^{32}Ar $\varepsilon+\beta^+$ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01

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

Parent: ^{32}Ar: E=0.0; J$^{\pi}$=0$^+$; T$_{1/2}$=98 ms *2*; Q(ε)=11134.4 *19*; %ε+%β^+ decay=100

^{32}Ar-T$_{1/2}$: From timing of delayed protons distinguishing β^+ and γ-rays through pulse-shape discrimination (1985Bj01); value is adopted in Adopted Levels. Others: 2008Bh08 quote 100.5 ms *3* from unpublished ISOLDE data (reference 10 in 2008Bh08; this value was also communicated to one of the evaluators by A. Garcia in an e-mail reply of November 21, 2006); ≈75 ms (1977Ha29).

^{32}Ar-Q($\varepsilon+\beta^+$): From 2021Wa16. Q(εp)(^{32}Ar)=9553.2 *18*, S(p)(^{32}Cl)=1581.1 *5* and S(2p)=7711.8 *6* (2021Wa16).

^{32}Ar-%ε+%β^+ decay: %εp=35.58 *22* (2008Bh08). Other: 43 *3* estimated by (1985Bj01) assuming the superallowed transition was followed uniquely by proton decay. Absolute intensities of proton groups are from the determination of total number of implanted ^{32}Ar ions and protons, and detector efficiencies (2008Bh08).

2021Bl02: ^{32}Ar ions were produced in projectile fragmentation of ^{36}Ar beam at 95 MeV/nucleon from the CSS cyclotrons of GANIL on a graphite target, and separated using the NANOGAN-III ECR ion source and isotopic identification system of SPIRAL1. Charged particles were detected with a cube of six double-sided silicon strip detectors (DSSSDs; FWHM=order of 50 keV) backed by large-area silicon detectors (LASDs) and γ rays were detected with three EXOGAM clover detectors. Measured β^+-delayed proton spectra, E(p), I(p), Eγ, Iγ, pγ-coin. Deduced absolute intensities of β^+-delayed proton branches, γ-ray branching ratios, β^++ε feedings to levels in ^{32}Cl and log *ft* values. Comparisons with available data and shell-model calculations.

2008Bh08: ^{32}Ar ions were produced in the reaction ^{9}Be(^{36}Ar,X) with a 100 MeV/nucleon beam on a ^{9}Be target at NSCL and separated by the A1200 fragment separator and the Reaction Product Mass Separator (RPMS) Wien filter. Charged particles were detected with a detector array consisting of a PIN silicon detector and a stack of three fully-depleted silicon surface barrier detectors; γ rays were detected with five large-volume HPGe detectors. Measured Eγ, Iγ, E(p), I(p), pγ-coin. Deduced levels, absolute intensities of β^+-delayed proton branches, log *ft* of T=2, superallowed transition from 0$^+$ parent state of ^{32}Ar to 0$^+$ excited state at 5246 keV in ^{32}Cl. Comparisons with available data and theoretical calculations. 2008Bh08 deduced isospin symmetry breaking correction in ^{32}Ar decay δ_C^{exp}=2.1% *8*.

Additional information 1.

1985Bj01: ^{32}Ar ions were produced in spallation reactions with 600 MeV protons from the CERN Synchro-cyclotron on a CaO target, and separated by the ISOLDE on-line isotope separator. Charged particles were detected with a CsI crystal, silicon detectors (FWHM=28 keV for proton at E=5.6 MeV) and a 4π β-detector of plastic scintillator; γ rays were detected with a Ge(Li) detector. Measured decay curves of β and proton, E(p), I(p), Eγ, Iγ, $\beta\gamma$-coin, pγ-coin. Deduced levels, parent T$_{1/2}$, absolute intensities of β^+-delayed proton branches, β-decay branching ratios, log *ft*, γ-ray branching ratios, Gamow-Teller strength functions. Comparisons with shell-model calculations.

1993Sc16: ^{32}Ar ions were produced in spallation reactions with 600 MeV protons on a CaO target and separated with the ISOLDE-II separator at CERN. Charged particles were detected with a silicon surface barrier detector (FWHM≈8 keV for proton at ≈3 MeV). Measured E(p), I(p). Deduced levels, absolute intensities of β^+-delayed proton branches, level widths from analysis of proton peak shape. Comparisons with theoretical calculations.

