^{100}Mo $2\beta^-$ decay (7.01×10^{18} y) 2019Ar04,2017Ar18,2014Ca46

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 172, 1 (2021)	31-Jan-2021

Parent: ^{100}Mo: E=0.0; $J^\pi=0^+$; $T_{1/2}=7.01\times10^{18}$ y *+21−17*; $Q(2\beta^-)$=3034.36 *17*; %$2\beta^-$ decay=100.0

^{100}Mo-$T_{1/2}$: $T_{1/2}=7.01\times10^{18}$ y *+21−17* for $2\nu\beta\beta$ decay to ^{100}Ru g.s. obtained from weighted average of 7.05×10^{18} y *+21−17* (2020Ar09, CUPID-MO, Modane, earlier value of 6.90×10^{18} y *40* in 2017Ar18); 6.81×10^{18} y *1*(stat) *+38−40*(syst) (2019Ar04, earlier value of 7.17×10^{18} y *54* in 2011Fl06, NEMO-3, see also previous papers e.g. 2005Ar27); 7.15×10^{18} y *76* (2014Ca46, NIIC, Russia); 7.2×10^{18} y *20* (2001As06, Gran Sasso, see also 2002As05,2001As05 and previous papers); 7.6×10^{18} y *26* (1997Al02, Silver mine at Osburn, Idaho); 6.82×10^{18} y *86* (1997De40, Valve house, Hoover Dam, USA; note that value listed in 2015Ba11 evaluation from 1997De40 is for ^{150}Nd $2\nu\beta\beta$ decay, not for ^{100}Mo). Half-life in 2015Ba11 evaluation is: 7.1×10^{18} y *4*, where some of the original values taken from literature seemed erroneous. About 1% $2\nu\beta\beta$ decay is found to proceed to the 1130, 0^+ level in ^{100}Ru with weighted averaged partial $T_{1/2}=6.9\times10^{20}$ y *9*, obtained from 7.5×10^{20} y *9* (2014Ar08, NEMO-3); 6.9×10^{20} y *12* (2010Be34, ARMONIA, Gran Sasso); 6.0×10^{20} y *+20−13* (2009Ki04, TUNL, ITEP); 6.1×10^{20} y *+18−11* (1995Ba29, Soudan mine, Minnesota). Value is 6.7×10^{20} y *+5−4* in 2015Ba11 evaluation which included somewhat different set of measurements. Note that in all cases, evaluators combined statistical and systematic uncertainties in quadrature. Decays to other excited states of ^{100}Ru make almost no contribution, as suggested by recent measurements by 2014Ar08 (NEMO-3) and 2009Ki04 (TUNL, ITEP).

^{100}Mo-$Q(2\beta^-)$: From 2017Wa10.

2019Kw01: meassured heat and light signals using metallic magnetic calorimeter and scintillation detector to detect $0\nu\beta\beta$ decay mode from six $CaMoO_4$ crystals enriched in ^{100}Mo at the AMoRE facility in Yangyang underground laboratory in South Korea. An upper limit for the half-life for this decay was deduced.

SuperNemo (super Neutrino Ettore Majorana Observatory in Modane, France) and NEMO-3 experiments for $2\nu\beta\beta$ and $0\nu\beta\beta$ half-lives of ^{100}Mo double β decay to g.s. and excited states of ^{100}Ru: 2019Ar04, 2014Ar05, 2014Ar08, 2012Si23, 2011Ba55, 2011Fl06, 2011TrZW, 2010Si06, 2009Da25, 2009KoZY, 2007Ar02, 2006Ar01, 2005Ar27. This project is a multi-national collaboration, and has been in existence since 1989 (http://nemo.in2p3.fr/nemow3/).

2017Ar18: CUPID (CUORE Upgrade with Particle ID) international collaboration (CUORE: Cryogenic Underground Observatory for Rare Events), laboratory located at Gran Sasso National Laboratories, Italy: measurement of half-life of $2\nu\beta\beta$ decay mode of ^{100}Mo.

2014Ca46: measurement of half-life of $2\nu2\beta^-$ decay mode using $ZnMoO_4$ crystals as bolometers at the Nikolaev Institute of Inorganic Chemistry (NIIC, Novosibirsk, Russia) and at the Novosibirsk State University.

