## $^{23}$Al $\varepsilon$ decay 2011Sa15,2011Ki26,2006Ia03

History

| Type | Author | Citation | Literature Cutoff Date |
|---|---|---|---|
| Full Evaluation | M. S. Basunia#, A. Chakraborty## | NDS 171, 1 (2021) | 1-Jun-2020 |

Parent: $^{23}$Al: E=0.0; J$^\pi$=5/2$^+$; $T_{1/2}$=446 ms *6*; Q($\varepsilon$)=12221.6 *4*; %$\varepsilon$+%$\beta^+$ decay=100.0

Other references: 2015Su15, 2014Ka01, 2012Tr08, 2002Wa33, 2001Wa54, 2000Pe28, 1998Jo20, 1995Ti08, 1972Go03, 1998RoZX (same group of 1995Ti08), and 2020Fr04.

2011Sa15,2012Tr08,2006Ia03: Source produced by $^1$H($^{24}$Mg,$^{23}$Al) at E($^{24}$Mg)=48 MeV/u. Target=2.5 mg/cm$^2$ thick liquid nitrogen cooled $H_2$ at 1.6 atm pressure. Detection system: double-sided Si strip detector (DSSSD) and a thick Si pad detector for particle detection. This system was used in implantation mode as a ΔE-E telescope to control the implantation for particles of interest, and in measurement mode to record spectra of protons. The thick Si detector served as a detector of $\beta^+$ particles. A 70% HPGe detector was used for detecting $\gamma$ rays. Measured E$\gamma$, I$\gamma$, delayed proton spectra, $\beta$p coin, $\beta\gamma$ coin.

Ref. 31 in 2006Ia03 and Ref. 25 in 2011Sa15 refer to a Ph.D. dissertation by Y. Zhai at Texas A & M (2007), which contains additional data (R. E. Tribble mentioned by e-mail to B. Singh (dated March 13, 2019) that identification of some of the gamma lines was uncertain and not included in the publication). The statements like “Transitions to and from 13 distinct excited levels in $^{24}$Mg levels are observed” or “Twenty $\gamma$-ray peaks in all were identified as originating from the decay of $^{23}$Al” in paragraphs 1 and 2 (section IV) could not be followed comparing the presented data in 2006Ia03 or dissertation.

2011Ki26: $^{23}$Al beam produced via the $^{24}$Mg(p,2n) reaction with beam energy of 40 MeV and natural self-supporting 4.3 mg/cm$^2$ thick Mg target. The mass separated ions were implanted in a carbon foil. The detection system consisted of four double-sided silicon strip detectors (DSSSD) and each one backed by unsegmented silicon detector. Measured $E_p$, $I_p$. Deduced excitation energies for proton unbound states, and branching ratios.

2014Ka01: Source produced via $^{24}$Mg(p,2n)$^{23}$Al, E=40 MeV, reaction. Measured E$\beta$, I$\beta$, E$\gamma$, I$\gamma$; deduced Gamow-Teller strengths.

2015Su15: $^{23}$Al ions were produced by fragmentation of a 75.8 MeV/nucleon primary beam of $^{28}$Si on a 1980 $\mu$m thick $^9$Be target. Measured $E_p$, $I_p$, $\beta\gamma$-coin, p$\gamma$-coin, $\beta$-proton coin, decay-time distribution. Deduced $\beta$-delayed proton decay branching ratios.

2020Fr04: $^{23}$Al $\varepsilon$p decay – measured proton emission of 204, 275, and 583 keV (c.m) resonances in $^{23}$Mg using the new device Gaseous Detector with Germanium Tagging system. Reported $I_p$ relative to $I_p$ (839 keV (lab)) of 2011Sa15. Deduced 204 keV (c.m.) resonance strength.

The decay scheme is incomplete.

