BNL-223019-2022-JAAM

Nuclear Data Sheets for A=269,273,277,281,285,289, and 293*

C. Morse

To be published in "Nuclear Data Sheets journal"

May 2022

Nuclear Science and Technology Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Nuclear Physics (NP) (SC-26)

DISCLAIMER

Nuclear Data Sheets for A=269,273,277,281,285,289, and 293*

C. Morse

National Nuclear Data Center
Brookhaven National Laboratory
Upton, New York 11973-5000, USA

(Received 20 August 2021; Revised 1 April 2022)

Abstract: Information on the production, identification, half-lives and decay modes for experimentally known nuclides with mass numbers of 269,273,277,281,285,289,and 293 are presented along with the recommended values. Data here supersede data from the previous evaluation in this region, 2005Gu33. Since the previous evaluation many new and conclusive experiments have explored the region of superheavy nuclei, thus significantly expanding our knowledge of the nuclear chart in this area.

Cutoff Date: All data prior to September 14, 2021 have been included in this evaluation. The main bibliographic source was the NSR database (2014Pr09) at Brookhaven Laboratory webpage: www.nndc.bnl.gov/nsr.

General Policies and Organization of Material: See the January issue of the *Nuclear Data Sheets* or http://www.nndc.bnl.gov/nds/NDSPolicies.pdf.

* Research sponsored by Office of Nuclear Physics, Office of Science, US Department of Energy, under contract DE-AC02-98CH10946

Adopted Levels

Q(β^-)=−1785 *syst*; S(n)=5179 *syst*; S(p)=4656 *syst*; Q(α)=8.58×10^3 *7* 2021Wa16
ΔQ(β^-)=525, ΔS(n)=596, ΔS(p)=645 (2021WA16).
S(2n)=12257 SY *452*, S(2p)=8330 SY *682* (2021WA16).

^{269}Sg has been observed as the α-decay daughter of ^{273}Hs at LBNL (2010EL06) and JINR (2015UT02,2018UT02). Events were identified by the observation of chains of α-decaying nuclei, terminated by spontaneous fission. Comparison of the properties of these chains with those in the literature allowed individual decays to be assigned to specific nuclei.

2018UT02 lists one decay of ^{269}Sg with a lifetime of 6486 s. Including it increases the average lifetime by nearly an order of magnitude, and on this basis it is excluded.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{269}Sg Levels

Cross Reference (XREF) Flags

A ^{273}Hs α decay (0.51 s)

E(level)	$T_{1/2}$	XREF	Comments
0	1.3×10^2 s *+10−4*	A	%α=100; %SF<15 E(level): Assumed ground state. $T_{1/2}$: From five events.

^{273}Hs α decay (0.51 s) 2010El06,2015Ut02,2018Ut02

Parent: ^{273}Hs: E=0; $T_{1/2}$=0.51 s *+30–13*; Q(α)=9.65×10^3 *6*; %α decay=100
^{273}Hs-$T_{1/2}$: From Adopted Levels.
^{273}Hs-Q(α): From 2021WA16.

^{269}Sg Levels

E(level)	$T_{1/2}$	Comments
0	1.3×10^2 s *+10–4*	%α=100; %SF<15

α radiations

Eα	E(level)	Comments
9.51×10^3 *2*	0	Eα: Weighted average of seven events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−4807 *syst*; S(n)=6546 *syst*; S(p)=3502 *syst*; Q(α)=9274 *syst* 2021Wa16

ΔQ(β^-)=338, ΔS(n)=327, ΔS(p)=404, ΔQ(α)=167 (2021WA16).

S(2n)=14307 SY *162*, S(2p)=5891 SY *292*, Q(εp)=405 SY *487* (2021WA16).

^{269}Hs has been observed as the α-decay daughter of ^{273}Ds at GSI (1996HO13,2002HO11) and RIKEN (2007MO09,2013SU04); and in gas-phase chemistry experiments at GSI (2002DU21,2004VO24,2006DV01,2008DV02). Chains of α-decaying nuclei were observed, and comparison of the decay properties of the chains with those in the literature allowed individual decays to be assigned to specific nuclei.

1996HO13 reports two decay chains, but a reanalysis of the data in 2002HO11 showed that one of the chains was reported in error.

2006DV01 suggests that all studies prior to that work that identify ^{270}Hs have actually observed ^{269}Hs, based on a previously unknown isomer in ^{261}Rf.

1996LA12 claims observation of several chains that should decay through ^{269}Hs, but the decay properties do not seem to agree with other publications.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{269}Hs Levels

Cross Reference (XREF) Flags

A ^{273}Ds α decay (0.19 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	13 s *+10−4*	A	%α=100; %SF<5 E(level): Assumed ground state. $T_{1/2}$: From five events.

^{273}Ds α decay (0.19 ms)

Parent: ^{273}Ds: E=0; $T_{1/2}$=0.19 ms *+14−6*; Q(α)=1.137×10^4 *5*; %α decay=100
^{273}Ds-$T_{1/2}$: From Adopted Levels.
^{273}Ds-Q(α): From 2021WA16.
References: 1996HO13,2002HO11,2007MO09,2013SU04.

^{269}Hs Levels

E(level)	$T_{1/2}$	Comments
0	13 s *+10−4*	%α=100; %SF<5

α radiations

Eα	E(level)	Comments
11.14×10^3 *1*	0	Weighted average of five events. Assumed g.s. to g.s. transition.

