Nuclear Data Sheets for A = 239*

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Abstract: Spectroscopic data and level schemes from radioactive decay and nuclear reaction studies are presented here for all nuclei with mass number $A=239$.

In general, a relatively small amount of new data on this mass chain has been reported since the previous evaluation in 2003. However, special evaluations, such as "Database of prompt gamma rays from slow neutron-capture from elemental analysis" (2007ChZX), have provided additional precise data for levels in ^{239}U . Also, new Coulomb excitation measurements in ^{239}Pu have extended the knowledge of the $1/2[631]$ rotational band up to $J\pi=(55/2+)$, and that of the octupole vibrational band up to $J\pi=(53/2-)$.

For historical knowledge it is worth mentioning the report on the "Discovery of isotopes of the transuranium elements with $93 \leq Z \leq 98$ " (2013Fr02), where the information for elements Np, Pu, Am, and Cf with mass number $A=239$ is presented.

The alpha hindrance factors (HF) presented in this evaluation were calculated using values of the radius parameter (r_0) interpolated from those for even-even adjacent nuclei given by 1998Ak04.

Cutoff Date: All data received by June 2013 have been evaluated.

General Policies and Organization of Material: see <http://www.nndc.bnl.gov/nds/NDSPolicies.pdf>.

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General Comments: For nuclides not observed but theoretical results see 2011Sa40 (^{239}Es), 2008Kh10 (^{239}Fm), and 2008Do10 (^{239}No).

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NUCLEAR DATA SHEETS

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Skeleton Scheme for $A=239$

NUCLEAR DATA SHEETS

Ground-State and Isomeric-Level Properties for A=239

Nuclide	Level	$J\pi$	$T_{1/2}$	Decay Modes
²³⁹ Pa	0.0	(3/2)	1.8 h 5	%β ⁻ =100
²³⁹ U	0.0	5/2+	23.45 min 2	%β ⁻ =100
²³⁹ Np	0.0	5/2+	2.356 d 3	%β ⁻ =100
²³⁹ Pu	0.0	1/2+	24110 y 30	%α=100; %SF=3.1×10 ⁻¹⁰ 6
	3100	(5/2+)	7.5 μs 10	%SF≤100
	3303	(9/2-)	2.6 ns +40-12	%SF≤100
²³⁹ Am	0.0	(5/2)-	11.9 h 1	%ε=99.990 1; %α=0.010 1
	2500	(7/2+)	163 ns 12	%SF≤100
²³⁹ Cm	0.0	(7/2-)	2.7 h 8	%ε=100; %α<0.001
²³⁹ Bk	0.0	(3/2-, 7/2+)		%ε>99; %SF<1; %α<1
²³⁹ Cf	0.0		39 s +37-12	%ε=?; %α=?
²⁴³ Am	0.0	5/2-	7364 y 22	%α=100
²⁴³ Cm	0.0	5/2+	28.9 y 4	%α=99.71 3; ...
²⁴³ Bk	0.0	(3/2-)	4.5 h 2	%α=0.150; ...
²⁴³ Cf	0.0	(1/2+)	10.7 min 5	%α=14.0; ...
²⁴³ Es	0.0	(7/2+, 3/2-)	23 s 3	%α=61 6; ...
²⁴³ Fm	0.0		0.231 s 9	%α=91 3; ...

Adopted Levels

Q(β⁻)=2760 SY; S(n)=5630 SY; S(p)=6580 SY; Q(α)=3560 SY 2012Wa38.
ΔQ(β⁻)=200, ΔS(n)=200, ΔS(p)=340, ΔQ(α)=200.
²³⁹Pa activity was produced by bombarding a uranium target with 900-MeV ¹⁸O projectiles. Protactinium was chemically separated and its genetic relation to its daughter nuclide ²³⁹U was established. The half-life of ²³⁹Pa was measured by following the growth and subsequent decay of the known 74.6-keV γ ray from ²³⁹U β⁻ decay (1995Yu01,1996Yu06).

²³⁹Pa Levels

E(level)	Jπ	T _{1/2}	Comments
0 . 0	(3 / 2)	1 . 8 h 5	T _{1/2} : From 1995Yu01, 1996Yu06. Jπ: Assigned by evaluator, based on its β ⁻ decay to the 715- (3/2+), 784- (5/2-), and 815-keV (1/2-) levels in ²³⁹ U. %β ⁻ =100.

Adopted Levels, Gammas

Q(β⁻)=1261.5 16; S(n)=4806.38 17; S(p)=7609 16; Q(α)=4131 13 2012Wa38.

2013Fr03: Discovery of ²³⁹U.

Other measurements, calculations, and compilations.

²³⁸U(n,γ).

2013De19: ²³⁸U(n,γ), E<20 MeV. Analyzed data.

2013He11: ²³⁸U(n,γ), E<20 MeV. Deduced σ.

2012Br11: ²³⁸U(n,γ), E=0 – 30 MeV. Calculated neutron yields.

2012Le17: ²³⁸U(n,γ), E<20 MeV. Deduced σ.

2012Na16: ²³⁸U(n,γ), E=3.7 MeV. Measured E_γ, I_γ. Deduced σ.

2012Pr13: ²³⁸U(n,γ), E=Thermal. σ compilation.

2012Tu03: ²³⁸U(n,γ), E=0.01 – 50 MeV. Deduced σ.

2011Go05: ²³⁸U(n,γ), E≤20 MeV. Deduced σ.

2011Go28: ²³⁸U(n,γ), E=0.001 – 30 MeV. Deduced σ.

2011Ro44: ²³⁸U(n,γ), E=0.1 – 20 MeV. Deduced σ.

2011U01: ²³⁸U(n,γ), E=10 eV – 100 keV. Deduced σ.

2010Ad13: ²³⁸U(n,γ), E=th – 1 GeV. Measured E_γ, I_γ. Deduced σ.

2010Co02: ²³⁸U(n,γ), E=0.001 – 1 MeV. Measured E_γ, I_γ. Deduced σ.

2009Ch04: ²³⁸U(n,γ), E<1.0 MeV. Deduced σ.

2009De04: ²³⁸U(n,γ), 0 – 20 keV. Deduced σ.

2009Go05: ²³⁸U(n,γ), 0.01 – 30 MeV. Deduced Fission σ.

2008Ha01: ²³⁸U(n,γ), E=0.003 – 11 MeV. Deduced σ.

2008Mu23: ²³⁸U(n,γ), E<1 MeV. Analyzed σ.

2008Re07: ²³⁸U(n,γ), E=low. Measured E_γ, I_γ.

2007Bo19: ²³⁸U(n,γ), 0 – 20 keV. Deduced σ.

2004Ko23: ²³⁸U(n,γ), E=reactor. Measured E_γ, I_γ.

2004St02: ²³⁸U(n,γ), 0 – 20 keV. Deduced σ.

Nuclear Structure.

2011Ad15: Calculated single-particle states.

2009Mi28: Calculated fission barrier; level energies.

2006Sh19: Rotational bands.

2006Fr21: Level densities.

2005Pa73: Single-particle states.

2004Fr11: Fission fragment yields.

2004Sa55: Calculated masses.

2002Be89: Calculated level densities.

2011He12: Compilation.

Radioactivity.

2012Ro34: Theory.

2012Sa31: ²³⁹U(²⁰O) cluster decay.

2004Fr11: β⁻ decay. Evaluated data.

²³⁹U Levels

All levels populated in (n,γ) reactions (from thermal or resonance neutron capture states with J_π=1/2+) have spins 1/2, 3/2, or 5/2. Band assignments presented here have been based on the energy systematics of Nilsson orbital configurations, and on the systematics of rotational band parameters (1978Bo12,1972Bo16,1984Ch05). J_π assignments to levels in the second potential well of the shape isomeric ground state are supported by tentative γ-ray multipolarities (1998Ob01,1995Ob01).

Chemical shift for the 6.67-eV n-resonance was measured, Δ<r²>/<r²>=5% relative to ²³⁹U g.s. was deduced, possibly caused by lack of deformation at 4.8 MeV (neutron binding energy) (1981Se14).

Cross Reference (XREF) Flags

A ²³⁸U(n,γ) E=thermal
B ²³⁸U(n,γ) E=res: Av
C ²³⁸U(d,p)
D ²³⁸U(n,γ) E=res
E ²³⁹Pa β⁻ Decay

E(level) [†]	J _π [§]	XREF	T _{1/2}	Comments
0.0 [#]	5/2+	ABC E	23.45 min 2	J _π : from (n,γ) average resonance. T _{1/2} : weighted average of: 23.54 min 5 (1943Mi10), 23.5 min 7 (1947Fe05), 23.40 min 5 (1969Hu21), 23.44 min 2 (1989Ab05). %β ⁻ =100.
42.534 [#] 7	7/2+	A C		J _π : 42.5γ E2(+M1) to 5/2+.
98.631 [#] 16	9/2+	A CD		J _π : L=4 in (d,p).

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²³⁹U Levels (continued)

E(level) [†]	Jπ [§]	XREF	T _{1/2}	Comments
133.7991 [@] 10	1/2+	ABC E	0.78 μs 4	Jπ: 133.8γ E2 to 5/2+. T _{1/2} : from (d,pγ) (1975Ya03).
145.767 [@] 6	3/2+	ABC E		Jπ: (n,γ) average resonance.
169.089? ^{&} 10	(7/2+)	A		Jπ: possible 169.1γ γ to 5/2+.
193.985 [@] 5	5/2+	AB E		Jπ: 60.2γ E2 to 1/2+, (n,γ) average resonance.
222.25 [@] 3	(7/2+)	A E		Jπ: 562.0γ (E1) from 5/2-.
226.3 ^{&} 15	(9/2+)	C		Jπ: from cross-section signature in (d,p).
292.5872 ^f 20	(7/2-)	A		Jπ: 292.2γ to 5/2+, 193.9γ to 9/2+. Systematics of Nilsson orbital configurations (1972El21).
301.8 ^{&} 20	(11/2+)	C		Jπ: from cross-section signature in (d,p).
307.8 [@] 15	(9/2+)	C		Jπ: from cross-section signature in (d,p).
372.7 ^f 20	(11/2-)	C		Jπ: from cross-section signature in (d,p).
498.6 ^f 15	(15/2-)	C		Jπ: from cross-section signature in (d,p).
539.283 ^g 9	5/2-	AB		Jπ: 539.3γ E1 to 5/2+, 496.7γ E1 to 7/2+; (n,γ) average resonance.
687.854 ^a 5	(1/2+)	ABC		Jπ: 1/2+ or 3/2+ from 554.0γ M1 to 1/2+; band parameter syst suggests 1/2+ (see for example ²⁴⁹ Cm, ²⁵¹ Cf).
694.7 5	5/2	B		Jπ: from (n,γ) average resonance. 1984Ch05 suggest configuration=5/2[633].
702.5 15	(9/2+)	C		Jπ: from cross-section signature in (d,p). 1978Er03 suggest configuration=7/2[613].
715.835 ^a 5	3/2+	ABC E		Jπ: 521.8γ M1(+E2) to 5/2+, 582.0γ M1(+E2) to 1/2+.
726.108 ^c 10	(3/2+)	AB		Jπ: 580.3γ M1+E2 to 3/2+, 592.3γ M1+E2 to 1/2+, band syst suggests 3/2+.
734.65 ^a 3	(5/2+)	ABC		Jπ: from (n,γ) average resonance.
739.380 ^b 6	1/2-	ABC		Jπ: 605.5γ E1 to 1/2+; γ-ray polarization in (n,γ).
746.054 ^b 4	3/2-	ABC		Jπ: 612.2γ E1 to 1/2+, 552.1γ E1 to 5/2+.
757.151 ^c 22	(5/2+)	ABC		Jπ: 563.1γ M1+E2 to 5/2+; (n,γ) average resonance.
784.273 ^b 14	5/2-	ABC E		Jπ: 638.5γ E1 to 3/2+; (n,γ) average resonance.
795.9 ^b 15	(7/2-)	C		Jπ: from cross-section signature in (d,p).
815.155 ^h 6	1/2-	ABC E		Jπ: from cross-section signature in (d,p); γ-ray polarization in (n,γ).
823.708 ^h 8	3/2-	ABC		Jπ: 629.7γ E1 to 5/2+, 690.0γ E1 to 1/2+.
838.3 15		C		1978Er03 suggest 11/2- member of 1/2[750] rotational band.
853.23 ^e 4	(3/2+)	ABC		Jπ: 853.2γ M1+E2 to 5/2+; (n,γ) average resonance.
858.81 ^h 10	5/2-	B		Jπ: from (n,γ) average resonance.
874.0 ^c 15	(9/2+)	C		Jπ: from cross-section signature in (d,p).
888.1 ^e 3	5/2+	ABC		Jπ: from (n,γ) average resonance.
893.30 10	5/2+	AB		Jπ: 893.3γ M1+E2 to 5/2+; (n,γ) average resonance.
897.9 15		C		
932.90 ^d 5	(1/2-)	ABC		Jπ: 787.2γ (E1) to 3/2+; (n,γ) average resonance.
944.8 ^e 20	(7/2+)	C		Jπ: from cross-section signature in (d,p).
961.88 ^d 14	(3/2-)	ABC		Jπ: 768.0γ (E1) to 5/2+, 827.9γ (E1) to 1/2+; (n,γ) average resonance.
965.638 ⁱ 19	3/2+	AB		Jπ: 831.8γ M1+E2 to 1/2+.
982.9 ^d 10	5/2-	BC		Jπ: from (n,γ) average resonance.
988.20 ⁱ 6	(5/2+)	AB		Jπ: 794.2γ M1+E2 to 3/2+, 842.4γ M1+E2 to 5/2+.
990.495 19	3/2+, 5/2+	AB D		Jπ: 990.2γ M1+E2 to 5/2+; (n,γ) average resonance.
996.1 ^e 15	(9/2+)	C		Jπ: from cross-section signature in (d,p).
1005.7 5	1/2+, 3/2+, 5/2+	AB		Jπ: from (n,γ) average resonance.
1018.6 10	5/2-	B		Jπ: from (n,γ) average resonance. 1984Ch05 suggest configuration=1/2[631]×2-.
1062.48 ^j 6	5/2+	AB		Jπ: 1062.5γ E0+M1+E2 to 5/2+; (n,γ) average resonance.
1066.81 12	1/2, 3/2	ABC		Jπ: 1/2-, 3/2- from (n,γ) average resonance; 3/2+, 5/2+, 7/2+ from 1066.8γ M1+E2 to 5/2+.
1115.0 15		C		
1146.74 23	5/2	B		Jπ: from (n,γ) average resonance.
1149.7 3		ABC		
1152.80 4	3/2+	AB		Jπ: 1007.0γ E0+M1+E2 to 3/2+.
1155.052 ^k 22	1/2+	AB		Jπ: 1021.3γ E0+M1 to 1/2+.
1167.02 ^k 3	3/2+	AB		Jπ: 1021.3γ E0+M1 to 3/2+; (n,γ) average resonance.
1194.63 ^l 5	(1/2-)	ABC		Jπ: 478.8γ (E1) to 3/2+; (n,γ) average resonance.
1201.02 ^k 6	5/2+	AB		Jπ: 1007.0γ E0+M1+E2 to 5/2+; (n,γ) average resonance.
1206.0 10	(5/2)	B		Jπ: from (n,γ) average resonance.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²³⁹U Levels (continued)

E(level) [†]	Jπ [§]	XREF	T _{1/2}	Comments
1223.31 ¹ 3	(3/2-)	AB		Jπ: (1/2+,3/2+) from 1089.6γ (M1) to 1/2+; 1/2-,3/2- from (n,γ) average resonance.
1225.5 10	1/2-	B		Jπ: 1/2-,3/2- from (n,γ) average resonance. 1984Ch05 suggest configuration=5/2[622]×2-.
1232.0 7		ABC		
1235.2 5		AB		
1237.7 7	1/2+, 3/2+	ABC		Jπ: from (n,γ) average resonance.
1241.96 6	1/2-, 3/2-	ABC		Jπ: 554.1γ E1 to 3/2+; (n,γ) average resonance.
1260.3 3	(1/2, 3/2)	ABC		Jπ: from (n,γ) average resonance.
1265.3 8		A		
1270.6 5	(1/2, 3/2)	ABC		Jπ: from (n,γ) average resonance.
1276.83 21	(1/2, 3/2)	AB		Jπ: from (n,γ) average resonance.
1295.2 10	1/2, 3/2, 5/2	B		Jπ: from (n,γ) average resonance.
1306.22 3	1/2-, 3/2-	AB		Jπ: 590.4γ E1 to 3/2+; (n,γ) average resonance. π=+.
1318.2 3		AB		
1320.5 7		AB		
1324.6 3	(1/2-, 3/2-)	AB		Jπ: from (n,γ) average resonance.
1338.3 10	(1/2+, 3/2+, 5/2+)	BC		Jπ: from (n,γ) average resonance.
1360.97 3	(1/2-, 3/2-)	ABC		Jπ: from (n,γ) average resonance.
1368.03 21		A		
1383.5 4		A		
1399.5 8		A		
1404.53 21		A		
1416.9 6		A		
1436.83 21		A C		XREF: C(1430).
1445.83 21		A		
1462.5 3		A		
1479.5 5		A C		XREF: C(1473).
1481.53 21		A		
1493.6 5	1/2, 3/2	A		Jπ: from γ-ray polarization in (n,γ).
1494.9 6	1/2, 3/2	A		Jπ: from γ-ray polarization in (n,γ).
1504.5 3		A		
1509.9 3	(1/2-, 3/2-)	A		Jπ: from γ-ray polarization in (n,γ).
1512.9 15		A C		XREF: C(1515).
1520.33 21	1/2-, 3/2-	A C		XREF: C(1524).
1573.2 5	1/2, 3/2+	A		Jπ: from γ-ray polarization in (n,γ).
1586.3 5	3/2	A		Jπ: from γ-ray polarization in (n,γ).
1609.2 5	1/2+, 3/2+	A		Jπ: from γ-ray polarization in (n,γ).
1614.7 5	3/2, (1/2)	A		Jπ: from γ-ray polarization in (n,γ).
1631.2 5	1/2, 3/2	A		Jπ: from γ-ray polarization in (n,γ).
1684.7 5	1/2, 3/2	A		Jπ: from γ-ray polarization in (n,γ).
1692.2 5	3/2, (1/2)	A		Jπ: from γ-ray polarization in (n,γ).
0.0+x [‡]	(5/2+)	D	>0.25 μs	T _{1/2} : from delayed γγ coin (1994Ob01). Jπ: 708.2γ to 3/2+, 5/2+.
1717.0 5	3/2, (1/2)	A		Jπ: from γ-ray polarization in (n,γ).
1807.9 5	(3/2)	A		Jπ: from γ-ray polarization in (n,γ).
174.0+x [‡]		D		
477.8+x [‡]	(3/2-)	D		
1083.4+x [‡]	(1/2+, 5/2+)	D		
1626.9+x [‡]	(1/2-, 3/2-)	D		
1630.6+x [‡]	(3/2-)	D		
1767.5+x [‡]	(1/2-, 3/2-)	D		
1776.5+x [‡]		D		
1808.2+x [‡]		D		
3107.0+x [‡]	(1/2+)	D		

[†] From least squares adjustment in (n,γ) thermal, unless otherwise specified.

[‡] x=1699 keV, from (n,γ) E=res experiment (2008ObZZ). See also 1998Ob01. Levels are in the second potential well.

[§] From rotational structure. Other supporting arguments, such as γ-ray multipolarities and reduced primary γ-ray intensities from (n,γ) resonance average reactions, are given with the individual levels.

(A): 5/2[622] Rotational parameter A=6.1 keV.

@ (B): 1/2[631] Rotational parameter A=6.8 keV, decoupling constant a=-0.41.

Footnotes continued on next page

Adopted Levels, Gammas (continued)

²³⁹U Levels (continued)

- & (C): 7/2[624] Rotational parameter A=6.9 keV.
 a (D): 1/2[620] Rotational parameter A=6.5 keV, decoupling constant a=+0.42.
 b (E): 1/2[761]? Rotational parameter A=4.9 keV, decoupling constant a=-0.55.
 c (F): 3/2[631]? Rotational parameter A=6.2 keV.
 d (G): 1/2[501] Rotational parameter A=6.9 keV, decoupling constant a=+0.39.
 e (H): 3/2[622] Rotational parameter A=6.8 keV.
 f (I): 7/2[743] Rotational parameter A=4.0 keV.
 g (J): 5/2[622]×0- Octupole vibration.
 h (K): 1/2[631]×0- Rotational parameter A=4.9 keV, decoupling constant a=-0.42. Octupole vibration.
 i (L): 3/2[631]-2+? Rotational parameter A=4.5 keV. Gamma vibration.
 j (M): 5/2[622]×0+? Beta vibration.
 k (N): 1/2[631]×0+ Rotational parameter A=5.4 keV, decoupling constant a=-0.26. Beta vibration.
 l (O): 1/2[750]? Rotational parameter A=6.0 keV, decoupling constant a=+0.59.

$\gamma(^{239}\text{U})$

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. †	α	Comments
42.534	42.540 8	100	E2 (+M1)		
133.7991	133.799 1	100	E2	3.72	B(E2)(W.u.)=0.040 3.
145.767	11.978 CA	100			
169.089?	169.089# 10	100			
193.985	48.230 17		[E2+M1]		
	60.185 10		E2	148	
292.5872	193.956 15	12 6			
	250.062# 7	100 40			
	292.587 2	47 18			
539.283	496.753 11	34 8	E1	0.01367	
	539.278 11	100 20	E1	0.01163	
687.854	542.085 12	28 7			
	554.054 8	100 24	M1	0.189	
	687.853 8	33 10	(E2)		
715.835	521.849 7	100 4	M1 (+E2)		
	582.034 8	22 5	M1 (+E2)		
	673.307 12	14 6			
	715.832 9	30 8	(E2)		Mult.: E2,E1 from α , $\Delta\pi$ =no from level scheme.
726.108	580.340 13	96 26	M1+E2		
	592.309 13	100 30	M1+E2		
734.65	588.88 3	100			
739.380	593.612 5	100 22	E1	0.00966	
	605.581 9	49 11	E1	0.00930	
746.054	552.069 6	90 2	E1	0.01111	
	600.284 10	13 4	E1	0.00946	
	612.253 5	100 22	[E1]	0.00911	
757.151	563.17 3	100 30	M1+E2		
	611.38 3	100 30			
784.273	562.027 22	78 24	[E1]	0.01073	
	638.505 12	100 29	E1	0.00842	
815.155	127.301 5	83 17			
	669.385 13	33 17			
	681.355 9	100 30	E1 ‡		
823.708	629.722 9	100 30	E1	0.00864	
	689.907 11	59 13	E1	0.00728	
853.23	853.23 4	100	M1+E2		
893.30	893.30 10	100	M1+E2		
932.90	787.15 7	25 8	(E1) ‡		
	799.12 7	100 25			
961.88	767.86 21	83 25	(E1) ‡		
	828.04 21	100 25	(E1) ‡		
965.638	819.868 21	19 8			
	831.837 19	100 30	M1+E2		
988.20	794.21 8	83 25	M1+E2		
	842.42 8	100 25	M1+E2		
990.495	451.213 23	100 40			
	990.49 3	100 40	M1+E2		

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued) $\gamma(^{239}\text{U})$ (continued)

E(level)	$E_{\gamma}^{\dagger}$	$I_{\gamma}^{\dagger}$	Mult. [‡]	α	Comments
1062.48	1062.48 6	100	E0+M1+E2		
1066.81	1066.82 12	100	M1+E2		
1149.7	1149.8 3	100			
1152.80	1007.03@ 6	79@ 20	E0+M1+E2		
	1110.27 6	100 40			
	1152.80 6	100 40			
1155.052	961.06 4	39 10			
	1021.25@ 4	79@ 20	E0+M1		
	1155.05 4	100 40			
1167.02	972.83 25				
	1021.25@ 4	40@ 10	E0+M1+E2		
	1167.01 4	100 30			
1194.63	478.79 8	75 25	(E1) [‡]		
	1048.85 8	75 25			
	1060.82 8	100 25			
1201.02	1007.03@ 6	100@	E0+M1+E2		
1223.31	535.45 5	76 16	(E1)		Mult.: measured E1 or E2. Decay scheme requires E1.
	1029.32 5	100 30	(E1)		Mult.: measured E1 or E2. Decay scheme requires E1.
	1089.50 5	38 11	(E1)		Mult.: measured (M1). Decay scheme requires E1.
1241.96	554.10 8	100	E1	0.01108	
1306.22	590.39 3	100	E1	0.00977	
1360.97	537.26 3	100			
0.0+x	708.2§				
	1600.3§				
477.8+x	477.8§ 4	100			
1083.4+x	605.6§ 5	100			
1630.6+x	549.8§ 11	100			
1776.5+x?	1298.8§# 10	100			
3107.0+x	1298.8§# 10	17 4			
	1339.5§# 10	15 2			
	1476.4§ 11	17 2			
	1480.1§# 11	33 4			
	2933.0§ 21	100 20			
	3107.0§ 23				

[†] From (n, γ) E=thermal.[‡] E1 or E2. Decay scheme requires E1.§ γ rays de-excite levels in the second potential well.

Placement of transition in the level scheme is uncertain.

@ Multiply placed; intensity suitably divided.

Adopted Levels, Gammas (continued)

Adopted Levels, Gammas (continued)

Adopted Levels, Gammas (continued)

(I) 7/2[743]

(J) 5/2[622]×0-

(K) 1/2[631]×0-

(L) 3/2[631]-2+?

