*	4430.5	7/2$^-$	M1+E2	+1.3 *3*	A_2=+0.92 *5*, A_4=+0.39 *6*.
		3085	25 *5*	3414.6	7/2$^+$			
6793	9/2$^-$	2362	75 *8*	4430.5	7/2$^-$	M1+E2	+0.29 *4*	A_2=−0.82 *5*, A_4=+0.08 *6*.
		3378	25 *8*	3414.6	7/2$^+$	D+Q		A_2=−0.32 *3*, A_4=+0.02 *4*.
6825	11/2$^-$	1482	40 *10*	5343.1	9/2$^+$	E1		A_2=−0.53 *4*, A_4=+0.07 *5* and A_2=−0.31 *10*, A_4=+0.01 *11*; POL=+0.52 *20*.
		2394	60 *10*	4430.5	7/2$^-$			
6932	5/2$^+$	4698	100	2233.6	5/2$^+$	M1+E2	−1.3 *3*	A_2=−0.52 *2*, A_4=−0.18 *2*.
7080		2649	100	4430.5	7/2$^-$			
7118	9/2$^+$	3703	100	3414.6	7/2$^+$	M1+E2	−0.18 *2*	A_2=−0.67 *1*, A_4=+0.06 *1*.
7441	11/2$^+$	989	9 *2*	6452	11/2$^+$	M1(+E2)	+0.3 *3*	A_2=+0.81 *8*, A_4=−0.19 *9*.
		4026	91 *2*	3414.6	7/2$^+$	E2		A_2=+0.45 *3*, A_4=−0.24 *4*.
7466		966	10 *5*	6500	9/2$^-$			
		3035	45 *10*	4430.5	7/2$^-$			
		4051	45 *10*	3414.6	7/2$^+$			

† From pγ(θ) in 1974Tw01, with magnetic or electric nature determined based on RUL and measured lifetime where available.
‡ Multiply placed with undivided intensity.

$^{28}Si(\alpha,p\gamma),^{4}He(^{28}Si,p\gamma)$ 1974Tw01,1979Po01

Level Scheme

Intensities: % photon branching from each level



^{28}Si(α,pγ),^{4}He(^{28}Si,pγ) 1974Tw01,1979Po01

Level Scheme (continued)

Intensities: % photon branching from each level
& Multiply placed: undivided intensity given