^{31}Ar ε decay (15.0 ms) 2000Fy01,2014Ko17,1998Ax02

History

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

Parent: ^{31}Ar: E=0; J$^{\pi}$=5/2^{+}; T$_{1/2}$=15.0 ms *3*; Q(ε)=18.49×10^{3} *10*; %ε+%β^{+} decay=100.0

^{31}Ar-J$^{\pi}$,T$_{1/2}$: From Adopted Levels of ^{31}Ar.

^{31}Ar-Q(ε): 18490 *100* from 2000Fy01, deduced from the energy of the IAS state at 12322 *50* (from observed proton groups) and estimated Coulomb displacement energy of 6.95 MeV *9* (extrapolated from three higher-A isotopes). Other: 18360 *200* (syst,2021Wa16).

^{31}Ar-%ε+%β^{+} decay: %ε+%β^{+}=100 (mostly β^{+}), %β^{+}p=68.3 *3*, %β^{+}2p=8.9 *2*, %β^{+}3p=0.07 *2* from Adopted Levels of ^{31}Ar, based on data from 2015Li20 and 2000Fy01. Note that summed proton branching ratio is 62% *6*, for all observed and resolved proton branches which are assigned to proton decay of excited states in ^{31}Cl from data in 2000Fy01. The missing delayed proton branch of 15% *9* is attributed by 2000Fy01 to unresolved one or two-proton decays.

Most studies deal with measurement of delayed protons following ε+β^{+} decay. No γ-rays are observed in the decay of ^{31}Ar to ^{31}Cl since the first excited state is unbound towards proton emission.

2000Fy01: ^{31}Ar from 1 GeV protons bombarding CaO target at CERN-ISOLDE facility. Measured protons, βp and βpp coin, pp energy correlations. 15 p-i-n diodes, a double sided Si strip and surface barrier detector used to distinguish p from β and measure protons, pβ, βpp coin. A HPGe was also used for γ-ray detection. 1999Fy01 from the same group measured upper limit of delayed three-proton decay mode. See also 2002Bo29, 2002Fy01, 2000Bo59 and 1999Th09.

2014Ko17, 2013Ko13, 2014Ko34, 2016Ma17: ^{31}Ar from Ca(p,X) at CERN-ISOLDE facility. Measured Eγ, E(p), I(p), pγ-coin, pp-coin, pp(θ), half-life of ^{31}Ar decay with six DSSSDs and two Miniball Miniball cluster detectors.

1998Ax02 (from same group as 2000Fy01): measured E(p), I(p), βp coin, β2p coin, $\beta\gamma$ coin. See 2000Fy01 for details.

1998Ax01 (from same group as 2000Fy01): mainly on measurement of two-proton emission from ^{31}Ar decay; three proton groups reported. See 2000Fy01 for details. 1998Mu06 is a conference report from the same group.

Others:

2016Ka15: mass excess of ^{31}Cl, produced in ^{32}S(p,2n), E=40 MeV, measured using JYFLTRAP double-Penning-trap mass spectrometer at the IGISOL facility. Analysis of IMME for T=3/2 quartet in A=31 nuclides. Measured mass excess=−7034.7 keV *34* (2016Ka15). From this value, authors deduce S(p)(^{31}Cl)=264.6 keV *34* (value in 2021Wa16 is 264 keV *3*).

2015Li20 (also 2016Ci05): ^{31}Ar from ^{9}Be(^{36}Ar,X) E=880 MeV/nucleon at GSI. Measured E(p), I(p), ^{31}Ar-p-coin using gaseous optical-readout time-projection chamber (OTPC). Deduced branching ratios for β^{+}p, β^{+}2p and β^{+}3p modes.

1992Ba01: ^{31}Ar from ^{36}Ar(^{58}Ni,X) E=85 MeV/nucleon at LISE-GANIL facility and implanted in a Si detector. Additional Si telescopes allowed measurement of βp and βpp coin. Other papers by the same group: 1987Bo36, 1991Bo32. It appears that there is an energy shift of as much as 400 keV between the spectra of 1992Ba01 and 2000Fy01, the former being higher. A proton peak at 9260 keV reported in 1992Ba01 possibly corresponds to 8860 keV group in 2000Fy01.