Others:

2007DoZX: Measured proton energies and intensities of 19 groups at GANIL facility, pγ coin. The protons range from 594.1 to 6056 keV. Most of these groups are in agreement with those from 2008Bh08 and earlier studies. However, one severe discrepancy is noted that 1203.7-keV proton group is shown to be in coin with a 2230-keV γ ray (presumably corresponding to known 2236γ in ^{31}S), but in 2008Bh08, this proton group was observed strongly in coin with 1248γ from the first excited state of ^{31}S. Moreover the deduced level excitation energy quoted by 2007DoZX as 6295 for the 1203.7 proton group seems to be in error if this group is in coin with 2236γ. In view of the lack of sufficient details in 2007DoZX and noted inconsistencies, the evaluators feel that it is premature to consider data from 2007DoZX for current evaluation.

2019ArZX: measured β-neutrino correlation.

1999Ad10, 2000Ga61: measured proton spectra, pβ coin. Same group as 2008Bh08.

1977Ha29: ^{32}Ar formed in 600-MeV proton bombardment of vanadium target at CERN-ISOLDE facility. Measured delayed protons, half-life.

The total energy deposit calculated using RADLIST code is 9390 *150*, and is about 1750 keV less than Q=11134.4 *19* (2021Wa16), which might be attributed to the unobserved or unidentified weak proton-decay branches. 2021Bl02 report a correction factor of 1.033 *14* as a ratio of all emitted protons to the sum of all observed proton branches.

^{32}Ar ε+β^+ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01 (continued)

^{32}Cl Levels

4167 and 4439 levels proposed in 1985Bj01 are discarded because the proton branches (E(p)=2512 and 2775 here) attributed to ^{31}S ground state by 1985Bj01 are clearly identified in 2021Bl02 as decay to the first excited states in ^{31}S, corresponding to 5425 and 5700 levels, respectively. The 5794 level only in 2008Bh08 from a broad 2870-keV proton peak is also discarded since the proton peak is not seen 2021Bl02 and 1985Bj01.

E(level)†	J^{π}‡	$T_{1/2}$#	Comments
0	1^+	298 ms *1*	ε feeding to g.s. is assumed to be negligible (2021Bl02). 1985Bj01 report that g.s. feeding is limited to <2% by intensity balance to levels in ^{32}S from the decay of g.s. of ^{32}Cl; 2021Bl02 give a range of 0.007% to 5.6% based on theoretical predictions.
89.90 *10*	$(2)^+$		No evidence of β feeding of this level.
461.12 *9*	$(0)^+$		No evidence of β feeding of this level.
1168.48 *14*	1^+		
2209.9 *11*	(1^+)		E(level): 2208 *6* from E(p). E(p0)=606.9 *60*.
3771 *4*	1^+	3 keV *2*	E(p0)=2121.3 *40*, E(p1)=912 *5*.
4082 *4*	1^+	17 keV *2*	E(p0)=2422.9 *40*, E(p1)=1210.8 *42*.
4561 *13*	(1)		E(p1)=1677 *12*.
4800 *5*	(1)		E(p0)=3117.4 *47*.
5046.24 *33*	0^+	20 eV *5*	T=2 Γ_{γ}=1.7 eV *4* (2008Bh08) E(level): 5044 *3* from E(p). E(p0)=3352.7 *30*, E(p1)=2145.5 *50*. Γ from ISOLDE data (quoted by 2008Bh08 as paper in preparation). E(level): IAR of ^{32}Ar g.s.
5303 *4*	1^+		E(p0)=3605 *8*, E(p1)=2395.1 *41*.
5425 *4*	1^+	35 keV *20*	E(p0)=3725.9 *48*, E(p1)=2511.9 *40*.
5531 *9*	1^+		E(p1)=2616 *9*.
5700 *5*	1^+	25 keV *15*	E(p0)=3991 *5*, E(p1)=2775.4 *65*.
6065 *6*	1^+		E(p0)=4344.9 *41*, E(p1)=3117 *11*.
6254 *5*	1^+		E(p0)=4526 *5*.
6529 *5*	1^+		E(p1)=3583 *5*.
6597 *5*	1^+		E(p1)=3649 *5*.
6732 *6*	1^+		E(p0)=4977 *9*, E(p1)=3782 *5*. E(level): 6686 *13* (1993Sc16), 6711 *30* (1985Bj01).
7320 *4*	1^+	20 keV *10*	E(p0)=5558 *4*, E(p1)=4348 *10*.
7450 *10*	1^+	<15 keV	E(p0)=5684 *10*.
7600 *6*	1^+		E(p0)=5822 *6*, E(p1)=4625 *5*.
7852 *5*	1^+		E(p0)=6068 *7*, E(p1)=4867 *5*.
8146 *9*	1^+		E(p0)=6358 *9*.