2009Ki04: measurement of partial half-lives to excited states of ^{100}Ru in double beta decay of ^{100}Mo using TUNL-ITEP $\beta\beta$ decay setup of two HPGe detectors surrounded by a NaI(Tl) annulus. Results were combined with those from 2006Ho17 from the same laboratory, but with $\gamma\gamma$ coincidence efficiency improved.

2006Ho17, 2001De17 (also 2002De18, 2000De41) at TUNL: study of population of first excited 0^+ state and search for population of other excited states above the first 2^+ state through $\gamma\gamma$-coin technique.

MOON (Molybdenum Observatory Of Neutrinos) project (a multi-national collaboration, mainly Osaka group of ELEGANT-V facility and University of Washington, Seattle): 2006Ej01, 2006Ej02, 2005No02, 2003Do13, 2002Ej03, 2002Ej05 for description of this project. No $\beta\beta$ decay results are available from this collaboration.

2015Ba11, 2011Ba28, 2010Ba07, 2010Ba04, 2006Ba35, 2002Tr04: compilation and evaluation of half-lives of double β decays.

Additional information 1.

Experimental papers and analyses, mainly for $2\nu\beta\beta$ and/or $0\nu\beta\beta$ $T_{1/2}$ of double β decay of ^{100}Mo: 2020Ar09, 2017Ar18, 2014Ar05, 2014Ar08, 2014Ca46, 2012Si23, 2011Ba55, 2011Fl06, 2011TrZW, 2010Be34, 2010Si06, 2010Ba07, 2009Da25, 2009Ki04, 2009KoZY, 2008KoZV, 2007Ar02,

2006Sh31, 2006Sh32, 2006Ba35, 2006Ar01, 2006Zu04, 2005Ar27, 2005Ba01, 2005Ba33, 2005Sa07, 2005Si06, 2004Ar29, 2004Ba27, 2004Ba97, 2004Ko61, 2003Ba22, 2003Oh07, 2002As05, 2002Ba52, 2001As05, 2001As06, 2001Va34, 2000Ar16, 1999As01, 1999As09, 1999Bb18, 1999Bb19, 1999Pi08, 1999Sa02, 1998As04, 1997De40; 2004Hi19 (geochemical method); 2002Fu05 (also 2002Ej05, 2001Ej01, 2001Ej03, 2000Ej01, 2000Ku21, 1998Ku09, 1997Ej01); 2001Be19 (also 2000Be57); 1997Al02 (also 1993Al11, 1989Al20), 1996Ej04 (also 1996Ej06, 1992Ku18, 1991Wa31, 1991Ej05, 1991Ej02, 1988Ok01), 1995Ba29 (also 1996Bb02, 1990Ba63, 1990Ba52), 1995Da37 (also 1994La42, 1992Bl06), 1991El04 (also 1987El13), 1990Va10. Others: 1993Ko28, 1984Fi16 (also 1982Be20), 1983Zd01, 1955Wi33, 1954Se93, 1952Fr23.

$T_{1/2}(2\nu\beta\beta)$(to ^{100}Ru g.s.): 7.05×10^{18} y *+21−17* (2020Ar09, CUPID-Mo, Modane, earlier value of 6.90×10^{18} y *15*(stat) *37*(syst)

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in 2017Ar18); 6.81×10^{18} y *1*(stat) *+38−40*(syst) (2019Ar04, earlier value: 7.17×10^{18} y *1*(stat) *54*(syst) in 2011Fl06, NEMO-3, also 2006Ar01,2005Ar27,2005Sa07, 2005Si06, 2004Ar29); 7.15×10^{18} y *37*(stat) *66*(syst) (2014Ca46, NIIC, Russia); 2.1×10^{18} y *3* (2004Hi19, geochemical); 7.6×10^{18} y *+22−14* (1997Al02); 11.5×10^{18} y *+30−20* (1991Ej05,1996Ej04, 1991Ej02); 9.5×10^{18} y *4* (stat) *9* (syst) (1995Da37, NEMO-2); 11.6×10^{18} y *+34−8* (1991El04, also 1987El13); 0.33×10^{19} y *+20−10* (1990Va10). A small contribution of ≈1% to total half-life is made by $T_{1/2}$(2$\nu\beta\beta$)(to 1130,0$^+$ level in ^{100}Ru)=7.5×10^{20} y *6*(stat) *6*(syst) (2014Ar08); 6.9×10^{20} y *+10−8*(stat) *7*(syst) (2010Be34); 5.7×10^{20} y *+15−12* (2007Ar02); 6.0×10^{20} y *+20−13* (2009Ki04,2006Ho17,2006Ba35); 6.1×10^{20} y *+18−11* (1995Ba29). Decay modes of 2$\nu\beta\beta$ to other excited states in ^{100}Ru, and 0$\nu\beta\beta$ modes make almost no contributions.

