

4. CHEMICAL, PHYSICAL, and RADIOLOGICAL INFORMATION

4.1 CHEMICAL IDENTITY

Americium is a human-made actinide element (atomic number 95) and has no stable isotopes. It was discovered by Glen Seaborg, Leon Morgan, Ralph James, and Albert Ghiorso in 1944 and isolated by B.B. Cunningham as the isotope ^{241}Am in $\text{Am}(\text{OH})_3$ in the fall of 1945. It was named after the Americas (Seaborg 1991; Seaborg and Loveland 1990). Actinides are the 15 elements starting with actinium, atomic number 89, and extending to lawrencium, atomic number 103. All of the isotopes of these elements are radioactive. Of the 15 americium isotopes and isomers currently identified, the longest-lived is ^{243}Am .

4.2 PHYSICAL, CHEMICAL, AND RADIOLOGICAL PROPERTIES

Americium is a silvery, ductile, very malleable, non-magnetic metal. Americium melts at 1,176 °C, boils at 2,011 °C, and has an electron configuration of $5f^7 7s^2$. The Chemical Abstract Service (CAS) registry numbers, decay modes, half-lives, and specific activities of the four principal americium isotopes and isomers, ^{241}Am , $^{242\text{m}}\text{Am}$, ^{242}Am , and ^{243}Am , are presented in Table 4-1. ^{241}Am and ^{243}Am decay by alpha emission forming neptunium (atomic number 93), ^{237}Np ($t_{1/2}=2.14 \times 10^6$ years) and ^{239}Np ($t_{1/2}=2.355$ days) as the respective products. ^{239}Np subsequently decays to ^{239}Pu ($t_{1/2}=2.41 \times 10^4$ years), and then to ^{235}U , which is also a naturally-occurring isotope of uranium. The decay of ^{241}Am to ^{237}Np is accompanied by a predominant gamma ray photon of 59.54 keV. $^{242\text{m}}\text{Am}$ is an isomer (long-lived excited state of the nucleus) of ^{242}Am and has a half-life of 141 years; 95.5% of $^{242\text{m}}\text{Am}$ undergoes an isomeric transition to ^{242}Am ($t_{1/2}=16.02$ hours) with the emission of a 48.6 keV gamma ray, and 0.5% decays by alpha emission to ^{238}Np . ^{242}Am primarily (87%) undergoes beta decay to curium 242 (atomic number 96) ($t_{1/2}=162.8$ days), which decays to ^{238}Pu ($t_{1/2}=87.74$ years) and then to ^{234}U ($t_{1/2}=2.45 \times 10^5$ years) (another naturally-occurring uranium isotope); 17% undergoes electron capture to ^{242}Pu ($t_{1/2}=3.76 \times 10^5$ years).

^{241}Am has a high specific activity of 3.428 Ci/g (0.1268 TBq/g), emitting $\sim 7 \times 10^9$ alpha particles/mg/minute. ^{243}Am has a specific alpha activity about 17 times lower than ^{241}Am and is therefore more attractive for chemical investigations of the element (ICRP 1983; Lide 1998; O'Neil 2001; Seaborg 1991).

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Table 4-1. Principal Americium Isotopes

Isotope ^a	CAS Registry No.	Decay mode/ percent (product)	Decay mode energy(MeV)	Particle energy			Specific activity ^b (Ci/g)	Gamma energy (keV)
				Energy (MeV)	Intensity (percent)	Half-life (years)		
²⁴¹ Am	14596-10-2 " (²³⁷ ₉₃ Np) 86954-36-1 ^c		5.637	5.4431	12.8	432.2	3.43	26.34
				5.4857	85.2			33.192
				5.3884	1.4			59.536
				Others	<1			
^{242m} Am	13981-54-9 I.T./95.5 (²⁴² Am)	" /0.5(²³⁸ ₉₃ Np)	0.048			141	10.5	48.63
				5.141	0.026			86.48
				5.2070	0.4			109.44 163.04
²⁴² Am	13981-54-9	$\$/83$ (²⁴² ₉₆ Cm)	0.665	0.63	46	16.02 hours	808,000	42.2
		EC/17 (²⁴² ₉₄ Pu)	0.750	0.67	37			44.53
²⁴³ Am	14993-75-0 "	" (²³⁹ ₉₃ Np)	5.438	5.1798	1.1	7,370	0.199	43.54
				5.2343	11			74.67
				5.2766	88			86.57
				Others	<1			117.70 141.97

^aAn m after the atomic mass indicates one of multiple isomers of a given atomic mass.