Adopted Levels, Gammas (continued)

^{239}Pa β^- Decay 1995Yu01,1996Yu06

 Parent ^{239}Pa : $E=0.0$; $J\pi=(3/2)$; $T_{1/2}=1.8\text{ h}$ 5; $Q(\text{g.s.})=2760\text{ syst}$; $\%\beta^- \text{ decay}=100$.

 Measured $E\gamma$ and $\gamma\gamma$ coin. Detectors: High-purity Ge. γ rays assigned to ^{239}Pa β^- decay had been previously seen in $^{238}\text{U}(\text{n},\gamma)$ (1992Sc18).

 ^{239}U Levels

$E(\text{level})^\dagger$	$J\pi^\ddagger$	$T_{1/2}^\ddagger$
0.0	5/2+	23.45 min 2
133.799 ‡ 1	1/2+	
145.777 ‡ 9	3/2+	
193.987 ‡ 6	5/2+	
222.25 ‡ 4	(7/2+)	
716.0 5	3/2+	
784.3 5	5/2-	
814.8 5	1/2-	

 † From γ -ray energies.

 ‡ From Adopted Levels.

 $\gamma(^{239}\text{U})$

$E\gamma$	$E(\text{level})$
522.0 5	716.0
562.0 5	784.3
638.5 5	784.3
681.0 5	814.8

Decay Scheme

 $^{238}\text{U}(\text{n},\gamma)$ E=thermal 1978Bo12,1972Bo46,1984Ch05

 1978Bo12: 99.98% depleted ^{238}U target. Measured $E\gamma$, $I\gamma$ of secondary γ rays, $\gamma\gamma$ coin, conversion electrons.

 Detectors: curved-crystal spectrometer and Ge(Li) anti-Compton detector for γ rays, two Ge(Li) detectors for $\gamma\gamma$ coin measurements, and a magnetic spectrometer for detecting conversion electrons.

 1972Bo46: >99.999% depleted ^{238}U target. Measured $E\gamma$, $I\gamma$ (per 100 captured neutrons) of primary γ rays. Detector: Annihilation-pair Ge(Li) spectrometer.

 1984Ch05: 99.999% depleted ^{238}U target. Polarized neutrons. Measured $E\gamma$, $I\gamma$ (per 100 captured neutrons) of circularly polarized primary γ rays with $E\gamma=2400 - 4200\text{ keV}$. Detectors: Ge(Li).

2007ChZX: Database of Prompt Gamma Rays from Slow Neutron Capture for Elemental Analysis. International Atomic Energy Agency. Evaluated Data.

238U(n,γ) E=thermal 1978Bo12,1972Bo46,1984Ch05 (continued)**239U Levels**

E(level) [‡]	Jπ [§]	E(level) [‡]	Jπ [§]	E(level) [‡]	Jπ [§]
0.0	5/2+	988.20 6	(5/2)+	1383.5 4	
42.534 7	7/2+	990.495 19	(3/2+, 5/2+)	1399.5 8	
98.631 16	9/2+	1005.7 5	(1/2, 3/2, 5/2)+	1404.53 21	(1/2, 3/2)+
133.7991 10	1/2+	1062.48 6	5/2+	1416.9 6	
145.767 6	3/2+	1066.81 12	1/2, 3/2	1436.83 21	(1/2, 3/2)+
169.089? 10	(7/2+)	1149.7 3	(1/2+, 3/2+)	1445.83 21	(1/2, 3/2)+
193.985 5	5/2+	1152.80 4	(3/2+, 5/2)	1462.5 3	(1/2, 3/2)+
222.25? 3	(7/2+)	1155.052 22	1/2+	1479.5 5	(1/2, 3/2)+
292.5872 20	(7/2-)	1167.02 3	3/2+	1481.53 21	(1/2, 3/2)-
539.283 9	(5/2)-	1194.63 5	1/2-	1493.6 5	1/2, 3/2
687.854 5	(1/2)+	1201.02 6	5/2+	1494.9 6	1/2, 3/2
715.835 5	3/2+	1223.31 3	3/2	1504.5 3	(1/2, 3/2)-
726.108 10	(3/2)+	1232.0 7	(1/2+, 3/2+)	1509.9 3	1/2-, 3/2-
734.65 3	(5/2+)	1235.2 5	(1/2+, 3/2+)	1512.9 15	(1/2, 3/2)+
739.380 6	1/2-	1237.7 7	1/2+, 3/2+	1520.33 21	1/2-, 3/2-
746.054 4	3/2-	1241.96 6	3/2-	1573.2 5	1/2, 3/2+#
757.151 22	(5/2)+	1243.4 [†] 5		1586.3 5	3/2 [#]
784.273 14	5/2-	1260.3 3	(1/2, 3/2)+	1609.2 5	1/2, 3/2+#
≈800?		1265.3 8	(5/2+)	1614.7 5	3/2, (1/2) [#]
815.155 6	1/2-	1270.6 5	(1/2+, 3/2+)	1631.2 5	1/2, 3/2 [#]
823.708 8	3/2-	1276.83 21	(1/2+, 3/2+)	1684.7 5	1/2, 3/2 [#]
853.23 4	(3/2)+	1306.22 3	1/2-, 3/2-	1692.2 5	3/2, (1/2) [#]
888.1 3	5/2+	1318.2 3	1/2, 3/2	1717.0 5	3/2, (1/2) [#]
893.30 10	(5/2)+	1320.5 7	1/2, 3/2	1807.9 5	3/2 [#]
932.90 5	(1/2)-	1324.6 3	(1/2, 3/2)-	4806.454 21	1/2+
961.85 13	(3/2-)	1360.97 3	1/2-, 3/2-		
965.637 15	3/2+	1368.03 21	(1/2, 3/2)+		

[†] Not seen by 1984Ch05.[‡] From least-squares fit to E_γ.[§] From multiplicities of secondary γ rays (1978Bo12), and from the energy dependence of primary γ-ray intensities in average neutron resonance capture (1972Bo46), unless otherwise specified.[#] From γ-ray circular polarization in ²³⁸U(n,γ) E=thermal (1984Ch05).**γ(²³⁹U)**For I_γ from average resonance capture, see 1971Wa12, 1972Bo46, 1984Ch05. Other measurements: 1999Ho33, 1995Ra25, 1991Ka34, 1977Li13, 1975BoZF, 1971Ar47, 1965Ma17, 1966Sh16.I_γ normalization: From 100/σ₀=100/2.680 19 b (2006MuZX), where σ₀ is the neutron radiative capture cross section measured at 2200 m/s.

E _γ [‡]	E(level)	I _γ [‡] &	Mult. [†]	α	I(γ+ce)&	Comments
(11.978 CA)	145.767				32 CA	I(γ+ce): from intensity balance.
42.540 8	42.534	@	E2 (+M1)			Mult.: from ce(L2)=0.8 2, ce(L3)=0.6 2 (1978Bo12).
48.230 17	193.985		[E2+M1]		13 CA	I(γ+ce): from intensity balance.
60.185 10	193.985	0.0755@	E2	148.1		ce(L2)=2.1 5. Mult.: from ce(L2):ce(M2):ce(M3)=4.5 3:2.1 4:1.1 2: 1.0 4 (1978Bo12).
127.301 5	815.155	0.0099 20				
133.799 1	133.7991	0.38 8	E2	3.72		Mult.: from α(L2)exp=1.6 4; ce(L1):ce(L2):ce(L3):ce(M1):ce(M2):ce(M3) : ce(N2):ce(N3):ce(O)= 2.6 2:30.0 3:18.5 2:0.9 1 :5.7 3:5.1 1:2.0 2:1.4 1:0.60 14 (1978Bo12).
169.089 ^a 10	169.089?	0.012 4				
193.956 15	292.5872	0.0039 20				
250.062 ^a 7	292.5872	0.034 12				
292.587 2	292.5872	0.016 6				
451.213 23	990.495	0.010 4				
×466.7 [§] 2		0.0040 [§] 10				

Continued on next page (footnotes at end of table)

²³⁸U(n,γ) E=thermal 1978Bo12,1972Bo46,1984Ch05 (continued)

γ(²³⁹U) (continued)

E _γ [†]	E(level)	I _γ [‡] &	Mult. [†]	α	Comments
478.79 8	1194.63	0.012 4	(E1)		Mult.: E1,E2, but decay scheme requires E1.
^x 487.15 [§] 25		0.028 [§] 8	E1,E2		Mult.: from α(K)exp=0.022 7 (1978Bo12).
496.753 11	539.283	0.034 8	E1 [#]	0.01367	
521.849 7	715.835	0.073 3	M1(+E2)		Mult.: from α(K)exp=0.17 5; ce(K):ce(L1)=0.86 9:0.16 2 (1978Bo12).
535.45 5	1223.31	0.028 6	E1,E2 [#]		
537.26 3	1360.97	0.0079 20			
539.278 11	539.283	0.099 20	E1	0.01163	Mult.: from α(K)exp=0.006 2 (1978Bo12).
542.085 12	687.854	0.024 6			
^x 542.338 [§] 11		0.036 [§] 8	M1(+E2)	0.12 8	Mult.: from α(L1)exp=0.027 8 (1978Bo12).
552.069 5	746.054	0.207 5	E1	0.01111	Mult.: from α(K)exp=0.009 3 (1978Bo12).
554.054 8	687.854	0.085 20	M1	0.189	Mult.: from α(K)exp=0.16 4; ce(K):ce(L1):ce(L2)=0.69 7: 0.14 2:0.040 16 (1978Bo12).
554.10 8	1241.96	0.028 6	E1 [#]	0.01103	
^x 558.50 [§] 15		0.012 [§] 4	M1+E2	0.11 8	Mult.: from α(K)exp=0.07 4 (1978Bo12).
562.027 22	784.273	0.032 10	[E1]	0.01073	
563.17 3	757.151	0.014 4	M1+E2		Mult.: from α(K)exp=0.12 7 (1978Bo12).
580.340 13	726.108	0.043 10	M1+E2		Mult.: from α(K)exp=0.10 3 (1978Bo12).
582.034 8	715.835	0.016 4	M1(+E2)		Mult.: from α(K)exp=0.13 4 (1978Bo12).
^x 586.90 [§] 11		0.007 [§] 2	M1	0.1618	Mult.: from α(K)exp=0.19 6 (1978Bo12).
588.88 3	734.65	0.024 6			
590.39 3	1306.22	0.034 12	E1		Mult.: from α(K)exp=0.003 3 (1978Bo12).
592.309 13	726.108	0.045 12	M1+E2		Mult.: from α(K)exp=0.095 3 (1978Bo12).
593.612 5	739.380	0.108 24	E1 [#]		
^x 600.28 1		0.030 8	E1,E2 [#]		
600.284 10	746.054	0.030 8	E1		Mult.: from α(K)exp=0.013 4 (1978Bo12).
605.581 9	739.380	0.053 12	E1 [#]		
611.38 3	757.151	0.014 4			
612.253 5	746.054	0.23 5	[E1]		
^x 620.97 ^a		@			ce(K)=0.05 3.
629.722 9	823.708	0.073 20	E1		Mult.: from α(K)exp=0.009 5 (1978Bo12).
638.505 12	784.273	0.041 12	E1 [#]		
^x 660.54 25		0.10 3			
^x 662.21 14		0.6 2			
669.385 13	815.155	0.0039 20			
673.307 12	715.835	0.010 4			
681.355 9	815.155	0.012 4	E1,E2 [#]		
687.853 8	687.854	0.028 8	(E2) [#]		
689.907 11	823.708	0.043 10	E1 [#]		
715.832 9	715.835	0.022 6	E2,E1 [#]		
^x 723.95 5		1.0 3			
^x 726.23 8		1.7 4			
^x 735.8 3		0.2 1			
^x 751.67 25		0.4 1			
^x 754.20 25		0.3 1			
^x 757.11 25		0.50 13	M1(+E2)		Mult.: from α(K)exp=0.08 4 (1978Bo12).
^x 758.92 25		0.3 1			
767.86 21	961.85	0.020 6	E1,E2 [#]		
787.15 7	932.90	0.020 6	E1,E2 [#]		
794.21 8	988.20	0.020 6	M1+E2		Mult.: from α(L1)exp=0.012 4 (1978Bo12).
799.12 7	932.90	0.079 20			
819.868 21	965.637	0.010 4			
828.04 21	961.85	0.024 6	E1,E2 [#]		
831.837 19	965.637	0.053 12	M1+E2		Mult.: from α(K)exp=0.024 7 (1978Bo12).
842.42 8	988.20	0.024 6	M1+E2		Mult.: from α(K)exp=0.024 8 (1978Bo12).
853.23 4	853.23	0.055 12	M1+E2		Mult.: from α(K)exp=0.026 8 (1978Bo12).
^x 858.75 25		0.20 5			
^x 860.23 25		0.6 2	M1(+E2)		Mult.: from α(K)exp=0.050 7 (1978Bo12).
^x 888.43 9		0.6 2			
893.30 10	893.30	0.016 4	M1+E2		Mult.: from α(K)exp=0.026 13 (1978Bo12).
^x 921.68 25		0.10 3			
961.06 4	1155.052	0.0039 20			

Continued on next page (footnotes at end of table)

²³⁸U(n,γ) E=thermal 1978Bo12,1972Bo46,1984Ch05 (continued)

γ(²³⁹U) (continued)

Eγ [‡]	E(level)	Iγ [‡] &	Mult. [†]	α	Comments
972.83 25	1167.02				Eγ: From 1978Bo12.
x983.42 7		1.3 3			
990.49 3	990.495	0.010 4	M1+E2		Mult.: from α(K)exp=0.012 10 (1978Bo12).
1007.03 ^b 6	1152.80	0.0079 ^b 20	E0+M1+E2		Mult.: from α(K)exp=0.19 6 (1978Bo12).
	1201.02	0.0079 ^b 20	E0+M1+E2		Mult.: from α(K)exp=0.19 6 (1978Bo12).
1021.25 ^b 4	1155.052	0.0079 ^b 20	E0+M1		Mult.: from α(K)exp=0.27 8 (1978Bo12).
	1167.02	0.0079 ^b 20	E0+M1+E2		Mult.: from α(K)exp=0.27 8 (1978Bo12).
1029.32 5	1223.31	0.037 8	E1, E2 [#]		
1048.85 8	1194.63	0.012 4			
x1053.77 25		0.5 2			
1060.82 8	1194.63	0.016 4			
x1061.50 25		0.3 1	E0+M1+E2		Mult.: from α(K)exp=1.0 5 (1978Bo12).
1062.48 6	1062.48	0.0079 20	E0+M1+E2		Mult.: from α(K)exp=0.24 8 (1978Bo12).
1066.82 12	1066.81	0.030 6	M1+E2		Mult.: from α(K)exp=0.015 5 (1978Bo12).
					Mult.: from av res (n,γ) the 1066.8 level is 1/2- or 3/2- in contradiction to the mult assignment of 1978Bo12.
x1069.41 ^a 25		0.20 5	E0+M1+E2		Mult.: from α(K)exp=0.22 8 (1978Bo12).
1089.50 5	1223.31	0.014 4	M1	0.0313	Mult.: from α(K)exp=0.03 1 (1978Bo12).
1110.27 6	1152.80	0.010 4			
x1139.22 25		0.30 8	M1	0.0278	Mult.: from α(K)exp=0.05 3 (1978Bo12).
1149.8 3	1149.7	0.010 4			
1152.80 6	1152.80	0.010 4			
1155.05 4	1155.052	0.010 4			
x1158.13 25		0.30 8			
1167.01 4	1167.02	0.020 6			
x1172.03 25		0.40 25			
x1174.45 25		0.20 5			
x1189.94 25		0.40 10			
x1192.74 25		0.6 2			
x1196.50 25		0.8 2			
2998.5 5	4806.454	0.012 4			
3089.4 5	4806.454	0.0071 24			
3114.2 5	4806.454	0.007 3			
3121.7 5	4806.454	0.008 3			
3175.2 5	4806.454	0.0067 22			
3191.7 5	4806.454	0.0047 16			
3197.2 5	4806.454	0.016 6			
3220.1 5	4806.454	0.012 4			
3233.2 5	4806.454	0.010 3			
3286.1 2	4806.454	0.0040 3			
3293.5 [§] 15	4806.454	0.00028 [§] 10			
3296.5 [§] 3	4806.454	0.354 [§] 18			
3301.9 [§] 3	4806.454	0.0015 [§] 1			
3311.5 [§] 6	4806.454	0.0037 [§] 10			
3312.8 5	4806.454	0.0040 10			
3324.9 [§] 2	4806.454	0.00252 [§] 14			
3326.9 [§] 5	4806.454	0.00024 [§] 8			
3343.9 [§] 3	4806.454	0.00042 [§] 6			
3360.6 [§] 2	4806.454	0.00156 [§] 12			
3369.6 [§] 2	4806.454	0.00092 [§] 10			
3389.5 [§] 6	4806.454	0.00014 [§] 6			
3401.9 [§] 2	4806.454	0.0025 [§] 2			
3406.9 [§] 8	4806.454	<0.00008 [§]			
3422.9 [§] 4	4806.454	0.00022 [§] 8			
3438.4 [§] 2	4806.454	0.00234 [§] 12			
3445.44 6	4806.454	0.0045 3			
3481.8 [§] 3	4806.454	0.00084 [§] 10			
3485.9 [§] 7	4806.454	0.00084 [§] 18			
3488.2 [§] 3	4806.454	0.00278 [§] 14			
3500.8 [§] 3	4806.454	0.00086 [§] 8			
3529.6 [§] 2	4806.454	0.00166 [§] 10			
3535.8 [§] 5	4806.454	0.00066 [§] 14			

Continued on next page (footnotes at end of table)

²³⁸U(n,γ) E=thermal 1978Bo12,1972Bo46,1984Ch05 (continued)

γ(²³⁹U) (continued)

Eγ [‡]	E(level)	I _γ [‡] &	Mult. [†]	Comments
3541.1 [§] 8	4806.454	0.00054 [§] 14		
3546.1 [§] 3	4806.454	0.00094 [§] 18		
3563.0 5	4806.454			
3564.45 9	4806.454	0.0042 4		
3568.7 [§] 7	4806.454	0.00042 [§] 12		
3571.2 [§] 5	4806.454	0.00116 [§] 24		
3574.4 [§] 7	4806.454	0.00070 [§] 16		
3583.10 7	4806.454	0.00053 4		
3611.78 9	4806.454	0.0146 10		
3639.39 6	4806.454	0.01228		
3651.36 6	4806.454	0.00695		
3653.9 [§] 8	4806.454	0.00198 [§] 30		
3656.9 [§] 5	4806.454	0.00014 [§] 6		
3739.8 6	4806.454	0.00383		
3744.0 [§] 2	4806.454	0.00014 [§] 6		
3800.7 [§] 5	4806.454	0.00018 [§] 6		
3815.9 [§] 5	4806.454	0.00168 [§] 10		
3817.9 [§] 5	4806.454	0.00128 [§] 8		
3840.8 [§] 4	4806.454	0.00202 [§] 10		
3844.56 21	4806.454	0.0068 5		
3873.9 [§] 2	4806.454	0.00268 [§] 12		
3913.1 [§] 20	4806.454	=0.00008 [§]		
3918.2 [§] a 10	4806.454	0.00020 [§] 8		
3953.4 [§] 3	4806.454	0.00052 [§] 8		
3982.69 5	4806.454	0.0259 14		
3991.25 5	4806.454	0.0241 12		
4005.7 ^a	4806.454		(E2)	Detected in 1971Wa12. I _γ (=4006)<3×10 ⁻³ (1978Bo12).
4049.7 [§] 5	4806.454	0.00030 [§] 6		
4060.35 5	4806.454	0.186 3		
4067.2 2	4806.454	0.0073 4		
4071.7 [§] 7	4806.454	0.00014 [§] 4		
4080.4 [§] 2	4806.454	0.00124 [§] 12		
4090.7 [§] 2	4806.454	0.00148 [§] 14		
4118.7 [§] 2	4806.454	0.00150 [§] 14		
4612.5 [§] 2	4806.454	0.00313 [§] 28		
4660.7 [§] 2	4806.454	0.00342 [§] 30		
4672.6 [§] 2	4806.454	0.00118 [§] 12		
4806.4 [§] 15	4806.454	≤0.00014 [§]		

[†] From conversion electron coefficients or sub-shell ratios. The scale of electron intensities was normalized to that of γ rays using the 133-keV E2 γ ray for E_γ<200 keV, and using the 539-, 552-, and 629-keV E1 γ rays for E_γ>480 keV. Authors estimated 20% to 30% uncertainties in I_γ (1978Bo12). Evaluator has used 25% for deducing uncertainties in experimental conversion coefficients.

[‡] From 2007ChZX, unless otherwise specified. I_γ=σ_γ(E_γ) measured at 2200 m/s.

[§] From 1972Bo46. I_γ are on the same scale as values given in 2007ChZX for primary γ rays.

Deduced from upper limit of conversion electron intensity (1978Bo12).

@ Only conversion electrons were detected. Given intensity is per 100 captured neutrons.

& For intensity per 100 neutron captures, multiply by 37.31 27.

^a Placement of transition in the level scheme is uncertain.

^b Multiply placed; undivided intensity given.

^x γ ray not placed in level scheme.

$^{238}\text{U}(\text{n},\gamma)$ E=res: Av 1984Ch05,1972Bo46

1984Ch05: Target: 99.999% depleted ^{238}U . Neutron beams of 2 keV, FWHM=0.85 keV; and of 24 keV, FWHM=1.9 keV.

Measured E_γ , I_γ for primary γ rays. Detector: three-crystal pair spectrometer.

Other measurements: 1971Ar47, 1971Wa12, 1972Bo46, 1991Ma40, 1991Oi01, 1991Sz05, 1992Ja05, 1992Po13, 1992Qu01, 1992Vo13, 1992Zh12, 1993Ro25, 1997Gu17, 1997Li11.

1972Bo46: Target: >99.999% depleted ^{238}U . Measured E_γ , I_γ (per 100 captured neutrons) of primary γ rays. Detector: Annihilation-pair Ge(Li) spectrometer.

 ^{239}U Levels

E(level) [‡]	J π [†]	Comments
0.0	5/2+	
133.9	1/2+, 3/2+	
145.6	1/2+, 3/2+	
193.6	5/2+	
538.6	5/2-	
687.6	1/2+, 3/2+	
694.7	5/2	
715.9	1/2+, 3/2+, 5/2+	
726.5	1/2+, 3/2+	
735.7	1/2+, 3/2+, 5/2+	
739.1	1/2-, 3/2-	
745.8	1/2-, 3/2-	
756.7	5/2+	
784.0	5/2-	
815.3	1/2-, 3/2-	
823.7	1/2-, 3/2-	
852.8	1/2+, 3/2+	
858.8	5/2-	
887.4	5/2+	
892.3	5/2	
932.5	1/2-, 3/2-	
961.9	1/2-, 3/2-	
965.4	1/2, 3/2	
982.9	5/2-	
988.1		
990.5		
1005.7	1/2+, 3/2+, 5/2+	
1018.6	5/2-	
1061.8	5/2	
1066.9	1/2-, 3/2-	
1146.9	5/2	
1150.4		
1152.7		
1155.2	1/2+, 3/2+	
1167.1	1/2+, 3/2+	
1195.5	1/2-, 3/2-	
1202.0	5/2	
1206.0	5/2	
1223.1	1/2-, 3/2-	
1225.5	1/2-, 3/2-	
1232.0		
1235.0		
1238.0	1/2+, 3/2+	
1243.3	1/2-, 3/2-	
1261.8	1/2, 3/2	
1271.1	1/2, 3/2	
1277.9	1/2, 3/2	
1295.2	1/2, 3/2, 5/2	
1306.1	1/2-, 3/2-	
1318.0		
1320.5		
1324.6	1/2-, 3/2-	
1338.3	1/2-, 3/2-, 5/2+	
1360.9	1/2-, 3/2-	
S(n)+x		S(n)=4806.26 2I; x=2 keV.
S(n)+y		S(n)=4806.26 2I; y=24 keV.

Footnotes continued on next page

²³⁸U(n,γ) E=res: Av 1984Ch05,1972Bo46 (continued)

²³⁹U Levels (continued)

† Spins and parities of levels populated by primary γ rays from 2-keV resonances (with Jπ=1/2+ for s-wave neutrons) are 1/2+, 1/2-, 3/2+, and 3/2- based on the assumption that γ rays carry one unit of angular momentum (E1 or M1 multipolarities). Those of levels populated from 24-keV resonances (with Jπ=1/2- and 3/2- for p-wave neutrons) are 1/2+, 3/2+, or 5/2+. Since s-wave neutron capture is dominant, and primary E1 γ rays are more intense than M1, the 1/2- and 3/2- levels are more strongly populated than 1/2+ and 3/2+. Population to 5/2 levels come from E1 primary γ rays from only 3/2- resonances (p-wave neutrons), with a weak contribution from E2 primary γ rays from 1/2+ resonances (s-wave neutrons) and 1/2- resonances (p-wave neutrons). Thus, reduced primary γ ray intensities (Iγ/Eγ³), which are distributed into three categories defined by the spins and parities (1/2-, 3/2-), (1/2+, 3/2+), and (5/2), have provided the arguments for spin and parity assignments.

‡ ΔE≤1 keV (1984Ch05).