Adopted Levels

S(n)=6885 *syst*; S(p)=1605 *syst*; Q(α)=1.151×10^4 *3* 2021Wa16
ΔS(n)=303, ΔS(p)=235 (2021WA16).
S(2n)=15188 SY *206*, S(2p)=2401 SY *100*, Q(εp)=4578 SY *302* (2021WA16).
^{269}Ds has been observed in the ^{208}Pb(^{62}Ni,n) reaction at GSI (1995HO03). Events were identified based on the observation of chains of α-decaying nuclei, correlated in time and position. Comparison of the decay properties of the chains with the literature allowed individual decays to be assigned to specific nuclei.
The data from 1995HO03 was reanalyzed in 2002HO11, and the left-most event in Fig. 5 was found to be reported in error.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{269}Ds Levels

E(level)	$T_{1/2}$	Comments
0	0.18 ms *+21−6*	%α=100; %SF≤25 E(level): Assumed ground state. $T_{1/2}$: From three events.

Adopted Levels

Q(β^-)=−3015 *syst*; S(n)=5309 *syst*; S(p)=4309 *syst*; Q(α)=9.65×10^3 *6* 2021Wa16
ΔQ(β^-)=565, ΔS(n)=632, ΔS(p)=650 (2021WA16).
S(2n)=12066 SY *464*, S(2p)=7428 SY *699* (2021WA16).
^{273}Hs has been observed as the α-decay daughter of ^{277}Ds at LBNL (2010EL06) and JINR (2015UT02,2018UT02). Events were identified based on the observation of chains of correlated α decays, terminated by spontaneous fission. Comparison of the properties of these chains with previous observations allowed individual decays to be assigned to specific nuclei.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{273}Hs Levels

Cross Reference (XREF) Flags

A ^{277}Ds α decay (3.5 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	0.51 s *+30−13*	A	%α=100; %SF≤12.5 E(level): Assumed ground state. $T_{1/2}$: From seven events.

^{277}Ds α decay (3.5 ms) 2010El06,2015Ut02,2018Ut02

Parent: ^{277}Ds: E=0; $T_{1/2}$=3.5 ms *+21−10*; Q(α)=10900 *syst*; %α decay=100
^{277}Ds-$T_{1/2}$: From Adopted Levels.
^{277}Ds-Q(α): From 2021WA16.

^{273}Hs Levels

E(level)	$T_{1/2}$	Comments
0	0.51 s *+30−13*	%α=100; %SF≤12.5

α radiations

Eα	E(level)	Comments
10.55×10^3 *3*	0	Eα: Weighted average of six events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−4600 *syst*; S(n)=5869 *syst*; S(p)=2485 *syst*; Q(α)=1.137×10^4 *5* 2021Wa16
ΔQ(β^-)=424, ΔS(n)=447, ΔS(p)=506 (2021WA16).
S(2n)=13810 SY *172*, S(2p)=3984 SY *310*, Q(εp)=1992 SY *529* (2021WA16).
^{273}Ds has been observed as the α-decay daughter of ^{277}Cn at GSI (1996HO13,2002HO11) and RIKEN (2007MO09,2013SU04). Chains of correlated α-decays were observed, and the properties of these chains were compared to previous studies in order to assign specific decays to individual nuclei.
1996HO13 reports two chains containing ^{273}Ds, but the data was reanalyzed in 2002HO11 and one chain was found to be reported in error.
1996LA12 reports several chains which are assigned to the decay of ^{273}Ds. However, the properties of these chains, especially the total decay time, are not in good agreement with other published results.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{273}Ds Levels

Cross Reference (XREF) Flags

A ^{277}Cn α decay (0.61 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	0.19 ms *+14−6*	A	%α=100; %SF<17 E(level): Assumed ground state. $T_{1/2}$: From five events.

^{277}Cn α decay (0.61 ms)

Parent: ^{277}Cn: E=0; $T_{1/2}$=0.61 ms *+46−18*; Q(α)=1.162×10^4 *6*; %α decay=100
^{277}Cn-$T_{1/2}$: From Adopted Levels.
^{277}Cn-Q(α): From 2021WA16.
References: 1996HO13,2002HO11,2007MO09,2013SU04.

^{273}Ds Levels

E(level)	$T_{1/2}$	Comments
0	0.19 ms *+14−6*	%α=100; %SF<17

α radiations

Eα	E(level)	Comments
11.30×10^3 *2*	0	Eα: Weighted average of five events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−1633 *syst*; S(n)=4882 *syst*; S(p)=4864 *syst*; Q(α)=9030 *syst* 2021Wa16
ΔQ(β^-)=799, ΔS(n)=848, ΔS(p)=748, ΔQ(α)=200 (2021WA16).
S(2n)=11260 SY *743* (2021WA16).
Only a single event has been observed to produce ^{277}Hs. It was observed as the α-decay daughter of ^{281}Ds at GSI (2011GA19) as part of a chain of α-decaying nuclei terminated by spontaneous fission. Agreement between the properties of the prior decays in the chain with those in the literature allowed a positive identification of ^{277}Hs.
2012HO12 tentatively identifies one chain (#1) including ^{277}Hs, but this assignment was later revised in 2016HO09.
Other: One decay chain containing ^{277}Hs is reported in 1999OG10, but these results have not been reproduced.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{277}Hs Levels

Cross Reference (XREF) Flags

A ^{281}Ds α decay (12 s)

E(level)	$T_{1/2}$	XREF	Comments
0	3 ms *+15−1*	A	%SF=100; %$\alpha\leq$50 E(level): Assumed ground state. $T_{1/2}$: From one event.