^bLANL 1999 (1 Ci=0.037 TBq)

^cCAS Registry Number for ²⁴¹Am³⁺ ion

Source: Baum 2002; DOE 1997b; ICRP 1983; LBL 2000; Lide 1998

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The known oxidation states of americium are +2, +3, +4, +5, and +6. However, the stable oxidation states are +3 and +4; the common oxidation state is +3, in which state, the behavior of americium and other actinides is similar to the lanthanides. The trivalent state is the only state of importance in biological systems. The +2 oxidation state is very unstable and has only been produced in solid compounds. The stability of the americium oxidation states higher than +3 is less than that of uranium, neptunium, and plutonium (Cotton and Wilkinson 1980; Nenot and Stather 1979; Seaborg 1991). Am^{+3} hydrolyzes and forms weak complexes with serum proteins and other ligands. The physical and chemical properties of americium and selected americium compounds are shown in Table 4-2. Properties of some americium ions are shown in Table 4-3. The decay schemes for ^{241}Am and ^{243}Am are shown in Tables 4-4 and 4-5.

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Table 4-2. Physical and Chemical Properties of Americium and Selected Americium Compounds

Property	Value			
	Americium	Americium(II) oxide	Americium(III) oxide	Americium(III) chloride
Atomic/molecular weight ^a	243	275	534	349
Chemical formula	Am	AmO ₂	Am ₂ O ₃	AmCl ₃
Synonyms	No data	No data	No data	No data
Chemical Abstracts Service Registry No.	7440-35-9 ^b	12005-67-3	12254-64-7	13464-46-5
Color	Silvery	Black	Tan	Pink
Physical form	Solid metal	Cubic crystals	Hexagonal crystals	Hexagonal crystals
Odor	No data	No data	No data	No data
Melting point, EC	1,176	>1,000 (decomposes)	No data	500
Boiling point, EC	2,011	Not relevant	No data	No data
Autoignition temperature	No data	Not relevant	Not relevant	Not relevant
Solubility:				
Water	Insoluble	No data	No data	Soluble
Other solvents	Soluble in acid	Soluble in acid	Soluble in acid	No data
Density, g/cm ³	12	11.68	11.77	5.87
Partition coefficients	No data	No data	No data	No data
Vapor pressure	No data	No data	No data	No data
Refractive index	No data	No data	No data	No data

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Table 4-2. Physical and Chemical Properties of Americium and Selected Americium Compounds

Property	Value		
	Americium(III) fluoride	Americium nitrate	Americium citrate
Atomic/molecular weight ^a	300	429	432
Chemical formula	AmF ₃	Am(NO ₃) ₃	AmC ₆ H ₅ O ₇
Synonyms	No data	Americium trinitrate	No data
Chemical Abstracts Service Registry No.	13708-80-0	25933-53-3	11078-88-9
Color	Pink	No data	No data
Physical form	Hexagonal crystals	No data	No data
Odor	No data	No data	No data
Melting point, EC	1,393	No data	No data
Boiling point, EC	No data	No data	No data
Autoignition temperature	Not relevant	Not relevant	Not relevant
Solubility:			
Water	No data	No data	No data
Other solvents	No data	No data	No data
Density, g/cm ³	9.53	No data	No data
Partition coefficients	No data	No data	No data
Vapor pressure	No data	No data	No data
Refractive index	No data	No data	No data

^aCalculated for ²⁴³Am

^bThis is also a generic CAS Registry Number for americium (unspecified form).