$T_{1/2}$(0ν,ββ to g.s.): >9.5×10^{22} y (2019Kw01, AMoRE detector); >2.6×10^{22} y (2017Ar18); >1.1×10^{24} y (2014Ar08,2011Ba55,NEMO-3, 90% CL; also >1.0×10^{24} y in 2012Si23 and 2011Fl06), >4.6×10^{23} y (2005Ar27,NEMO-3); >5.5×10^{22} y (2002Fu05,2001Ej03,ELEGANT-5); >4.9×10^{21} y (2001As06, 2001As05); >2.2×10^{22} y (1997Al02); >5.2×10^{22} y (1996Ej04); >1.2×10^{22} y (1995Da37).
$T_{1/2}$(0ν,ββ, Majorana neutrino to g.s.)>5.4×10^{21} y (1996Ej04,1991Ej02), >7.5×10^{20} y (1995Da37).
$T_{1/2}$(0ν,ββ,Majorana neutrino emission)>2.7×10^{27} y (2006Ar01).

$T_{1/2}$(2ν+0ν,ββ to 539,2$^+$ level)>25×10^{20} y (2014Ar08).
$T_{1/2}$(2ν,ββ to 539.5,2$^+$ level)>11×10^{20} y (2007Ar02) (90% confidence limit); >16×10^{20} y (1995Ba29); >5×10^{20} y (1992Bl06).
$T_{1/2}$(0ν,ββ to 539.5,2$^+$ level)>1.6×10^{23} y (2007Ar02) (90% confidence limit); >1.1×10^{21} y (1995Da37).

$T_{1/2}$(2ν,ββ to 1130,0$^+$ level)=7.5×10^{20} y *6*(stat) *6*(syst) (2014Ar08).
$T_{1/2}$(2ν+0ν,ββ to 1130,0$^+$ level)=6.9×10^{20} y *+10−8*(stat) *7*(syst) (2010Be34).
$T_{1/2}$(0ν+2ν)=6.0×10^{20} y *+20−13* (2009Ki04,2006Ho17) for decay to the 1130, 0$^+$ state. The statistical uncertainty of +1.9-1.1 and systematic uncertainty of 0.6 have been combined in quadrature. Earlier value from the same group=5.9×10^{20} y *+18−13* in 2001De17.
$T_{1/2}$(2ν,ββ to 1130,0$^+$ level)=5.7×10^{20} y *+15−12* (2007Ar02) (90% confidence limit); 6.1×10^{20} y *+18−11* (1995Ba29); >12×10^{20} y (1992Bl06).
$T_{1/2}$(0ν,ββ to 1130,0$^+$ level)>8.9×10^{22} y (2007Ar02) (90% confidence limit); >1.7×10^{21} y (1995Da37).

$T_{1/2}$(2ν+0ν,ββ to 1362,2$^+$ level)>108×10^{20} y (2014Ar08).
$T_{1/2}$(ββ)>44×10^{20} y at 90% confidence level for decay to 1362.2 keV 2$^+$ level (2009Ki04,2006Ho17).
$T_{1/2}$(2ν,ββ to 1362,2$^+$ level)>13×10^{20} y (1995Ba29); >6×10^{20} y (1992Bl06).

$T_{1/2}$(2ν+0ν,ββ to 1741,0$^+$ level)>40×10^{20} y (2014Ar08).
$T_{1/2}$(ββ)>48×10^{20} y at 90% confidence level for decay to 1741.0 keV 0$^+$ level (2009Ki04,2006Ho17).
$T_{1/2}$(2ν,ββ to 1741,0$^+$ level)>13×10^{20} y (1995Ba29).