1990Bo24: ^{31}Ar produced by 600-MeV protons bombarding CaO target at CERN-ISOLDE. Mass separation measured E(p) and βp coin and pp coin. No evidence found for two-proton decay.

1989Re02: ^{31}Ar from reaction: Mg(^{3}He,X) E=110, 135 MeV at LBNL. Measured delayed one-proton and two-proton spectra, mass excess.

Re-analysis of existing delayed proton decay data:

Measured mass excess=−7034.7 keV *34* (2016Ka15). From this value, authors deduce S(p)(^{31}Cl)=264.6 keV *34*, which is combined with the β-delayed proton decay data for ^{31}Ar and used by 2016Ka15 to obtain revised values of level energies and proton resonances of ^{31}Cl.

2009Wr03: in the analysis of ^{30}S(p,γ)^{31}Cl reaction rates they refer to two resonances in ^{31}Cl at 461 *15* and 1462 *5*, apparently from beta decay experiments of 1998Ax01. It should be noted however that the so-called first excited state at 754 (resonance at 461) is non-existent in the most recent work from the authors of 1998Ax01. Although a level is expected from mirror arguments.

All data given here are from 2000Fy01, unless otherwise stated. The evaluators assume that data in 2000Fy01 supersede those in their earlier work in 1998Ax02. It is mentioned in 2000Fy01 that a number of proton peaks were incorrectly assigned to feed low-lying states in ^{30}S.

^{31}Ar ε decay (15.0 ms) 2000Fy01,2014Ko17,1998Ax02 (continued)

^{31}Cl Levels

Measured (lab) proton energies and relative (100 for 2084 keV group from 2444 level in ^{31}Cl) proton branches deexciting ^{31}Cl levels from 2000Fy01 are given under comments. Absolute branches can be obtained using a multiplicative factor of 0.26 *3*. This normalization factor is from weighted averaged absolute intensity of 29% *3* for 2008+2084 unresolved group measured by 1992Ba01 and 1991Bo32.

E(level)†	Jπ‡	$T_{1/2}$	Comments
0	3/2+	190 ms *1*	$T_{1/2}$: from ^{31}Cl Adopted Levels.
737 *22*	(1/2+)		E(level): from ^{31}Cl Adopted Levels.
1728 *4*	(5/2)+		E(level): from ^{31}Cl Adopted Levels. Others: 1749 *5* (1998Ax02), 1820 (1992Ba01).
2418 *4*	(3/2,5/2,7/2)+		E(p)=2084 *2* to g.s. in ^{30}S, I(p)=100.0 *6*. Additional information 1.
2593 *4*	(3/2,5/2,7/2)		E(p)=2253 *2* to g.s. in ^{30}S, I(p)=4.0 *3*. Additional information 2.
2669 *5*	(3/2,5/2,7/2)+		E(p)=2327 *4* to g.s. in ^{30}S, I(p)=5.1 *4*.
3622 *5*	(3/2,5/2,7/2)		E(p)=3249 *4* to g.s. in ^{30}S, I(p)=1.17 *15*.
4020 *4*	(3/2,5/2,7/2)+		E(p)=3634 *3* to g.s. in ^{30}S, I(p)=6.1 *8*; E(p)=1504 *2* to 2211 level, I(p)=6.2 *2*. Additional information 3.
5365 *4*	(3/2,5/2,7/2)+		E(p)=1643 *2* to 3403 level in ^{30}S, I(p)=2.88 *14*.
5598 *4*	(3/2,5/2,7/2)+		E(p)=3020 *3* to 2211 level in ^{30}S, I(p)=1.08 *14*; E(p)=1870 *3* to 3403 level, I(p)=0.8 *2*.
5731 *7*	(3/2,5/2,7/2)+		E(p)=5276 *5* to g.s. in ^{30}S, I(p)=17.6 *3*; E(p)=3153 *4* to 2211 level, I(p)=0.44 *10*; E(p)=2008 *2* to 3403 level, I(p)=10.0 *2*. Additional information 4.
6512 *4*	(3/2,5/2,7/2)+		E(p)=6049 *9* to g.s. in ^{30}S, I(p)=0.51 *12*; E(p)=3902 *3* to 2211 level, I(p)=2.22 *14*. Additional information 5.
6640 *7*	(5/2,7/2)+#		E(p)=6145 *7* to g.s. in ^{30}S, I(p)=0.51 *12*; E(p)=4030 *3* to 2211 level, I(p)=7.0 *2*; E(p)=2881 *3* to 3403 level, I(p)=0.99 *13*; E(p)=1211 *4* to 5136 level, I(p)=1.7 *5*; E(p)=1131 *5* to 5217 level, I(p)=2.7 *16* (connected with two-proton decay). Additional information 6. E(level): other: 6674 *6* (2014Ko17). pp(θ): A_2=−0.12 *14* (2014Ko17).
6825 *14*	(3/2,5/2,7/2)		E(p)=1300 *13* to 5217 level in ^{30}S, I(p)=0.70 *11* (connected with two-proton decay). Additional information 7.
7361 *3*	(3/2,5/2,7/2)+		E(p)=4730 *5* to 2211 level in ^{30}S, I(p)=1.68 *18*; E(p)=3561 *11* to 3403 level, I(p)=3.6 *8*; E(p)=1819 *3* to 5217 level, I(p)=3.0 *4* (connected with two-proton decay). E(level): other: 7380 *6* (2014Ko17). pp(θ): A_2=+0.16 *11* (2014Ko17).
7465 *9*	(3/2,5/2,7/2)+		E(p)=6950 *9* to g.s. in ^{30}S, I(p)=0.70 *9*; E(p)=3432 *3* to 3668 level, I(p)=0.89 *11*; E(p)=1923 *3* to 5217 level, I(p)=0.44 *14* (connected with two-proton decay). Additional information 8. E(level): other: 7512 *7* (2014Ko17) could be a different level considering the unmatched energy. pp(θ): A_2=+0.35 *19*.
7576 *10*	(3/2,5/2,7/2)		E(p)=7074 *9* to g.s. in ^{30}S, I(p)=0.49 *7*. Additional information 9.
7919 *8*	(3/2)+#		E(level): from 2014Ko17 only, based on measured proton decay to 5217 *3* level in ^{30}S; not reported in 2000Fy01. pp(θ): A_2=+0.48 *19* (2014Ko17).
9416 *5*	(3/2,5/2,7/2)+		E(p)=8860 *19* to g.s. in ^{30}S, I(p)=0.22 *19*; E(p)=3806 *4* to 5217 level, I(p)=0.53 *13* (doubly placed divided I(p) given). E(level): other: 9434 *9* (2014Ko17). pp(θ): A_2=+0.04 *19* (2014Ko17).
12282 *7*	5/2+		Additional information 10.

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^{31}Ar ε decay (15.0 ms) 2000Fy01,2014Ko17,1998Ax02 (continued)

^{31}Cl Levels (continued)