† From Eγ data for excited levels connected with γ transitions and from measured proton energies E(p)(lab) of β-delayed proton branches for other levels, with E(level)=E(p)(lab)*[1+m(p)/m(^{31}S)]+S(p)+E(level)(^{31}S). E(p)(lab) under comments are average (weighted or unweighted) of values from 2021Bl02, 2008Bh08, 1985Bj01 and 1993Sc16 if available, where p0 for proton decay to g.s. in ^{31}S and p1 for proton to the first excited state at 1248.6 in ^{31}S. See all E(p) data in the dataset of ^{32}Ar εp decay for ^{31}S in the ENSDF database (2022 update).

‡ From Adopted Levels.

Half-life from Adopted Levels and Γ from 1993Sc16 deduced from measured peak shape and calculated recoil broadening.

^{32}Ar ε+β^+ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01 (continued)

ε,β^+ radiations

E(decay)	E(level)	Iβ^+ ‡	Iε‡	Log *ft*	I($\varepsilon+\beta^+$)†‡	Comments
(2988 *9*)	8146	0.0115 *17*	1.3×10^{-4} *2*	4.6 *1*	0.0116 *17*	av Eβ=854.2 *43*; εK=0.01019 *14*; εL=9.73×10^{-4} *14*; εM+=1.254×10^{-4} *18* E(p0)=6358 *9*, %I(p0)=0.0116 *17*.
(3282 *6*)	7852	0.074 *7*	5.6×10^{-4} *5*	4.08 *4*	0.075 *7*	av Eβ=991.4 *25*; εK=6.704×10^{-3} *48*; εL=6.404×10^{-4} *46*; εM+=8.248×10^{-5} *59* E(p0)=6068 *7*, %I(p0)=0.0222 *23*. E(p1)=4867 *5*, %I(p1)=0.053 *6*.
(3534 *7*)	7600	0.121 *11*	6.6×10^{-4} *6*	4.07 *4*	0.122 *11*	av Eβ=1110.1 *30*; εK=4.884×10^{-3} *37*; εL=4.665×10^{-4} *35*; εM+=6.008×10^{-5} *45* E(p0)=5822 *6*, %I(p0)=0.087 *7*. E(p1)=4625 *5*, %I(p1)=0.035 *8*.
(3684 *10*)	7450	0.0043 *16*	2.0×10^{-5} *7*	5.6 *+1−2*	0.0043 *16*	av Eβ=1181.2 *48*; εK=4.106×10^{-3} *47*; εL=3.922×10^{-4} *45*; εM+=5.051×10^{-5} *58* E(p0)=5684 *10*, %I(p0)=0.0043 *16*.
(3814 *5*)	7320	0.139 *10*	5.5×10^{-4} *4*	4.22 *3*	0.139 *10*	av Eβ=1242.9 *21*; εK=3.561×10^{-3} *17*; εL=3.401×10^{-4} *16*; εM+=4.380×10^{-5} *21* E(p0)=5558 *4*, %I(p0)=0.112 *5*. E(p1)=4348 *10*, %I(p1)=0.027 *8*.