### $^{23}$Mg Levels

| E(level)† | J$^\pi$‡ | Comments |
|---|---|---|
| 0.0 | 3/2$^+$ | |
| 451 *1* | 5/2$^+$ | |
| 2051 *1* | 7/2$^+$ | |
| 7788 *1* | 3/2$^+$,5/2$^+$ | E(level): Others: 7787 *11* from E(p)(c.m.)=206 *11* (2011Sa15), 7787 *15* from E(p)(c.m.)=206 *15* (2015Su15).<br>$\Gamma_p/\Gamma$=0.0065 *8* (2020Fr04), 0.0010 *8* for 2000Pe28 in 2020Fr04 and 0.038 *20* based on $\Gamma\gamma$=63 meV *20* and $\Gamma_p$=2.5 meV *11* in 2011Sa15 (unit “meV” not listed), however, 2020Fr04 list as 0.037 *9*.<br>$\omega\gamma$=0.24 meV *8* (2020Fr04), 1.4 meV *+5−4* (2011Sa15), and 0.4 meV *3* for 2000Pe28 in 2020Fr04. All using $\tau$=10 fs *3* (2004Je02). |
| 7803 *1* | 5/2$^+$ | E(level): IAS of $^{23}$Al g.s. No proton decay was observed from this state (2011Sa15). This is in contrast to what was observed in 1995Ti08 and 2000Pe28. |
| 7848 *9* | (7/2$^+$) | E(p)(c.m.)=267 *9* (2011Sa15). Others: E(p)(c.m.)=269 *16* (2015Su15), E(p)(lab)=246 *20* (1998RoZX). |
| 7918 *15* | | E(p)(c.m.)=337 *15* (2011Sa15). |
| 8024 *15* | (5/2,7/2) | E(p)(c.m.)=443 *15* (2011Sa15). |
| 8070 *10* | | E(p)(lab)=468 *10* (1998RoZX). |
| 8164.7 *12* | 5/2$^+$ | %p=100<br>E(p)(c.m.)=583.8 *12* from E(p)(Lab)=558.2 *12* (2011Ki26). Others: E(p)(c.m.)=579 *8* (2011Sa15) and 586 *15* (2015Su15), E(p)(lab)=556 *5* (1998RoZX). |

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**$^{23}$Al ε decay 2011Sa15,2011Ki26,2006Ia03 (continued)**

$^{23}$Mg Levels (continued)

| E(level)† | Jπ‡ | Comments |
|---|---|---|
| 8287 *10* | | E(p)(lab)=675 *10* (1998RoZX). |
| 8448 *2* | 3/2+,5/2+ | %p=100<br>E(p)(c.m.)=866.8 *19* from E(p)(Lab)=828.8 *19* (2011Ki26) Others: E(p)(c.m.)=866 *8* (2011Sa15) and 875 *12* (2015Su15), E(p)(lab)=838 *5* (1998RoZX). |
| 8579 *2* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=998 *2* from E(p)(Lab)=954 *2* (2011Ki26). Other: $E(p)(lab)=942 *10* (1998RoZX). |
| 8705 *10* | | E(level): Not adopted − source is a secondary publication.<br>E(p)(lab)=1075 *10* (1998RoZX). |
| 8782 *3* | (7/2+) | %p=100<br>E(p)(c.m.)=1201 *3* from E(p)(Lab)=1148 *3* (2011Ki26). Others: E(p)(c.m.)=1204 *8* (2011Sa15), E(p)(lab)=1156 *10* (1998RoZX). |
| 8840 *3* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=1259 *3* from E(p)(Lab)=1204 *3* (2011Ki26). Other: E(p)(lab)=1215 *10* (1998RoZX). |
| 8905 *3* | (5/2+) | %p=100<br>E(p)(c.m.)=1324 *3* from E(p)(Lab)=1266 *3* (2011Ki26). Others: E(p)(c.m.)=1338 *9* (2011Sa15), E(p)(lab)=1277 *10* (1998RoZX).<br>E(level): Other: 8916 (2001Wa54). |
| 9000 *10* | 3/2+,5/2+,7/2+ | E(p)(c.m.)=1419 *10* (2011Sa15). |
| 9023 *4* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=1442 *4* from E(p)(Lab)=1379 *4* (2011Ki26). |
| 9102 *5* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=1521 *5* from E(p)(Lab)=1454 *5* (2011Ki26). |
| 9144 *4* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=1563 *4* from E(p)(Lab)=1495 *4* (2011Ki26). Others: E(p)(c.m.)=1561 *9* (2011Sa15), E(p)(lab)=1505 *10* (1998RoZX). |
| 9321 *4* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=1740 *4* from E(p)(Lab)=1664 *4* (2011Ki26). Other: E(p)(c.m.)=1729 *25* (2011Sa15). |
| 9422 *4* | 3/2+,5/2+,7/2+# | %p=100<br>E(p)(c.m.)=1841 *4* from E(p)(Lab)=1760 *4* (2011Ki26) Others: E(p)(c.m.)=1843 9 (2011Sa15), E(p)(lab)=1748 *10* (1998RoZX). |
| 9469 *5* | 3/2+,5/2+,7/2+ | %p=100<br>E(p)(c.m.)=1888 *5* from E(p)(Lab)=1805 *5* (2011Ki26). Other: E(p)(lab)=1797 *10* (1998RoZX). |
| 9565 *10* | | E(level): Not adopted − source is a secondary publication.<br>E(p)(lab)=1897 *10* (1998RoZX). |
| 9605 *5* | 3/2,5/2,7/2# | %p=100<br>E(p)(c.m.)=2024 *5* from E(p)(Lab)=1935 *5* (2011Ki26). |
| 9682 *7* | 3/2− | %p=100<br>E(p)(c.m.)=2101 *7* from E(p)(Lab)=2009 *7* (2011Ki26). |
| 9883 *10* | | E(level): Not adopted − source is a secondary publication.<br>E(p)(lab)=2201 *10* (1998RoZX). |

† For levels up to 7803-keV from least-squares fit to γ-ray energies and above from E(c.m.)+S(p)($^{23}$Mg), where E(c.m.)=[(m(p)+m($^{22}$Na)/m($^{22}$Na)]*Ep (Lab). S(p)=7580.97 *23*, m(p)=1.007825 *9*, and m($^{22}$Na)= 21.9944437 *18* (2017Wa10). E(p)(Lab) values from 2011Ki26 are listed in comments section. From 2011Sa15 E(p)(c.m.) values are listed.
‡ From Adopted Levels, except otherwise noted.
# Assigned by evaluators from log *ft* value.

## $^{23}$Al ε decay 2011Sa15,2011Ki26,2006Ia03 (continued)

### ε,β+ radiations

%Ip from 2011Ki26, obtained by multiplying relative Ip by 0.0041 *1* (β-decay branching ratio to the 8448 keV level in 2011Sa15).

| E(decay) | E(level) | Iβ+ [@] | Iε [@] | Log *ft* | I(ε+β+) [†@] | Comments |
|---|---|---|---|---|---|---|
| (2540 *7*) | 9682 | 0.0008 *2* | 6.×10$^{-6}$ *2* | 6.0 *1* | 0.0008[#] *2* | av Eβ=643.4 *32*; εK=0.00715 *11*; εL=0.000622 *9*; εM+=4.01×10$^{-5}$ *6*<br>%Ip=0.0008 *2* from 0.20 *5* (2011Ki26). |
| (2617 *5*) | 9605 | 0.0025 *3* | 1.7×10$^{-5}$ *2* | 5.6 *1* | 0.0025[#] *3* | av Eβ=678.5 *23*; εK=0.00615 *6*; εL=0.000536 *6*; εM+=3.45×10$^{-5}$ *4*<br>%Ip=0.0025 *3* from 0.62 *7* (2011Ki26). |
| (2753 *5*) | 9469 | 0.0084 *6* | 4.4×10$^{-5}$ *3* | 5.23 *4* | 0.0084[#] *6* | av Eβ=740.9 *23*; εK=0.00480 *5*; εL=0.000418 *4*; εM+=2.692×10$^{-5}$ *24*<br>%Ip=0.0084 *6* from 2.04 *13* (2011Ki26). |
| (2800 *4*) | 9422 | 0.05 *1* | 0.0002 | 4.5 *1* | 0.05[‡] *1* | av Eβ=762.6 *19*; εK=0.00443 *3*; εL=0.000385 *3*; εM+=2.483×10$^{-5}$ *17*<br>%Ip=0.05 *1* (2011Sa15); Other: %Ip=0.021 *1* from 5.21 *19* (2011Ki26). |
| (2901 *4*) | 9321 | 0.02 *1* | 8.×10$^{-5}$ *4* | 5.0 *2* | 0.02[‡] *1* | av Eβ=808.8 *19*; εK=0.003754 *25*; εL=0.0003267 *2*; εM+=2.105×10$^{-5}$ *14*<br>%Ip=0.02 *1* (2011Sa15); Other: %Ip=0.0059 *4* from 1.44 *10* (2011Ki26). |
| (3078 *4*) | 9144 | 0.03 *1* | 9.×10$^{-5}$ *3* | 5.0 *2* | 0.03[‡] *1* | av Eβ=891.2 *19*; εK=0.002862 *17*; εL=0.0002491 *1*; εM+=1.604×10$^{-5}$ *10*<br>%Ip=0.03 *1* (2011Sa15); Other: %Ip=0.017 *1* from 4.2 *2* (2011Ki26). |
| (3120 *5*) | 9102 | 0.0032 *6* | 9.4×10$^{-6}$ *18* | 6.01 *9* | 0.0032[#] *6* | av Eβ=911.3 *24*; εK=0.002689 *20*; εL=0.0002340 *1*; εM+=1.507×10$^{-5}$ *11*<br>%Ip=0.0032 *6* from 0.78 *14* (2011Ki26). |
| (3199 *4*) | 9023 | 0.0032 *3* | 8.4×10$^{-6}$ *8* | 6.08 *5* | 0.0032[#] *3* | av Eβ=947.8 *19*; εK=0.002410 *14*; εL=0.0002097 *1*; εM+=1.351×10$^{-5}$ *8*<br>%Ip=0.0032 *3* from 0.77 *7* (2011Ki26). |
| (3222 *10*) | 9000 | 0.02 *1* | 5.×10$^{-5}$ *3* | 5.3 *2* | 0.02[‡] *1* | av Eβ=958.6 *47*; εK=0.00233 *4*; εL=0.000203 *3*; εM+=1.309×10$^{-5}$ *18*<br>%Ip=0.02 *1* (2011Sa15). |
| (3317 *3*) | 8905 | 0.02 *1* | 4.×10$^{-5}$ *2* | 5.4 *2* | 0.02[‡] *1* | av Eβ=1003.3 *15*; εK=0.002057 *9*; εL=0.0001790 *8*; εM+=1.153×10$^{-5}$ *5*<br>%Ip=0.02 *1* (2011Sa15); %Ip=0.017 *1* from 4.11 *16* (2011Ki26). |
| (3382 *3*) | 8840 | 0.0058 *4* | 1.2×10$^{-5}$ *1* | 5.97 *3* | 0.0058[#] *4* | av Eβ=1033.9 *15*; εK=0.001891 *8*; εL=0.0001646 *7*; εM+=1.060×10$^{-5}$ *4*<br>%Ip=0.0058 *4* from 1.42 *10* (2011Ki26). |
| (3440 *3*) | 8782 | 0.02 *1* | 4.×10$^{-5}$ *2* | 5.5 *2* | 0.02[‡] *1* | av Eβ=1061.8 *15*; εK=0.001756 *7*; εL=0.0001528 *6*; εM+=9.85×10$^{-6}$ *4*<br>%Ip=0.02 *1* (2011Sa15); Other: %Ip=0.013 *1* from 3.17 *15* (2011Ki26). |
| (3642.6 *21*) | 8579 | 0.0064 *4* | 9.7×10$^{-6}$ *6* | 6.13 *3* | 0.0064[#] *4* | av Eβ=1157.94 *97*; εK=0.001380 *4*; εL=0.0001201 *3*; εM+=7.735×10$^{-6}$ *18*<br>%Ip=0.0064 *4* from 1.55 *10* (2011Ki26). |
| (3773.6 *21*) | 8448 | 0.41 *1* | 0.00054 *1* | 4.42 *1* | 0.41[‡] *1* | av Eβ=1219.79 *98*; εK=0.001194 *3*; εL=0.00010392; εM+=6.694×10$^{-6}$ *15*<br>%Ip=0.41 *1* (2011Sa15); %Ip=0.41 *1* from 100 (2011Ki26). |