E(level)†	Jπ‡	Comments
		E(level): IAS of ^{31}Ar ground state. Other: 12314 *4* (2014Ko17). E(p)=11654 *28* to g.s. in ^{30}S, I(p)=0.27 *4*; E(p)=9493 *20* to 2211 level, I(p)=0.30 *4*; E(p)=8347 *15* to 3403 level, I(p)=0.51 *6*; E(p)=8092 *14* to 3670 level, I(p)=0.25 *4*. Branches connected with two-proton decay: E(p)=6540 *8* to 5217 level in ^{30}S, I(p)=0.84 *11*; E(p)=6386 *7* to 5389 level, I(p)=0.26 *5*; E(p)=5952 *7* to 5842 level, I(p)=0.19 *6*; E(p)=5632 *6* to 6202 level, I(p)=0.37 *9*; E(p)=4389 *5* to 7485 level, I(p)=0.59 11; E(p)=4289 *4* to 7598 level, I(p)=0.31 *8*; E(p)=4200 *4* to 7693 level, I(p)=1.09 *18*; E(p)=3806 *4* to 8077 level (doubly placed). Contribution from delayed two-proton branches to ^{29}P (I(p) given as absolute intensity): %I(p)=1.86 *21* for Q_{2p}=7620 *5* (to g.s. in ^{29}P); %I(p)=1.07 *13* for Q_{2p}=6246 *2* (to 1383.55 level in ^{29}P); %I(p)=0.75 *10* for Q_{2p}=5679 *3* (to 1953.91 level in ^{29}P); %I(p)=0.22 *5* for Q_{2p}=5223 *5* (to 2422.7 level in ^{29}P). pp(θ): A_2=+0.03 *18* (2014Ko17).
12521 *30*	(3/2,5/2,7/2)$^+$	E(p)=11858 *29* to g.s. in ^{30}S, I(p)=0.034 *3* (2000Fy01).

† Values given in 2000Fy01 from E(p)(lab)×[1+M(p)/M(^{30}S)]+E_x(^{30}S)+S(p)(^{31}Cl), where S(p)=290 *50* (2003Au03) was used. These values have been adjusted by the evaluators using S(p)=264 *3* (2021Wa16). Average is taken where multiple proton branches are available. Note that 1998Ax02 (from the same group as 2000Fy01) proposed many additional levels based on their observed proton branches, but 2000Fy01 state that a number of assignments in 1998Ax02 of proton groups to corresponding levels in ^{31}Cl were incorrect since the two-proton branches were not appropriately considered. Some proton branches (446, 754, 844, 974, 4466 and 4624 keV) listed in table 3 of 1998Ax02 were not reported by 2000Fy01. The evaluators assume that data in 2000Fy01 supersede those in 1998Ax02. Values from 2014Ko17 are given under comments, which are deduced by the authors from measured proton decay to 5227 3 level in ^{30}S, which corresponds to the 5217.4 *7* level with J^π=(0$^+$) in Adopted Levels of ^{30}S in the ENSDF database (2010Ba29).

‡ (3/2,5/2,7/2)$^+$ for allowed β feeding (log *ft*<5.9 and (3/2,5/2,7/2) for others, unless otherwise noted. The same assignments are adopted in Adopted Levels.

\# From 2014Ko17 based on pp(θ) analysis and concluded J^π=3$^+$ for 5227 *3* level in ^{30}S, which corresponds to the 5217.4 *7* level with J^π=(0$^+$) in Adopted Levels of ^{30}S in the ENSDF database (2010 update).

ε,β$^+$ radiations

E(decay)	E(level)	Iβ$^+$ ‡	Iε‡	Log *ft*	I(ε+β$^+$)†‡	Comments
(5.97×10^3 *11*)	12521	0.0090 *12*		5.72 *8*	0.0090 *12*	av Eβ=2286 *51*
(6.21×10^3 *10*)	12282	5.3 *3*	0.0033 *3*	3.04 *5*	5.3 *3*	av Eβ=2403 *50*; εK=0.00056 *4*; εL=5.4×10^{-5} *4*; εM+=6.9×10^{-6} *5* I(ε+β$^+$): from sum of one-proton and two-proton branches. It appears that single-proton branches connected with sequential two-proton decay were omitted by 2000Fy01 in determination of total ε+β$^+$ feeding of a 12314 level. 2000Fy01 give 4.25 *30*. Others: 5.5 *13* (1992Ba01), 4.8 *14* (1991Bo32).
(9.07×10^3 *10*)	9416	0.21 *6*		5.34 *13*	0.21 *6*	av Eβ=3815 *50*
(1.091×10^4 *10*)	7576	0.13 *2*		5.98 *7*	0.13 *2*	av Eβ=4727 *50*
(1.103×10^4 *10*)	7465	0.53 *8*		5.39 *7*	0.53 *8*	av Eβ=4782 *50*
(1.113×10^4 *10*)	7361	2.2 *3*		4.79 *7*	2.2 *3*	av Eβ=4834 *50*
(1.167×10^4 *10*)	6825	0.18 *3*		5.99 *8*	0.18 *3*	av Eβ=5100 *51*
(1.185×10^4 *10*)	6640	3.4 *3*		4.75 *5*	3.4 *3*	av Eβ=5192 *50*
(1.198×10^4 *10*)	6512	0.71 *9*		5.45 *6*	0.71 *9*	av Eβ=5256 *50*
(1.276×10^4 *10*)	5731	7.4 *8*		4.58 *5*	7.4 *8*	av Eβ=5644 *50*
(1.289×10^4 *10*)	5598	0.50 *7*		5.77 *7*	0.50 *7*	av Eβ=5710 *50*