γ(²³⁹U)

Eγ [†]	E(level)	Iγ/Eγ ^{3‡}	Comments
3483.7\$	S(n)+x	2.72\$ 25	
3487.8	S(n)+x		
3490.3\$	S(n)+x	2.74\$ 24	Iγ/Eγ ³ : 3490.3γ + 3487.8γ.
3492.0#	S(n)+y	0.34# 8	
3502.2\$	S(n)+x	1.67\$ 24	
3505.7#	S(n)+y	0.72# 9	
3509.8	S(n)+y		
3512.3#	S(n)+y	0.68# 9	Iγ/Eγ ³ : 3512.3γ + 3509.8γ.
3524.2	S(n)+y		Weak.
3535.1#	S(n)+y	0.23# 8	
3552.4#	S(n)+y	0.48# 7	
3559.2#	S(n)+y	0.51# 7	
3565.0\$	S(n)+x	2.56\$ 25	
3568.5#	S(n)+y	0.49# 7	
3570.3\$	S(n)+x	0.7\$ 3	
3573.3	S(n)+x		
3576.3\$	S(n)+x	0.9\$ 3	Iγ/Eγ ³ : 3573.3γ + 3576.3γ.
3582.8\$	S(n)+x	1.3\$ 9	
3585.2\$	S(n)+x	3.4\$ 9	
3587.0#	S(n)+y	0.90# 10	
3592.3#	S(n)+y	0.87# 11	
3595.3	S(n)+y		
3598.3#	S(n)+y	0.48# 12	Iγ/Eγ ³ : 3598.3γ + 3595.3γ.
3604.8	S(n)+y		
3607.2#	S(n)+y	1.12# 7	Iγ/Eγ ³ : 3607.2 + 3604.8γ.
3612.8\$	S(n)+x	1.93\$ 20	
3624.3#	S(n)+y	0.17# 5	
3628.3#	S(n)+y	0.17# 5	
3634.8#	S(n)+y	0.77# 6	
3641.2\$	S(n)+x	0.70\$ 16	
3653.1\$	S(n)+x	1.07\$ 23	
3655.6	S(n)+x		
3657.9\$	S(n)+x	1.14\$ 23	Iγ/Eγ ³ : 3655.6γ + 3657.9γ.
3663.2#	S(n)+y	0.28# 6	
3675.1#	S(n)+y	0.54# 25	
3677.6	S(n)+y		
3679.9#	S(n)+y	0.76# 23	Iγ/Eγ ³ : 3679.9γ + 3677.6γ.
3683.4#	S(n)+y	0.19# 8	
3741.4\$	S(n)+x	1.05\$ 15	
3763.4#	S(n)+y	0.28# 6	
3768.5#	S(n)+y	0.23# 6	
3802.6\$	S(n)+x	0.41\$ 12	
3811.7#	S(n)+y	0.15# 5	
3817.8	S(n)+x		
3820.2\$	S(n)+x	1.21\$ 15	Iγ/Eγ ³ : 3817.8γ + 3820.2γ.
3839.8	S(n)+y		
3842.2#	S(n)+y	0.64# 5	Iγ/Eγ ³ : 3842.2γ + 3839.8γ.
3842.9\$	S(n)+x	0.88\$ 22	
3846.4\$	S(n)+x	1.67\$ 24	
3847.4#	S(n)+y	0.15# 5	

Continued on next page (footnotes at end of table)

²³⁸U(n,γ) E=res: Av 1984Ch05,1972Bo46 (continued)

γ(²³⁹U) (continued)

Eγ [†]	E(level)	Iγ/Eγ ^{3‡}	Comments
3864.9#	S(n)+y	0.42# 9	
3868.4#	S(n)+y	0.62# 9	
3875.8§	S(n)+x	1.64§ 14	
3897.8#	S(n)+y	0.47# 4	
3938.0#	S(n)+y	0.16# 6	
3942.9#	S(n)+y	0.29# 6	
3955.5§	S(n)+x	0.83§ 11	
3971.5#	S(n)+y	0.10# 5	
3977.5#	S(n)+y	0.58# 11	
3984.6§	S(n)+x	2.38§ 18	
3993.0§	S(n)+x	1.95§ 14	
4006.6#	S(n)+y	0.56# 4	
4015.0#	S(n)+y	0.50# 4	
4046.3#	S(n)+y	0.08# 3	
4062.5§	S(n)+x	2.32§ 15	
4069.2§	S(n)+x	1.72§ 25	
4072.6§	S(n)+x	0.50§ 21	
4073.6#	S(n)+y	0.29# 3	
4081.8§	S(n)+x	0.71§ 13	
4084.5#	S(n)+y	0.61# 4	
4091.2	S(n)+y		
4092.4§	S(n)+x	0.54§ 11	
4094.6#	S(n)+y	0.71# 4	Iγ/Eγ ³ : 4094.6γ + 4091.2γ.
4103.8#	S(n)+y	0.55# 3	
4114.4#	S(n)+y	0.42# 4	
4120.7§	S(n)+x	0.62§ 10	
4135.6#	S(n)+y	0.21# 3	
4142.7#	S(n)+y	0.55# 4	
4291.7#	S(n)+y	0.15# 4	
4614.7§	S(n)+x	0.39§ 5	
4636.7#	S(n)+y	0.49# 3	
4662.4§	S(n)+x	1.02§ 7	
4674.4§	S(n)+x	1.00§ 7	
4684.7#	S(n)+y	0.96# 3	
4696.4#	S(n)+y	1.00# 2	
4808.3§	S(n)+x	0.64§ 6	
4830.3#	S(n)+y	0.52# 2	

[†] Nominal values deduced by evaluator from S(n)+x, S(n)+y, and level energies of 1984Ch05.

[‡] Reduced average γ-ray intensity (1984Ch05).

§ From 2-keV neutrons.

From 24-keV neutrons.

²³⁸U(n,γ) E=res 2008ObZZ,1998Ob01,1995Ob01

1998Ob01,1995Ob01 – s-wave neutron resonance energies: 708.3–, 721.6–, 730.1–, 765.1 eV.

Target: 99.999% depleted ²³⁸U. Measured neutrons with a time-of-flight spectrometer. Measured Eγ, Iγ for individual resonances using a coaxial high-purity Ge detector. γ rays populate and de-excite levels in the second potential well of the shape-isomeric ground state. This shape isomer may eventually undergo spontaneous fission or decay by γ rays to levels in the first potential well.

2008ObZZ – Target: depleted ²³⁸U. Measured neutrons and γ-ray energies and intensities depopulating the superdeformed ground state in the first potential well.

Others: 1994Ob01, 1991Ad08.

For ²³⁸U(n,γ) Fission see: 2001Vl04, 1998Mi22, 1996Eg02, 1994Mu20, 1993ObZZ, 1993Ku03, 1992LaZP.

$^{238}\text{U}(\text{n},\gamma)$ E=res 2008ObZZ,1998Ob01,1995Ob01 (continued) ^{239}U Levels

$E(\text{level})^{\dagger\dagger}$	$J\pi$	$T_{1/2}$	Comments
0.0	5/2+		
98.6	9/2+		
990.5	3/2+, 5/2+		
0.0+x [§]	(5/2+)	>0.25 μs	$T_{1/2}$: from delayed $\gamma\gamma$ coin (1994Ob01).
174.0+x			
477.8+x	(3/2-)		
1083.4+x	(1/2+, 5/2+)		
1626.9+x	(1/2-, 3/2-)		
1630.6+x	(3/2-)		
1767.5+x	(1/2-, 3/2-)		
1776.5+x?			
1808.2+x?			
3107.0+x	(1/2+)		

[†] From 1998Ob01.[‡] x=1699 keV, from (n, γ) E=res experiment (2008ObZZ). x=1700 keV, proposed by 1998Ob01 on the basis of neutron resonance spacings.[§] From 2008ObZZ. $\gamma(^{239}\text{U})$

$E\gamma^{\dagger}$	$E(\text{level})$	$E(\text{n})(\text{eV})=708.3^{\dagger}$	$E(\text{n})(\text{eV})=721.6^{\dagger}$	$E(\text{n})(\text{eV})=730.1^{\dagger}$	$E(\text{n})(\text{eV})=765.1^{\dagger}$	Comments
98.6	98.6					
^x 472.8 11		0.37 3	0.19 2	0.27 3	0.18 2	
477.8 4	477.8+x	0.20 2	0.42 2	0.20 2	0.17 1	Multipolarity: (E1).
549.8 11	1630.6+x	0.07 2	0.58 7	0.31 4	0.04 1	
^x 597.9 5		0.37 3	0.19 2	0.26 2	0.18 2	
605.6 5	1083.4+x	0.19 6	0.41 2	0.31 12	0.10 4	Multipolarity: (E1).
^x 632.5 5		0.03 1	0.51 4	0.22 3	0.24 3	
708.0 [‡]	0.0+x					
990.5	990.5					
1298.8 [§] 10	1776.5+x?	0.08 [§] 2	0.41 6	0.28 4	0.23 4	
	3107.0+x	0.08 [§] 2	0.41 6	0.28 4	0.23 4	
1339.5 [#] 10	3107.0+x	0.07 1	0.67 6	0.24 3	0.02 1	Multipolarity: (E1).
^x 1343.8 10		0.25 4	0.46 5	0.28 4		
1476.4 11	3107.0+x	0.08 1	0.56 4	0.26 2	0.10 1	Multipolarity: (E1).
1480.1 [#] 11	3107.0+x	0.15 2	0.67 6	0.17 2	0.01 1	Multipolarity: (E1).
1600.3 [‡]	0.0+x					
2933.0 21	3107.0+x	0.46 9	0.30 7	0.24 6		
3107.0 23	3107.0+x		0.52 12	0.47 11	0.01 1	Multipolarity: (E2).

[†] I γ from 1998Ob01, 1995Ob01.[‡] From 2008ObZZ.[§] Multiply placed; undivided intensity given.[#] Placement of transition in the level scheme is uncertain.^x γ ray not placed in level scheme. **$^{238}\text{U}(\text{d},\text{p})$ 1978Er03**

E(d)=12 MeV, magnetic spectrometer, angular distribution. Other measurements: 1964Ma24, 1966Sh16, 1972Er03. Levels reported by 1966Sh16 and not observed by 1978Er03 are probably from impurities.

 ^{239}U Levels

$E(\text{level})$	$J\pi^{\dagger}$	L	$S^{\ddagger}$
0.0	5/2+		0.0067 12
43 2	7/2+		
98.1 15	9/2+	4	0.075 6

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$^{238}\text{U}(\text{d},\text{p})$ 1978Er03 (continued) **^{239}U Levels (continued)**

E(level)	$J\pi^\dagger$	$T_{1/2}^\S$	L	$S^\ddagger$	Comments
133.5 15	1/2+	0.78 μs 4	(0)	0.017 3	
146.1 15	3/2+		(2)	0.050 9	
165? 5	(7/2+)				E(level): from 1966Sh16.
226.3 15	9/2+				
301.8 20	11/2+				
307.8 15	9/2+			0.020 4	
372.7 20	11/2-				
498.6 15	15/2-				
689.0 15	1/2+				
702.5 15	9/2+				
717.3 15	3/2+				
≈ 738	5/2+				
738.3 15	1/2-				
748.0 20	3/2-				
759.0 20	5/2+				
781.4 20	5/2-				
795.9 15	7/2-				
814.5 15	1/2-				
823.9 15	3/2-				
838.3 15	11/2-				
854.1 15	3/2+				
874.0 15	9/2+				
887.6 15	5/2+				
897.9 15					
919.3? 20					
936.9 20	1/2-				
944.8 20	7/2+				
963.6 15	3/2-				
978.4 15					
996.1 15	9/2+				
1066.5 15					
1115.0 15					
1151.1 20					
1197.3 15					
1232.6 15					
1240 3					
1260.1 15					
1273 3					
1337.7 20					
1364.7 20					
1430 3					
1473 3					
1515 2					
1524 3					

 † From 1978Er03 based on signature pattern of cross sections. ‡ From 1972Er03. § E(d)=12 MeV, pulsed beam (1975Ya03).

Adopted Levels, Gammas

$Q(\beta^-)=722.5$ 10; $S(n)=6215.2$ 11; $S(p)=5285.5$ 15; $Q(\alpha)=4599$ 14 2012Wa38.
 Calculations.
 Single-particle levels: 2004Pa40.
 Half-life: 2013Zd01, 2008Do12.
 β^- decay: 2009So02.
 Evaluation of ²³⁹U β^- decay: 2008BeZV.
 Nuclear reactions.
²³⁸Np(n, γ) E=thermal. Calculated σ : 2012Pr13, 2011Ch57, 2004Ha11, 2010Pr07.
²³²Th, U(n,F), U(n, γ), U(n,2n): Deduced reaction rates: 2011Ad18.
 Cluster decay.
²³⁹Np(³⁰Mg): 2012Sa31.
 Alpha decay.
²³⁹Np (α): Calculated $T_{1/2}$, $Q(\alpha)$: 2011Sa40.
²⁴³Am(α): Theory: 2003De17.

²³⁹Np Levels

Cross Reference (XREF) Flags

A ²³⁹U β^- Decay
 B ²⁴³Am α Decay
 C ²³⁸U(³He,d),(α ,t)

E(level) [†]	J π [§]	XREF	T _{1/2}	Comments
0.0&	5/2+	ABC	2.356 d 3	$\% \alpha = 1 \times 10^{-10}$ from α syst (1980Sc26). $\% \beta^- = 100$. $J\pi$: atomic beam (1969Fu11), E1 from 5/2-. $T_{1/2}$: Weighted average (Limited Relative Statistical Weight Method) of 2.346 d 4 (1956Wi25), 2.366 d 3 (1959Co93), 2.340 d 20 (1959Co63), 2.354 d 8 (1966Qa01), 2.346 d 4 (1969Bi12), and 2.3565 d 4 (1990Ab06). ($\chi^2/\nu=4.9$, data are discrepant.).
31.1309& 12	7/2+	ABC		
71.13& 3	9/2+	ABC		
74.6640 ^a 10	5/2-	ABC	1.39 ns 3	$J\pi$: Favored α decay (HF=1.14) from 5/2-5/2[523] in ²⁴³ Am. $T_{1/2}$: From ²⁴³ Am α decay. $\mu=+2.0$ 3. μ : From 2011StZZ, 1967Gu08 Integral perturbed angular correlation. Compare to +1.95 15 for 5/2[523] in ²³⁷ Np and +3.14 4 for 5/2[642] in ²³⁷ Np. In ²⁴³ Am the 5/2[523] g.s. has $\mu=+1.503$ 14 (2011StZZ,1990Iz01).
117.715 ^{‡a} 10	7/2-	ABC	≤ 40 ps	$T_{1/2}$: from ²⁴³ Am α decay.
122.5& 10	(11/2+)	ABC		
173.086 ^{‡a} 18	9/2-	ABC		
180.0& 12	(13/2+)	C		
220.2 ^b 12	(1/2+) [#]	C		$J\pi$: Tentative assignment is based on the analogy with the same rotational band in ²³⁷ Np.
241.312 ^a 24	(11/2-)	ABC		
257.63? ^b 25	(3/2+) [#]	A C		
260.81 ^c 3	(3/2-) [@]	A C		$J\pi$: Assignment is based on the analogy with the same rotational band in ²³⁷ Np.
267? [‡] 3		B		
270.9 ^c 14	(1/2-) [@]	C		
315.5 ^c 11	(7/2-) [@]	C		
317.4 ^{‡a} 15	(13/2-)	B		
325 ^{‡c} 3	(5/2-) [@]	BC		
347.33 23	(9/2+, 7/2+)	ABC		$J\pi$: 9/2+ from (³ He,d). However, from α HF and analogy to ²³⁷ Np, this could be 7/2+ member of 1/2[400].
359.12 ^b 20	(9/2+) [#]	AB		
411 [‡] 3		B		
420.6 22		C		
427 [‡] 3		B		
438.79 ^b 5	(11/2+) [#]	ABC		
448.15 ^d 3	(3/2-)	A C		$J\pi$: Fingerprint of (³ He,d) cross-section.
452.76 4	(5/2+, 7/2-)	A		$J\pi$: γ 's to 9/2+ and (3/2-).
474.36? 6		A		
482.6 ^d 11	(5/2-)	C		

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Adopted Levels, Gammas (continued)

²³⁹Np Levels (continued)

E(level) [†]	Jπ [§]	XREF	Comments
517.98 ^d 3	(7/2-)	A C	
530.21 [?] 8		A	
547.0 [?] 23	(13/2+)	C	
563.87 5		A	
579.34 ^d 7	(9/2-)	A C	
600 [?] 3		C	
616 [?] 3		C	
637.2 [?] 18		C	
657 [?] d 3	(11/2-)	C	
662.261 ^g 15	(5/2-)	AB	Jπ: Low α hindrance factor (HF=7.13) from ²⁴³ Am α decay. γ rays to 5/2 and 7/2 levels.
695.10 ^g 4	(7/2-)	A C	
723.7 22		C	
741.6 ^g 21	(9/2-)	C	
778.6 13		C	
784.96 [?] 5		A	
819.209 18	(7/2-)	A	Jπ: γ to (3/2-) and (11/2-).
823.4 17		C	
844.072 15	(7/2-)	A	Jπ: γ rays to 5/2+, 9/2+, (11/2-); Possible bandhead of 7/2[633].
849.45 4		A	
863.43 [?] 9		A	
864.9 ^e 12	(9/2+)	C	Jπ: from (³ He,d).
890.6 12		C	
917.1 11		C	
951.5 13		C	
959.17 3		A	
964.08 17	(7/2-)	A	Jπ: γ to (5/2-), (11/2-).
966.53 6		A	
992.05 ^f 3	(7/2-)	A C	Jπ: Tentatively assigned (7/2-) in (³ He,d).
1019.9 ^e 12	(13/2+)	C	
1040.39 4	(5/2-, 7/2-)	A	Jπ: 780γ to (3/2-), 867γ to 9/2-.
1049.45 ^f 5	(9/2-)	A C	
1077.2 14		C	
1096.98 5	(7/2+)	A	Jπ: γ to (11/2+), (5/2-), (5/2+).
1117.8 ^f 13	(11/2-)	C	
1141.1 17		C	
1155.3 19		C	
1182.5 14		C	
1197.14 [?] 10		A	

[†] From ²³⁹U β⁻ Decay, unless otherwise specified.

[‡] From ²⁴³Am α Decay.

[§] Jπ and configuration assignments are based on rotational band structure and systematics of Nilsson orbitals in nearby odd-A nuclei. Individual arguments are given mostly for rotational bandheads.

From (³He,d), based on measured L values and a comparison between experimental and calculated spectroscopic factors for various Nilsson orbitals.

@ From (³He,d), rotational band parameter analogy to ²³⁷Np.

& (A): 5/2[642].

a (B): 5/2[523].

b (C): 1/2[400]?

c (D): 1/2[530].

d (E): 3/2[521].

e (F): 7/2[633]?

f (G): 7/2[514].

g (H): 5/2[523]×0+.

γ(²³⁹Np)

E(level)	Eγ [†]	Iγ [†]	Mult.	δ	α	Comments
31.1309	31.131 2	100	M1+E2	0.08 2	196 20	δ: from α decay; other: 0.17 I in β ⁻ decay.
71.13	(71.2)	100	[E2]		73.5	
74.6640	43.533 1	8.27 15	E1		1.16	B(E1)(W.u.)=8.7×10 ⁻⁵ 5.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)
 $\gamma(^{239}\text{Np})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult.	δ	α	Comments
74.6640	74.664 1	100	E1		0.28	B(E1)(W.u.)=0.000208 15.
117.715	43.1 $\S$	11.5 $\S$	M1+E2	=0.38	=159	B(M1)(W.u.)>0.032; B(E2)(W.u.)>690.
	86.71 $\S$ 2	59 $\S$ 7	E1		0.19	B(E1)(W.u.)>0.00013.
	117.60 $\S$ 15	100 $\S$ 14	E1		0.086	B(E1)(W.u.)>0.00013.
173.086	50.6 $\ddagger$	$\approx$ 2.6 $\ddagger$	[E1]		0.78	
	55.4 $\ddagger$	$\approx$ 8.7 $\ddagger$	M1+E2	0.6 2	87 25	
	98.5 $\ddagger$	$\approx$ 8.2 $\ddagger$	(E2)		15.9	
	141.89 $\ddagger$ 3	100 $\ddagger$ 7	E1		0.226	
241.312	169	100	[E1]		0.15	
260.81	142.93	7.1				
	186.15 4	100 10				
	260.86 9	11 1				
317.4	195 $\ddagger$	100 $\ddagger$	[E1]			
438.79	197.28 12	75 13				
	407.70 5	100				
448.15	187.28 8	23 3				
	330.14 14	2.8 6				
	373.51 4	100 7				
	448.19 6	37 3				
452.76	191.97 6	25				
	378.06 6	100 9				
	381.27 16	6.4 18				
474.36?	399.13 13	89 16				
	474.5 1	100 13				
517.98	486.87 3	100 7				
	518.01 9	7.3 7				
530.21?	455.26 18	40 16				
	499.1 1	100 13				
	530.5 2	53				
563.87	111.0 2	100				
	492.76 7	26 2				
	532.86 10	12 2				
	564.09 20	2 1				
579.34	504.76 8	100 8				
	547.99 16	38 8				
662.261	544.48 9	2.1 2				
	587.63 5	11.4 5				
	631.10 3	40 2				
	662.26 2	100 6				
695.10	220.52 4	100 10				
	522.12 10	8.5 10				
	577.15 $\#$ 14	$\leq$ 4.8 $\#$				
	624.11 7	22 1				
	664.17 9	19 2				
	695.18 8	13 1				
819.209	240.00 15	0.67 18				
	255.71 12	0.9 2				
	558.46 17	0.46 18				
	577.15 $\#$ 14	$\leq$ 1.1 $\#$				
	646.26 10	2.2 2				
	748.09 3	69 4				
	788.19 7	3.8 3				
	819.19 2	100 5				
844.072	326.21 7	3.2 3				
	602.79 2	3.5 2				
	769.52 17	0.3 1				
	772.95 5	2.1 2				
	812.93 4	50 3				
	844.10 4	100 5				
849.45	490.33 13	4.5 9				
	502.12 17	3.9 12				
	588.70 8	36 2				
	591.82 19	6 2				

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued) $\gamma(^{239}\text{Np})$ (continued)

E(level)	$E\gamma^\dagger$	$I\gamma^\dagger$	E(level)	$E\gamma^\dagger$	$I\gamma^\dagger$
849.45	727.52 10	17 2	992.05	874.22 7	32 2
	774.77 4	100 6		917.40 8	25 2
	849.44 §# 9	13 §# 1		920.95 8	25 2
863.43?	201.09 8	12 4		960.99 5	100 5
	746.06 11	100 13		992.00 7	27 2
	862.56 18	10 3	1040.39	258.80 16	3.8 10
959.17	174.07 6	100 10		345.13 8	20 2
	296.93 8	≤15		567.88 18	2 1
	395.19 11	21 3		587.63 5	100 5
	841.48 12	26 4		779.57 14	3 1
	884.45 5	89 5		867.11 10	4.0 5
	887.83 10	24 3		922.83 13	3.1 6
	928.00@ 6	53 3		965.58 10	10
	959.48 6	80 5		1009.38 18	1.50 5
964.08	301.64 15	1.2 3		1040.19 9	5.8 5
	703.63 10	2.6 3	1049.45	876.14 7	35
	722.85 4	30 2		931.97 7	100 7
	791.33 6	8.3 5		974.91 14	7.5 15
	846.39 4	35 2		1018.14 13	≤19
	889.49 4	23 1	1096.98	312.05 3	100
	933.09 3	29 2		434.44 13	23 4
	964.30 5	100 5		644.12 14	38 8
966.53	304.17 10	57		658.5 4	11
	514.1 3	23		1065.76 12	12 2
	793.55 8	100		1096.92 8	33 3
	849.44# 9	72# 8	1197.14?	535.01 14	100
	895.15 15	30 7		1122.8 3	52
992.05	296.93 13	≤14		1196.90 15	70

† From ^{239}U β^- Decay, unless otherwise specified.‡ From ^{243}Am α Decay.§ $E\gamma$ from ^{243}Am α Decay. $I\gamma$, weighted average from ^{239}U β^- Decay and ^{243}Am α Decay.

Multiply placed; undivided intensity given.

@ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas (continued)

(A) 5/2[642]

(B) 5/2[523]

(C) 1/2[400]?

(D) 1/2[530]

Adopted Levels, Gammas (continued)

²³⁹U β⁻ Decay 1969Cl12,1996Sa23,2006Wo03

Parent ²³⁹U: E=0; Jπ=5/2+; T_{1/2}=23.45 min 2; Q(g.s.)=1261.5 16; %β⁻ decay=100.
Includes 2008GrZS.
Other: 1986LoZT.

²³⁹Np Levels

E(level) [‡]	Jπ [†]	E(level) [‡]	Jπ [†]	E(level) [‡]	Jπ [†]
0.0	5/2+	448.15 3	(3/2-)	849.45 4	(7/2-)
31.1309 12	7/2+	452.76 4	(5/2+, 7/2-)	863.43? 9	3/2, 5/2, 7/2
71.13 3	9/2+	474.43? 5		959.17 3	
74.6640 10	5/2-	517.98? 3	(7/2-)	964.208 17	(7/2-)
117.715 20	7/2-	530.21? 8		966.53 6	(7/2, 9/2-)
122.5? 10	(11/2+)	563.87 5	(5/2+, 7/2)	992.05 3	(7/2-)
173.086 18	9/2-	579.34? 7	(9/2-)	1013.41? 6	
241.312 22	(11/2-)	662.261 15	(5/2-)	1040.39 4	(5/2-, 7/2-)
257.63 25		695.10 4	(7/2-)	1049.45? 5	(9/2-)
260.81 3	(3/2-)	781.85? 7		1096.98 5	(7/2+)
347.33 23		784.96? 5		1197.14? 10	
359.1 2		819.209 18	(7/2)		
438.79 5	(11/2+)	844.072? 15	(5/2, 7/2)		

[†] All Jπ are from adopted levels. Jπ assignments for Levels with E >200 keV are tentative and based on (³He,d) in 1975Vo01.