^{281}Ds α decay (12 s) 2011Ga19

Parent: ^{281}Ds: E=0; $T_{1/2}$=12 s *+4−2*; Q(α)=9473 *syst*; %α decay=6.0
^{281}Ds-$T_{1/2}$: From Adopted Levels.
^{281}Ds-Q(α): From 2021WA16.

^{277}Hs Levels

E(level)	$T_{1/2}$	Comments
0	3 ms *+15−1*	%SF=100; %$\alpha\leq$50

α radiations

Eα	E(level)	Comments
8.73×10^3 *3*	0	Eα: From one event. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−2084 *syst*; S(n)=6376 *syst*; S(p)=2466 *syst*; Q(α)=9900 *syst* 2021Wa16

ΔQ(β^-)=770, ΔS(n)=850, ΔS(p)=979, ΔQ(α)=100 (2021WA16).

S(2n)=11901 SY *767*, S(2p)=7350 SY *894* (2021WA16).

^{277}Mt has been observed as the α-decay daughter of ^{281}Rg at JINR (2013OG04) and GSI (2019KH04). Events were identified by the observation of chains of correlated α-decays terminated by spontaneous fission. Individual decays were assigned to specific nuclei by comparing the properties of the observed chains to those previously observed in the literature.

Both 2013OG04 and 2019KH04 note that it is possible that ^{277}Mt undergoes electron-capture or β^+ decay, in which case the observed spontaneous-fission activity would be due to ^{277}Hs.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{277}Mt Levels

Cross Reference (XREF) Flags

A ^{281}Rg α decay (15 s)

E(level)	$T_{1/2}$	XREF	Comments
0	4 ms *+4−1*	A	%SF=100; %α≤20 E(level): Assumed ground state. $T_{1/2}$: From four events.

^{281}Rg α decay (15 s)

Parent: ^{281}Rg: E=0; $T_{1/2}$=15 s *+4–3*; Q(α)=9900 *syst*; %α decay=18.0
^{281}Rg-$T_{1/2}$: From Adopted Levels.
^{281}Rg-Q(α): From 2021WA16.
References: 2013OG04,2019KH04.

^{277}Mt Levels

E(level)	$T_{1/2}$	Comments
0	4 ms *+4–1*	%SF=100; %$\alpha\leq$20

α radiations

Eα	E(level)	Comments
9.34×10^3 *3*	0	Eα: Weighted average of four events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−3315 *syst*; S(n)=5519 *syst*; S(p)=3509 *syst*; Q(α)=10900 *syst* 2021Wa16
ΔQ(β^-)=611, ΔS(n)=674, ΔS(p)=661, ΔQ(α)=119 (2021WA16).
S(2n)=12716 SY *519*, S(2p)=5978 SY *711* (2021WA16).

^{277}Ds has been observed as the α-decay daughter of ^{281}Cn at LBNL (2010EL06) and JINR (2015UT02,2018UT02). Events were identified by the observation of chains of α-decaying nuclei terminated by spontaneous fission. Comparison of the properties of the chains with those previously observed in the literature allowed decays to be assigned to specific nuclei.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{277}Ds Levels

Cross Reference (XREF) Flags

A ^{281}Cn α decay (0.18 s)

E(level)	$T_{1/2}$	XREF	Comments
0	3.5 ms *+21−10*	A	%α=100; %SF≤12.5 E(level): Assumed ground state. $T_{1/2}$: From seven events.

^{281}Cn α decay (0.18 s)

Parent: ^{281}Cn: E=0; $T_{1/2}$=0.18 s *+10−5*; Q(α)=1.043×10^4 *6*; %α decay=100
^{281}Cn-$T_{1/2}$: From Adopted Levels.
^{281}Cn-Q(α): From 2021WA16.
References: 2010EL06,2015UT02,2018UT02.

^{277}Ds Levels

E(level)	$T_{1/2}$	Comments
0	3.5 ms *+21−10*	%α=100; %SF≤12.5

α radiations

Eα	E(level)	Comments
10.28×10^3 *2*	0	Eα: Weighted average of six events. Assumed g.s. to g.s. transition.

Adopted Levels

S(n)=6099 *syst*; S(p)=2343 *syst*; Q(α)=1.162×10^4 *6* 2021Wa16
ΔS(n)=523, ΔS(p)=647 (2021WA16).
S(2p)=3912 SY *373*, Q(εp)=2504 SY *569* (2021WA16).
^{277}Cn has been observed in the ^{208}Pb(^{70}Zn,n) reaction at GSI (1996HO13,2002HO11) and RIKEN (2007MO09,2013SU04). Events were identified by the observation of chains of correlated α decays. Comparison of the properties of these chains with those previously observed allowed individual decays to be assigned to specific nuclei.
1996HO13 reports two decay chains. However, the data is reanalyzed in 2002HO11 and the chain from 01-Feb-1998 is found to be reported in error.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{277}Cn Levels

E(level)	$T_{1/2}$	Comments
0	0.61 ms *+46−18*	%α=100; %SF<17 E(level): Assumed ground state. $T_{1/2}$: From five events.