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^{31}Ar ε decay (15.0 ms) 2000Fy01,2014Ko17,1998Ax02 (continued)

ϵ,β^+ radiations (continued)

E(decay)	E(level)	Iβ^+ ‡	Log *ft*	I($\varepsilon+\beta^+$)†‡	Comments
(1.313×10^4 *10*)	5365	0.76 *9*	5.63 *6*	0.76 *9*	av Eβ=5826 *50*
(1.447×10^4 *10*)	4020	3.2 *4*	5.23 *6*	3.2 *4*	av Eβ=6496 *50*
(1.487×10^4 *10*)	3622	0.31 *5*	6.30 *8*	0.31 *5*	av Eβ=6694 *50*
(1.582×10^4 *10*)	2669	1.3 *2*	5.82 *7*	1.3 *2*	av Eβ=7169 *50*
(1.590×10^4 *10*)	2593	1.05 *13*	5.92 *6*	1.05 *13*	av Eβ=7207 *50*
(1.607×10^4 *10*)	2418	26 *3*	4.55 *6*	26 *3*	av Eβ=7294 *50* I($\varepsilon+\beta^+$): other: 26.2 *29* in 1998Ax02. Additional information 11.
(1.676×10^4 *10*)	1728	9.0 *9*	5.11 *5*	9.0 *9*	av Eβ=7638 *50* I($\varepsilon+\beta^+$): other: 9.8 *2* in 1998Ax02.
(1.849×10^4 *10*)	0	22.6 *3*	4.93 *2*	22.6 *3*	av Eβ=8500 *50* I($\varepsilon+\beta^+$): from 100−%(β^+p+β^+2p+β^+3p) in 2015Li20. Other: 23 *8* from 1998Ax02, deduced from measured total intensity of delayed protons normalized to 29% *3* for the intensity of the 2008+2084 proton group. Using other (less accurate) methods, 1998Ax02 have deduced the following values for g.s. feeding: >16% by comparing intensities of emitted protons and positrons and using I(ce)/I(β^+)<0.0001; 30 *10* from measured delayed proton activity from ^{31}Cl decay (assuming the isotope is formed only as daughter of ^{31}Ar decay); and 28 *4* from log *ft*=4.77 *5* for the mirror transition. Note that 2000Fy01 list 23.0 *8* as taken from 1998Ax02, but uncertainty is a misprint.

† From 2000Fy01 for excited states, deduced from summed proton branches, normalization factor of 0.26 *3* is used to convert relative intensities to absolute intensities. The evaluators have added 10% in quadrature to the uncertainties for feedings to 2444 level since 2000Fy01 did not seem to account for the uncertainty in the normalization factor of 0.29 *3* from 1992Ba01 and 1991Bo32. It should be noted that 15% *9* of the delayed-proton decay branch is still unaccounted for and is not assigned to any level, which is attributed by 2000Fy01 to unresolved one or two-proton decays.

‡ Absolute intensity per 100 decays.