[‡] Deduced by evaluator from a least-squares fit to γ-ray energies.

β⁻ radiations

Eβ ^{-†}	E(level)	Iβ ^{-‡} #	Log ft	Comments
(64.4 [@] 16)	1197.14?	0.0032 1	6.2	
(164.5 16)	1096.98	0.013 1	6.8	
(221.1 16)	1040.39	0.035 2	6.8	
(248.1 [@] 16)	1013.41?	0.013 1	7.4	
(269.5 16)	992.05	0.027 2	7.2	
(297.3 16)	964.208	0.24 1	6.4	
(417.4 16)	844.072?	0.26 1	6.8	
(442.3 16)	819.209	0.27 1	6.9	
(566.4 16)	695.10	0.049 4	8.0	
(599.2 16)	662.261	0.30 2	7.3	
(1143.8 16)	117.715	1.96 [§] 24	7.4	Iβ ⁻ : %Iβ=0.15 3, from γ-ray transition-intensity balance.
1211	74.6640	69.0 [§] 14	5.9	Iβ ⁻ : %Iβ=77.0 25, from γ-ray transition-intensity balance. Other result: Iβ(1211)/Iβ(1285)=3.5 7 (1964Bl11).
(1230.4 16)	31.1309	9.4 [§] 19	6.9	Iβ ⁻ : %Iβ=8.5 22, from γ-ray transition-intensity balance.
1285	0.0	18.7 [§] 24	6.6	Iβ ⁻ : %Iβ=13 4, from γ-ray transition-intensity balance.

[†] From 1964Bl11.

[‡] From γ-ray transition intensity balances. β⁻ branches with Iβ<0.5% are tentative because of unplaced γ rays.

[§] Experimental value deduced by measuring absolute γ-ray intensities from ²³⁹U β-decay and ²³⁹Np β-decay in equilibrium (1996Sa23).

Absolute intensity per 100 decays.

@ Existence of this branch is questionable.

γ(²³⁹Np)

Iγ normalization: From weighted average of Iγ(74)=49.2% 12 (1996Sa02) and Iγ=53.9% 5 (2008GrZS).

Eγ [†]	E(level)	Iγ [†] @	Mult.#	δ	α	Comments
31.131 [‡] 2	31.1309	13.0 [‡] 14	M1+E2	0.18 1	263 13	δ: from α(exp)=274 11; Average of α(exp)=284 45, deduced by evaluator from a γ-ray transition intensity balance in ²³⁹ U β ⁻ decay, and α(exp)=273 11, also deduced by evaluator from γ-ray transition intensity balance in ²⁴³ Am α decay. Iγ: from 0.064% 7 (1996Sa23); Other: 0.068% 10 (1986LoZT).

Continued on next page (footnotes at end of table)

²³⁹U β⁻ Decay 1969Cl12,1996Sa23,2006Wo03 (continued)

γ(²³⁹Np) (continued)

Eγ [†]	E(level)	Iγ [†] @	Mult.#	δ	α	Comments
(43.1)	117.715		M1+E2	0.38	154.4	δ: From α(M)exp=31 in ²⁴³ Am α decay. Eγ: From 2003Br12, 1971Ar47, 1969Cl12.
43.533 1	74.6640	827 15	E1		1.143	Eγ: From 1979Bo30. Iγ: from 4.07% 11 (1996Sa23); Other: 4.16% 11 (1986LoZT).
(48)	1096.98					
(50.6)	173.086					Eγ: From 2003Br12, 1971Ar47, 1969Cl12.
(55.18 [‡])	173.086	0.017 [‡]	M1+E2	0.6 2	90 30	δ: from ²⁴³ Am α Decay.
(71.2)	71.13		[E2]		72.0	Eγ: From 2003Br12, 1971Ar47, 1969Cl12.
74.664 1	74.6640	10000	E1		0.276	Eγ: From 2003Br12, 1971Ar47, 1969Cl12. Iγ: from 49.2% 12 (1996Sa23); others: 48.1% 10 (1986LoZT); Iγ=48% 2 if Iγ(277.6γ)=14.1% 4 in ²³⁹ Np β ⁻ decay (1976GlZY). Iγ=59.3% (1969Cl12).
86.72 7	117.715	10.8 12	E1		0.186	Eγ: From 2003Br12, 1971Ar47, 1969Cl12. Iγ: from 0.053% 6 (1996Sa23); Other: 0.052% 6 (1986LoZT).
111.0 [‡] 2	563.87	4.1 [‡]				
117.66 3	117.715	28 4	E1		0.0841	Eγ: From 2003Br12, 1971Ar47, 1969Cl12. Iγ: from 0.14% 3 (1996Sa23); Other: 0.13% 4 (1986LoZT).
x134.71 13		0.41 9				
141.97 2	173.086	0.34	[E1]		0.224	
142.93	260.81	0.45	[E2]		3.03	
(169)	241.312					Eγ: From 2003Br12, 1971Ar47, 1969Cl12.
174.07 6	959.17	2.1 2				
186.15 4	260.81	6.3 6	[M1+E2]		2.6 16	
187.28 8	448.15	1.22 14	[M1+E2]		2.6 16	
191.97 [‡] 6	452.76	0.56 [‡]				
x196.85 [‡] 10		0.44 [‡]				
197.28 12	438.79	0.53 9	[E1]		0.1038	
201.09 18	863.43?	0.11 4				
220.52 4	695.10	6.2 6				
231.70 [‡] 10	1013.41?	0.62 [‡]				
x236.28 14		0.20 4				
240.00 15	819.209	0.19 5				
255.71 12	819.209	0.25 5				
258.80 16	1040.39	0.16 4				
260.86 9	260.81	0.67 7	[E1]		0.0549	
x262.89 19		0.18 7				
x265.44 17		0.20 7				
296.93& 13	959.17	≤0.31&				
	992.05	≤0.31&	[M1+E2]		0.7 5	
301.64 15	964.208	0.24 6	[M1+E2]		0.6 5	
304.17 [‡] 10	966.53	0.35 [‡]				
312.05 [‡] 3	1096.98	1.1 [‡]				
x321.71 [‡] 15		0.24 [‡]				
326.21 7	844.072?	0.95 10				
330.14 14	448.15	0.15 3	[E2]		0.1494	
332.06 14	784.96?	0.25 6				
x343.74 [‡] 10		0.39 [‡]				
345.13 8	1040.39	0.85 10				
x348.23 18		0.16 6				
351.33 15	1013.41?	0.16 4				
x361.83 8		0.97 9				
x363.1 [‡] 2		0.17 [‡]				
373.51 4	448.15	5.37 40	[M1+E2]		0.35 25	
378.06 6	452.76	2.2 2				
381.27 16	452.76	0.14 4				
x393.01 18		0.14 5				
395.19 11	959.17	0.45 6				
399.13 13	474.43?	0.34 6				
x400.55 15		0.20 5				

Continued on next page (footnotes at end of table)

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued) $\gamma(^{239}\text{Np})$ (continued)

$E\gamma^\dagger$	$E(\text{level})$	$I\gamma^\dagger @$	Mult.#	α
$^{x}404.84\ 18$		0.19 7		
$407.70^\ddagger\ 5$	438.79	0.71 ‡	[E2]	0.0830
$434.44\ 13$	1096.98	0.25 4	[E1]	0.0185
$^{x}445.81\ 12$		0.24 3		
$448.19\ 6$	448.15	1.97 15	[E1]	0.01733
$^{x}452.17\ 12$		0.34 6		
$455.26\ 18$	530.21?	0.18 7		
$474.5\ 1$	474.43?	0.38 5		
$^{x}478.13\ 19$		0.12 5		
$^{x}479.55\ 14$		0.22 5		
$486.87\ 3$	517.98?	13.5 9	[E1]	0.01469
$490.33^\S\ 13$	849.45	0.15 § 3		
$492.76\ 7$	563.87	1.09 9		
$499.1\ 1$	530.21?	0.45 6		
$502.12^\S\ 17$	849.45	0.13 § 4		
$504.76\ 8$	579.34?	1.14 9	[E2]	0.0488
$^{x}506.80\ 14$		0.22 5		
$514.1^\ddagger\ 3$	966.53	0.14 ‡		
$518.01\ 9$	517.98?	0.98 9	[E1]	0.01301
$522.12\ 10$	695.10	0.53 6	[M1+E2]	0.14 10
$530.5^\ddagger\ 2$	530.21?	0.24 ‡		
$532.86\ 10$	563.87	0.50 6		
$535.01^\ddagger\ 14$	1197.14?	0.27 ‡		
$^{x}541.32\ 10$		0.63 7		
$544.48\ 9$	662.261	0.79 7	[M1+E2]	0.13 9
$547.99\ 16$	579.34?	0.43 9	[E1]	0.01166
$558.46\ 17$	819.209	0.13 5		
$560.63\ 7$	1013.41?	1.27 9		
$564.09\ 20$	563.87	0.09 4		
$567.88\ 18$	1040.39	0.09 3		
$^{x}575.27\ 5$		2.85 15		
$577.15^\&\ 14$	695.10	$\leq 0.3^\&$	[M1+E2]	0.11 8
	819.209	$\leq 0.3^\&$		
$^{x}585.49\ 14$		0.27 5		
$587.63\ 5$	662.261	4.2 2	[M1+E2]	0.11 7
	1040.39	4.2 2		
$588.70^\S\ 8$	849.45	1.19 § 8		
$591.82^\S\ 19$	849.45	0.20 § 8		
$^{x}599.13\ 15$		0.16 4		
$^{x}602.68^\ddagger\ 4$		0.98 ‡		
$602.79\ 2$	844.072?	1.05 7		
$^{x}604.85\ 16$		0.21 6		
$^{x}607.96\ 15$		0.29 7		
$^{x}614.53\ 17$		0.14 5		
$^{x}618.03\ 16$		0.16 4		
$624.11\ 7$	695.10	1.35 8	[E1]	
$^{x}629.00\ 11$		0.58 8		
$631.10\ 3$	662.261	14.7 7	[E1]	
$644.12\ 14$	1096.98	0.42 9		
$646.26\ 10$	819.209	0.63 6		
$^{x}649.79\ 19$		0.20 8		
$658.5^\ddagger\ 4$	1096.98	0.12 ‡	[E2]	0.0269
$662.26\ 2$	662.261	37 2	[E1]	
$664.17\ 9$	695.10	1.17 10	[E1]	
$^{x}668.76\ 18$		0.12 4		
$^{x}670.88\ 20$		0.13 6		
$^{x}691.01\ 6$		1.61 9		
$^{x}692.61\ 13$		0.36 6		
$695.18\ 8$	695.10	0.79 6	[E1]	
$^{x}700.93^\ddagger\ 8$		0.42 ‡		
$^{x}701.21\ 10$		0.52 5		
$703.63\ 10$	964.208	0.51 6	[E2]	0.0235
$707.38\ 9$	781.85?	0.48 5		

Continued on next page (footnotes at end of table)

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued) $\gamma(^{239}\text{Np})$ (continued)

$E\gamma^\dagger$	$E(\text{level})$	$I\gamma^\dagger @$	Mult.#	α
710.35 $\frac{1}{2}^+$ 15	784.96?	0.25 $\frac{1}{2}^+$		
x714.22 9		0.81		
722.85 4	964.208	5.89 30	[E2]	0.0222
x727.52 10		0.56 6		
727.52 $\frac{1}{2}^+$ 10	849.45	0.56 $\frac{1}{2}^+$ 6		
x730.92 $\frac{1}{2}^+$ 4		2.5 $\frac{1}{2}^+$		
x730.95 6		2.05 11		
746.06 11	863.43?	0.93 12		
748.09 3	819.209	19.4 10		
752.39 14	1013.41?	0.28 6		
x764.04 11		0.56 7		
x768.15 11		0.44 5		
769.52 17	844.072?	0.09 3		
772.94 9	844.072?	0.64 6		
774.77 $\frac{1}{2}^+$ 4	849.45	3.3 $\frac{1}{2}^+$ 2		
779.57 14	1040.39	0.14 3		
788.19 7	819.209	1.06 7		
x791.3 $\frac{1}{2}^+$		1.8 $\frac{1}{2}^+$		
791.33 6	964.208	1.63 9	[M1+E2]	0.05 3
793.55 $\frac{1}{2}^+$ 8	966.53	0.61 $\frac{1}{2}^+$		
x795.13 15		0.18 4		
812.89 3	844.072?	15.0 8		
819.19 2	819.209	28.1 14		
x829.59 17		0.10 3		
x831.86 $\frac{1}{2}^+$ 4		0.71 $\frac{1}{2}^+$		
x831.89 9		0.45 5		
x840.3 $\frac{1}{2}^+$ 3		0.93 $\frac{1}{2}^+$		
841.48 12	959.17	0.54 8		
844.05 2	844.072?	30.3 15		
846.39 4	964.208	6.8 4	[M1+E2]	0.04 3
849.44 $\frac{1}{2}^+$ 9	849.45	0.44 $\frac{1}{2}^+$ 4		
	966.53	0.44 $\frac{1}{2}^+$ 5		
862.56 18	863.43?	0.09 3		
867.11 10	1040.39	0.165 20		
x869.57 9		0.35 3		
874.22 7	992.05	0.72 5	[M1+E2]	0.038 23
876.14 $\frac{1}{2}^+$ 7	1049.45?	0.41 $\frac{1}{2}^+$	[M1+E2]	0.038 23
884.45 5	959.17	1.87 10		
887.83 10	959.17	0.51 5		
889.49 4	964.208	4.56 23	[M1+E2]	0.036 22
895.15 15	966.53	0.18 4		
x913.68 9		0.41 3		
917.40 8	992.05	0.58 4	[M1+E2]	0.034 20
920.95 8	992.05	0.56 4	[E1]	
922.83 13	1040.39	0.132 24		
928.00 $\frac{1}{2}^+$ 6	959.17	1.12 6		
931.97 7	1049.45?	1.16 8	[M1+E2]	0.032 19
933.09 3	964.208	5.7 3	[E1]	
938.59 16	1013.41?	0.067 18		
x948.88 19		0.05 2		
959.48 6	959.17	1.69 10		
960.99 5	992.05	2.28 12	[E1]	
964.30 5	964.208	19.7 10	[E1]	
965.58 $\frac{1}{2}^+$ 10	1040.39	0.44 $\frac{1}{2}^+$		
x970.07 14		0.20 4		
974.91 14	1049.45?	0.087 17	[E2]	0.01229
x988.51 14		0.097 21		
992.00 7	992.05	0.61 4	[E1]	
x1002.40 13		0.11 2		
x1005.27 13		0.14 2		
1009.38 18	1040.39	0.065 2		
1018.14 $\frac{1}{2}^+$ 13	1049.45?	$\leq 0.22\frac{1}{2}^+$	[E1]	
1040.19 9	1040.39	0.245 22		

Continued on next page (footnotes at end of table)

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued) $\gamma(^{239}\text{Np})$ (continued)

$E\gamma^\dagger$	E(level)	$I\gamma^\dagger@$	Mult.#	α
1065.76 12	1096.98	0.13 2	[M1+E2]	0.023 13
^x 1078.88 [‡] 15		0.32 [‡]		
1096.92 8	1096.98	0.36 3	[M1+E2]	0.022 12
^x 1101.99 16		0.067 19		
1122.8 [‡] 3	1197.14?	0.14 [‡]		
^x 1161.4 [‡] 2		0.20 [‡]		
1196.90 [‡] 15	1197.14?	0.19 [‡]		
^x 1204.9 [‡] 2		0.32 [‡]		

[†] From 2006Wo03, unless otherwise specified. Uncertainties in γ -ray intensities given in 2006Wo03 do not include the contribution from the detector efficiency. Evaluators have corrected the uncertainties given here as suggested in 2006Wo03 by combining them with fractional uncertainties as follows: 15% for $E\gamma < 150$ keV; 10% for $150 \text{ keV} < E\gamma < 360$ keV; 7% for $360 \text{ keV} < E\gamma < 500$ keV; 5% for $E\gamma > 500$ keV. Other: 1968Ma06.

[‡] From 2003Br12, 1971Ar47, 1969Cl12.

[§] From 2006Wo03.

[#] From ce data of 1964Bl11, 1957Ho07, 1969En02 and from ^{243}Am α decay.

[@] For absolute intensity per 100 decays, multiply by 0.00532 17.

[&] Multiply placed; undivided intensity given.

^a Placement of transition in the level scheme is uncertain.

^x γ ray not placed in level scheme.

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued)

Decay Scheme

 Intensities: I(γ +ce) per 100 parent decays
 & Multiply placed; undivided intensity given

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued)

Decay Scheme (continued)

^{239}U β^- Decay 1969Cl12,1996Sa23,2006Wo03 (continued)

Decay Scheme (continued)

 Intensities: I(γ +ce) per 100 parent decays
& Multiply placed; undivided intensity given

²⁴³Am α Decay 1992Ga01,1996Wo05,1996Sa23

Parent ²⁴³Am: E=0.0; Jπ=5/2-; T_{1/2}=7364 y 22; Q(g.s.)=5438.8 10; %α decay=100.

Others: 1986LoZT, 1964Ba26, 1975Pa04.

αγ, (α)(ce): 1968Va09 (semi-semi), 1969En02 (semi-semi), 1963Le17 (semi-scin).

αγ(θ): 1962Si12, 1963Fl01, 1967Fa01, 1967Hu03.

αγ(θ,H): deduced effective hyperfine field (1970An13).

²³⁹Np Levels

E(level) [†]	Jπ [§]	T _{1/2}	Comments
0.0	5/2+		
31.130 21	7/2+		
71.5 9	9/2+		
74.660 18	5/2-	1.39 ns 3	μ=+2.0 3 (1967Gu08,2011StZZ). g=0.79 10 from αγ(θ,H,t) (1967Gu08). T _{1/2} : Weighted average of 1.2 ns 1 (1960Un02), 1.40 ns 6 (1963Ch07), 1.41 ns 4 (1968Ob02), 1.38 ns 3 (1969Hu09), and 1.41 ns 4 (1970To08).
117.84 3	7/2-	≤0.04 ns	T _{1/2} : From 1969Hu09.
122.4 10	(11/2+)		
173.02 4	9/2-		
240.8 9	(11/2-)		
267 [‡] 3	(5/2+)		
317.4 15	(13/2-)		
325 [‡] 3	(5/2-)		
347 [‡] 3	(7/2+, 9/2+)		Jπ: analogy to ²³⁷ Np suggests 7/2+ 1/2[400] band; however, from (³ He,d), Jπ=9/2+.
359 [‡] 3	(9/2+)		Jπ: analogy to ²³⁷ Np.
411 [‡] 3			
427 [‡] 3			
438 [‡] 3	(11/2+)		
662.2	(5/2-)		

[†] Deduced by evaluator from a least-squares fit to γ-ray energies, unless otherwise specified.

[‡] From alpha particle energy.

[§] From adopted levels, unless stated otherwise.

α radiations

Eα [†]	E(level)	Iα ^{§@}	HF [#]	Comments
4695 3	662.2	1.7×10 ⁻³ 5	7.1	Iα: measurement of 1966Le13. α intensity in coincidence with gammas is 0.0016% 5, in coincidence with ce's is 0.00007% 3. Iα: 0.00148% 3, deduced by evaluator from γ-ray transition intensity balance.
4919 3	438	8.5×10 ⁻⁵	5400	Iα: From Iα=0.000085% (1964Ba26), recommended in 2010BeZQ.
4930 3	427	1.8×10 ⁻⁴	3000	Iα: From Iα=0.00018% (1964Ba26), recommended in 2010BeZQ.
4946 3	411	3.4×10 ⁻⁴	2000	Iα: From Iα=0.00034% (1964Ba26), recommended in 2010BeZQ.
4997 3	359	≤0.0016	≥1000	Average of Iα(5008α + 4997α)=0.0016% 5 (1992Ga01) and Iα=0.0020% 4 (1996Sa24). Other value: Iα=0.0016 (1964Ba26).
5008 3	347	≤0.0016	≥1200	
5029 3	325	≤0.004	≥700	Iα(5035α + 5029α)=0.0039% 6, average of Iα=0.0022% (1964Ba26), Iα=0.0033% 5 (1992Ga01), and Iα=0.0044% 5 (1996Sa24).
5035 3	317.4	≤0.003	≥1000	Iα: 0.00104% 2, deduced by evaluator from γ-ray transition intensity balance.
5088 5	267	0.0055 6	1100	Iα: Average of Iα=0.004% (1964Ba26), Iα=0.0056% 7 (1992Ga01), and Iα=0.0055% 6 (1996Sa24).
5113 1	240.8	0.008 3	1100	Iα: Average of Iα=0.0054% (1964Ba26), Iα=0.010% 1 (1992Ga01), and Iα=0.010% 10 (1996Sa24).
5181 1	173.02	1.383 7	17	Iα: 0.0046% 1, deduced by evaluator from γ-ray transition intensity balance. Iα: Weighted average (Limited Relative Statistical Weight Method) of Iα=1.1% 2 (1964Ba26,1991Ry01), Iα=1.1% 3 (1955St98, uncertainty estimated by evaluator), Iα=1.3% 2 (1956Hu96), Iα=1.36% 1 (1992Ga01), Iα=1.388% 8 (1996Sa24), and Iα=1.391% 7 (2002Da21). Iα: 1.1% 4, deduced by evaluator from γ-ray transition intensity balance.

Continued on next page (footnotes at end of table)

²⁴³Am α Decay 1992Ga01,1996Wo05,1996Sa23 (continued)

α radiations (continued)

Eα [†]	E(level)	Iα ^{§@}	HF [#]	Comments
5233.3 [‡] 10	117.84	11.46 5	4.7	Iα: Weighted average (Limited Relative Statistical Weight Method) of Iα=10.6% 2 (1964Ba26,1991Ry01), Iα=11.5% 3 (1955St98,1991Ry01), Iα=11.5% 3 (1956Hu96), Iα=11.46% 3 (1992Ga01), Iα=11.37% 3 (1996Sa24), and Iα=11.52% 2 (2002Da21).
5275.3 [‡] 10	74.660	86.74 5	1.1	Iα: 10.3% 4, deduced by evaluator from γ-ray transition intensity balance. Iα: Weighted average (Limited Relative Statistical Weight Method) of Iα=87.9% 3 (1964Ba26, 1991Ry01), Iα=87.1% 4 (1955St98,1991Ry01), Iα=86.9% 4 (1956Hu96), Iα=86.74% 6 (1992Ga01), Iα=86.79% 3 (1996Sa24), and Iα=86.60% 7 (2002Da21).
5321 1	31.130	0.192 3	940	Iα: 88.1% 17, deduced by evaluator from γ-ray transition intensity balance. Iα: Average of Iα=0.190% 7 (1992Ga01), Iα=0.194% 3 (1996Sa24), and Iα=0.190% 3 (2002Da21). Other values: Iα=0.12% (1964Ba26), Iα=0.16% (1955St98), and Iα=0.16% (1956Hu96).
5349.4 [‡] 23	0.0	0.240 3	1200	Iα: Average of Iα=0.230% 7 (1992Ga01), Iα=0.243% 3 (1996Sa24), Iα=0.240% 3 (2002Da21). Other values: Iα=0.16% (1964Ba26), Iα=0.17% (1955St98), Iα=0.17% (1956Hu96).

[†] Deduced from values in 2002Da21 (s), 1996Sa24 (s), and 1964Ba26 (s), recommended in 2010BeZQ, unless otherwise specified.
Other: 1968Ba25 (s).

[‡] From 1991Ry01.

[§] Deduced from values in 2002Da21, 1996Da24, 1992Ga01, 1964Ba26, 1956Hu96, and 1955St98, recommended in 2010BeZQ.

[#] Using r₀(²³⁹Np)=1.505, average of r₀(²³⁸U)=1.5143 9, r₀(²⁴⁰U)=1.5062 10, r₀(²³⁸Pu)=1.5013 10, and r₀(²⁴⁰Pu)=1.4979 7 (1998Ak04).

[@] Absolute intensity per 100 decays.

γ(²³⁹Np)

I(L x ray)=41% 5 (αγ pc, 1969Al14).

From decay scheme (Using program RADLST), I(L x ray)=18.8% 7, and I(K x ray)=0.0195% 10. The value I(K x ray)=13.5% reported by 1977St35 is clearly in error; 1972Ah02 did not observe any K x ray in spite of having a better spectrum.

Iγ normalization: from weighted average (Limited Relative Statistical Weights Method) of Iγ(74.7γ)=68.5% 15 (1984Va41), Iγ(74.7γ)=69% 3 (1960As02), Iγ(74.7γ)=61% 6 (1968Va09), Iγ(74.7γ)=66% 3 (1972Ah02), Iγ(74.7γ)=59% 4 (1977St35), Iγ(74.7γ)=60% 4 (1979Po20), Iγ(74.7γ)=68% 2 (1982Ah04), Iγ(74.7γ)=66.7% 12 (1996Wo05), Iγ(74.7γ)=68.4% 13 (1996Sa23). Other values: Iγ(74.7γ)=73% 1 (1969Al14); Iγ(74.7γ)=68.2% 14, evaluated intensity (1986LoZT).