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## $^{23}$Al ε decay 2011Sa15,2011Ki26,2006Ia03 (continued)

### ε,$\beta^+$ radiations (continued)

| E(decay) | E(level) | I$\beta^+$ @ | Iε@ | Log *ft* | I(ε+$\beta^+$)†@ | Comments |
|---|---|---|---|---|---|---|
| (4056.9 *13*) | 8164.7 | 0.28 *1* | | 4.77 *2* | 0.28‡ *1* | av Eβ=1355.16 *61*<br>%Ip=0.28 *1* (2011Sa15); %Ip=0.19 *1* from 46.2 *8* (2011Ki26); 0.281 *6* − deduced from 0.685 *22* (2020Fr04). |
| (4198 *15*) | 8024 | 0.02 *1* | | 6.0 *2* | 0.02‡ *1* | av Eβ=1422.7 *72*<br>%Ip=0.02 *1* (2011Sa15). |
| (4304 *15*) | 7918 | 0.03 *1* | | 5.9 *2* | 0.03‡ *1* | av Eβ=1473.6 *73*<br>%Ip=0.03 *1* (2011Sa15). |
| (4374 *9*) | 7848 | 0.118 *3* | | 5.3 *1* | 0.118‡ *3* | av Eβ=1507.3 *44*<br>%Ip=0.18 *4* (2011Sa15), 0.19 *6* (2015Su15), 0.118 *3* − deduced from 0.288 *10* (2020Fr04). |
| (4418.6 *11*) | 7803 | 13.4 *7* | 0.0093 *5* | 3.31 *2* | 13.4 *7* | av Eβ=1529.21 *99*; εK=0.0006374 *1*; εL=$5.546\times10^{-5}$ *10*; εM+=$3.572\times10^{-6}$ *7* |
| (4433.6 *11*) | 7788 | 4.89 *25* | 0.00336 *18* | 3.759 *23* | 4.89 *25* | av Eβ=1536.54 *99*; εK=0.0006290 *1*; εL=$5.473\times10^{-5}$ *10*; εM+=$3.525\times10^{-6}$ *7*<br>%Ip=0.14 *3* (2011Sa15), 0.15 *5* (2015Su15), 0.026 *2* − deduced from 0.063 *4* (2020Fr04). |
| (10170.6 *11*) | 2051 | 5.91 *10* | | 5.67 *1* | 5.91 *10* | av Eβ=4357.49 |
| (11770.6 *11*) | 451 | 26.2 *5* | | 5.36 *1* | 26.2 *5* | av Eβ=5152.44 |
| (12221.6 *4*) | 0.0 | 36.3 *16* | | 5.30 *2* | 36.3 *16* | av Eβ=5376.75<br>I(ε+$\beta^+$): Quoted in 2006Ia03 − appears to be from Ref. 31 (Ph.D. dissertation by Y. Zhai at Texas A & M (2007)): deduced from γ-ray intensity balance. R. E. Tribble mentioned by e-mail to B. Singh (dated March 13, 2019) that identification of some of the gamma lines in the thesis was uncertain and not included in the publication. The datum should be considered with caution. |