Adopted Levels

Q(β^-)=−2060 *syst*; S(n)=5119 *syst*; S(p)=4526 *syst*; Q(α)=9473 *syst* 2021Wa16
ΔQ(β^-)=918, ΔS(n)=896, ΔS(p)=776, ΔQ(α)=208 (2021WA16).
S(2n)=11894 SY *780*, S(2p)=7805 SY *776* (2021WA16).
^{281}Ds has been observed as the α-decay daughter of ^{285}Cn at JINR (2000OG05,2002OG09,2004OG07), GSI (2011GA19,2012HO12) and RIKEN (2017KA66); and in gas-phase chemistry experiments at JINR (2010WI14) and GSI (2014YA33). Events were identified by the observation of chains of α-decaying nuclei terminated by spontaneous fission. Comparison of the properties of the decay chains with those in the literature allowed individual decays to be assigned to specific nuclei.
Other: One decay chain containing ^{281}Ds is reported in 1999OG10, but these results have not been reproduced.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{281}Ds Levels

Cross Reference (XREF) Flags

A ^{285}Cn α decay (33 s)

E(level)	$T_{1/2}$	XREF	Comments
0	12 s *+4−2*	A	%SF=94; %α=6 E(level): Assumed ground state. $T_{1/2}$: From 18 events.

^{285}Cn α decay (33 s)

Parent: ^{285}Cn: E=0; $T_{1/2}$=33 s *+10−6*; Q(α)=9388 *syst*; %α decay=100
^{285}Cn-$T_{1/2}$: From Adopted Levels.
^{285}Cn-Q(α): From 2021WA16.
References: 2000OG05,2002OG09,2004OG07,2011GA19,2012HO12,2017KA66,2014YA33, 2010WI14.

^{281}Ds Levels

E(level)	$T_{1/2}$	Comments
0	12 s *+4−2*	%SF=94; %α=6

α radiations

Eα	E(level)	Comments
9.21×10^3 *1*	0	Eα: Weighted average of 17 events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−2614 *syst*; S(n)=6624 *syst*; S(p)=2276 *syst*; Q(α)=9900 *syst* 2021Wa16
ΔQ(β^-)=870, ΔS(n)=939, ΔS(p)=1076, ΔQ(α)=400 (2021WA16).
S(2n)=12531 SY *882*, S(2p)=6830 SY *1024* (2021WA16).

^{281}Rg has been observed as the α-decay daughter of ^{285}Nh at JINR (2011OG04,2012OG02,2012OG06,2013OG01,2013OG04) and GSI (2019KH04). Events were identified based on the observation of time- and position-correlated chains of α-decaying nuclei, terminated by spontaneous fission. Comparison of the decay chains to previous observations allowed individual decays to be assigned to specific nuclei.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{281}Rg Levels

Cross Reference (XREF) Flags

A ^{285}Nh α decay (0.93 s)

E(level)	$T_{1/2}$	XREF	Comments
0	15 s *+4−3*	A	%α=18; %SF=82 E(level): Assumed ground state. $T_{1/2}$: From 21 events.

^{285}Nh α decay (0.93 s)

Parent: ^{285}Nh: E=0; $T_{1/2}$=0.93 s *+45−23*; Q(α)=1.001×10^4 *4*; %α decay=100
^{285}Nh-$T_{1/2}$: From Adopted Levels.
^{285}Nh-Q(α): From 2021WA16.
References: 2011OG04,2012OG02,2012OG06,2013OG01,2013OG04,2019KH04.

^{281}Rg Levels

E(level)	$T_{1/2}$	Comments
0	15 s *+4−3*	%α=18; %SF=82

α radiations

Eα	E(level)	Comments
9.85×10^3 *2*	0	Eα: Weighted average of ten events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−3863 *syst*; S(n)=5779 *syst*; S(p)=3228 *syst*; Q(α)=1.043×10^4 *6* 2021Wa16
ΔQ(β^-)=498, ΔS(n)=706, ΔS(p)=664 (2021WA16).
S(2n)=13216 SY *560*, S(2p)=5655 SY *724*, Q(εp)=338 SY *847* (2021WA16).
^{281}Cn has been observed as the α-decay daughter of ^{285}Fl at LBNL (2010EL06) and JINR (2015UT02,2018UT02). Events were identified by the observation of chains of α-decaying nuclei terminated by spontaneous fission. Comparison of the decay properties of these chains to those in the literature allowed specific decays to be assigned to individual nuclei.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{281}Cn Levels

Cross Reference (XREF) Flags

A ^{285}Fl α decay (101 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	0.18 s *+10−5*	A	%α=100; %SF≤12.5 E(level): Assumed ground state. $T_{1/2}$: From seven events.

^{285}Fl α decay (101 ms)

Parent: ^{285}Fl: E=0; $T_{1/2}$=101 ms *+59−27*; Q(α)=1.056×10^4 *7*; %α decay=100
^{285}Fl-$T_{1/2}$: From Adopted Levels.
^{285}Fl-Q(α): From 2021WA16.
References: 2010EL06,2015UT02,2018UT02.

^{281}Cn Levels

E(level)	$T_{1/2}$	Comments
0	0.18 s *+10−5*	%α=100; %SF≤12.5

α radiations

Eα	E(level)	Comments
10.41×10^3 *3*	0	Eα: Weighted average of six events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−2682 *syst*; S(n)=5400 *syst*; S(p)=4173 *syst*; Q(α)=9388 *syst* 2021Wa16
ΔQ(β^-)=926, ΔS(n)=915, ΔS(p)=712, ΔQ(α)=116 (2021WA16).
S(2n)=12393 SY *797*, S(2p)=7321 SY *712* (2021WA16).
^{285}Cn has been observed as the α-decay daughter of ^{289}Fl at JINR (2000OG05,2002OG09,2004OG07), GSI (2011GA19,2012HO12), and RIKEN (2017KA66); and in gas-phase chemistry experiments at JINR (2010WI14) and GSI (2014YA33). Events were identified based on the observation of time- and position-correlated α-decay chains terminated by spontaneous fission. The decay properties of the chains were compared to those known in the literature to assign each decay to specific nuclei.
Other: One decay chain containing ^{285}Cn is reported in 1999OG10, but these results have not been reproduced.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{285}Cn Levels

Cross Reference (XREF) Flags

A ^{289}Fl α decay (2.4 s)

E(level)	$T_{1/2}$	XREF	Comments
0	33 s *+10−6*	A	%α=100; %SF<6 E(level): Assumed ground state. $T_{1/2}$: From 17 events.

^{289}Fl α decay (2.4 s)

Parent: ^{289}Fl: E=0; $T_{1/2}$=2.4 s *+8–5*; Q(α)=9.95×10^3 *7*; %α decay=100
^{289}Fl-$T_{1/2}$: From Adopted Levels.
^{289}Fl-Q(α): From 2021WA16.
References: 2000OG05,2002OG09,2004OG07,2011GA19,2012HO12,2017KA66,2010WI14, 2014YA33.

^{285}Cn Levels

E(level)	$T_{1/2}$	Comments
0	33 s *+10–6*	%α=100; %SF<6

α radiations

Eα	E(level)	Comments
9.86×10^3 *1*	0	Eα: Weighted average of 17 events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−3164 *syst*; S(n)=6894 *syst*; S(p)=1936 *syst*; Q(α)=1.001×10^4 *4* 2021Wa16
ΔQ(β^-)=874, ΔS(n)=941, ΔS(p)=1087 (2021WA16).
S(2n)=12938 SY *890*, S(2p)=6190 SY *1030* (2021WA16).

^{285}Nh has been observed as the α-decay daughter of ^{289}Mc at JINR (2011OG04,2012OG02,2012OG06,2013OG01,2013OG04) and GSI (2019KH04). Events were identified through observation of time- and position-correlated chains of α-decaying nuclei, terminated by spontaneous fission. Comparison of the properties of the observed decay chains with those known in the literature allowed specific nuclei to be assigned to each decay.

A wide range of α-decay energies have been assigned to ^{285}Nh in the literature, suggesting that excited states may be populated in the daughter nucleus. There appears to be one grouping of α-decay energies around 9.8 MeV that is assumed to correspond with decay from ground state to ground state, but it is difficult to tell whether one or more excited states may be populated. In addition, the lower-energy decays appear to have a systematically longer lifetime (on the order of ten seconds compared to one second). These lower-energy but longer-lived decays are not used in the calculation of the lifetime here.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{285}Nh Levels

Cross Reference (XREF) Flags

A ^{289}Mc α decay (296 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	0.93 s *+45−23*	A	%α=100; %SF<5 E(level): Assumed ground state. $T_{1/2}$: From nine events.

^{289}Mc α decay (296 ms)

Parent: ^{289}Mc: E=0; $T_{1/2}$=296 ms *+97−59*; Q(α)=1.049×10^4 *5*; %α decay=100
^{289}Mc-$T_{1/2}$: From Adopted Levels.
^{289}Mc-Q(α): From 2021WA16.
References: 2011OG04,2012OG02,2012OG06,2013OG01,2013OG04,2019KH04.

^{285}Nh Levels

E(level)	$T_{1/2}$	Comments
0	0.93 s *+45−23*	%α=100; %SF<5

α radiations

Eα	E(level)	Comments
10.31×10^3 *2*	0	Eα: Weighted average of 17 events. Assumed g.s. to g.s. transition.

Adopted Levels

S(n)=5919 *syst*; S(p)=2948 *syst*; Q(α)=1.056×10^4 *7* 2021Wa16
ΔS(n)=770, ΔS(p)=669 (2021WA16).
S(2p)=4983 SY *736*, Q(εp)=1228 SY *863* (2021WA16).
^{285}Fl has been observed in the ^{242}Pu(^{48}Ca,5n) reaction at LBNL (2010EL06) and the ^{240}Pu(^{48}Ca,3n) reaction at JINR (2015UT02,2018UT02). Events were identified based on the observation of chains of α-decaying nuclei terminated by spontaneous fission. The observed decay properties were compared to those in the literature in order to assign decays to specific nuclei.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{285}Fl Levels

E(level)	$T_{1/2}$	Comments
0	101 ms *+59−27*	%α=100; %SF≤12.5 E(level): Assumed ground state. $T_{1/2}$: From seven events.

Adopted Levels

Q(β^-)=−3217 *syst*; S(n)=5523 *syst*; S(p)=3793 *syst*; Q(α)=9.95×10^3 *7* 2021Wa16
ΔQ(β^-)=929, ΔS(n)=918, ΔS(p)=866 (2021WA16).
S(2n)=12606 SY *801*, S(2p)=6482 SY *866* (2021WA16).
^{289}Fl has been reported as the product of the ^{244}Pu(^{48}Ca,3n) reaction at JINR (2000OG05,2004OG07) and GSI (2010DU06,2011GA19); as the α-decay daughter of ^{293}Lv at JINR (2017KA66), at GSI (2012HO12), and at RIKEN (2017KA66); and in a chemistry experiment using a gas chromatography system at GSI (2014YA33). In all cases, ^{289}Fl was identified as a member of a chain of α-decaying nuclei terminated by spontaneous fission. Identification of the isotopes in the chains was based on the comparison of the observed decay properties with those of previously known nuclei.
Note: 2000OG05, 2001OG01, and 2002OG09 identify ^{289}Fl as ^{288}Fl, but this assignment was later revised.
Other: 1999OG10 reports one chain assigned to ^{289}Fl, but the decay properties of this chain have not been reproduced in subsequent publications.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{289}Fl Levels

Cross Reference (XREF) Flags

A ^{293}Lv α decay (95 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	2.4 s +*8*−*5*	A	%α=100; %SF<6 E(level): Assumed ground state. $T_{1/2}$: From 15 events.

^{293}Lv α decay (95 ms)

Parent: ^{293}Lv: E=0; $T_{1/2}$=95 ms *+63−27*; Q(α)=1.068×10^4 *6*; %α decay=100
^{293}Lv-$T_{1/2}$: From Adopted Levels.
^{293}Lv-Q(α): From 2021WA16.
References: 2002OG09,2012HO12,2017KA66.

^{289}Fl Levels

E(level)	$T_{1/2}$	Comments
0	2.4 s *+8−5*	%α=100; %SF<6

α radiations

Eα	E(level)	Comments
10.55×10^3 *2*	0	Eα: Weighted average of six events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−3774 *syst*; S(n)=7054 *syst*; S(p)=1523 *syst*; Q(α)=1.049×10^4 *5* 2021Wa16
ΔQ(β^-)=925, ΔS(n)=943, ΔS(p)=1088 (2021WA16).
S(2n)=13208 SY *894*, S(2p)=5350 SY *1050* (2021WA16).
^{289}Mc has been reported as the product of the ^{243}Am(^{48}Ca,2n) reaction at JINR (2012OG02,2013OG01) and as the α-decay daughter of ^{293}Ts produced at GSI (2019KH04) and JINR (2011OG04,2012OG06,2013OG04). ^{289}Mc was identified based on the detection of time- and position-correlated chains of α decays which were initiated by the implantation of an evaporation residue into a position-sensitive silicon detector and terminated by spontaneous fission. Comparison of the decay chains with reported decay properties of various nuclei allowed the chain members to be assigned to specific isotopes. A total of 22 chains containing ^{289}Mc have been identified.
Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{289}Mc Levels

Cross Reference (XREF) Flags

A ^{293}Ts α decay (21 ms)

E(level)	$T_{1/2}$	XREF	Comments
0	296 ms *+97−59*	A	%α=100; %SF<5 E(level): Assumed ground state. $T_{1/2}$: From 16 events.

^{293}Ts α decay (21 ms)

Parent: ^{293}Ts: E=0; $T_{1/2}$=21 ms *+7−4*; Q(α)=1.132×10^4 *5*; %α decay=100
^{293}Ts-$T_{1/2}$: From Adopted Levels.
^{293}Ts-Q(α): From 2021WA16.
Sixteen α-decay events from ^{293}Ts have been observed (2011OG04,2012OG06,2013OG04,2019KH04). Two outliers (at 9.7 and 10.6 MeV) are not included in the calculation of the α-decay energy.

^{289}Mc Levels

E(level)	$T_{1/2}$	Comments
0	296 ms *+97−59*	%α=100; %SF<5

α radiations

Eα	E(level)	Comments
11.06×10^3 *2*	0	Eα: Weighted average of 14 α-decay events. Assumed g.s. to g.s. transition.

Adopted Levels

Q(β^-)=−3860 *syst*; S(n)=5636 *syst*; S(p)=3321 *syst*; Q(α)=1.068×10^4 *6* 2021Wa16
ΔQ(β^-)=933, ΔS(n)=920, ΔS(p)=869 (2021WA16).
S(2n)=12819 SY *808*, S(2p)=5510 SY *869* (2021WA16).

Four publications have reported the production of ^{293}Lv through the ^{248}Cm(^{48}Ca,3n) reaction, two using DGFRS at JINR (2001OG01,2002OG09), one using SHIP at GSI (2012HO12), and one using GARIS at RIKEN (2017KA66). In the DGFRS experiments, ^{293}Lv was originally identified as ^{292}Lv, but the assignment was later revised. Evaporation residues from the reaction were implanted into position-sensitive silicon detectors, and identified by the observation of subsequent time- and position-correlated α-decay chains terminated by spontaneous fission. Comparison of the decay chains with the properties of the known daughter nuclei allowed assignment of the evaporation residues to ^{293}Lv. A total of seven events were positively identified, with another three events being considered tentative.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{293}Lv Levels

E(level)	$T_{1/2}$	Comments
0	95 ms *+63−27*	%α=100; %SF≤12.5 E(level): Assumed ground state. $T_{1/2}$: From six events.

Adopted Levels

Q(β^-)=−4374 *syst*; S(n)=7264 *syst*; S(p)=994 *syst*; Q(α)=1.132×10^4 *5* 2021Wa16
ΔQ(β^-)=1053, ΔS(n)=1026, ΔS(p)=1090 (2021WA16).
S(2n)=13368 SY *980*, S(2p)=4330 SY *1070*, Q(εp)=539 SY *1046* (2021WA16).

Four publications have reported the production of ^{293}Ts through the ^{249}Bk(^{48}Ca,4n) reaction, one using TASCA at GSI (2019KH04) and three using DGFRS at JINR (2012OG06,2013OG04,2011OG04). Evaporation residues were implanted into position-sensitive silicon detectors, and identified based on the observation of time- and position-correlated α-decay chains terminated by spontaneous fission, with properties matching those of the known daughter nuclei. Eighteen such chains have been observed in total, with two missing the α-decay of ^{293}Ts.

Half-lives, branching ratios, and α-decay energies in this evaluation have been computed from the individual events listed in the references above. Half-life uncertainties have been computed according to the method of 1984SC13. An additional 10 keV systematic uncertainty is assumed for the α-decay energies, which is added in quadrature to the averaged statistical uncertainty.

^{293}Ts Levels

E(level)	$T_{1/2}$	Comments
0	21 ms *+7−4*	%α=100; %SF<6 E(level): Assumed ground state. $T_{1/2}$: From 16 events.

REFERENCES FOR A=269

1984Sc13 K.-H.Schmidt, C.-C.Sahm, K.Pielenz, H.-G.Clerc - Z.Phys. A316, 19 (1984).
Some Remarks on the Error Analysis in the Case of Poor Statistics.

1995Ho03 S.Hofmann, V.Ninov, F.P.Hessberger, P.Armbruster et al. - Z.Phys. A350, 277 (1995).
Production and Decay of ^{269}Ds.

1996Ho13 S.Hofmann, V.Ninov, F.P.Hessberger, P.Armbruster et al. - Z.Phys. A354, 229 (1996).
The New Element 112.

1996La12 Yu.A.Lazarev, Yu.V.Lobanov, Yu.Ts.Oganessian, V.K.Utyonkov et al. - Phys.Rev. C54, 620 (1996).
α Decay of $^{273}110$: Shell closure at N = 162.

1999Og10 Yu.Ts.Oganessian, V.K.Utyonkov, Yu.V.Lobanov, F.Sh.Abdullin et al. - Phys.Rev.Lett. 83, 3154 (1999).
Synthesis of Superheavy Nuclei in the $^{48}Ca + ^{244}Pu$ Reaction.

2000Og05 Yu.Ts.Oganessian, V.K.Utyonkov, Yu.V.Lobanov, F.Sh.Abdullin et al. - Phys.Rev. C62, 041604 (2000).
Synthesis of Superheavy Nuclei in the $^{48}Ca + ^{244}Pu$ Reaction: $^{288}114$.

2001Og01 Yu.Ts.Oganessian, V.K.Utyonkov, Yu.V.Lobanov, F.Sh.Abdullin et al. - Phys.Rev. C63, 011301 (2001).
Observation of the Decay of $^{292}116$.

2002Du21 Ch.E.Dullmann, W.Bruchle, R.Dressler, K.Eberhardt et al. - Nature(London) 418, 859 (2002).
Chemical investigation of hassium (element 108).

2002Ho11 S.Hofmann, F.P.Hessberger, D.Ackermann, G.Munzenberg et al. - Eur.Phys.J. A 14, 147 (2002).
New Results on Elements 111 and 112.

2002Og09 Y.T.Oganessian, V.K.Utyonkov, Y.V.Lobanov, F.S.Abdullin et al. - Eur.Phys.J. A 15, 201 (2002).
Synthesis of superheavy nuclei in the reactions of ^{244}Pu and ^{248}Cm with ^{48}Ca.

2004Og07 Yu.Ts.Oganessian, V.K.Utyonkov, Yu.V.Lobanov, F.Sh.Abdullin et al. - Phys.Rev. C 69, 054607 (2004).
Measurements of cross sections for the fusion-evaporation reactions $^{244}Pu(^{48}Ca,xn)^{292-x}114$ and $^{245}Cm(^{48}Ca,xn)^{293-x}116$.

2004Vo24 A.von Zweidorf, R.Angert, W.Bruchle, S.Burger et al. - Radiochim.Acta 92, 855 (2004).
Evidence for the formation of sodium hassate(VIII).

2005Gu33 M.Gupta, T.W.Burrows - Nucl.Data Sheets 106, 251 (2005); Erratum Nucl.Data Sheets 107, 789 (2006).
Nuclear Data Sheets for A = 266-294.

2006Dv01 J.Dvorak, W.Bruchle, M.Chelnokov, R.Dressler et al. - Phys.Rev.Lett. 97, 242501 (2006).
Doubly Magic Nucleus $^{270}_{108}Hs_{162}$.

2007Mo09 K.Morita, K.Morimoto, D.Kaji, T.Akiyama et al. - J.Phys.Soc.Jpn. 76, 043201 (2007).
Experiment on Synthesis of an Isotope $^{277}112$ by $^{208}Pb + ^{70}Zn$Reaction.

2008Dv02 J.Dvorak, W.Bruchle, M.Chelnokov, Ch.E.Dullmann et al. - Phys.Rev.Lett. 100, 132503 (2008).
Observation of the 3n Evaporation Channel in the Complete Hot-Fusion Reaction $^{26}Mg+^{248}Cm$ Leading to the New Superheavy Nuclide ^{271}Hs.