Eγ [†]	E(level)	Iγ ^{§@}	Mult.	δ	α	Comments
31.14 [‡] 3	31.130	0.105 7	M1+E2	0.09 2	187 16	Mult.: M1+<30% E2 was deduced by 1972Sc44 from L x ray spectra in coincidence with 43.5γ (contribution from other gammas subtracted by use of (74.6γ)(L x ray) coincidence spectra). Intensity balance at 31.10-keV level requires that α=189 15 corresponding to δ=0.09 2.
43.1	117.84	0.097	M1+E2	0.38	154.4	Iγ: deduced by the evaluator from α(M)exp=31, Ice(M)(43.1γ)/Iγ(117.6γ)=3.56 as measured by 1969En02, and Iγ(117.6γ)=0.84 (from intensity balance Iγ=0.11).
43.53 [‡] 2	74.660	8.78 15	E1		1.143	Mult.: α(M)exp=31 from (α)(ce)/αγ (1969En02). Iγ: Weighted average (Limited Relative Statistical Weight Method) of Iγ=6.04% 13 (1984Va41), Iγ=4.0% 10 (1960As02), Iγ=5.3% 5 (1968Va09), Iγ=5.0% 10 (1969Al14), Iγ=5.5% 3 (1972Ah02), Iγ=5.3% 12 (1979Po20), Iγ=6.2% 3 (1982Ah04), Iγ=5.93% 10 (1996Wo05), Iγ=5.72% 17 (1996Sa23) renormalized to Iγ(74.7γ)=100.
50.6	173.02	0.0044	[E1]		0.769	Mult.: from intensity balance. Also from ce data in ²³⁹ U decay.
55.4	173.02	0.0154	M1+E2	0.6 2	80 30	Mult., δ: α(L)exp=90, L12/L3=2.9 from (α)(ce)/αγ (1969En02).
(68.1)	240.8		[E2]		89.0	I(γ+ce) [@] : 0.0045 CA.
(71.2)	71.5		[E2]		72.0	

Continued on next page (footnotes at end of table)

^{243}Am α Decay 1992Ga01,1996Wo05,1996Sa23 (continued) $\gamma(^{239}\text{Np})$ (continued)

$E\gamma^\dagger$	E(level)	$I\gamma^\S@$	Mult.	α	Comments
74.66 2	74.660	100.0	E1	0.276	$I\gamma$: $I\gamma=67.2\%$ 12, weighted average (Limited Relative Statistical Weight Method) of $I\gamma=68.5\%$ 15 (1984Va41), $I\gamma=69\%$ 3 (1960As02), $I\gamma=61\%$ 6 (1968Va09), $I\gamma=66\%$ 3 (1972Ah02), $I\gamma=59\%$ 4 (1977St35), $I\gamma=60\%$ 4 (1979Po20), $I\gamma=68\%$ 2 (1982Ah04), $I\gamma=66.7\%$ 12 (1996Wo05), $I\gamma=68.4\%$ 13 (1996Sa23). Mult.: $\alpha(\text{L})\text{exp}=0.170$ from $\alpha(\text{ce})/\alpha\gamma$, $\text{L}12/\text{L}3=2.2$ (1969En02).
86.71 $\frac{1}{2}$ 2	117.84	0.515 13	E1	0.186	$I\gamma$: Weighted average (Limited Relative Statistical Weight Method) of $I\gamma=0.350\%$ 10 (1984Va41), $I\gamma=0.37\%$ 4 (1968Va09), $I\gamma=0.340\%$ 15 (1982Ah04), $I\gamma=0.342\%$ 15 (1996Wo05), $I\gamma=0.344\%$ 9 (1996Sa23) renormalized to $I\gamma(74.7\gamma)=100$. Mult.: $\alpha(\text{M})\text{exp}\leq 0.034$ from $\alpha(\text{ce})/\alpha\gamma$ (1969En02).
98.5	173.02	0.014 CA	(E2)	15.56	$I\gamma$: calculated by evaluator from $(\text{Ice}(\text{L})(98.5\gamma))/(\text{Ice}(\text{L})(142\gamma))=21.4$ (1969En02), $I\gamma(142\gamma)$, and $\alpha(\text{L})(98.5\gamma)=11.5$, $\alpha(\text{L})(142.18\gamma)=0.0394$ (theory). Mult.: $\alpha(\text{L})\text{exp}\geq 2.2$, $\text{L}12/\text{L}3=1.81$ by $\alpha(\text{ce})$ coincidences; photon was not observed (1969En02).
117.60 15	117.84	0.84 12	E1	0.0842	Mult.: $\alpha(\text{L})\text{exp}=0.070$ from $\alpha(\text{ce})/\alpha\gamma$ (1969En02).
141.89 $\frac{1}{2}$ 3	173.02	0.171 12	E1	0.224	$I\gamma$: Weighted average (Limited Relative Statistical Weight Method) of $I\gamma=0.130\%$ 10 (1984Va41), $I\gamma=0.130\%$ 10 (1968Va09), $I\gamma=0.128\%$ 6 (1982Ah04), $I\gamma=0.117\%$ 5 (1996Wo05), $I\gamma=0.107\%$ 3 (1996Sa23) renormalized to $I\gamma(74.7\gamma)=100$. Mult.: $\alpha(\text{L})\text{exp}=0.055$ from $\alpha(\text{ce})/\alpha\gamma$ (1969En02).
169	240.8	0.0020	[E1]	0.1489	$E\gamma$: measured by 1968Va09 ($\alpha\gamma$ semi).
195	317.4	0.0014	[E1]	0.1067	$E\gamma$: measured by 1968Va09 ($\alpha\gamma$ semi).
$\times 220$					Observed by 1968Va09 in coincidence with 5088 α .
544.58 $\#$ &	662.2				
587.77 $\#$ &	662.2				
631.09 $\#$	662.2	0.0005			$I\gamma(544\gamma+588\gamma)=0.0005$ (1966Le13).
662.24 $\#$	662.2	0.0017			

† From 1975Pa04 (semi), 1972Ah02 (semi), 1969En02 ($\alpha\gamma$, $\alpha(\text{ce})$ semi), unless otherwise noted. Other measurements: 1957As84, 1960As02, 1963Le17, 1966Le13, 1967Ch12, 1968Va09, 1969Al14.

$\frac{1}{2}$ From 1982Ah04 equilibrium ^{243}Am source; semi.

§ From 1986LoZT, 1982Ah04, 1975Pa04, 1972Ah02, 1968Va09. $I\gamma$ normalized to 100 for 74.67 γ .

$\#$ From ^{239}U β^- decay. Transition was observed in 1966Le13 in $\alpha\gamma$ coincidence spectrum and placed in level scheme. The measured energy was not given in 1966Le13.

@ For absolute intensity per 100 decays, multiply by 0.672 12.

& Placement of transition in the level scheme is uncertain.

$\times$ γ ray not placed in level scheme.

²⁴³Am α Decay 1992Ga01,1996Wo05,1996Sa23 (continued)

²³⁸U(³He,d),(α,t) 1975Vo01
²³⁹Np Levels

(³He,d) measured at 3 angles (1975Vo01).

E(level) [†]	Jπ [§]	L [‡]	E(level) [†]	Jπ [§]	L [‡]	E(level) [†]	Jπ [§]	L [‡]
=0.0 [#]	5/2+		346.8 ^b 14	(9/2+)	2,3,4,5,6	778.6 13		0,1,2,3,4
28.0 [#] 3	7/2+		420.6 22			823.4 17		0,1,2
70.0 [#] 12	9/2+	2,3,4	437? ^b 3	(11/2+)		864.9 ^d 12	(9/2+)	4,5,6
70.0 [@] 12	5/2-	2,3,4	449.8 ^c 11	3/2-	0,1	890.6 12		4,5,6
117.8 [@] 16	7/2-	0,1,2,3,4	482.6 ^c 11	5/2-	(3),4,5	917.1 11		3,4,5
117.8 [#] 16	11/2+	0,1,2,3,4	521.2 ^c 11	7/2-	3,4	951.5 13		4,5,6
173.7 [@] 12	9/2-	2,3,4,5,6	547.0? ^b 23	(13/2+)	5,6	992.9 ^e 12	(7/2-)	2,3,4
180.0 [#] 12	13/2+	5,6	581.0 ^c 22	9/2-	5,6	1019.9 ^d 12	(13/2+)	5,6
220.2 ^{&} 12	(1/2+)	0,1,2,3,4	600? 3			1049.0 ^e 12	(9/2-)	4,(5)
239.4 [@] 21	11/2-	4,5,6	616? 3		0,1,2,3	1077.2 14		3,4,5,6
258.3 ^a 13	(3/2-)	0,1,2,3	637.2 18		0,1,2	1117.8 ^e 13	(11/2-)	3,4,5
258.3? ^{&} 13	(3/2+)	0,1,2,3	657? ^c 3	(11/2-)		1141.1 17		0,1,2,3
270.9 ^a 14	1/2-	0,1,2	695.4 11		3,4	1155.3 19		2,3,4
315.5 ^a 11	7/2-	(3),4	723.7 22			1182.5 14		4,5,6
324? ^a 4	(5/2-)		741.6 21		2,3,4,5,6			

[†] Calibration is based on 10 known levels in ²³⁹Np (1975Vo01).

[‡] From 1975Vo01 based on angular distribution in (³He,d) and on the ratio of cross sections (³He,d)/(α,t).

[§] From 1975Vo01 based on L values and on comparison of cross sections with DWBA calculations.

[#] (A): 5/2[642].

[@] (B): 5/2[523].

[&] (C): 1/2[400]?

^a (D): 1/2[530].

^b (E): 3/2[651]?

^c (F): 3/2[521].

^d (G): 7/2[633]?

^e (H): 7/2[514].

Adopted Levels, Gammas

Q(β^-)=-802.1 17; S(n)=5646.2 3; S(p)=6155.4 4; Q(α)=5244.50 21 2012Wa38.
 Other reactions:
 Fission: 1997Vl02, 1997Vl01, 1997Ar09, 1996Vl01, 1993De17, 1992Ge01.
 Spontaneous fission: 2012Ha06, 2011Yo12, 2008Ku21, 2006En04, 2005Re16, 2004Ro01, 2001Vl02.
 239Pu(n,f): 2012PrZZ, 2011Ho11, 2011Hu06, 2011Ki09, 2011Mu07.
 239Pu(n,n'): 1996Yu05, 1992Lo08.
 239Pu(n,n') E<10 MeV (2003Hi21).
 239Pu(n,n') E<20 MeV. Calculated σ , neutron spectrum (2011Ro24). Others: 2012Ba38, 2011Mu04.
 239Pu(n,n') E<300 MeV, calculated σ (2010Ha06).
 239Pu(γ,γ') E<5.5 MeV deduced prompt γ -ray transitions (2011Jo11).
 239Pu(α,α') E=55 MeV, measured $E_\gamma, I_\gamma(\theta)$, $\gamma\gamma$ coin (2011Bu11).
 Cluster decay:
 239Pu(α): calculated $T_{1/2}$, branching ratios (2012Sa31). Others: 2013Fe03, 2010Ni02, 2009Dr05, 2007Ro08.
 239Pu(33Si): calculated $T_{1/2}$ (2011Sh13).
 239Pu(28Mg): calculated Q(β^-)value, $T_{1/2}$ (2012Sa31).
 239Pu(34Mg): calculated $T_{1/2}$ (2012Ku29).
 239Pu(30Mg): calculated $T_{1/2}$ (2010Ni13).
 Nuclear Structure.
 239Pu: calculated single-quasiparticle energies (2005Pa73).
 239Pu: calculated Coriolis decoupling factors (2009Mi02).
 239Pu: rotational bands (2009Ra27).
 239Pu: K-forbidden log ft values (2009So02).
 239Pu: evaluated data, Decay Data Evaluation Project (DDEP) (2008BeZV).
 239Pu: compiled data on superdeformed bands and fission isomers (2002Si26).
 239Pu: x-ray transition energies (2003De44).
 Others: 2005Si30, 2004Sa55, 2003Ad31, 2003Ad34, 2003Ka23, 2003Ok01.

239Pu Levels

Cross Reference (XREF) Flags

A 239Np β^- Decay
 B Muonic Atom
 C 238U($\alpha, 3n\gamma$)
 D 239Am ε Decay

E 243Cm α Decay
 F 238Pu(n, γ) E=th
 G 238Pu(d,p)
 H 239Pu(n,n')

I 239Pu(d,d')
 J Coulomb Excitation
 K 239Pu(γ,γ')

E(level)	$J\pi^\dagger$	XREF	$T_{1/2}$	Comments
0.0&	1/2+	ABCDEFGHIJK	24110 y 30	<p>$\mu=+0.203$ 4 (2011StZZ). Quadrupole deformation parameter deduced from splitting of giant-dipole resonance in photoabsorption $\beta(2)=0.29$ 3 (1976Gu15), $\beta(2)=0.245$ (1986Be38). From muonic x-rays 1986Zu01 deduce $\beta(2)=0.2607$ 7, $\beta(4)=0.0896$ 18 and $Q=11.56$ 6. 1978Cl03 deduce $Q=11.66$ 11. From optical isotope shifts 1985Ge08 deduce $Q=11.3$ 10. Jπ: Atomic beam (1969Fu11). 285γ E2 from 5/2+ at 285.4 keV. $T_{1/2}$: from 1986LoZT. 1990GlZZ recommend 24113 y 40 with a confidence level of >99% (the standard deviation is 11 y). Others: 24060 y 19, specific α activity (1975Al15); 24048 y 25, calorimetry, value corrected by 1977Ja08 (1970OeZZ); 24124 y 14, specific α activity, and 24139 y 14, mass spectrometry (1977Ja08); 24164 y 14 mass spectrometry (1978Ma45); 24101 y 8 calorimetry (1978Se12); 24019 y 21 specific α activity, and 24089 y 23 mass spectrometry (1978Pr07). $\% \alpha=100$; $\%SF=3.1 \times 10^{-10}$ 6. $T_{1/2}$: $T_{1/2}(SF)=8 \times 10^{15}$ y 2, value recommended in 2000Ho27. Other values: $T_{1/2}(SF)=7.8 \times 10^{15}$ y 16 (1985Dr09); $T_{1/2}(SF)=5.5 \times 10^{15}$ y 16 (1952Se67) ($\Delta T_{1/2}$ is due to statistics only). $Q=-2.319$ 7 (2011StZZ). $T_{1/2}$: from B(E2)=5.313 22 in muonic atom. $Q=-3.345$ 13 (2011StZZ). $T_{1/2}$: from Moss (1972Ga28). Others: =0.2 ns from Coul. ex., 102 ps 8 from B(E2)(1/2+ to 5/2+)=7.95 4 in muonic atom and adopted γ branching.</p>
7.861#a 2	3/2+	ABCDEFGH JK	36 ps 3	
57.275#& 2	5/2+	ABCDEF HIJ	101 ps 5	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²³⁹Pu Levels (continued)

E(level)	Jπ [†]	XREF	T _{1/2}	Comments
75.705# ^a 3	7/2+	ABCDEFGHIJ		Q=-3.83 3 (2011StZZ). T _{1/2} : 111 ps from B(E2) (3/2+ to 7/2+)=7.00 4 in muonic atom and assuming I _γ (67γ)=100%.
163.76#& 3	9/2+	ABCDEFGHIJ	73 ps 4	T _{1/2} : from B(E2)=6.43 3 in muonic atom and adopted I _γ branching.
192.8# ^a 10	11/2+	C E GHIJ		
285.460# ^d 2	5/2+	A DE GH	1.12 ns 5	μ=-1.3 3 (2011StZZ). μ: from β ⁻ decay. Jπ: favored α decay (HF=1.33) from ²⁴³ Cm (Jπ=5/2+). T _{1/2} : from 1974Pa03. Other: 1951Gr34.
318.5& 7	13/2+@	C IJ		
330.124# ^d 4	7/2+	A DE G		
358.1 ^a 1	15/2+@	C IJ		
387.42# ^d 2	9/2+	A DE G		
391.584# ^e 3	7/2-	A DE	193 ns 4	Jπ: 61.5γ E1 to 7/2+, 106.1γ E1(+M2) to 5/2+. α decay HF=130 is comparable to HF=90 for the analogous transition in ²⁴¹ Pu α decay; γ(θ) in ²³⁹ Np β ⁻ decay. T _{1/2} : from 1955En07. Other: 1974Pa03.
434# ^e 3	(9/2-)	E		
462# ^d 3	(11/2+)	E G		
469.8# ^b 4	(1/2-)\$	A EFG IJ		Jπ: from (d,d').
487# ^e 3	(11/2-)	E G		
492.1# ^c 3	3/2-	A EFG IJ		
505.6# ^b 2	(5/2-)	A DEFG IJ		
511.838 ^f 13	7/2+	A D		Jπ: 124γ M1(+E2) to 9/2+, 226γ M1+E2 to 5/2+.
519.3& 6	17/2+@	C J		
538# 3		E G		
556.2# ^c 5	(7/2-)	A EF IJ		
565 ^f	(9/2+)	G		
570.6 ^a 7	19/2+@	C J		
583 ^b 3	(9/2-)	IJ		
620 ^e	(15/2-)	G		
634 ^f	11/2+	G		
661.1 ^c 11	(11/2-)@	G IJ		
698.7 ^b 10	(13/2-)	J		
716		G		
752.5 5	1/2+, 3/2\$	EFG I		
756# 3		E		
763# 3		E		
764.6& 6	(21/2+)@	C J		
779 3		G I		
798.2 5	1/2, 3/2\$	F I		
805.1 5	1/2, 3/2\$	F		
806.7 ^c 15	(15/2-)@	J		
813# 3		E		
825.5 10	1/2, 3/2\$	F I		
828.0 ^a 7	(23/2+)@	C J		
854 2		E I		
857.5 ^b 10	(17/2-)	J		
888.0 5	1/2, 3/2\$	FG		
900 2		G I		
915 3		I		
933.3 10	1/2, 3/2\$	F		
948 3		I		
990 ^g	(3/2-)	G I		
992.4 ^c 18	(19/2-)@	J		
1017 ^g	(1/2-)	G		
1027 2		I		
1038 ^g	(7/2-)	G		
1052.9& 3	(25/2+)	C J		
1058.1 ^b 11	(21/2-)	J		
1062 2		I		
1099.9 5	1/2, 3/2\$	F		

E(level)	Jπ [†]	XREF
1100 ^g	(5/2-)	G
1127.6 ^a 7	(27/2+)@	C J
1137 ^g	(11/2-)	G
1174		G
1214 ^h	(1/2+)	G
1219.7 ^c 21	(23/2-)@	J
1233 ^h	(3/2+)	G
1233 ⁱ	(9/2-)	G
1261 ^h	(5/2+)	G
1261 ^j	(3/2+)	G
1289 ^j	(5/2+)	G
1300.9 ^b 12	(25/2-)	J
1311 ^h	(7/2+)	G
1342 ^j	(7/2+)	G
1359 ^h	(9/2+)	G
1381.1& 7	(29/2+)@	C J
1390		G
1409 ^j	(9/2+)	G
1437		G
1465		G
1467.3 ^a 8	(31/2+)@	C J
1487.7 ^c 23	(27/2-)@	J
1488		G
1584.9 ^b 14	(29/2-)	J
1748.2& 7	(33/2+)@	C J
1795.5 ^c 25	(31/2-)	J
1846.3 ^a 8	35/2+@	J
1908.9 ^b 15	(33/2-)	J
2040.25 21	(1/2, 3/2)‡	K
2046.9 3	(1/2, 3/2)‡	K
2135.0 4	(1/2, 3/2)‡	K
2143.56 13	(1/2, 3/2)‡	K
2144 ^c 3	(35/2-)@	J
2151.0 3	(1/2, 3/2)‡	K
2151.8& 7	(37/2+)@	J

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²³⁹Pu Levels (continued)

E(level)	Jπ [†]	XREF	T _{1/2}	Comments
2262.0 ^a 8	(39/2+) [@]	J		
2272.0 ^b 16	(37/2-)	J		
2289.0 3	(1/2, 3/2) [‡]	K		
2431.7 3	(1/2, 3/2) [‡]	K		
2454.4 3	(1/2, 3/2) [‡]	K		
2460.5 4	(1/2, 3/2) [‡]	K		
2464.6 3	(1/2, 3/2) [‡]	K		
2471.1 3	(1/2, 3/2) [‡]	K		
2529.4 ^c 23	(39/2-)	J		
2589.4 ^{&} 8	(41/2+) [@]	J		
2672.0 ^b 17	(41/2-)	J		
2712.8 ^a 8	(43/2+) [@]	J		
2951.4 ^c 25	(43/2-)	J		
3059.7 ^{&} 8	(45/2+) [@]	J		
3100 ^k 200	(5/2+)	K	7.5 μs 10	T _{1/2} : from 1977GoZH. Others: 8 μs 1 (1970Po01), 9 μs 1 (1973Na35), 8.1 μs 8 (1972Wo07), 11 μs 2 (1979Ba02), 6.5 μs 4 (1980Gu20). See also: 1971Ta17. E(level): from ²³⁹ Pu(γ,n) (1972Ga04). E=2.7 MeV from ²³⁸ U(α,3n) (1971Br38,1972Wo07,1980Bj02). Others: 1970Bu02, 1974Ga41, 1973PoZA. Ratio of isomeric to prompt fission 7.9×10 ⁻⁵ in ²⁴⁰ Pu(γ,n) E(γ)≤45 MeV (1980Gu20). Mass distribution in fission of the isomer studied by 1977GoYZ. %SF≤100. Q of rotational band built on g.s. of second potential minimum studied by 1977Ha01. Q=36.5 25 assuming moment of inertia for the band 5% lower than the ²⁴⁰ Pu case. K≥5/2 from decay time of high-charge states. Other: 1977GoZH.
3108.0 ^b 20	(45/2-)	J		
3124.3 ^k	(7/2+)	K		
3156.2 ^k	(9/2+)			
3196.1 ^a 9	(47/2+) [@]	J		
3303	(9/2-)	K	2.6 ns +40-12	Assignment: ²³⁸ U(α,3n), ce-fission coin (1979Ba02). Jπ: γ-ray deexcitation, Alaga ratios. Calculations suggest 9/2[734]. T _{1/2} : from 1979Ba02. Others: 1977Ha01, 1980Gu20, 1977GoZH. %SF≤100.
3407 ^c 3	(47/2-)	J		
3558.2 ^{&} 9	(49/2+) [@]	J		
3578.0 ^b 22	(49/2-)	J		
3713.0 ^a 24	(51/2+)	J		
3895 ^c 3	51/2-	J		
4080.0 ^b 24	(53/2-)	J		
4087.1 ^{&} 24	(53/2+)	J		
4256 ^a 3	(55/2+)	J		
4413 ^c 3	55/2-	J		

[†] From γ-ray multipolarities, rotational band structure, and systematics of Nilsson orbitals in nearby odd-A nuclei. Individual arguments are given mostly for rotational bandheads. Jπ assignments from ²³⁸Pu(d,p) are based on angular distributions and cross section fingerprints.

[‡] From expected dominance of dipole excitation in ²³⁹Pu(γ,γ).

[§] Fed in ²³⁸Pu(n,γ), E=thermal from 1/2+, γ-ray deexcitation to 1/2+ and 3/2+.

From ²⁴³Cm α decay.

@ From Coulomb Excitation.

& (A): 1/2[631], α=+1/2.

a (B): 1/2[631], α=-1/2.

b (C): 1/2[631]×0-, α=+1/2 (octupole vibration on g.s.).

c (D): 1/2[631]×0-, α=-1/2 (octupole vibration on g.s.).

d (E): 5/2[622].

e (F): 7/2[743].

f (G): 7/2[624].

g (H): 1/2[761].

Footnotes continued on next page

Adopted Levels, Gammas (continued)

239Pu Levels (continued)

h (I): 1/2[620].

i (J): 7/2[613]?

j (K): 3/2[622]?

k (L): 5/2[633] in second potential minimum. Rotational parameters A=3.36 10 keV, B=4 3 eV (1979Ba02). Q and δ suggest that spin and angular momentum for the band are antiparallel, consistent with 5/2[633].