(4402 *7*)	6732	0.088 *31*	2.0×10^{-4} *7*	4.8 *+1−2*	0.088 *31*	av Eβ=1524.3 *30*; εK=2.014×10^{-3} *11*; εL=1.923×10^{-4} *11*; εM+=2.477×10^{-5} *14* E(p0)=4977 *9*, %I(p0)=0.0129 *35*. E(p1)=3782 *5*, %I(p1)=0.075 *31*.
(4537 *6*)	6597	0.066 *6*	1.3×10^{-4} *1*	4.99 *4*	0.066 *6*	av Eβ=1589.3 *26*; εK=1.7928×10^{-3} *81*; εL=1.7118×10^{-4} *78*; εM+=2.205×10^{-5} *10* E(p1)=3649 *5*, %I(p1)=0.066 *6*.
(4605 *6*)	6529	0.051 *8*	1.0×10^{-4} *2*	5.1 *1*	0.051 *8*	av Eβ=1622.1 *26*; εK=1.6935×10^{-3} *75*; εL=1.6169×10^{-4} *72*; εM+=2.0824×10^{-5} *93* E(p1)=3583 *5*, %I(p1)=0.051 *8*.
(4880 *6*)	6254	0.093 *4*	1.40×10^{-4} *6*	5.02 *2*	0.093 *4*	av Eβ=1755.0 *26*; εK=1.3593×10^{-3} *56*; εL=1.2978×10^{-4} *54*; εM+=1.6714×10^{-5} *69* E(p0)=4526 *5*, %I(p0)=0.093 *4*.
(5069 *7*)	6065	0.117 *9*	1.5×10^{-4} *1*	5.02 *4*	0.117 *9*	av Eβ=1846.5 *31*; εK=1.1793×10^{-3} *55*; εL=1.1258×10^{-4} *52*; εM+=1.4500×10^{-5} *67* E(p0)=4344.9 *41*, %I(p0)=0.101 *4*. E(p1)=3117 *11*, %I(p1)=0.016 *8*.
(5434 *6*)	5700	0.300 *22*	3.0×10^{-4} *2*	4.78 *3*	0.300 *22*	av Eβ=2023.9 *26*; εK=9.126×10^{-4} *33*; εL=8.712×10^{-5} *31*; εM+=1.1220×10^{-5} *40* E(p0)=3991 *5*, %I(p0)=0.212 *15*. E(p1)=2775.4 *65*, %I(p1)=0.088 *16*.
(5603 *9*)	5531	0.051 *12*		5.6 *1*	0.051 *12*	av Eβ=2106.2 *45*; εK=8.163×10^{-4} *49*; εL=7.792×10^{-5} *47*; εM+=1.0036×10^{-5} *60* E(p1)=2616 *9*, %I(p1)=0.051 *12*.
(5709 *5*)	5425	0.79 *4*	6.7×10^{-4} *4*	4.48 *2*	0.79 *4*	av Eβ=2157.9 *22*; εK=7.628×10^{-4} *21*; εL=7.281×10^{-5} *21*; εM+=9.377×10^{-6} *26* E(p0)=3725.9 *48*, %I(p0)=0.082 *4*. E(p1)=2511.9 *40*, %I(p1)=0.71 *4*. 1985Bj01 and 1993Sc16 attribute this proton branch to ^{31}S g.s., which however is clearly identified in 2021Bl02 as decay to the first excited states in ^{31}S.
(5831 *5*)	5303	0.191 *24*	1.50×10^{-4} *19*	5.15 *6*	0.191 *24*	av Eβ=2217.4 *22*; εK=7.068×10^{-4} *19*; εL=6.747×10^{-5} *19*; εM+=8.689×10^{-6} *24* E(p0)=3605 *8*, %I(p0)=0.073 *8*.