$T_{1/2}$(2ν+0ν,ββ to 1865,2$^+$ level)>49×10^{20} y (2014Ar08).

$T_{1/2}$(2ν+0ν,ββ to 2051,0$^+$ level)>43×10^{20} y (2014Ar08).
$T_{1/2}$(ββ)>38×10^{20} y at 90% confidence level for decay to 2051.7 keV 0$^+$ level (2009Ki04,2006Ho17).

$T_{1/2}$(ββ)>40×10^{20} y at 90% confidence level for decay to 2387.2 keV 0$^+$ level (2009Ki04,2006Ho17).

Measurements: 2020Ar09, 2019Ar04, 2019Kw01, 2017Ar18, 2014Ar05, 2014Ar08, 2014Ca46, 2012Si23, 2011Ba55, 2011Fl06, 2011TrZW, 2010Be34, 2010Si06, 2009Da25, 2009Ki04, 2009KoZY, 2008KoZV, 2007Ar02, 2006Ho17, 2006Ba35, 2006Ar01 (also 2005Ar27,2005Ba01,2005Ba33,2005Sa07,2005Si06, 2004Ar29,2004Ba27,2004Ba97,2004Ko61,2003Ba22,2003Oh07,2002As05, 2002Ba52,2001As05,2001As06,2001Va34,2000Ar16,1999As01,1999As09, 1999Bb18,1999Bb19,1999Pi08,1999Sa02,1998As04); 2004Hi19 (geochemical method); 2002Fu05 (also 2002Ej05,2001Ej01, 2001Ej03,2000Ej01,2000Ku21,1998Ku09,1997Ej01); 2001Be19 (also 2000Be57); 1997Al02 (also 1993Al11,1989Al20), 1996Ej04 (also 1996Ej06, 1992Ku18,1991Wa31,1991Ej05,1991Ej02,1988Ok01), 1995Ba29 (also 1996Bb02,1990Ba63,1990Ba52), 1995Da37 (also 1994La42,1992Bl06), 1991El04 (also 1987El13), 1990Va10. Others: 1997De40, 1993Ko28, 1984Fi16 (also 1982Be20), 1983Zd01, 1955Wi33, 1954Se93, 1952Fr23.

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Search has been made by 2006Ho17 (also 1995Ba29, 1992Bl06) for the population of higher states at 1362, 2^+; 1741, 0^+; 2052, 0^+; and 2387, 0^+, but no evidence was found from $\gamma\gamma$ coincidence data with gates on 539.5γ and 1362γ. In the study by 2006Ho17, one count each was found for 379-1362 cascade (from 1741 level) and 1512-539.5 cascade (from 2052 level), but both these were consistent with the expected contribution from background. No coincidence counts were found for 822-540 cascade (from 1362 level), 1201-540 cascade (from 1741 level), 689-1362 cascade (from 2052 level) and 1848-540 cascade (from 2387 level). The population of 1130, 0^+ state is well confirmed by 2006Ho17 and 2001De17.

The main feeding is to the ground state, the feeding to the 1130,0^+ level is ≈1%. There is almost no direct feeding of the first 2^+ state.