γ(239Pu)

E(level)	Eγ	Iγ	Mult.§	δ	α	Comments
7.861	7.860# 3	100#	M1+E2	0.055 3	5.7×10 ³ 4	B(M1)(W.u.)=0.220 24; B(E2)(W.u.)=3.1×10 ³ 5. B(E2)(W.u.)>>RUL.
57.275	49.412# 4	100#	M1+E2	0.50 3	126 8	Iγ: from 239Np β ⁻ . From B(E2) ratios in muonic atom and δ=0.50 Iγ(49.4γ)=66, if Iγ were exactly 85 then δ=0.59 rather than 0.50 3. B(M1)(W.u.)=0.0075 16; B(E2)(W.u.)=220 50. B(E2)(W.u.)=291 47.
75.705	57.273# 4 (18.4 CA)	≈30#	E2 [M1+E2]		222	
	67.841 7		E2		98.5	
163.76	88.06# 3	12#	M1+E2	0.50	12.26	B(M1)(W.u.)=0.00295 18; B(E2)(W.u.)=27.7 17.
	106.47# 4	100#	E2		11.80	B(E2)(W.u.)=450 30.
192.8	117.3 ^a 3	100	E2		7.55 14	
285.460	209.753# 2	23.6# 7	M1+E2 ^c	0.37 ^c 8	2.93 13	B(M1)(W.u.)=7.4×10 ⁻⁵ 7; B(E2)(W.u.)=0.07 3.
	228.183# 2	75.7# 21	M1+E2 ^c	0.28 ^c 7	2.41 9	B(M1)(W.u.)=0.000194 15; B(E2)(W.u.)=0.09 4.
	277.599# 2	100# 3	M1+E2 ^c	0.23 ^c 10	1.42 7	B(M1)(W.u.)=0.000145 13; B(E2)(W.u.)=0.029 25.
	285.460# 2	5.2# 1	E2		0.247	B(E2)(W.u.)=0.0262 15.
318.5	125 ^a					
	154.3 4	100	E2		2.38 5	Eγ: From (α,3nγ).
330.124	44.663# 5	100# 15	M1+E2	0.20 3	86 8	
	166.319# 6	9# 2	M1		6.23	
	254.40# 3	85# 8	M1+E2	-0.159 6	1.85	
	272.87# 9	62# 8	M1+E2	+0.165 9	1.518	
	322.3# 2	5.4# 8	[E2]		0.1699	
358.1	165.3 ^a 3		E2		1.80	
387.42	57.30# CA	≈100#	M1(+E2)		28.6 4	α: For M1.
	101.96# 2	≈8.9#	E2		14.42	
	311.7# 2	19# 2	(M1+E2)	≤0.2	1.06 2	
391.584	(4.2#)	#	[E1]			
	61.460# 2	4.8# 6	E1		0.473	B(E1)(W.u.)=1.42×10 ⁻⁷ 22.
	106.125# 2	100# 10	E1(+M2)	-0.007 7	0.117 11	α(L)exp=0.19 3; α(M)exp=0.050 8; α(N+...)exp=0.017 3. Mult.: conversion is anomalous.
						B(E1)(W.u.)=5.7×10 ⁻⁷ 8; B(M2)(W.u.)=0.011 +23-11.
	315.880# 3	5.8# 6	E1(+M2)	+0.008 8	0.0372 9	B(E1)(W.u.)=1.26×10 ⁻⁹ 17; B(M2)(W.u.)=4.×10 ⁻⁶ +8-4.
	334.310# 3	7.7# 6	E1(+M2)	+0.006 4	0.0329	B(E1)(W.u.)=1.41×10 ⁻⁹ 17; B(M2)(W.u.)=2.1×10 ⁻⁶ +28-21.
469.8	461.9@ 5	100@	[E1]		0.01684	
	469.8@ 5	69@	[E1]		0.01628	
492.1	434.7@ 5	100@	E1(+M2)	-0.002 2	0.0190	
	484.3@ 5	8@	[E1]		0.01533	
	492.3@ 5	46@	[E1]		0.01485	
505.6	430.0& 3	100& 18				
	448.3& 5	≈7&				
	497.8& 3	88& 18				
511.838	124.416& 15	3.0& 3	M1(+E2)	<0.26	13.8 4	
	181.715& 10	33& 2	M1+E2	-0.150 7	4.77	
	226.383& 12	100& 6	M1+E2	+0.133 6	2.58	
	436.0& 3	0.24& 3	[M1]		0.428	
	454.6& 3	0.36& 4	[M1]		0.382	
	504.0& 3	0.42& 4	[E2]		0.0516	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)
 $\gamma(^{239}\text{Pu})$ (continued)

E(level)	E γ	I γ	Mult.§	α
519.3	160 ^a			
	201.0 ^a 2	100	E2	0.839
556.2	392.4 [@] 5	100 [@]	[E1]	0.0234
	=498.7 [@]	=62 [@]	[E1]	0.01448
570.6	212.0 ^a 2	100	E2	0.688
661.1	343 ^a			
	497 ^a			
698.7	340			
	505			
752.5	695.6 ^b	40 ^b		
	744.6 ^b	80 ^b		
	752.5 ^b	100 ^b		
764.6	194 ^a			
	245.3 ^a 2		(E2)	0.409
798.2	790.4 ^b	100 ^b		
	798.2 ^b	71 ^b		
805.1	797.3 ^b	100 ^b		
	805.1 ^b	30 ^b		
806.7	145.6 ^a		(E2)	3.03
	287 ^a			
	488 ^a d			
825.5	817.5 ^b	45.5 ^b		
	825.5 ^b	100.0 ^b		
828.0	256.9 ^a 2		(E2)	0.350
857.5	159 ^a			
	287 ^a			
	498 ^a			
888.0	888.4 ^b	100 ^b		
933.3	925.7 ^b	25 ^b		
	933.6 ^b	100 ^b		
992.4	185.8 ^a		(E2)	1.132
	228 ^a			
1052.9	288.2 1	100	(E2)	0.240
1058.1	201			
	230			
	487			
1127.6	299.5 ^a 2	100	(E2)	0.213
1219.7	166 ^a			
	227.3 ^a		(E2)	0.534
	455 ^a			
1300.9	173			
	243 ^a		(E2)	0.423
	473			
1381.1	254 ^a			
	328.5 ^a 2	100	[E2]	0.1605
1467.3	340.0 ^a 2	100	(E2)	0.1451
1487.7	268.0 ^a	100	(E2)	0.304
1584.9	283.5 ^a	100	(E2)	0.253
	457			
1748.2	281 ^a			
	367.1 ^a 2	100	(E2)	0.1166
1795.5	308 ^a		(E2)	0.195
1846.3	379.0 ^a 2	100	(E2)	0.1067
1908.9	323.9 ^a		(E2)	0.1674
	441			
2040.25	2040.25 21	100		
2046.9	2046.9 3	100		
2135.0	2135.0 4	100		
2143.56	2135.0 ^d 4	31		
	2143.56 ^e 13	100		
2144	348 ^a		(E2)	0.1356

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Adopted Levels, Gammas (continued) $\gamma(^{239}\text{Pu})$ (continued)

E(level)	E γ	I γ	Mult.§	δ	α	I(γ +ce)	Comments
2151.0	2143.56 ^e 13	100					
	2151.0 3	39					
2151.8	305 ^a						
	403.5 ^a 2	100	(E2)		0.0901		
2262.0	415.4 ^a 2	100	(E2)		0.0835		
2272.0	362.8 ^a		(E2)		0.1205		
	425						
2289.0	2289.02 25	100					
2431.7	2423.48 22	100					
	2431.66 25	90					
2454.4	2454.4 3	100					
2460.5	2460.5 4	100					
2464.6	2464.6 3	100					
2471.1	2471.1 3	100					
2529.4	386						
2589.4	327 ^a						
	437.7 ^a 2	100	(E2)		0.0730		
2672.0	400						
	409						
2712.8	450.8 ^a 2	100	(E2)		0.0677		
2951.4	422						
3059.7	470.3 ^a 2	100	(E2)		0.0610		
3108.0	436						
3124.3	24.3		‡			73 [†] 15	
3156.2	31.9		M1+E2‡	>0.85	2.7×10 ³ 11	55 [†] 10	
	56.2		E2‡		243	25 [†] 5	
3196.1	483.3 ^a 4	100	(E2)		0.0571		
3303	146.6		(E1)‡		0.211	91 [†] 20	B(E1)(W.u.)=1.2×10 ⁻⁵ .
	178.5		(E1)‡		0.1335	41 [†] 10	B(E1)(W.u.)=3.2×10 ⁻⁶ .
	202.8 ^d		[M2]‡		14.58	4 [†] 2	B(M2)(W.u.)=1.7.
3407	456						
3558.2	498.5 ^a 4	100	(E2)		0.0530		
3578.0	470	100					
3713.0	515	100					
3895	488	100					
4080.0	502	100					
4087.1	528	100					
4256	543	100					
4413	518	100					

† Intensity in second potential minimum (1979Ba02). Other: 1976BeZM.

‡ From ce data of 1979Ba02, L12/L3 ratios.

§ Based on ^{239}Np β^- decay and ^{243}Cm α decay (1991Sh06).# From ^{243}Cm α decay.@ From ^{239}Np β^- Decay.& From ^{239}Am ϵ Decay.^a From Coulomb Excitation.^b From $^{238}\text{Pu}(n,\gamma)$ E=th.^c From conversion electron data in ^{243}Cm α decay.^d Placement of transition in the level scheme is uncertain.^e Multiply placed.

Adopted Levels, Gammas (continued)(A) $1/2[631]$, $\alpha=+1/2$ (B) $1/2[631]$, $\alpha=-1/2$ (C) $1/2[631]\times 0-$, $\alpha=+1/2$

Adopted Levels, Gammas (continued)

Adopted Levels, Gammas (continued)

(G) 7/2[624]

(H) 1/2[761]

(I) 1/2[620]

(J) 7/2[613]?

(K) 3/2[622]?

(L) 5/2[633]

 $^{239}_{94}\text{Pu}_{145}$

^{239}Np β^- Decay 1959Ew90,1965Da04,1996Wo05

 Parent ^{239}Np : E=0; $J\pi=5/2+$; $T_{1/2}=2.356$ d 3; Q(g.s.)=722.5 10; % β^- decay=100.

 ^{239}Pu Levels

E(level)	$J\pi$	$T_{1/2}$	Comments
0.0	1/2+	24110 y 30	
7.861	3/2+		
57.276 2	5/2+		
75.706?	7/2+		
163.76	9/2+		
285.460	5/2+	1.12 ns [†] 5	$g=-0.49$ 11 (1974Pa03). g-factor: assuming paramagnetic correction $\beta=2.16$.
330.125	7/2+		
387.41	9/2+		
391.586	7/2-	193 ns [†] 4	
469.8	(1/2-)		
492.2	3/2-		
505.2	5/2-		
511.81 6	7/2+		
556.2	(7/2-)		

[†] Average of values from 1974Pa03, 1955En07, 1951Gr34.

 β^- radiations

$E\beta^-$ [†]	E(level)	$I\beta^-$ ^{‡§#}	Log ft	Comments
(166.3 10)	556.2	=0.003	=9.7	
(210.7 10)	511.81	1.70 6	7.3	
(217.3 10)	505.2	0.0074 2	9.7	
(230.3 10)	492.2	0.020 1	9.3	
(252.7@ 10)	469.8	≥0.0027	≤9.9 ^{1u}	
341 3	391.586	44 2	6.5	
393 3	330.125	7 2	7.5	
438 3	285.460	45 3	6.8	
(646.8@ 10)	75.706?			
(665.2@ 10)	57.276			
713 3	7.861	2 1	8.9	$I\beta^-$: 1952Fr25, 1956Ba95, 1959Co63.

[†] From 1959Co63.

[‡] $I(\beta^-)$ to 7.85, 57 and 75 levels deduced from $I(\beta^- \text{ to } 7.85)/I(\beta^- \text{ to } 57+75)=1.6$ (1959Co63) and from $\Sigma(I\beta^-)$ to higher levels)=100.

[§] $I(\beta^- \text{ to } 57+75 \text{ level}) < 2$.

[#] Absolute intensity per 100 decays.

[@] Existence of this branch is questionable.

 $\gamma(^{239}\text{Pu})$

x-rays (Pu):

$E\gamma$ (1982Ah04)	$I\gamma$ (% α) (1982Ah04)	$I\gamma$ (% α) (1972Ah02)	Calculated (RADLST)
99.53	12.8 4	K α_2 x ray	13.1 5
103.74	20.4 6	K α_1 x ray	20.8 7
117.6	7.3 3	K β_1 ' x ray	10.3 4 (K β x ray)
120.6	2.6 1	K β_2 ' x ray	2.8 1

 The agreement between measured and calculated Kx ray supports the experimental γ -ray intensities and assigned multipolarities.

Others: 1975Pa04, 2008Gr11.

 $I\gamma$ normalization: all γ -ray intensities were measured on an absolute scale (per 100 disintegrations of ^{239}Np).

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²³⁹Np β⁻ Decay 1959Ew90,1965Da04,1996Wo05 (continued)

γ(²³⁹Pu) (continued)

E _γ	E(level)	I _γ ^{†c}	Mult.	δ ^a	α	I(γ+ce) ^c	Comments
(4.2 CA)	391.586		[E1]			2.6 CA	I(γ+ce): from transition intensity balance at 387-keV level, where no significant β ⁻ feeding is expected (5/2 ⁺ to 9/2 ⁺). δ: from ²³⁹ Am ε decay.
7.85 [§] (18.4)	7.861 75.706?		M1+E2 [M1+E2]	0.055 3	5.7×10 ³ 4		
44.66 ^{&} 2	330.125	0.13 1	M1+E2	0.20 3	86 8		I _γ : from 1982Ah04. δ: from ²³⁹ Am ε decay.
49.41 ^{&} 2	57.276	0.12 2	M1+E2	0.50 3	126 8		δ: from ²³⁹ Am ε. I _γ : weighted average of 0.11% 1 (1982Ah04) and 0.18% 3 (1974HeYW). I _γ ; =0.11 from ce(L) of 1959Ew90 and α(L)=95.
57.28 ^{&d}	57.276	=0.036 ^d	E2		222		I _γ : from I _γ (57γ, 57 level)/I _γ (49γ)=0.3 in ²⁴³ Cm α decay and I _γ (49γ)=0.12% 2 in ²³⁹ Np β ⁻ Decay.
(57.3 ^d)	387.41	=0.09 ^d	[M1]		28.6 4		I(γ+ce): from I _γ (doublet)=0.135% 7 (1982Ah04) and I _γ (57γ, 57-keV level)=0.036%.
61.460 [‡] 2	391.586	1.30 2	E1		0.473		I _γ : weighted average (Limited Relative Statistical Weight Method) of 1.40% 7 (1996Wo05), 1.29% 2 (1984Va41), and 1.29% 6 (1982Ah04).
67.86 [§] 2	75.706?	0.10 3	E2		98.4		I _γ : from 1974HeYW.
88.06 [§] 3	163.76	0.006 [#] 2	M1+E2	0.50	12.26		
101.965 13	387.41	0.008 CA	E2		14.42		I _γ ,E _γ : from ²³⁹ Am ε decay.
106.123 [‡] 2	391.586	25.34 17	E1(+M2)	-0.007 7	0.26 3		α(L)exp=0.19 3; α(M)exp=0.050 8; α(N+...)exp=0.017 3. α: L1/L2=0.87 9/0.93 9 1959Ew90, conversion is anomalous. Other: 1957Ew30, 2008Go10.
							I _γ : Other value: 26.3% 10, weighted average (Limited Relative Statistical Weight Method) of 25.23% 28 (1996Wo05), 27.4% 4 (1984Va41), 26.4% 8 (1982Ah04), 26.6% 10 (1977St35), and 27.8% 9 (1972Ah02).
106.47 [§] 4	163.76	0.049 [#] 8	E2		11.80		
124.4	511.81	=0.01	M1(+E2)	<0.26	13.8 4		Mult.,I _γ : from ²³⁹ Am ε decay.
166.39 [§] 6	330.125	0.016 [#] 7	M1		6.22		
181.70 3	511.81	0.082 3	M1+E2	-0.150 7	4.77		α(K)exp=3.0 4; α(L)exp=0.62 8. I _γ : Other value: 0.0831% 24, weighted average (Limited Relative Statistical Weight Method) of 0.085% 5 (1996Wo05), 0.07% 1 (1984Va41), 0.083% 4 (1982Ah04), and 0.075% 8 (1972Ah02).
209.753 [‡] 2	285.460	3.363 20	M1(+E2)	0.37 ^b 8	2.93 13		I _γ : Other value: 3.42% 3, weighted average (Limited Relative Statistical Weight Method) of 3.43% 7 (1996Wo05), 3.46% 5 (1984Va41), 3.30% 10 (1982Ah04), 3.36% 14 (1977St35,1991Po17), and 3.42% 10 (1972Ah02).

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²³⁹Np β⁻ Decay 1959Ew90,1965Da04,1996Wo05 (continued)

γ(²³⁹Pu) (continued)

E _γ	E(level)	I _γ ^{†c}	Mult.	δ ^a	α	Comments
226.38 2	511.81	0.259 16	M1+E2	+0.133 6	2.58	I _γ : weighted average (Limited Relative Statistical Weight Method) of 0.230% 14 (1996Wo05), 0.28% 2 (1984Va41), and 0.24% 3 (1977St35,1991Po17). E _γ : from 1982Ah04.
227.83 ^d CA	391.586	0.51 ^d CA	[E1]		0.080	
228.183 [‡] 1	285.460	10.730 87	M1 (+E2)	0.28 ^b 7	2.41 9	I _γ : After subtracting I _γ =0.51% for the 227.83-keV γ-ray component that deexcites the 391.5-keV level, and I _γ =0.259% 16 for the 226.38-keV γ-ray component from the 511-keV level. I _γ : Other value: 11.14% 11, weighted average (Limited Relative Statistical Weight Method) of 10.91% 16 (1996Wo05), 11.21% 18 (1984Va41), 11.20% 30 (1982Ah04), 11.78% 44 (1977St35,1991Po17), 11.40% 3 (1972Ah02), after subtracting I _γ =0.51% for the 227.83-keV γ-ray component that deexcites the 391.5-keV level.
254.40 ^{&} 3	330.125	0.1092 22	M1+E2	-0.159 6	1.85	I _γ : Other value: 0.109% 2, weighted average (Limited Relative Statistical Weight Method) of 0.1078% 27 (1996Wo05), 0.12% 1 (1984Va41), 0.110% 6 (1982Ah04), and 0.11% 1 (1972Ah02).
272.84 ^{&} 3	330.125	0.0766 19	M1+E2	+0.165 9	1.519	I _γ : Other value: 0.077% 2, weighted average (Limited Relative Statistical Weight Method) of 0.0762% 24 (1996Wo05), 0.08% 1 (1984Va41), 0.077% 4 (1982Ah04), and 0.08% 1 (1972Ah02).
277.599 [‡] 1	285.460	14.505 79	M1+E2	0.23 ^b 10	1.42 7	I _γ : Other value: 14.44% 10, weighted average (Limited Relative Statistical Weight Method) of 14.53% 17 (1996Wo05), 14.38% 21 (1984Va41), 14.5% 4 (1982Ah04), 14.30% 24 (1979Mo25), 15.0% 5 (1977St35,1991Po17), 14.1% 4 (1974Yu04), and 14.5% 4 (1972Ah02).
285.460 [‡] 2	285.460	0.7939 64	E2		0.247	I _γ : Other value: 0.79% 1, weighted average (Limited Relative Statistical Weight Method) of 0.797% 10 (1996Wo05), 0.77% 2 (1984Va41), 0.790% 25 (1982Ah04), 0.93% 6 (1977St35,1991Po17), and 0.76% 2 (1972Ah02).
315.880 [‡] 3	391.586	1.600 12	E1 (+M2)	+0.008 8	0.0372 9	I _γ : Other value: 1.60% 2, weighted average (Limited Relative Statistical Weight Method) of 1.604% 20 (1996Wo05), 1.60% 3 (1984Va41), 1.60% 5 (1982Ah04), 1.63% 7 (1977St35,1991Po17), and 1.52% 5 (1972Ah02).
(322.26 CA)	330.125	0.0052 CA	[E2]		0.174	I _γ : from I _γ branchings in ²³⁹ Am ε decay and ²⁴³ Cm α decay.
334.310 2	391.586	2.056 13	E1 (+M2)	+0.006 6	0.0329 6	I _γ : Other value: 2.06% 2, weighted average (Limited Relative Statistical Weight Method) of 2.050% 25 (1996Wo05), 2.08% 3 (1984Va41), 2.06% 6 (1982Ah04), 2.10% 10 (1977St35,1991Po17), and 1.95% 7 (1972Ah02). E _γ : from 1974HeYW, 1959Ew90.
392.4@ 5	556.2	0.0016@				
429.5@ 5	505.2	0.0039@				
434.7@ 5	492.2	0.013@	E1 (+M2)	-0.002 2	0.0190	
447.6@ 5	505.2	0.00026@				
454.2@ 5	511.81	0.00082@	[M1]		0.383	
461.9@ 5	469.8	0.0016@				
469.8@ 5	469.8	0.0011@				

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²³⁹Np β⁻ Decay 1959Ew90,1965Da04,1996Wo05 (continued)

γ(²³⁹Pu) (continued)

E _γ	E(level)	I _γ [†] c	Mult.	α
484.3@ 5	492.2	0.0010@		
492.3@ 5	492.2	0.0060@		
497.8@ 5	505.2	0.0032@		
=498.7@	556.2	=0.001@		
504.2@ 5	511.81	0.00078@	[E2]	0.0516

[†] Unless otherwise specified, absolute γ-ray intensities are values deduced from thermal neutron activations analysis [²³⁸U(n,γ)] combined with absolute intensities measured by several authors, and included as fitted parameters in a least-squares fit (2005Tr08).

[‡] From 1976BoYH corrected for change in calibration line of K_{α1} x ray of U from 98.440 to 98.4346 eV (cryst). See also 1979Bo30.

[§] From 1959Ew90, magnetic spectrometer ce.

[#] From ce data of 1959Ew90 and theoretical conversion coefficient α.

@ From 1965Da04; Ge(Li), ΔI_γ estimated by evaluator at 15-30%.

& From 1982Ah04.

a From 1972Kr07, 1959Ew90, 1990Si12, unless otherwise specified. Other: 1974Pa03.

b Deduced by evaluator from conversion electron data of 1991Sh06 in ²⁴³Cm α decay.

c Absolute intensity per 100 decays.

d Multiply placed; intensity suitably divided.

Decay Scheme

Muonic Atom

Muonic atom (T_{1/2}=50.8 ns 20) muon decay electrons measured (1977Jo09). Muonic atom (T_{1/2}=48.6 ns 5) fission fragments measured (1980Wi06); the longer T_{1/2} obtained by measuring electrons may be due to interference of long-lived background caused by muon capture by prompt fission fragments.

Muonic x-rays measured with Ge(Li). Muons stopped in 99.1% ²³⁹Pu target. From analysis of K, L, and M x-rays 1986Zu01 derived B(E2) and Q values for the g.s. band up to 9/2+ as well as parameters for the deformed-Fermi charge distribution (1986Zu01).

Muonic Atom (continued)

²³⁹Pu Levels

B(E2) and Q (spectroscopic moment) values from 1986Zu01.

E(level)	J π	Comments
0.0	1/2+	$\beta(2)=0.2607$ 7, $\beta(4)=0.0896$ 18, Q=11.56 6, moment (E4)=0.0896 18 (1986Zu01). Other: Q=11.66 11, moment (E4)=0.85 16 (1978Cl03). The analysis is model dependent, see 1986Zu01 for details.
7.861	3/2+	B(E2)(1/2+ to 3/2+)=5.313 22, Q=-2.319 7.
57.276	5/2+	B(E2)(1/2+ to 5/2+)=7.95 4, B(E2)(3/2+ to 5/2+)=1.10 3 Q=-3.345 13.
75.706	7/2+	B(E2)(3/2+ to 7/2+)=7.00 4, B(E2)(5/2+ to 7/2+)=0.476 13 Q=-3.826 26.
163.76	9/2+	B(E2)(5/2+ to 9/2+)=6.43 3.

²³⁹Am ϵ Decay 1972Po04

Parent ²³⁹Am: E=0; J π =(5/2)-; T_{1/2}=11.9 h 1; Q(g.s.)=802.1 17; % ϵ decay=99.990 1.

Other measurements: 1957Sm77, 1960Gl01, 1972Po12.

²³⁹Pu Levels

E(level) [†]	J π [†]	Comments
0.0	1/2+	
7.860 3	3/2+	
57.273 4	5/2+	
75.701 8	7/2+	
163.76 2	9/2+	
285.46 1	5/2+	T _{1/2} : 1.09 ns 6, from $\gamma\gamma(0, H, t)$ (1973PaYM).
330.12 1	7/2+	
387.42 1	9/2+	
391.60 1	7/2-	
505.7 2	(5/2-)	
511.84 1	7/2+	

[†] From adopted levels.

[‡] Deduced by evaluator from a least-squares fit to γ -ray energies.

β^+, ϵ Data

E ϵ	E(level)	I $\epsilon^{\dagger\ddagger}$	Log ft
(290.3 17)	511.84	18.1 21	5.9 1
(296.4 18)	505.7	0.0033 6	9.7 1
(410.5 17)	391.60	0.065 10	8.8 1
(472.0 17)	330.12	≈ 3.5	≈ 7.2
(516.6 17)	285.46	71 8	6.0 1
(726.4 § 17)	75.701	≈ 3.4	≈ 7.7
(744.8 § 17)	57.273	≈ 2.4	≈ 7.8

[†] Deduced by evaluator from γ -ray transition intensity balance.

[‡] For intensity per 100 decays, multiply by 0.99990 1.

§ Existence of this branch is questionable.

²³⁹Am ε Decay 1972Po04 (continued)

γ(²³⁹Pu)

Kα₂ x ray=35.5% , Kα₁ x ray=56.2% , and Kβ x ray=27.8% calculated by evaluator (RADLST) agree well with experimental Kα₂ x ray=35.0% 15, Kα₁ x ray=53.9% 23, and Kβ x ray=27.0% 12 (1972Po04), respectively. This agreement suggests negligible ε feeding to g.s. and 7.86-keV levels.

Iγ normalization: assuming negligible ε feeding to g.s. and first excited state; this assumption is consistent with the measured x-ray intensities (Iε<1% to g.s. from log *f*^{Lu}*t*>8.5).

Eγ	E(level)	Iγ [§]	Mult. [†]	δ [†]	α	I(γ+ce) [§]	Comments
(4.2 CA)	391.60		[E1]				
7.860 3	7.860		M1+E2	0.055 3	5.7×10 ³ 4	≈88	
(18.4)	75.701		[M1+E2]			<3	
44.663 5	330.12	0.09 1	M1+E2	0.20 3	86 8		
49.412 4	57.273	0.11 1	M1+E2	0.50 3	126 8		
57.273 4	57.273	≈0.09	E2		222		Iγ: from Iγ=0.170 17 after subtracting ≈0.08 for 57.3γ deexciting the 387 level. Iγ(57γ)=0.09 disagrees with Iγ(57γ, 57 level) in ²⁴³ Cm α decay and ²³⁹ Np β ⁻ Decay.
57.3 CA	387.42	≈0.08	M1 (+E2)		27.9		α: for M1. Iγ: from Iγ(57γ, 387 level)/Iγ(311γ)=4.7 in ²⁴³ Cm α decay, and Iγ(311γ)0.017 2.
(61.480 4)	391.60	0.0020 4	E1		0.472		
67.841 7	75.701	0.130 13	E2		98.5		
88.06 3	163.76	≈0.0008	(M1+E2)	0.50	12.26		Iγ: from ²³⁹ Np β ⁻ decay Iγ(88.06γ)/Iγ(106.50γ)=0.12 5, and Iγ(106.50γ)=0.007 1.
101.965 13	387.42	≈0.008	E2		14.42		
106.1 2	391.60	0.043 5	E1 (+M2)		0.26 3		α(L)exp=0.19 3; α(M)exp=0.050 8; α(N+...)exp=0.017 3. Iγ: from Iγ(106γ doublet)=0.05 1 after subtracting Iγ(106γ, 163-keV level)=0.007 1. α: anomalous E1 conversion (from ²³⁹ Np β ⁻ of 1959Ew90).
106.50 3	163.76	0.007 1	E2		11.78		Iγ: from intensity balance at 163-keV level.
124.416 15	511.84	0.10 1	M1 (+E2)	<0.26	13.8 4		
(166.39 6)	330.12	≈0.009	M1		6.22		Iγ: deduced from Iγ(166.39γ)/Iγ(254.4γ)=0.111 23, using I(ce(L1))(166.39γ)/I(ce(K))(254.4γ)=7 1/105 15 from ²³⁹ Am ε decay (1959Ew90), the following theoretical conversion coefficients: α(L1)(166.39γ; M1)=0.932, and α(K)(254.4γ; M1+E2)=1.556, and Iγ(254.4γ)=0.084 6.
181.715 10	511.84	1.08 6	M1+E2	-0.12 6	4.80 10		δ: from 1972Kr07, 1972Po04, 1959Ew90.
209.8 1	285.46	3.5 2	M1+E2	0.37 [±] 8	2.93 13		
226.383 12	511.84	3.3 2	M1+E2	0.55 10	2.13 14		
228.184 12	285.46	11.3 6	M1+E2	0.28 [±] 7	2.41 9		
254.4 1	330.12	0.084 6	M1+E2	-0.12 6	1.86 4		
272.8 1	330.12	0.064 5	M1		1.553		
277.604 16	285.46	15.0 7	M1+E2	0.23 [±] 10	1.42 7		
285.5 1	285.46	0.80 5	E2		0.247		
311.7 2	387.42	0.017 2	(M1+E2)		0.6 5		
315.9 2	391.60	0.0032 5	E1 (+M2)	-0.10 12	0.07 12		Iγ: from ²³⁹ Np β ⁻ decay, the value Iγ=0.0170 15 in 1972Po04 is probably a typographical error.
322.3 2	330.12	0.0026 3	[E2]		0.1699		
334.3 2	391.60	0.0042 5	E1 (+M2)	+0.02 3	0.034 6		
430.0 3	505.7	0.0017 3					
436.0 3	511.84	0.008 1	[M1]		0.428		

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239Am ε Decay 1972Po04 (continued) $\gamma(^{239}\text{Pu})$ (continued)

E_γ	E(level)	$I_\gamma^\S$	Mult. [†]	α	Comments
(448.3 5)	505.7	=0.00012			From ^{239}Np β^- decay.
454.6 3	511.84	0.0120 12	[M1]	0.382	
497.8 3	505.7	0.0015 3			
504.0 3	511.84	0.0140 14	[E2]	0.0516	

[†] Based on ce data of 1957Sm77,1972Po04 and $\gamma(0)$ of 1972Kr07, unless otherwise specified.

[‡] Deduced by evaluator from conversion electron data of 1991Sh06 in ^{243}Cm α decay.

[§] For absolute intensity per 100 decays, multiply by 1.00 10.

Decay Scheme

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

243Cm α Decay

Parent ^{243}Cm : $E=0.0$; $J\pi=5/2^+$; $T_{1/2}=28.9$ y 4; $Q(\text{g.s.})=6168.8$ 10; $\% \alpha$ decay=99.71 3.

$^{243}\text{Cm}-Q(\alpha)$: From 2012Wa38.

$^{243}\text{Cm}-T_{1/2}$: Recommended in 2012Ch30, weighted average (using the Limited Statistical Weight method) of 29.0 y 8 (1958Ch38) and 29.20 y 12 (1986Ti03). Other value: 29.1 y 1 (1989Ho24).

See also the evaluation from the Decay Data Evaluation Project (ddep) (2012Ch30).

$\alpha\gamma$: 1953As14, 1963Le17, 1966Ba07, 1977VaZW.

$\alpha\gamma(0)$: 1963Fl01.

(L x ray) $\gamma(0)$: 1975Za11.

(K x ray)(L x ray)(0): 1974Ma27.

239Pu Levels

E(level) [‡]	$J\pi^\dagger$	$T_{1/2}$	Comments
0.0	1/2+		
7.8607 20	3/2+		
57.2750 20	5/2+		
75.7055 23	7/2+		
163.755 23	9/2+		
192.8 10	11/2+		
285.4594 17	5/2+	=1.2 ns	$T_{1/2}$: from 1956St23.
330.124 3	7/2+		

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²⁴³Cm α Decay (continued)

²³⁹Pu Levels (continued)

E(level) [†]	J π [†]	Comments
387.419 20	9/2+	
391.5847 22	7/2-	
427? 3		
434 3	(9/2-)	
451? 5		
462 3	(11/2+)	
469.8 4	(1/2-)	E(level): from adopted levels.
481? 3		
487 3	(11/2-)	
492.1 3	3/2-	
499? 3		
505.56 20	(5/2-)	
538 3		
543? 3		
556.2 5	(7/2-)	E(level): from adopted levels; from E α E(level)=552 3.
746 3		
756 3		
763 3		
813 3		
850 15		

[†] From adopted levels.

[‡] Deduced by evaluator from a least-squares fit to γ -ray energies.

 α radiations

E α [†]	E(level)	I α ^{‡@}	HF [§]	Comments
5226 15	850	0.00039	138	E α : from 1963Le17 ($\alpha\gamma$ semi).
5267 3	813	0.0015	61.0	
5316 3	763	0.001	185	
5323 3	756	0.003	68.1	
5332 3	746	0.003	78.4	
5523 3	556.2	0.002	1550	
5532& 3	543?	0.006	614	
5537 3	538	0.002	1970	
5568 3	505.56	0.007	861	
5575& 3	499?	0.007	937	
5582 3	492.1	=0.009	=797	
5587 3	487	=0.02	=383	
5593& 3	481?	0.01	828	
5607&				
5609 3	469.8	≤ 0.01	≥ 957	I α : I(5609 α + 5607 α)=0.01 was measured by 1966Ba07.
5612 3	462	=0.03	=353	
5622&	451?	0.06	203	
5639 3	434	0.14	108	
5646&	427?	0.03	553	
5682 3	391.5847	0.2	130	I α =0.41% 4, deduced by evaluator from γ -ray transition intensity balance.
5686	387.419	1.6	17.1	I α =2.5% 1, deduced by evaluator from γ -ray transition intensity balance.
5713& 5		≤ 0.04		From 1963Dz07 (s).
5742.1# 9	330.124	11.5# 5	4.89	I α =9.5% 21, deduced by evaluator from γ -ray transition intensity balance.
5785.2# 9	285.4594	73.2# 23	1.33	I α =72% 3, deduced by evaluator from γ -ray transition intensity balance.
5876 3	192.8	0.7	430	
5907 3	163.755	0.1	4260	I α =0.11% 2, deduced by evaluator from γ -ray transition intensity balance.
5991.8# 15	75.7055	5.7# 2	211	I α =7%, deduced by evaluator from γ -ray transition intensity balance.
6010	57.2750	1.1	1350	
6058# 1	7.8607	4.7# 3	559	I α =6%, deduced by evaluator from γ -ray transition intensity balance.
6066.2# 17	0.0	1.5# 2	1920	

[†] From 1966Ba07 (s), unless otherwise specified. 1966Ba07 reported uncertainties of 1 keV near their alpha calibration lines of 5167.7 (²⁴⁰Pu), 5498.8 (²³⁸Pu), 5806.1 (²⁴⁴Cm), and 2-3 keV elsewhere. Others: 1953As14, 1957As70, 1957As83, 1962Iv01, 1963Le17, 1963Dz07, 1970By01, 1971Bb10, 1976BaZZ, 1977VaZW.

Footnotes continued on next page

²⁴³Cm α Decay (continued)

α radiations (continued)

‡ From 1966Ba07, unless otherwise specified. Others: 1976BaZZ, 1963Dz07, 1963Le17.
§ Using $r_0(^{239}\text{Pu})=1.4996$, average of $r_0(^{238}\text{Pu})=1.5013$ 10 and $r_0(^{240}\text{Pu})=1.4979$ 7 (1998Ak04).
From 1979Ry03 and 1991Ry01.
@ For α intensity per 100 decays, multiply by 0.9971 3.
& Existence of this branch is questionable.

$\gamma(^{239}\text{Pu})$

x-rays (Pu) :

E_γ (1972Ah02)	$I_\gamma(\% \alpha)$ (1972Ah02)	Calculated (RADLST)
99.536	13.5 5	K α_2 x ray 12.5 5
103.750	20.8 8	K α_1 x ray 19.8 8
117.1	7.6 3	K β_1 ' x ray 9.8 4 (K β x ray)
120.6	2.6 1	K β_2 ' x ray

The agreement between measured and calculated K x ray supports the experimental γ -ray intensities and assigned multipolarities.
I γ normalization: from 1972Ah02.

$E_\gamma^\dagger$	E(level)	$I_\gamma^\ddagger \&$	Mult.@	$\delta^\@$	α	I(γ +ce)&	Comments
(4.2 CA)	391.5847		[E1]				
(7.860 § 3)	7.8607	=0.015	M1+E2	0.055 3	5.7×10^3 4	=85	I(γ +ce): deduced by evaluator from γ -ray and α -particle transition intensity balance at 7.86-keV level. I(γ +ce)(7.86 γ)=I(γ +ce)(49 γ) + I(γ +ce)(67 γ) + I(γ +ce)(277 γ) + I α (6058 α)=85%. I γ : deduced by evaluator from I(γ +ce)(7.86 γ)=85% and α =5700 400.
(18.43 CA)	75.7055		(M1+E2)				ce lines were obscured by Auger lines in ²³⁹ Am decay; an upper limit of 3% for its transition intensity was given by 1972Po04.
44.663 5	330.124	0.13 2	M1+E2	0.20 3	86 8		I γ : deduced from I γ (44.66 γ)/I γ (254.4 γ)=0.13 1/0.11 6, as observed in ²³⁹ Np β^- decay (1982Ah04), and I γ (254.4 γ)=0.11 1.
(49.412 § 4)	57.2750	=0.2	M1+E2	0.50 3	126 8		I γ : From decay scheme and transition intensity balance.
57.273 ^b 4	57.2750	=0.05 ^b	E2		222		I γ : γ ray placed twice in level scheme. I γ =0.14 1 was measured for the doublet. I γ from transition intensity balance at 57-keV level. I(γ +ce)(228 γ) + I(γ +ce)(272 γ) + I(γ +ce)(334 γ) + I α (6010) - I(γ +ce)(49 γ)=0.06%.
57.30 ^b	387.419	=0.09 ^b	[M1+(E2)]		28.6 5		I γ : from I γ (doublet)=0.14% 1 and I γ (57 γ , 57-keV level)=0.05%. E γ : from E(level) difference. E=57.273 4 measured for the doublet. α : for M1. Transition intensity balance at 387-keV level and theoretical α (E2)=221 suggest a negligibly small E2 admixture.

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²⁴³Cm α Decay (continued)

γ(²³⁹Pu) (continued)

Eγ [†]	E(level)	Iγ [‡] &	Mult.@	δ@	α	Comments
(61.460 [§] 2)	391.5847	0.015 2	E1		0.473	Iγ: deduced from Iγ(61.46γ)/Iγ(334.31γ)=129 2/207 3, which was recommended by 1986LoZT, and from ²³⁹ Np β ⁻ decay.
(67.841 [§] 7)	75.7055	0.20 5	E2		98.5	Iγ: From decay scheme and transition intensity balance.
(88.06 [§] 3)	163.755	0.0016	M1+E2	0.50	12.26	Iγ: from Iγ(88.06)/Iγ(106.47)=0.12 5, from ²³⁹ Np β ⁻ decay.
(101.96 [§] 2)	387.419	0.008 CA	E2		14.42	Iγ: from Iγ(101.96γ)/Iγ(311.7γ)=8/17, as deduced by 1972Po04 in ²³⁹ Am ε decay.
(106.125 [§] 2)	391.5847	0.31 3	E1 (+M2)	-0.007 7	0.26 3	α: experimental anomalous conversion coefficient (1959Ew90). Other: 1957Ew30. Iγ: deduced from Iγ(106.12γ)/Iγ(334.31γ)=27.2 4/2.07 3, as measured in ²³⁹ Np β ⁻ decay.
(106.47 [§] 4)	163.755	0.0136	E2		11.80	Iγ: from intensity balance at 163.76 level.
(117.1 CA)	192.8					
(166.39 [§] 6)	330.124	0.012 3	M1		6.22	Iγ: deduced from Iγ(166.39γ)/Iγ(254.4γ)=0.111 23, using I(ce(L1))(166.39γ)/I(ce(K))(254.4γ)=7 1/105 15 from ²³⁹ Am ε decay (1959Ew90), and the following theoretical conversion coefficients: α(L1)(166.39γ; M1)=0.932, and α(K)(254.4γ; M1+E2)=1.457.
209.753 2	285.4594	3.30 10	M1+E2	0.37 8	2.93 13	δ: from α(K)exp=2.42 14; α(L12)exp=0.488 15 (1991Sh06). Other value: δ=-0.004 +1-24 from γ(θ) (1972Kr07,1990Si12).
228.183 2	285.4594	10.6 3	M1+E2	0.28 7	2.41 9	δ: from α(K)exp=2.01 7; α(M)exp=0.0968 59 (1991Sh06). Other value: δ=+0.001 +9-1 from γ(θ) (1972Kr07,1990Si12).
254.40 3	330.124	0.11 1	M1+E2	-0.159 6	1.85	
272.87 9	330.124	0.08 1	M1+E2	+0.165 9	1.518	
277.599 2	285.4594	14.0 4	M1+E2	0.23 10	1.42 7	δ: from α(K)exp=1.19 5; α(L12)exp=0.238 10, α(M)exp=0.0579 29 (1991Sh06). Other value: δ=+0.165 2, from γ(θ) (1972Kr07,1990Si12).
285.460 2	285.4594	0.73 2	E2		0.247	
311.7 2	387.419	0.017 2	[M1+E2]	≤0.2	1.057 23	δ: assumed by evaluator.
315.880 3	391.5847	0.018 2	E1 (+M2)	+0.008 8	0.0372 9	
322.3 2	330.124	0.007 1	[E2]		0.1699	
334.310 3	391.5847	0.024 2	E1 (+M2)	+0.006 6	0.0329 6	
(392.4 [§] 5)	556.2					
(430.0 [§] 3)	505.56					
(434.7 [§] 5)	492.1					
(447.6 [§] 5)	505.56					
(461.9 [§] 5)	469.8					
(469.8 [§] 5)	469.8					
(484.3 [§] 5)	492.1					
(492.3 [§] 5)	492.1					
(497.8 [§] 3)	505.56					
(499 [§])	556.2					
x=640# ^a						Uncertain transition.
x=680#						
x=720#						
x=740#						
x=760#						

[†] Measurements of 1959Ew90 (s ce), 1965Ma17 (cryst), 1972Po04 (s ce, semi), and 1979Bo30 (cryst), and 1982Ah04 (semi) observed in ²³⁹Np and ²³⁹Am decays, except as noted. Other measurements: 1953As14 (scin), 1955Sc08 (s ce), 1956Ne17 (pc, scin), 1964Ba31 (αγ, semi).

[‡] From 1972Ah02. Photon intensity per 100 α decays. Other measurements: 1956Ne17, 1964Ba31.

[§] Transition was not observed in ²⁴³Cm α decay. Eγ is from the decay of ²³⁹Np and ²³⁹Am.

From 1963Le17 (αγ and (α)(ce) coin).

@ From ce data in ²³⁹Am, ²³⁹Np, and ²⁴³Cm decays; and γ(θ) measurements by 1972Kr07, 1990Si12 from polarized ²³⁹Np, unless otherwise specified.

²⁴³Cm α Decay (continued)

γ(²³⁹Pu) (continued)

& For absolute intensity per 100 decays, multiply by 0.9971 3.

a Placement of transition in the level scheme is uncertain.

b Multiply placed; intensity suitably divided.

x γ ray not placed in level scheme.

Decay Scheme

@ Multiply placed; intensity suitably divided
Intensities: I(γ+ce) per 100 parent decays

5/2+ 0.0 28.9 y
²⁴³Cm₁₄₇ ↓ %α=99.71 3
Q_α=6168.8¹⁰

²³⁸U(α,3nγ) 1983Ha44

E(α)=35 MeV; ce mag spect, γ Ge(Li), ceγ coin.

Moment of inertia parameters for the g.s. 1/2[631] band deduced.

²³⁹Pu Levels

E(level)	Jπ	E(level)	Jπ	E(level)	Jπ
0.0	1/2+	318.21	13/2+	1053.2	25/2+
7.861	3/2+	358.22	15/2+	1126.9	27/2+
57.276	5/2+	519.27	17/2+	1382.8	29/2+
75.706	7/2+	570.31	19/2+	1466.9	31/2+
163.76	9/2+	764.8	21/2+		
192.81	11/2+	827.2	23/2+		

²³⁸U($\alpha,3n\gamma$) ¹⁹⁸³Ha44 (continued)

 $\gamma(^{239}\text{Pu})$

E γ	E(level)	Mult. [†]	Comments
(7.861 2)	7.861		
(57.276 2)	57.276		
(67.846 2)	75.706		
106.47 4	163.76	E2	E γ : from Adopted Gammas.
117.1 1	192.81	E2	
154.45 8	318.21	E2	
165.41 8	358.22	E2	
201.06 8	519.27	E2	
212.09 8	570.31	E2	
245.6 1	764.8	[E2]	
256.9 1	827.2	[E2]	
288.3 2	1053.2	[E2]	
299.7 2	1126.9	[E2]	
329.6 4	1382.8	[E2]	
340.0 4	1466.9	[E2]	

[†] From L conversion electron subshell ratios.

²³⁸Pu(n, γ) E=th ¹⁹⁷⁵WeZA,1975MaXY

²³⁹Pu Levels

E(level)	J π [†]	E(level)	J π [†]	E(level)	J π [†]
0.0	1/2+	492.1	3/2-	825.5	1/2, 3/2
7.9	3/2+	505.4	(5/2-)	888.0	1/2, 3/2
57.3	5/2+	556.6	(7/2-)	933.3	1/2, 3/2
75.7	7/2+	752.5	1/2+, 3/2	1099.5	1/2, 3/2
163.8	9/2+	798.2	1/2, 3/2	(5646.6 3)	1/2+
470.1	1/2-	805.1	1/2, 3/2		

[†] From adopted levels.

 $\gamma(^{239}\text{Pu})$

E γ	E(level)	I γ [‡]	E γ	E(level)	I γ [‡]	E γ	E(level)	I γ [‡]
392.7	556.6	0.3 [†]	744.6	752.5	0.8 [†]	4547.1 3	(5646.6)	7.3 15
429.7	505.4	1.4 [†]	752.5	752.5	1.0 [†]	4714.7 3	(5646.6)	1.8 7
434.9	492.1	3.1 [†]	790.4	798.2	1.7 [†]	4759.0 8	(5646.6)	1.0 5
448.5	505.4	0.2 [†]	797.3	805.1	1.0 [†]	4821.8 3	(5646.6)	24 5
462.2	470.1	4.3 [†]	798.2	798.2	1.2 [†]	4842.0 5	(5646.6)	3.6 12
470.1	470.1	2.4 [†]	805.1	805.1	0.3 [†]	4848.8 6	(5646.6)	2.0 5
484.3	492.1	0.4 [†]	817.5	825.5	1.0 [†]	4894.9 7	(5646.6)	2.0 5
492.2	492.1	2.3 [†]	825.5	825.5	2.2 [†]	5154.6 5	(5646.6)	3.5 8
497.6	505.4	1.4 [†]	888.4	888.0	0.5 [†]	5176.9 2	(5646.6)	23 5
499.4	556.6	0.5 [†]	925.7	933.3	0.1 [†]	5638.0	(5646.6)	
695.6	752.5	0.4 [†]	933.6	933.3	0.4 [†]	5646.6 5	(5646.6)	2.0 5

[†] Relative intensities.

[‡] Absolute intensity per 100 neutron captures.

²³⁸Pu(d,p) 1973Gr26

E(d)=12.1, 13.1 MeV; measured scattered protons, $\sigma(90^\circ, 125^\circ, 150^\circ)$. Detector: magnetic spectrograph, FWHM=13 keV.

²³⁹Pu Levels

E(level) [‡]	J π [†]	E(level) [‡]	J π [†]	E(level) [‡]	J π [†]
0.0 [§]	1/2+	565 ^a	9/2+	1214 ^c	(1/2+)
8 [§]	3/2+	620 ^{&}	(15/2-)	1233 ^c	(3/2+)
75 [§]	7/2+	634 ^a	11/2+	1233 ^d	(9/2-)
163 [§]	9/2+	658		1261 ^c	(5/2+)
191 [§]	11/2+	716		1261 ^e	(3/2+)
284 [@]	5/2+	749		1289 ^e	(5/2+)
326 [@]	(7/2+)	780		1311 ^c	(7/2+)
386 [@]	9/2+	885		1342 ^e	(7/2+)
464 [#]	(1/2-)	901		1359 ^c	(9/2+)
464 [@]	(11/2+)	990 ^b	(3/2-)	1390	
488 [#]	(3/2-)	1017 ^b	(1/2-)	1409 ^e	(9/2+)
488 ^{&}	(11/2-)	1038 ^b	(7/2-)	1437	
507 [#]	(5/2-)	1100 ^b	(5/2-)	1465	
507 ^a	(7/2+)	1137 ^b	(11/2-)	1488	
538		1174			

[†] Based on angular distributions and cross-section fingerprints.

[‡] FWHM=13 keV (1973Gr26).

[§] (A): 1/2[631].

[#] (B): 1/2[631]×0-.

[@] (C): 5/2[622].

[&] (D): 7/2[743]?

^a (E): 7/2[624].

^b (F): 1/2[761].

^c (G): 1/2[620].

^d (H): 7/2[613]?

^e (I): 3/2[622]?

²³⁹Pu(γ,γ') 2008Be31

J π (²³⁹Pu g.s.)=1/2+.

E=2.8 MeV bremsstrahlung radiation provided by 4 MeV Van de Graaff electron accelerator at High Voltage Research Laboratory (HVRL), Massachusetts Institute of Technology (MIT) facility. Measured E γ , I γ using two HPGe detectors. Other: 2011Jo11.

²³⁹Pu Levels

E(level)	J π	Integrated cross section (eV*b) [†]	Comments
0.0	1/2+ [‡]		
7.861 3	3/2+ [‡]		
2040.25 21	(1/2, 3/2) [§]	8 2	
2046.9 3	(1/2, 3/2) [§]	5 2	
2135.0? 4	(1/2, 3/2) [§]	4 2	
2143.56 13	(1/2, 3/2) [§]	<17	Integrated cross section (eV*b): Total cross section estimated by evaluators.
2151.0 3	(1/2, 3/2) [§]	12 7	Total cross section estimated by evaluators.
2289.0 3	(1/2, 3/2) [§]	8 2	
2431.7 3	(1/2, 3/2) [§]	19 4	
2454.4 3	(1/2, 3/2) [§]	9 3	
2460.5 4	(1/2, 3/2) [§]	6 4	
2464.6 3	(1/2, 3/2) [§]	8 4	
2471.1 3	(1/2, 3/2) [§]	6 2	

[†] The cross section data were normalized by 2008Be31 to that of the 2211-keV transition in ²⁷Al and its known strength.

[‡] From Adopted Levels.

[§] From expected dominance of dipole excitation in (γ,γ').

²³⁹Pu(γ, γ') 2008Be31 (continued)

 $\gamma(^{239}\text{Pu})$

E γ	E(level)	Comments
7.860 [†] 3	7.861	
2040.25 21	2040.25	
2046.9 3	2046.9	
2135.0 [‡] § 4	2135.0?	Cross section=4 eVb 2.
	2143.56	Cross section=4 eVb 2.
		E γ : placement is tentative since the energy difference is 8.6 keV 3 as compared to an expected 7.86 keV.
2143.56 [‡] 13	2143.56	Cross section=13 eVb 2.
	2151.0	Cross section=13 eVb 2.
2151.0§ 3	2151.0	Cross section=5 eVb 2.
2289.02 25	2289.0	
2423.48 22	2431.7	Cross section=10 eVb 2.
2431.66 25	2431.7	Cross section=9 eVb 3.
2454.4 3	2454.4	
2460.5 4	2460.5	
2464.6 3	2464.6	
2471.1 3	2471.1	

[†] From Adopted Gammas.

[‡] Multiply placed.

§ Placement of transition in the level scheme is uncertain.

²³⁹Pu(n,n') 1982Ha34

E(n)=700, 3400 keV. Optical-model fit to data. Deduced deformations $\beta(2)=0.220$ 11, $\beta(4)=0.070$ 7 (1982Ha34).

²³⁹Pu Levels

E(level)	J π [†]
0.0	1/2+
8	3/2+
57	5/2+
76	7/2+
164	9/2+
193	11/2+
286	5/2+

[†] From Adopted Levels.

²³⁹Pu(d,d') 1976Th01

E(d)=16-MeV, FWHM=12 keV. $\sigma(90^\circ, 125^\circ)$ measured (1976Th01). Other measurement: 1973Gr26.

²³⁹Pu Levels

E(level)	J π [†]	E(level)	J π [†]	E(level)
0.0 [‡]	1/2+	491§ 4	3/2-	824 2
57 [‡] 2	5/2+	505§ 2	5/2-	854 2
76 [‡] 2	7/2+	555§ 2	7/2-	900 2
164 [‡] 2	9/2+	583§ 3	9/2-	915 3
194 [‡] 2	11/2+	659§ 3	11/2-	948 3
317 [‡] 2	13/2+	750 3		993 3
360 [‡] 2	15/2+	779 3		1027 2
470§ 2	1/2-	800 3		1062 2

Footnotes continued on next page

²³⁹Pu(d,d') 1976Th01 (continued)

²³⁹Pu Levels (continued)

[†] From 1976Th01 based upon cross section signature pattern for rotational bands.

[‡] (A): 1/2[631].

[§] (B): 1/2[631]×0- octupole vibration on g.s.

Coulomb Excitation 2005Zh20,1957Ne07

2005Zh20: ²⁰⁷Pb beam, E=1300 MeV. Measured E_γ, I_γ, γ_γ, γ_γ(θ)(DCO) with the Gammasphere array of 101

Compton-suppressed HPGe detectors.

1993De12: 99.967% enriched ²³⁹Pu target. Projectile: ¹¹⁷Sn, E=42.9 MeV. Measured E_γ, γ_γ coin. Detector: Spin

Spectrometer, an array of 45 NaI detectors and 18 BGO or NaI shielded, Compton-suppressed Ge detectors. Other:

1995Cr01.

1990StZZ: ²³⁹Pu target. Projectile: ⁹⁰Zr, E=500 MeV. Measured E_γ, γ_γ coin. Detector: Ge(Li) array.

1957Ne07: ²³⁹Pu target. Projectile: Alpha particles, E=2.85 MeV. Measured E_γ, I_γ. Detector: proportional counter.

²³⁹Pu Levels

E(level) [†]	Jπ	Comments
0.0 [§]	1/2+	
7.861 [‡] # 2	3/2+	
57.275 [‡] § 2	5/2+	B(E2)=5.3 3 (1957Ne07) using α=214.
75.705 [‡] # 3	7/2+	
163.76 [‡] § 3	9/2+	
193.5 [#] 8	11/2+	
318.5 [§] 7	13/2+	
359.2 [#] 9	15/2+	
469.8 [@]	(1/2-)	
492.1 ^{&}	(3/2-)	
505.6 [@]	(5/2-)	
519.5 [§] 9	17/2+	
556.0 ^{&} 7	(7/2-)	
570.9 [#] 10	19/2+	
583 [@]	(9/2-)	
661.2 ^{&} 8	11/2-	
698.7 [@] 10	13/2-	
764.7 [§] 10	21/2+	
806.4 ^{&} 9	15/2-	
828.0 [#] 11	23/2+	
857.5 [@] 10	17/2-	
992.5 ^{&} 10	19/2-	
1053.1 [§] 11	25/2+	
1058.1 [@] 11	21/2-	
1127.8 [#] 13	27/2+	
1219.4 ^{&} 11	23/2-	
1300.9 [@] 12	25/2-	
1381.5 [§] 13	29/2+	
1467.8 [#] 14	31/2+	
1487.4 ^{&} 15	27/2-	
1584.9 [@] 14	29/2-	
1748.5 [§] 14	33/2+	
1795.4 ^{&} 18	31/2-	
1847.0 [#] 15	35/2+	
1908.9 [@] 15	33/2-	
2143.4 ^{&} 21	35/2-	
2152.2 [§] 16	37/2+	
2263.0 [#] 16	39/2+	
2272.0 [@] 16	37/2-	
2529.4 ^{&} 23	39/2-	
2590.1 [§] 17	41/2+	
2672.0 [@] 17	41/2-	
2714.0 [#] 19	43/2+	
2951.4 ^{&} 25	43/2-	

Continued on next page (footnotes at end of table)

Coulomb Excitation 2005Zh20,1957Ne07 (continued)

²³⁹Pu Levels (continued)

E(level) [†]	Jπ	E(level) [†]	Jπ	E(level) [†]	Jπ
3060.1 § 20	45/2+	3559.1 § 22	(49/2+)	4080.0 @ 24	(53/2-)
3108.0 @ 20	45/2-	3578.0 @ 22	(49/2-)	4087.1 § 24	(53/2+)
3198.0 # 22	47/2+	3713.0 # 24	(51/2+)	4256 # 3	(55/2+)
3407 & 3	47/2-	3895 & 3	51/2-	4413 & 3	55/2-

[†] Deduced by evaluators from least-squares fit to Eγ's; ΔEγ=1 keV assumed for each transition, unless otherwise noted.

[‡] From ²³⁹Pu in Adopted Gammas.

§ (A): 1/2[631], α=+1/2.

(B): 1/2[631], α=-1/2.

@ (C): Octupole band, α=+1/2. Band associated with octupole vibration at low spin.

& (D): Octupole band, α=-1/2. Band associated with octupole vibration at low spin.

γ(²³⁹Pu)

Eγ	E(level)	Mult.	Eγ	E(level)	Mult.	Eγ	E(level)	Mult.
7.860 [†] 3	7.861		257	828.0	E2 §	425	2272.0	#
49.412 [†] 4	57.275	M1+E2 [‡]	268	1487.4	(E2) @	436	3108.0	
57.273 [†] 4	57.275	E2	281	1748.5		438	2590.1	E2 §
67.841 [†] 7	75.705	E2	284	1584.9	(E2) @	441	1908.9	#
88.06 [†] 3	163.76	M1+E2 [‡]	287 &	806.4	#	451	2714.0	E2 §
106.47 [†] 4	163.76	E2		857.5	#	455	1219.4	#
118	193.5	E2 §	288	1053.1	§	456	3407	
125	318.5		300	1127.8	§	457	1584.9	#
145	806.4	(E2) @	305	2152.2		470 &	3060.1	E2 §
155	318.5	E2 §	308	1795.4	(E2) @		3578.0	
159	857.5		324	1908.9	(E2) @	473 &	992.5	#
160	519.5		327	2590.1			1300.9	#
166 &	359.2	E2 §	328	1381.5	E2 §	484	3198.0	E2 §
	1219.4	#	340 &	698.7	#	487	1058.1	#
173	1300.9	#		1467.8	E2 §	488 &	806.4	#
186	992.5	(E2) @	343	661.2	#		3895	
194	764.7		348	2143.4	(E2) @	497	661.2	#
201 &	519.5	E2 §	363	2272.0	(E2) @	498	857.5	#
	1058.1		367	1748.5	§	499 &	556.0	#
212	570.9	E2 §	379	1847.0	E2 §		3559.1	E2
225	1053.1		386	2529.4		502	4080.0	
227	1219.4	(E2) @	392	556.0	#	505	698.7	#
228	992.5	#	400	2672.0		515	3713.0	
230	1058.1	#	404	2152.2	E2 §	518	4413	
243	1300.9	(E2) @	409	2672.0	#	528	4087.1	
245	764.7	E2 §	416	2263.0	E2 §	543	4256	
254	1381.5		422	2951.4				

[†] From ²³⁹Pu in Adopted Gammas.

[‡] From Adopted Gammas.

§ γγ(0) analysis supports stretched E2 transition (2005Zh02).

Linking transition suggested by 2005Zh20 as E1.

@ From γ-ray angular distributions (1993De12).

& Multiply placed.

Adopted Levels, Gammas

Q(β⁻)=-1756 54; S(n)=7102 51; S(p)=4061.7 17; Q(α)=5922.4 14 2012Wa38.

²³⁹Am Levels

Cross Reference (XREF) Flags

A ²³⁹Cm ε Decay
B ²⁴³Bk α Decay

E(level)	Jπ [†]	XREF	T _{1/2}	Comments
0.0 [‡]	(5/2) ⁻	AB	11.9 h 1	Jπ: favored (HF=1.4) α-particle transition to ²³⁵ Np(49 keV, (5/2) ⁻ , 5/2[523]). T _{1/2} : from 1972Po04. Others: 12.1 h 4 (1960Gl01), 11.9 h 5 (1972PoZS). %ε=99.990 1; %α=0.010 1. %ε, %α (1972Po04). Other measurements: 1960Gl01, 1952Hi63. Calculated T _{1/2} (³² Si)=1.3×10 ²³ s (2012Ba35), 1.12×10 ²³ s, 8.1×10 ²⁴ s (using two-different proximity potentials 2012Ku29). Calculated T _{1/2} (³⁴ Si)=7.8×10 ²⁶ s (2012Sa31). Other similar calculations: 2011Sa40, 2011Sh13, 2010Ni13.
40.7 [‡] 7	(7/2) ⁻	AB		
94 [‡] 6	(9/2) ⁻	B		
156 [‡] 7	(11/2) ⁻	B		
187.1 [§] 5	(5/2) ⁺	AB		Jπ: 146.4γ (E1) to (7/2) ⁻ , 187.1γ (E1) to (5/2) ⁻ . Low HF(=111) from ²⁴³ Bk α Decay is consistent with no spin flip (1972El21).
220 [§] 6	(7/2) ⁺	B		
260 [§] 6	(9/2) ⁺	B		
317 [§] 7	(11/2) ⁺	B		
≈370 [§]	(13/2) ⁺	B		
557 [#] 6	(3/2) ⁻	B		Jπ: favored α Decay (HF=4.1) from ²⁴³ Bk ((3/2) ⁻ , 3/2[521]).
586 [#] 6	(5/2) ⁻	B		Jπ: HF=10 from ²⁴³ Bk α Decay suggests Jπ=(5/2) ⁻ .
2500 200	(7/2) ⁺		163 ns 12	%SF≤100. SF isomer. T _{1/2} from 1971Br38, 1972Br35. Others: 1969La14, 1973Fl03, 1970Vi05, 1985Ra28. T _{1/2} (SF) calc=161 ns (2005Re16). E(level): from ²⁴⁰ Pu(p,2n) (1972Br35,1969La14), ²³⁷ Np(α,2n) and ²³⁹ Pu(d,2n) (1971Br38). E=2.4 MeV (1980Bj02). μ=(+)2.6 2 (2011StZZ). μ: g=0.74 5 (1985Ra28). g-factor measured by perturbed angular correlation of fission fragments in a magnetic field (1985Ra28). Jπ: 7/2[404] orbital was assigned from g-factor by 1985Ra28 (g-factor was assumed to be positive).

[†] From rotational band structure and systematics of Nilsson orbitals. Additional arguments for spin and parity assignments are given mostly for bandheads.

[‡] (A): g.s. rotational band (2013Ni13).

[§] (B): Rotational band built on 187 level (2013Ni13).

[#] (C): Favored rotational band built on 557 level (2013Ni13).

γ(²³⁹Am)

E(level)	Eγ [†]	Iγ [†]	Mult. [†]	α
187.1	146.4 5	20 8	(E1)	0.215 4
	187.1 5	100 25	(E1)	0.1220 19

[†] From ²⁴³Bk α decay.

Adopted Levels, Gammas (continued)

^{239}Cm ϵ Decay 1952Ca42,1958Va37

Parent ^{239}Cm : $E=0$; $J\pi=(7/2-)$; $T_{1/2}=2.7$ h 8; $Q(\text{g.s.})=1756$ 54; $\epsilon+\beta^+$ decay=100.

^{239}Cm : $T_{1/2}, Q(\text{g.s.})$ From ^{239}Cm Adopted Levels.

2008Qi03: ^{239}Cm was produced via the fusion reaction $^{232}\text{Th}(^{12}\text{C},5n)$, $E=70-74$ MeV. Curium was chemically separated.

Measured $E\gamma$, $I\gamma$. Determined upper limit on α emission from ^{239}Cm : $\alpha/\epsilon<0.00001$.

The decay scheme is based on 2008Qi03, on unpublished results in 1952Ca42, 1958Va37, and ^{243}Bk α decay.

^{239}Am Levels

E(level)	$J\pi^\dagger$
0.0	(5/2-)
42	(7/2-)
188	(5/2+)

† From Adopted Levels.

β^+, ϵ Data

$E\epsilon$	E(level)	Comments
(1570 60)	188	<p>$I\epsilon$: ϵ feeding to g.s. ((5/2-)) and 42-keV ((7/2-)) level is expected.</p> <p>Log ft: $I\epsilon<100\%$ yields $\log ft>6.3$. This value is consistent with a 5/2+,5/2[642] configuration assignment for this level. Similar transitions in neighboring nuclei have: $\log ft=6.59$ in ^{239}Np (5/2+,5/2[642]) β^- decay to the 391-keV level (7/2-,7/2[743]), $\log ft\leq 6.8$ in ^{237}Pu (7/2-,7/2[743]) ϵ Decay to ^{237}Np (g.s., 5/2+,5/2[642]) Analogy to ^{237}Pu ϵ Decay suggests that ^{239}Cm ϵ Decay to ^{239}Am(g.s., 5/2-,5/2[523]) should be $\approx 12\%$ ($\log ft=7.3$), and to ^{239}Am(220 keV, 7/2+,5/2[642]), $\approx 9\%$ ($\log ft=7.4$).</p>
(1710 60)	42	
(1760 60)	0.0	

²⁴³Bk α Decay 1966Ah02,1991Ry01 (continued)

α radiations (continued)

† From 1966Ah02 (semi) recalibrated by 1991Ry01.

‡ From 1966Ah02. Intensity per 100 α decays.

§ Using $r_0(^{239}\text{Am})=1.496$, average of $r_0(^{238}\text{Pu})=1.5013$ 10, $r_0(^{240}\text{Pu})=1.4979$ 7, $r_0(^{238}\text{Cm})=1.490$ 20, and $r_0(^{240}\text{Cm})=1.495$ 12 (1998Ak04). HF values are approximate because of the imprecise value of $\approx 0.15\%$ for the alpha-particle branching.

For α intensity per 100 decays, multiply by ≈ 0.0015 .

 $\gamma(^{239}\text{Am})$

$E_\gamma^\dagger$	E(level)	$I_\gamma^{\ddagger\#}$	Mult.	α	Comments
42@ 3	40.7	4	[M1]	79 20	I_γ is inconsistent with decay scheme; $I_\gamma \leq 0.3$ from transition intensity balance.
146.4 5	187.1	8 3	(E1) §	0.215 4	
187.1 5	187.1	40 10	(E1) §	0.1220 19	
536@& 10	557	<10&	[E2]	0.0473 22	E_γ : probable unresolved doublet to g.s. and 40.7 levels. I_γ has not been divided.
	557	<10&	[M1, E2]	0.16 11	E_γ : probable unresolved doublet to g.s. and 40.7 levels. I_γ has not been divided.

† From 1966Ah02 (αγ-semi), 1956Ch77 (αγ-scin).

‡ Photon intensity per 100 α decays (1966Ah02,1956Ch77).

§ Multipolarity is E1 or E2 from relative photon and K x ray intensities. However, the ratio of reduced transition probabilities suggests E1 multipolarity.

For absolute intensity per 100 decays, multiply by ≈ 0.0015 .

@ Placement of transition in the level scheme is uncertain.

& Multiply placed; undivided intensity given.

Decay Scheme

Intensities: $I(\gamma+\text{ce})$ per 100 parent decays
& Multiply placed; undivided intensity given

Adopted Levels

Q(β⁻)=-3103 SY; S(n)=6368 55; S(p)=4564 74; Q(α)=6540 50 2012Wa38.

ΔQ(β⁻)=214 syst (2012Wa38).

²³⁹Cm Levels

Cross Reference (XREF) Flags

A ²⁴³Cf α Decay

E(level)	Jπ	XREF	T _{1/2}	Comments
0.0	(7/2-)		2.7 h 8	T _{1/2} : Estimated by 2008Qi03 from 188.2γ(t). T _{1/2} =2.5 h 4 from 188γ(t), Am K x ray(t) (2002ShZS). Others: 3 h (1952Ca42) unpublished results, 2.9 h (1958Va37) unpublished results. Jπ: Nilsson orbital syst (1972El21) suggest 7/2[743]; The close lying 1/2[631] orbital is an unlikely assignment given the intense 188γ (deexciting the 5/2+ level in ²³⁹ Am), which suggests that ²³⁹ Cm populates the 188-keV (5/2+,5/2[642]) level. %ε=100; %α<0.001 (2008Qi03). No α observed; %α<0.001 (2008Qi03). In a private communication to 2008Qi03, 2002ShZS report three alpha events with an energy of 6.43 MeV 14 assigned to ²³⁹ Cm decay. Other %α<0.1 (1958Va37) T _{1/2} (α)=11 d (theory, 1997Mo25) gives %α=1. Assignment: ²³⁹ Pu(α,4n) (1952Ca42), parent of ²³⁹ Am (1958Va37). E(level): from Eα and syst value for Q(α)(²⁴³ Cf)=7420 (2012Wa38) (in ²³⁷ Pu the analogous level lies at 145 keV above the 7/2-,7/2[743] state). Jπ: favored α from 1/2[631] ²⁴³ Cf.
≈242	(1/2+)	A		

²⁴³Cf α Decay

Parent ²⁴³Cf: E=0.0; Jπ=(1/2+); T_{1/2}=10.7 min 5; Q(g.s.)=7420 syst; %α decay=14.0.

Q(α)=7420 keV, systematic value for ²⁴³Cf g.s. decay (2012Wa38) suggests that the observed 7170- and 7060-keV α's feed levels in ²³⁹Cm at about 130 and 242 keV, respectively.

²³⁹Cm Levels

E(level)	Jπ [†]	Comments
0.0	(7/2-)	Alpha decay to this level was not detected (1967Fi04).
≈130?		
≈242	(1/2+)	

[†] From adopted levels.

α radiations

Eα [‡]	E(level)	Iα [§]	HF [†]	Comments
7060 10	≈242	≈71	≈0.70	Iα: 7060α/7171α=2.5 is given in 1967Fi04. HF: the α HF is low for J=1/2 (compare HF=2.7 and 2.5 for the favored transitions in the α decay of ²³⁹ Pu and ²⁴¹ Cm, respectively) suggesting that the α branch for ²⁴³ Cf is <14%, as estimated in 1967Si08. Eα: 7050 20 is reported in 1967Si08.
7170 [@] 10	≈130?	≈29	≈4.5	Not seen by 1967Si08. It may have been obscured in their spectrum by the presence of the 7.22-MeV α from ²⁴⁴ Cf.

[†] Using r₀(²³⁹Cm)=1.493, average of r₀(²³⁸Cm)=1.490 20 and r₀(²⁴⁰Cm)=1.495 12 (1998Ak04).

[‡] Measurements of 1967Fi04 (semi). Other measurement: 1967Si08.

[§] From 1967Fi04.

[#] For α intensity per 100 decays, multiply by ≈0.14.

[@] Existence of this branch is questionable.

Adopted Levels

Q(β^-)=-3995 SY; S(n)=8036 SY; S(p)=2483 SY; Q(α)=7200 SY 2012Wa38.
 $\Delta Q(\beta^-)$ =294 syst; $\Delta S(n)$ =328 syst; $\Delta S(p)$ =207 syst; $\Delta Q(\alpha)$ =200 syst (2012Wa38).
 Others:
 Discovery of ²³⁹Bk: 2013Fr02.
 Calculated T_{1/2} for α decay of ²⁴³Es: 2013Zd01, 2011Sa40.
 Calculated single-particle energies: 2004Pa40.

²³⁹Bk Levels

Cross Reference (XREF) Flags

A ²⁴³Es α Decay

E(level)	J π	XREF	Comments
0.0	(3/2-, 7/2+)	A	% ϵ >99; %SF<1; % α <1. T _{1/2} : decay of ²³⁹ Bk was not detected. T _{1/2} ≈100 s from systematics and theory (2010An08). No a nor SF observed (2010An08). Partial half-life estimates are: T _{1/2} (α)=115 h (1997Mo25), T _{1/2} (ϵ)=12 min (1973Ta30). J π : J π =3/2- or 7/2+ depending upon whether ²⁴³ Es g.s. J π is 7/2+ or 3/2- respectively. From syst 3/2[521] or 7/2[633] are the expected low-lying states. α HF suggests that 7/2+ is the g.s. (the HF for 7/2[633] to 3/2[521] should be a factor 4 bigger than the HF for 3/2[521]. to 7/2[633] transition because of phase space considerations). J π : J π =7/2+ or 3/2- depending upon whether ²⁴³ Es g.s. J π is 7/2+ or 3/2-, respectively. J π : Configuration=7/2+[633] or 3/2-[521].
47 10	(7/2+, 3/2-)	A	
197? 14		A	

²⁴³Es α Decay 1973Es02,1989Ha27,2010An08

Parent ²⁴³Es: E=0; J π =(7/2+,3/2-); T_{1/2}=23 s 3; Q(g.s.)=8072 10; % α decay=61 6.
²⁴³Es-T_{1/2}: Measured in 2010An08 from timing of 7893 α .
²⁴³Es-Q(α): From 2012Wa38.
²⁴³Es: Configuration=7/2+[633] or 3/2-[521].
²⁴³Es-% α decay: from ²⁴³Es α decay (2010An08).
Decay scheme based on α -particle measurements and using Q(α) (²⁴³Es)=8072 10 (2012Wa38).
2010An08, 2006An13:
²⁴³Es source obtained from ²⁴⁷Md α decay.
²⁴⁷Md was produced via ²⁰⁹Bi(⁴⁰Ar,2n). ⁴⁰Ar beam with E=187 and 198 MeV from the UNILAC bombarded a 0.450 $\mu\text{g}/\text{cm}^2$ metallic ²⁰⁹Bi target evaporated on a 40 $\mu\text{g}/\text{cm}^2$ Carbon backing. The target was covered with a 10 $\mu\text{g}/\text{cm}^2$ Carbon foil. The experiments were performed at the velocity filter SHIP at GSI.
Measured: α , γ , (recoil) α , half-lives, α decay branching ratios.
Detection system: at the focal plane of SHIP two time-of-flight detectors, an array of position-sensitive Si detectors and a Ge clover detector consisting of four Ge crystals were placed.
HIVAP code was used to predict the cross sections reported in 1989Ha27. Theoretical calculations: Woods-Saxon potential.

²³⁹Bk Levels

E(level)	J π	Comments
0.0	(3/2-, 7/2+)	
47 10	(7/2+, 3/2-)	E(level): level not in 2010An08. Suggested from adopted Q(α).
197 14		

^{243}Es α Decay 1973Es02,1989Ha27,2010An08 (continued)

α radiations

$E\alpha^\dagger$	E(level)	$I\alpha^{\ddagger\#}$	HF §	Comments
7745@ 10	197	3.8 11	15	$I\alpha$: Tentative α from $\alpha(\text{ER})$ correlated events.
7850 20		14.6 20	18	
7893 10	47	71 5	2.6	$E\alpha, I\alpha$: $E\alpha=7899$ 3, $I\alpha=87$ 12 in 1989Ha27. 1973Es02 reported one α group at $E\alpha=7890$ 20.
7939@ 10	0.0	11 5	24	$E\alpha, I\alpha$: From 1989Ha27. $E\alpha$: 2010An08 has not reported this α -particle. $I\alpha$: From $I\alpha(7939)/I\alpha(7899)=(13\ 7)/(87\ 12)=0.149\ 83$ (1989Ha27) and $I\alpha(7893)=79.4\ 25$ (2010An08).

† From 2010An08, unless otherwise specified.

‡ Renormalized by evaluators to intensities per 100 alpha-particle decays.

§ Using $r_0(^{239}\text{Bk})=1.49$, average of $r_0(^{238}\text{Cm})=1.490\ 20$, and $r_0(^{238}\text{Cf})=1.495\ 12$ (1998Ak04).

$^\#$ For α intensity per 100 decays, multiply by 0.61 6.

@ Existence of this branch is questionable.

Adopted Levels

Q(β^-)=-5310 SY; S(n)=7103 SY; S(p)=3260 SY; Q(α)=7810 SY 2012Wa38.
 $\Delta Q(\beta^-)$ =364 syst, $\Delta S(n)$ =364 syst, $\Delta S(p)$ =330 syst, $\Delta Q(\alpha)$ =56 syst (2012Wa38).
 Assignment: daughter of ²⁴³Fm (1981Mu12,2013Fr02).

²³⁹Cf Levels

Cross Reference (XREF) Flags

A ²⁴³Fm α Decay

E(level)	XREF	T _{1/2}	Comments
(0.0)	A	39 s +37-12	$\% \epsilon = ?$; $\% \alpha = ?$ T _{1/2} : from 1981Mu12. Calculated values of T _{1/2} (ϵ): =100 s (1973Ta30); =5.6 s (1997Mo25). From α syst, $\% \alpha > 50$. Calculated T _{1/2} (SF)=5.7×10 ³ y (1994EfZW). J π : expected low-lying configurations are 5/2[633] and 3/2[631].

²⁴³Fm α Decay 1981Mu12

Parent ²⁴³Fm: E=0; J π =?; T_{1/2}=0.231 s 9; Q(g.s.)=8693 50; $\% \alpha$ decay=91 3.
²⁴³Fm-T_{1/2}: from 2008Kh10 for 2700 8.55 MeV α 's. Earlier value of 0.18 s +8-4 based only on 10 α 's.
²⁴³Fm- $\% \alpha$ decay: from 2008Kh10. Other value: $\% BR$ =40 20 from α - α parent-daughter correlations (1981Mu12).
²⁰⁶Pb(⁴⁰Ar,3n), E(Ar)=194 MeV; velocity filter; position-sensitive surface barrier detectors, α - α parent-daughter correlations; excitation curve (1981Mu12).

²³⁹Cf Levels

E(level)
 (0.0)

α radiations

E α
 8546 25

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