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^{32}Ar ε+β^+ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01 (continued)

ϵ,β^+ radiations (continued)

E(decay)	E(level)	Iβ^+ ‡	Iε‡	Log *ft*	I($\varepsilon+\beta^+$)†‡	Comments
						E(p1)=2395.1 *41*, %I(p1)=0.118 *23*.
(6088.2 *22*)	5046.24	22.29 *43*	0.01496 *33*	3.19 *1*	22.30 *43*	av Eβ=2342.93 *94*; εK=6.0578×10^{-4} *68*; εL=5.7822×10^{-5} *65*; εM+=7.4468×10^{-6} *84* E(p0)=3352.7 *30*, %I(p0)=20.39 *32*. E(p1)=2145.5 *50*, %I(p1)=0.263 *13*. I($\varepsilon+\beta^+$): from I(p)+Iγ intensity balance at this level. Other: 17 *+16−7* (1977Ha29).
(6334 *6*)	4800	0.0269 *27*		6.20 *5*	0.0269 *27*	av Eβ=2463.5 *26*; εK=5.263×10^{-4} *16*; εL=5.023×10^{-5} *15*; εM+=6.469×10^{-6} *19* E(p0)=3117.4 *47*, %I(p0)=0.0269 *27*.
(6573 *13*)	4561	0.029 *14*		6.3 *+2−3*	0.029 *14*	av Eβ=2580.6 *65*; εK=4.619×10^{-4} *33*; εL=4.409×10^{-5} *31*; εM+=5.678×10^{-6} *40* E(p1)=1677 *12*, %I(p1)=0.029 *14*.
(7052 *5*)	4082	7.60 *15*	3.04×10^{-3} *7*	4.01 *1*	7.60 *15*	av Eβ=2815.9 *22*; εK=3.6142×10^{-4} *79*; εL=3.4493×10^{-5} *75*; εM+=4.4423×10^{-6} *97* E(p0)=2422.9 *40*, %I(p0)=7.28 *15*. E(p1)=1210.8 *42*, %I(p1)=0.320 *21*.
(7363 *5*)	3771	3.61 *8*	1.25×10^{-3} *3*	4.43 *1*	3.61 *8*	av Eβ=2968.9 *22*; εK=3.1137×10^{-4} *65*; εL=2.9716×10^{-5} *62*; εM+=3.8271×10^{-6} *79* E(p0)=2121.3 *40*, %I(p0)=3.60 *8*. E(p1)=912 *5*, %I(p1)=0.014 *8*.
(8924.5 *24*)	2209.9	0.143 *32*		6.3 *1*	0.143 *32*	av Eβ=3740.9 *11*; εK=1.6222×10^{-4} *13*; εL=1.5480×10^{-5} *13*; εM+=1.9936×10^{-6} *17* I($\varepsilon+\beta^+$): from I(p)+Iγ intensity balance at this level. E(p0)=606.9 *60*, %I(p0)=0.383 *10*.
(9965.9 *22*)	1168.48	63.1 *14*	0.0079 *2*	3.89 *1*	63.1 *14*	av Eβ=4256.61 *95*; εK=1.12365×10^{-4} *71*; εL=1.07218×10^{-5} *68*; εM+=1.38080×10^{-6} *87* I($\varepsilon+\beta^+$): from γ intensity balance at this level. I($\varepsilon+\beta^+$): uncertainty 0.29 in 62.57 *29* from 2021Bl02 is probably a typo, since Iγ(707.3γ)=37.2 *18* in 2021Bl02 alone has an uncertainty of 1.8 much greater than 0.29.

† From absolute intensities of β-delayed proton branches levels above S(p)=1581.1 *6* and observed γ transitions. Absolute intensities %I(p) of β-delayed proton branches are obtained by normalizing ΣI(p)(rel) to the total proton emission probability of 35.58% *22* measured by 2008Bh08 with a correction factor 1.033 *14* deduced by 2021Bl02 as a ratio of all emitted protons to the sum of all observed proton branches. Absolute proton intensities %I(p) under comments are deduced from average (weighted or unweighted) of relative I(p)(rel) values from 2021Bl02, 2008Bh08, 1985Bj01 and 1993Sc16 if available, relative to I(p)(rel)=100 of the proton branch from 5046 level to ^{31}S ground state. p0 is for proton decay to g.s. in ^{31}S and p1 for proton to the first excited state at 1248.6 in ^{31}S. See I(p) data in the dataset of ^{32}Ar εp decay for ^{31}S in the ENSDF database (2022 update).

‡ Absolute intensity per 100 decays.