^{100}Ru Levels

E(level)†	J^π†	Comments
0.0	0^+	
539.5?‡	2^+	Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 539,2^+ level)>25×10^{20} y (2014Ar08). Partial $T_{1/2}$(2ν,$\beta\beta$ to 539.5,2^+ level)>11×10^{20} y (2007Ar02) (90% confidence limit); >16×10^{20} y (1995Ba29); >5×10^{20} y (1992Bl06). Partial $T_{1/2}$(0ν,$\beta\beta$ to 539.5,2^+ level)>1.6×10^{23} y (2007Ar02) (90% confidence limit); >1.1×10^{21} y (1995Da37).
1130.3	0^+	Population of this level in ^{100}Mo $\beta\beta$ decay is confirmed by the observation of 22 $\gamma\gamma$ coin events between 539.5γ and 590.8γ (2006Ho17,2009Ki04,2001De17). Partial $T_{1/2}$(2ν,$\beta\beta$ to 1130,0^+ level)=7.5×10^{20} y *6*(stat) *6*(syst) (2014Ar08). Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 1130,0^+ level)=6.9×10^{20} y *+10−8*(stat) *7*(syst) (2010Be34). Partial $T_{1/2}$(0ν+2ν)=6.0×10^{20} y *+20−13* (2009Ki04,2006Ho17) for decay to the 1130, 0^+ state. The statistical uncertainty of +1.9-1.1 and systematic uncertainty of 0.6 have been combined in quadrature. Partial $T_{1/2}$(2ν,$\beta\beta$ to 1130,0^+ level)=5.7×10^{20} y *+15−12* (2007Ar02) (90% confidence limit); 6.1×10^{20} y *+18−11* (1995Ba29); >12×10^{20} y (1992Bl06). Partial $T_{1/2}$(0ν+2ν)=5.9×10^{20} y *+17−11*(stat) *6*(syst) (2001De17). Partial $T_{1/2}$(0ν,$\beta\beta$ to 1130,0^+ level)>8.9×10^{22} y (2007Ar02) (90% confidence limit); >1.7×10^{21} y (1995Da37). Others for partial $T_{1/2}$ for decay to 1130 level: 2002De18, 2000De41, 1999Bb19.
1362.2?‡	2^+	Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 1362,2^+ level)>108×10^{20} y (2014Ar08). Partial $T_{1/2}$($\beta\beta$)>44×10^{20} y at 90% confidence level for decay to 1362.2 keV 2^+ level (2009Ki04,2006Ho17). Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 1362,2^+ level)>13×10^{20} y (1995Ba29); >6×10^{20} y (1992Bl06).
1741.0?‡	0^+	Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 1741,0^+ level)>40×10^{20} y (2014Ar08). Partial $T_{1/2}$($\beta\beta$)>48×10^{20} y at 90% confidence level for decay to 1741.0 keV 0^+ level (2009Ki04,2006Ho17). Partial $T_{1/2}$(2ν,$\beta\beta$ to 1741,0^+ level)>13×10^{20} y (1995Ba29).
1865.1?‡	2^+	Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 1865,2^+ level)>49×10^{20} y (2014Ar08).
2051.7?‡	0^+	Partial $T_{1/2}$(2ν+0ν,$\beta\beta$ to 2051,0^+ level)>43×10^{20} y (2014Ar08). Partial $T_{1/2}$($\beta\beta$)>38×10^{20} y at 90% confidence level for decay to 2051.7 keV 0^+ level (2009Ki04,2006Ho17).
2387.2?‡	0^+	Partial $T_{1/2}$($\beta\beta$)>40×10^{20} y at 90% confidence level for decay to 2387.2 keV 0^+ level (2009Ki04,2006Ho17).

† From the Adopted Levels, energies are rounded values.

‡ Population of this level in 2β decay (0ν+2ν modes) is not confirmed, as indicated by lower limits of measured $T_{1/2}$=25×10^{20} y to 108×10^{20} y (2014Ar08,2010Be34).

γ(^{100}Ru)

E_γ†	E_i(level)	J^π_i	E_f	J^π_f
378.9	1741.0?	0^+	1362.2?	2^+
539.5	539.5?	2^+	0.0	0^+
590.8	1130.3	0^+	539.5?	2^+
734.8	1865.1?	2^+	1130.3	0^+

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γ(^{100}Ru) (continued)

E_γ †	E_i(level)	J^π_i	E_f	J^π_f	E_γ †	E_i(level)	J^π_i	E_f	J^π_f	E_γ †	E_i(level)	J^π_i	E_f	J^π_f
822.6	1362.2?	2^+	539.5?	2^+	1325.6	1865.1?	2^+	539.5?	2^+	1847.7	2387.2?	0^+	539.5?	2^+
1025.0	2387.2?	0^+	1362.2?	2^+	1362.1	1362.2?	2^+	0.0	0^+	1865.1	1865.1?	2^+	0.0	0^+
1201.5	1741.0?	0^+	539.5?	2^+	1512.1	2051.7?	0^+	539.5?	2^+					

† Rounded values from the Adopted dataset.

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Legend

Decay Scheme