2010Du06 Ch.E.Dullmann, M.Schadel, A.Yakushev, A.Turler et al. - Phys.Rev.Lett. 104, 252701 (2010).
Production and Decay of Element 114: High Cross Sections and the New Nucleus ^{277}Hs.

2010El06 P.A.Ellison, K.E.Gregorich, J.S.Berryman, D.L.Bleuel et al. - Phys.Rev.Lett. 105, 182701 (2010).
New Superheavy Element Isotopes: $^{242}Pu(^{48}Ca,5n)^{285}114$.

2010Wi14 D.Wittwer, F.Sh.Abdullin, N.V.Aksenov, Yu.V.Albin et al. - Nucl.Instrum.Methods Phys.Res. B268, 28 (2010).
Gas phase chemical studies of superheavy elements using the Dubna gas-filled recoil separator – Stopping range determination.

2011Ga19 J.M.Gates, Ch.E.Dullmann, M.Schadel, A.Yakushev et al. - Phys.Rev. C 83, 054618 (2011).
First superheavy element experiments at the GSI recoil separator TASCA: The production and decay of element 114 in the $^{244}Pu(^{48}Ca,3-4n)$ reaction.

2011Og04 Yu.Ts.Oganessian, F.Sh.Abdullin, P.D.Bailey, D.E.Benker et al. - Phys.Rev. C 83, 054315 (2011).
Eleven new heaviest isotopes of elements Z = 105 to Z = 117 identified among the products of $^{249}Bk+^{48}Ca$ reactions.

2012Ho12 S.Hofmann, S.Heinz, R.Mann, J.Maurer et al. - Eur.Phys.J. A 48, 62 (2012).
The reaction $^{48}Ca + ^{248}Cm \rightarrow ^{296}116^{*}$ studied at the GSI-SHIP.

2012Og02 Yu.Ts.Oganessian, F.Sh.Abdullin, S.N.Dmitriev, J.M.Gostic et al. - Phys.Rev.Lett. 108, 022502 (2012).
New Insights into the $^{243}Am+^{48}Ca$ Reaction Products Previously Observed in the Experiments on Elements 113, 115, and 117.

2012Og06 Yu.Ts.Oganessian, F.Sh.Abdullin, C.Alexander, J.Binder et al. - Phys.Rev.Lett. 109, 162501 (2012).
Production and Decay of the Heaviest Nuclei $^{293,294}117$ and $^{294}118$.

2013Og01 Yu.Ts.Oganessian, F.Sh.Abdullin, S.N.Dmitriev, J.M.Gostic et al. - Phys.Rev. C 87, 014302 (2013).
Investigation of the $^{243}Am + ^{48}Ca$ reaction products previously observed in the experiments on elements 113, 115, and 117.

2013Og04 Yu.Ts.Oganessian, F.Sh.Abdullin, C.Alexander, J.Binder et al. - Phys.Rev. C 87, 054621 (2013).
Experimental studies of the $^{249}Bk+^{48}Ca$ reaction including decayproperties and excitation function for isotopes of element 117, and discovery of the new isotope ^{277}Mt.

2013Su04 T.Sumita, K.Morimoto, D.Kaji, H.Haba et al. - J.Phys.Soc.Jpn. 82, 024202 (2013).
New Result on the Production of ^{277}Cn by the $^{208}Pb + ^{70}Zn$ Reaction.

2014Pr09 B.Pritychenko, E.Betak, B.Singh, J.Totans - Nucl.Data Sheets 120, 291 (2014).
Nuclear Science References Database.

2014Ya33 A.Yakushev, J.M.Gates, A.Turler, M.Schadel et al. - Inorg. Chem. 53, 1624 (2014).

REFERENCES FOR A=269(CONTINUED)

Superheavy Element Flerovium (Element 114) Is a Volatile Metal.

2015Ut02 V.K.Utyonkov, N.T.Brewer, Yu.Ts.Oganessian, K.P.Rykaczewski et al. - Phys.Rev. C 92, 034609 (2015).
Experiments on the synthesis of superheavy nuclei ^{284}Fl and ^{285}Fl in the $^{239,240}Pu + ^{48}Ca$ reactions.

2016Ho09 S.Hofmann, S.Heinz, R.Mann, J.Maurer et al. - Eur.Phys.J. A 52, 180 (2016).
Review of even element super-heavy nuclei and search for element.

2017Ka66 D.Kaji, K.Morita, K.Morimoto, H.Haba et al. - J.Phys.Soc.Jpn. 86, 034201 (2017).
Study of the Reaction $^{48}Ca + ^{248}Cm \rightarrow ^{296}Lv^{*}$ at RIKEN-GARIS.

2018Ut02 V.K.Utyonkov, N.T.Brewer, Yu.Ts.Oganessian, K.P.Rykaczewski et al. - Phys.Rev. C 97, 014320 (2018).
Neutron-deficient superheavy nuclei obtained in the $^{240}Pu + ^{48}Ca$ reaction.

2019Kh04 J.Khuyagbaatar, A.Yakushev, Ch.E.Dullmann, D.Ackermann et al. - Phys.Rev. C 99, 054306 (2019).
Fusion reaction $^{48}Ca + ^{249}Bk$ leading to formation of the element Ts (Z=117).

2021Wa16 M.Wang, W.J.Huang, F.G.Kondev, G.Audi, S.Naimi - Chin.Phys.C 45, 030003 (2021).
The AME 2020 atomic mass evaluation (II). Tables, graphs and references.