† From 2006Ia03, except otherwise noted. Deduced from γ-ray intensity balance quoted in 2006Ia03, appears to be from Ref. 31 in 2006Ia03 (Ph.D. dissertation by Y. Zhai at Texas A & M (2007)). Note that 2006Ia03 state “Transitions to and from 13 distinct excited levels in $^{24}$Mg levels are observed” or “Twenty γ-ray peaks in all were identified as originating from the decay of 23Al” in paragraphs 1 and 2 (section IV) could not be followed comparing the presented data in 2006Ia03 or in the dissertation (Ref. 31 in 2006Ia03 and Ref. 25 in 2011Sa15). Note total I(ε+β+) < 100 − the decay scheme is incomplete.

‡ From 2011Sa15, based on %Ip.

# From 2011Ki26, based on %Ip.

@ Absolute intensity per 100 decays.

### γ($^{23}$Mg)

Iγ normalization: Dataset appears to be incomplete and not normalized for γ-ray transition intensities. See comments for the 451γ from 451 keV level.

| $E_i$(level) | $J^\pi_i$ | Eγ† | Iγ@ | $E_f$ | $J^\pi_f$ | Comments |
|---|---|---|---|---|---|---|
| 451 | 5/2+ | 451 *1* | 100 | 0.0 | 3/2+ | Eγ: Other: 450.7 (2011Sa15).<br>Iγ: From 2011Sa15. Absolute intensity=43.3% *10* quoted in 2011Sa15 appears to be using data from Ref. 25 (Ph.D. dissertation by Y. Zhai at Texas A & M (2007)). The procedure to deduce the value was not available. In an e-mail reply, R. E. |

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## $^{23}$Al $\varepsilon$ decay 2011Sa15,2011Ki26,2006Ia03 (continued)

### $\gamma$($^{23}$Mg) (continued)

| $E_i$(level) | $J^\pi_i$ | $E_\gamma$ [†] | $I_\gamma$ [@] | $E_f$ | $J^\pi_f$ | Comments |
|---|---|---|---|---|---|---|
| | | | | | | Tribble mentioned to B. Singh (dated March 13, 2019) that identification of some of the gamma lines in the thesis was uncertain and not included in the publication. It is not clear which $\gamma$-ray intensity was considered to deduce the 43.3% *10* value. The datum should be considered with caution. |
| 2051 | 7/2+ | 1598 *2* | | 451 | 5/2+ | $E_\gamma$: Other: 1600.0 (2011Sa15). |
| | | 2053 *2* | | 0.0 | 3/2+ | $E_\gamma$: Other: 2050.8 (2011Sa15). |
| 7788 | 3/2+,5/2+ | 5736[‡] | 20 *5* | 2051 | 7/2+ | $I_\gamma$: 1.53 with respect to I$\gamma$(450)=100 (2011Sa15). |
| | | 7335[‡] | 100 | 451 | 5/2+ | $I_\gamma$: 1.53 with respect to I$\gamma$(450)=100 (2011Sa15). |
| | | 7786 | 3.8 *25* | 0.0 | 3/2+ | $E_\gamma$: From 2006Ia03; not reported in 2011Sa15. |
| 7803 | 5/2+ | 5751[‡] | 5.5 *21* | 2051 | 7/2+ | |
| | | 7350 *2* | 45 *5* | 451 | 5/2+ | $E_\gamma$: Other: 7351 (2011Sa15). |
| | | 7801 *2* | 100 | 0.0 | 3/2+ | $E_\gamma$: Other: 7801.3 (2011Sa15). |

[†] From 2000Pe28, unless otherwise stated.
[‡] From 2011Sa15.
[#] From Fig 2 in 2006Ia03, not placed in the level scheme by the authors. Evaluators list as unplaced.
[@] From 2006Ia03, except otherwise noted.
[x] $\gamma$ ray not placed in level scheme.

**$^{23}$Al $\varepsilon$ decay 2011Sa15,2011Ki26,2006Ia03**

## Decay Scheme

Intensities: Relative photon branching from each level