$\gamma(^{32}Cl)$

Iγ normalization: Absolute %Iγ for transitions from levels below 5046 level are obtained by normalizing Σ[I(rel)(γ to g.s.)]=100−%I(p)(total)-%Iγ(5048γ), where %I(p)(total)=35.58 *22* (2008Bh08) and %Iγ(5048γ)=0.10 *2* (average of values in 2021Bl02 and 2008Bh08), which gives a normalization factor of 0.372 *12* for relative Iγ values as given under comments. No ε feeding to g.s. is assumed.

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^{32}Ar $\varepsilon+\beta^+$ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01 (continued)

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

E_γ	I_γ ‡#	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α †	Comments
89.9 *1*	13.8 *7*	89.90	(2)$^+$	0	1$^+$	[M1]	0.00979 *14*	α(K)=0.00899 *13*; α(L)=0.000732 *10*; α(M)=6.67×10^{-5} *10* E_γ: from 1985Bj01. I_γ: from Iγ(rel)=37.0 *18*, weighted average of 38.3 *32* (2021Bh02) and 37.0 *16* (1985Bj01). Mult.: M1 assumed by the evaluators based on possible shell-model description of the state. The transition cannot be pure E2 (α=0.288) since it will imply β feeding of 3.5% and allowed transition, in contradiction with J^π=(2)$^+$ for 89.9 level.
461.1 *1*	37.2 *10*	461.12	(0)$^+$	0	1$^+$			E_γ: from 1985Bj01. Other: 460.7 *4* (2021Bl02). I_γ: from Iγ(rel)=100 *5*, average of 100 *7* (2021Bl02) and 100 *5* (1985Bj01).
707.3 *2*	37.2 *10*	1168.48	1$^+$	461.12	(0)$^+$			E_γ: weighted average of 707.1 *4* (2021Bl02) and 707.4 *2* (1985Bj01). I_γ: from Iγ(rel)=100 *5*, equal to Iγ(461.1γ) (2021Bl02,1985Bj01).
1078.6 *3*	13.8 *7*	1168.48	1$^+$	89.90	(2)$^+$			E_γ: weighted average of 1078.1 *4* (2021Bl02) and 1078.7 *2* (1985Bj01). I_γ: from Iγ(rel)=37.0 *18*, equal to Iγ(89.9γ) (2021Bl02, 1985Bj01).
1168.5 *2*	13.4 *7*	1168.48	1$^+$	0	1$^+$			I_γ: from Iγ(rel)=36.0 *20*, weighted average of 31.8 *38* (2021Bh02) and 36.9 *18* (1985Bj01).
2836.2 *10*	0.24 *3*	5046.24	0$^+$	2209.9	(1$^+$)			E_γ: weighted average of 2838.7 *34* (2021Bl02) and 2836 *1* (2008Bh08). I_γ: weighted average of 0.50 *37* (2021Bl02) and 0.24 *3* (2008Bh08).
3877.5 *3*	1.31 *28*	5046.24	0$^+$	1168.48	1$^+$			E_γ: weighted average of 3877.7 *42* (2021Bl02) and 3877.5 *3* (2008Bh08). I_γ: unweighted average of 1.03 *22* (2021Bl02) and 1.58 *8* (2008Bh08).
5048 *5*	0.10 *2*	5046.24	0$^+$	0	1$^+$			E_γ: from 2021Bl02. I_γ: weighted average of 0.22 *14* (2021Bl02) and 0.10 *2* (2008Bh08).

† Additional information 2.

‡ Absolute %Iγ for transitions from levels below 5046 level are obtained by normalizing ΣI(relative γ to g.s.)=100−%I(p)(total)-%Iγ(5048γ), where %I(p)(total)=35.58 *22* (2008Bh08) and %Iγ(5048γ)=0.10 *2* (average of values in 2021Bl02 and 2008Bh08), which gives a normalization factor of 0.372 *12* for relative Iγ values as given under comments.

\# Absolute intensity per 100 decays.

^{32}Ar ε+β^+ decay (98 ms) 2021Bl02,2008Bh08,1985Bj01

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays