Isotopes of americium

Americium ($_{95}$Am) is an artificial element, and thus a standard atomic weight cannot be given. Like all artificial elements, it has no known stable isotopes. The first isotope to be synthesized was ^{241}Am in 1944. The artificial element decays by ejecting alpha particles. Americium has an atomic number of 95 (the number of protons in the nucleus of the americium atom).

Nineteen radioisotopes of americium—^{223}Am, ^{229}Am, ^{230}Am, and those ranging from ^{232}Am to ^{247}Am—have been characterized, with the most stable being ^{243}Am with a half-life of 7,370 years, and ^{241}Am with a half-life of 432.2 years. All of the remaining radioactive isotopes have half-lives that are less than 51 hours, and the majority of these have half-lives that are less than 100 minutes. This element also has 8 meta states, with the most stable being ^{242m}Am ($t_{1/2}$ = 141 years).

Main isotopes of americium ($_{95}$Am)

Isotope			Decay	
	abundance	half-life ($t_{1/2}$)	mode	product
^{241}Am	syn	432.2 y	SF	–
			α	^{237}Np
^{242m1}Am	syn	141 y	IT	^{242}Am
			α	^{238}Np
			SF	–
^{243}Am	syn	7370 y	SF	–
			α	^{239}Np

Contents

List of isotopes

Nuclide [n 1]	Z	N	Isotopic mass (Da) [n 2][n 3] / Excitation energy[n 6]	Half-life	Decay mode [n 4]	Daughter isotope	Spin and parity [n 5][n 6]
^{223}Am[1]	95	128		5.2(+12.0-4.4) ms	α	^{219}Np	
^{229}Am[1]	95	134	229.04525(9)	1.8(1.5) s	α	^{225}Np	
^{230}Am[2]	95	135	230.04609(14)#	32(+22-9) s	β^+ (64.7%)	^{230}Pu	
					β^+, SF (35.3%)	(various)	
^{232}Am	95	137	232.04659(32)#	79(2) s	β^+ (98%)	^{232}Pu	
					α (2%)	^{228}Np	
					β^+, SF (.069%)	(various)	
^{233}Am	95	138	233.04635(11)#	3.2(8) min	β^+	^{233}Pu	
					α	^{229}Np	
^{234}Am	95	139	234.04781(22)#	2.32(8) min	β^+ (99.95%)	^{234}Pu	
					α (.04%)	^{230}Np	
					β^+, SF (.0066%)	(various)	
^{235}Am	95	140	235.04795(13)#	9.9(5) min	β^+	^{235}Pu	5/2−#
					α (rare)	^{231}Np	
^{236}Am	95	141	236.04958(11)#	3.6(1) min	β^+	^{236}Pu	
					α	^{232}Np	
^{237}Am	95	142	237.05000(6)#	73.0(10) min	β^+ (99.97%)	^{237}Pu	5/2(−)
					α (.025%)	^{233}Np	
^{238}Am	95	143	238.05198(5)	98(2) min	β^+	^{238}Pu	1+
					α (10^{-4}%)	^{234}Np	
^{238m}Am	2500(200)# keV			35(10) μs			
^{239}Am	95	144	239.0530245(26)	11.9(1) h	EC (99.99%)	^{239}Pu	(5/2)−
					α (.01%)	^{235}Np	
^{239m}Am	2500(200) keV			163(12) ns			(7/2+)
^{240}Am	95	145	240.055300(15)	50.8(3) h	β^+	^{240}Pu	(3−)
					α (1.9×10^{-4}%)	^{236}Np	
^{241}Am[n 7]	95	146	241.0568291(20)	432.2(7) y	α	^{237}Np	5/2−
					CD (7.4×10^{-10}%)	^{207}Tl, ^{34}Si	
					SF (4.3×10^{-10}%)	(various)	
^{241m}Am	2200(100) keV			1.2(3) μs	SF		
^{242}Am	95	147	242.0595492(20)	16.02(2) h	β^- (82.7%)	^{242}Cm	1−
					EC (17.3%)	^{242}Pu	
^{242m1}Am	48.60(5) keV			141(2) y	IT (99.54%)	^{242}Am	5−
					α (.46%)	^{238}Np	
					SF (1.5×10^{-8}%)	(various)	
^{242m2}Am	2200(80) keV			14.0(10) ms			(2+, 3−)
^{243}Am[n 7]	95	148	243.0613811(25)	7,370(40) y	α	^{239}Np	5/2−

					SF (3.7×10^{-9}%)	(various)	
^{244}Am	95	149	244.0642848(22)	10.1(1) h	β^-	^{244}Cm	(6−)#
^{244m}Am	86.1(10) keV			26(1) min	β^- (99.96%)	^{244}Cm	1+
					EC (.0361%)	^{244}Pu	
^{245}Am	95	150	245.066452(4)	2.05(1) h	β^-	^{245}Cm	(5/2)+
^{246}Am	95	151	246.069775(20)	39(3) min	β^-	^{246}Cm	(7−)
^{246m1}Am	30(10) keV			25.0(2) min	β^- (99.99%)	^{246}Cm	2(−)
					IT (.01%)	^{246}Am	
^{246m2}Am	~2000 keV			73(10) μs			
^{247}Am	95	152	247.07209(11)#	23.0(13) min	β^-	^{247}Cm	(5/2)#

1. ^{m}Am – Excited nuclear isomer.
2. ( ) – Uncertainty (1σ) is given in concise form in parentheses after the corresponding last digits.
3. # – Atomic mass marked #: value and uncertainty derived not from purely experimental data, but at least partly from trends from the Mass Surface (TMS).
4. Modes of decay:
   - CD: Cluster decay
   - EC: Electron capture
   - IT: Isomeric transition
   - SF: Spontaneous fission
5. ( ) spin value – Indicates spin with weak assignment arguments.
6. # – Values marked # are not purely derived from experimental data, but at least partly from trends of neighboring nuclides (TNN).
7. Most common isotopes

Actinides vs fission products

Actinides and fission products by half-life

Actinides[3] by decay chain				Half-life range (a)	Fission products of ^{235}U by yield[4]		
4*n*	4*n*+1	4*n*+2	4*n*+3		4.5–7%	0.04–1.25%	<0.001%
^{228}Ra$^{№}$				**4–6 a**	†	^{155}Eu^{þ}	
^{244}Cm^{f}	^{241}Pu^{f}	^{250}Cf	^{227}Ac$^{№}$	**10–29 a**	^{90}Sr	^{85}Kr	^{113m}Cd^{þ}
^{232}U^{f}		^{238}Pu^{f}	^{243}Cm^{f}	**29–97 a**	^{137}Cs	^{151}Sm^{þ}	^{121m}Sn
^{248}Bk[5]	^{249}Cf^{f}	^{242m}Am^{f}		**141–351 a**	No fission products have a half-life in the range of 100–210 ka ...		
	^{241}Am^{f}		^{251}Cf^{f}[6]	**430–900 a**			
		^{226}Ra$^{№}$	^{247}Bk	**1.3–1.6 ka**			
^{240}Pu	^{229}Th	^{246}Cm^{f}	^{243}Am^{f}	**4.7–7.4 ka**			
	^{245}Cm^{f}	^{250}Cm		**8.3–8.5 ka**			
			^{239}Pu^{f}	**24.1 ka**			
		^{230}Th$^{№}$	^{231}Pa$^{№}$	**32–76 ka**			
^{236}Np^{f}	^{233}U^{f}	^{234}U$^{№}$		**150–250 ka**	‡	^{99}Tc$^{⚛}$	^{126}Sn
^{248}Cm		^{242}Pu		**327–375 ka**		^{79}Se$^{⚛}$	
				1.53 Ma		^{93}Zr	
	^{237}Np^{f}			**2.1–6.5 Ma**		^{135}Cs$^{⚛}$	^{107}Pd
^{236}U			^{247}Cm^{f}	**15–24 Ma**			^{129}I$^{⚛}$
^{244}Pu				**80 Ma**			
^{232}Th$^{№}$		^{238}U$^{№}$	^{235}U$^{f№}$	**0.7–14.1 Ga**	... nor beyond 15.7 Ma[7]		

Legend for superscript symbols
₡ has thermal neutron capture cross section in the range of 8–50 barns
ƒ fissile
m metastable isomer
№ primarily a naturally occurring radioactive material (NORM)
þ neutron poison (thermal neutron capture cross section greater than 3k barns)
† range 4–97 a: Medium-lived fission product
‡ over 200 ka: Long-lived fission product

Notable isotopes

Americium-241

Americium-241 is the most prevalent isotope of americium in nuclear waste.[8] It is the isotope used in an americium smoke detector based on an ionization chamber. It is a potential fuel for long-lifetime radioisotope thermoelectric generators.

Americium-241 is used in ionization smoke detectors.

Parameter	Value
Atomic mass	241.056829 u
Mass excess	52930 keV
Beta decay energy	-767 keV
Spin	5/2−
Half-life	432.6 years
Spontaneous fissions	1200 per kg s
Decay heat	114 watts/kg

Possible parent nuclides: beta from ^{241}Pu, electron capture from ^{241}Cm, alpha from ^{245}Bk.

Americium-241 decays by alpha emission, with a by-product of gamma rays. Its presence in plutonium is determined by the original concentration of plutonium-241 and the sample age. Because of the low penetration of alpha radiation, Americium-241 only poses a health risk when ingested or inhaled. Older samples of plutonium containing plutonium-241 contain a buildup of ^{241}Am. A chemical removal of americium from reworked plutonium (e.g. during reworking of plutonium pits) may be required.

Americium-242m

^{242m}Am decay modes (half-life: 141 years)

Probability	Decay mode	Decay energy	Decay product
99.54%	isomeric transition	0.05 MeV	^{242}Am
0.46%	alpha decay	5.64 MeV	^{238}Np
$(1.5\pm0.6) \times 10^{-10}$ [10]	spontaneous fission	~200 MeV	fission products

Americium-242m has a mass of 242.0595492 g/mol. It is one of the rare cases, like ^{180m}Ta, ^{210m}Bi and multiple holmium isomers, where a higher-energy nuclear isomer is more stable than the lower-energy one, **Americium-242**.[11]

^{242m}Am is fissile (because it has an odd number of neutrons) and has a low critical mass, comparable to that of ^{239}Pu.[12] It has a very high cross section for fission, and if in a nuclear reactor is destroyed relatively quickly. Work has been done investigating if this isotope could be used for a novel type of nuclear rocket.[13][14]

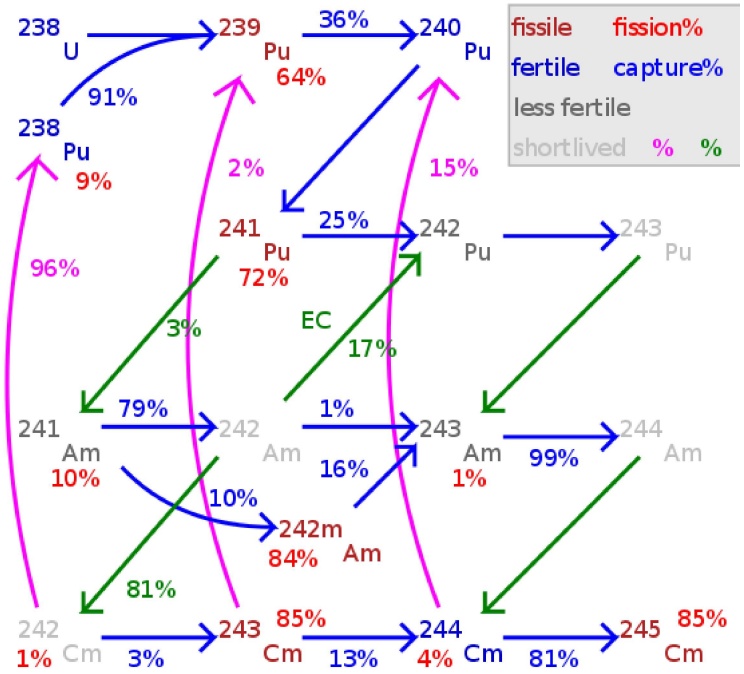
^{242}Am decay modes (half-life: 16 hours)

Probability	Decay mode	Decay energy	Decay product
82.70%	beta decay	0.665 MeV	^{242}Cm
17.30%	electron capture	0.751 MeV	^{242}Pu

Americium-243

Americium-243 has a mass of 243.06138 g/mol and a half-life of 7,370 years, the longest lasting of all americium isotopes. It is formed in the nuclear fuel cycle by neutron capture on plutonium-242 followed by beta decay.[15] Production increases exponentially with increasing burnup as a total of 5 neutron captures on ^{238}U are required.

It decays by either emitting an alpha particle (with a decay energy of 5.27 MeV)[15] to become ^{239}Np, which then quickly decays to ^{239}Pu, or infrequently, by spontaneous fission.[16]



Transmutation flow between ^{238}Pu and ^{244}Cm in LWR.[9]
Fission percentage is 100 minus shown percentages.
Total rate of transmutation varies greatly by nuclide.
^{245}Cm–^{248}Cm are long-lived with negligible decay.

As for the other americium isotopes, and more generally for all alpha emitters, ^{243}Am is carcinogenic in case of internal contamination after being inhaled or ingested. ^{243}Am also presents a risk of external irradiation associated with the gamma ray emitted by its short-lived decay product ^{239}Np. The external irradiation risk for the other two americium isotopes (^{241}Am and ^{242m}Am) is less than 10% of that for americium-243.[8]

See also

References

1. "Observation of new neutron-deficient isotopes with Z ≥ 92 in multinucleon transfer reactions" http://inspirehep.net/record/1383747/files/scoap3-fulltext.pdf
2. Kaji, D.; Morimoto, K.; Haba, H.; Ideguchi, E.; Koura, H.; Morita, K. (2016). "Decay Properties of New Isotopes ^{234}Bk and ^{230}Am, and Even–Even Nuclides ^{234}Cm and ^{230}Pu" (https://www.researchgate.net/publication/291009584) (PDF). *Journal of the Physical Society of Japan*. **84** (15002): 015002. doi:10.7566/JPSJ.85.015002 (https://doi.org/10.7566%2FJPSJ.85.015002).
3. Plus radium (element 88). While actually a sub-actinide, it immediately precedes actinium (89) and follows a three-element gap of instability after polonium (84) where no nuclides have half-lives of at least four years (the longest-lived nuclide in the gap is radon-222 with a half life of less than four *days*). Radium's longest lived isotope, at 1,600 years, thus merits the element's inclusion here.
4. Specifically from thermal neutron fission of U-235, e.g. in a typical nuclear reactor.
5. Milsted, J.; Friedman, A. M.; Stevens, C. M. (1965). "The alpha half-life of berkelium-247; a new long-lived isomer of berkelium-248". *Nuclear Physics*. **71** (2): 299. Bibcode:1965NucPh..71..299M (https://ui.adsabs.harvard.edu/abs/1965NucPh..71..299M). doi:10.1016/0029-5582(65)90719-4 (https://doi.org/10.1016%2F0029-5582%2865%2990719-4).
"The isotopic analyses disclosed a species of mass 248 in constant abundance in three samples analysed over a period of about 10 months. This was ascribed to an isomer of Bk^{248} with a half-life greater than 9 [years]. No growth of Cf^{248} was detected, and a lower limit for the β^- half-life can be set at about 10^4 [years]. No alpha activity attributable to the new isomer has been detected; the alpha half-life is probably greater than 300 [years]."
6. This is the heaviest nuclide with a half-life of at least four years before the "Sea of Instability".

7. Excluding those "classically stable" nuclides with half-lives significantly in excess of ^{232}Th; e.g., while ^{113m}Cd has a half-life of only fourteen years, that of ^{113}Cd is nearly eight quadrillion years.
8. "Americium" (http://www.ead.anl.gov/pub/doc/Americium.pdf) Archived (https://www.webcitation.org/69WMA7eTu?url=http://www.ead.anl.gov/pub/doc/Americium.pdf) 2012-07-29 at WebCite. Argonne National Laboratory, EVS. Retrieved 25 December 2009.
9. Sasahara, Akihiro; Matsumura, Tetsuo; Nicolaou, Giorgos; Papaioannou, Dimitri (April 2004). "Neutron and Gamma Ray Source Evaluation of LWR High Burn-up UO2 and MOX Spent Fuels" (https://www.tandfonline.com/doi/pdf/10.1080/18811248.2004.9715507?needAccess=true). *Journal of Nuclear Science and Technology*. **41** (4): 448–456. doi:10.3327/jnst.41.448 (https://doi.org/10.3327%2Fjnst.41.448).
10. J. T. Caldwell; S. C. Fultz; C. D. Bowman; R. W. Hoff (March 1967). "Spontaneous Fission Half-Life of Am^{242m}". *Physical Review*. **155** (4): 1309–1313. Bibcode:1967PhRv..155.1309C (https://ui.adsabs.harvard.edu/abs/1967PhRv..155.1309C). doi:10.1103/PhysRev.155.1309 (https://doi.org/10.1103%2FPhysRev.155.1309). (halflife (9.5±3.5)×10^{11} years)
11. 95-Am-242 (http://www.matpack.de/Info/Nuclear/Nuclids/A/Am242.html) Archived (https://web.archive.org/web/20110719060944/http://www.matpack.de/Info/Nuclear/Nuclids/A/Am242.html) 2011-07-19 at the Wayback Machine
12. "Critical Mass Calculations for ^{241}Am, ^{242m}Am and ^{243}Am" (https://web.archive.org/web/20110722105207/http://typhoon.jaea.go.jp/icnc2003/Proceeding/paper/6.5_022.pdf) (PDF). Archived from the original (http://typhoon.jaea.go.jp/icnc2003/Proceeding/paper/6.5_022.pdf) (PDF) on July 22, 2011. Retrieved February 3, 2011.
13. "Extremely Efficient Nuclear Fuel Could Take Man To Mars In Just Two Weeks" (https://www.sciencedaily.com/releases/2001/01/010103073253.htm) (Press release). Ben-Gurion University Of The Negev. December 28, 2000.
14. Ronen, Yigal; Shwageraus, E. (2000). "Ultra-thin 241mAm fuel elements in nuclear reactors". *Nuclear Instruments and Methods in Physics Research A*. **455** (2): 442–451. Bibcode:2000NIMPA.455..442R (https://ui.adsabs.harvard.edu/abs/2000NIMPA.455..442R). doi:10.1016/s0168-9002(00)00506-4 (https://doi.org/10.1016%2Fs0168-9002%2800%2900506-4).
15. "Americium-243" (http://www.ornl.gov/sci/isotopes/r_am243.html) Archived (https://web.archive.org/web/20110225120159/http://www.ornl.gov/sci/isotopes/r_am243.html) 2011-02-25 at the Wayback Machine. Oak Ridge National Laboratory. Retrieved 25 December 2009.
16. "Isotopes of the Element Americium" (http://education.jlab.org/itselemental/iso095.html). Jefferson Lab Science Education. Retrieved 25 December 2009.

Sources

- Isotope masses from:
  - National Nuclear Data Center. "NuDat 2.x database" (http://www.nndc.bnl.gov/nudat2/). Brookhaven National Laboratory.
- Isotopic compositions and standard atomic masses from:
  - de Laeter, John Robert; Böhlke, John Karl; De Bièvre, Paul; Hidaka, Hiroshi; Peiser, H. Steffen; Rosman, Kevin J. R.; Taylor, Philip D. P. (2003). "Atomic weights of the elements. Review 2000 (IUPAC Technical Report)" (https://doi.org/10.1351%2Fpac200375060683). *Pure and Applied Chemistry*. **75** (6): 683–800. doi:10.1351/pac200375060683 (https://doi.org/10.1351%2Fpac200375060683).
  - Wieser, Michael E. (2006). "Atomic weights of the elements 2005 (IUPAC Technical Report)" (https://doi.org/10.1351%2Fpac200678112051). *Pure and Applied Chemistry*. **78** (11): 2051–2066. doi:10.1351/pac200678112051 (https://doi.org/10.1351%2Fpac200678112051). Lay summary (http://old.iupac.org/news/archives/2005/atomic-weights_revised05.html).
- Half-life, spin, and isomer data selected from the following sources.
  - National Nuclear Data Center. "NuDat 2.x database" (http://www.nndc.bnl.gov/nudat2/). Brookhaven National Laboratory.
  - IAEA - Nuclear Data Section. Live Chart of Nuclides. (https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html) Vienna International Centre.
  - Holden, Norman E. (2004). "11. Table of the Isotopes". In Lide, David R. (ed.). *CRC Handbook of Chemistry and Physics* (85th ed.). Boca Raton, Florida: CRC Press. ISBN 978-0-8493-0485-9.