Source: Chemical Abstract Service 2000; Lide 1994, 1998, 2000

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Table 4-3. Properties of Some Americium Ions

Ion	Color	Stability
Am^{3+}	Pink or yellow	Stable; difficult to oxidize
Am^{4+}	Color unknown	Occurs in solution only as complex fluoride and carbonate ions
AmO_2^+	Yellow	Disproportionates in strong acid; reduces fairly rapidly under action of own alpha emissions (^{241}Am) at low acidification
AmO_2^{2+}	Rum colored	Easily reduced; reduces fairly rapidly under the action of its own alpha radiation (^{241}Am)

Source: Seaborg 1991

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Table 4-4. ²⁴¹Am Decay Scheme^a

Nuclide	Half-life	Energies and intensities of emitted radiation					
		Alpha (α)		Beta (β) max		Gamma (γ)	
		keV	%	MeV	%	keV	%
²⁴¹ Am ↓	432.2 years	5,485 5,443	84.5 13.0			13.9 59.5 26.3	42 35.9 2.4
²³⁷ Np ↓	2.144x10 ⁶ years	4,788 4,771 4,766 4,639 4,664	47 25 8 6.2 3.3			13.3 29.4 86.5 8.2 95.9	58 15 12.4 9 2.7
²³³ Pa ↓	26.97 days			232 156 260 174 572	40 27.7 17 16.4 4	13.6 312.2 98.4 94.7 111.0	56 38.6 17.7 10.9 8.2
²³³ U ↓	1.592x10 ⁵ years	4,824 4,784	84.4 13.2			13.0	6.0
²²⁹ Th ↓	7,340 years	4,845 4,901 4,815 5,053 4,968	56.2 10.2 9.3 6.6 6.0			12.3 88.5 85.4 100.0 11.1	79 24.7 15.0 11.3 8
²²⁵ Ra ↓	14.9 days			331 371	69.5 30.5	40.0 12.7	30.0 15.2
²²⁵ Ac ↓	10.0 days	5,830 5,792 5,791 5,732 5,637	50.7 18.1 8.6 8.0 4.4			12.0 10.6	20.9 9.3
²²¹ Fr ↓	4.9 minutes	6,341 6,126	83.4 15.1			218.2 11.4	11.6 2.2
²¹⁷ At ↓	0.323 seconds	7,066	99.9			258.5	0.056
²¹³ Bi 97.84% ↓ 2.16%	45.59 minutes	5,869	1.94	1422 982	65.9 31.0	440.5 79.3	26.1 2.0
²¹³ Po ↓	3.65 micro-seconds	8,376	100.0			778.8	0.005
²⁰⁹ Tl ↓	2.2 minutes			660	98.8	1567.1 465.1 117.2 75.0 10.6	99.8 96.9 84.3 10.7 9.4
²⁰⁹ Pb ↓	3.253 hours			0.644	100		
²⁰⁹ Bi	stable						

^aMinimum intensity 2%, up to five energies, with at least one entry per radiation type (DOE 2003)

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Table 4-5. ²⁴³Am Decay Scheme^a

Nuclide	Half-life	Energies and intensities of emitted radiation					
		Alpha (α)		Beta (β) max		Gamma (γ)	
		keV	%	MeV	%	keV	%
²⁴³ Am ↓	7,370 years	5,275	87.4			74.7	68.2
		5,233	11.0			13.9	21.4
		5,181	1.1			43.5	5.9
²³⁹ Np ↓	2.3565 days			436.5	45	14.3	63
				330.4	40.5	106.1	27.2
				391.9	11	103.8	22.5
				714.1	2.0	277.6	14.4
						99.6	14.0
²³⁹ Pu ↓	24,110 years	5,157	73.3			13.6	4.9
		5,144	15.1				
		5,106	11.5				
²³⁵ U ↓	703,800,000 years	4,398	55			185.7	57.2
		4,366	17.0			13.0	36
		4,215	5.7			143.8	11.0
		4,596	5.0			93.4	5.8
		4,325	4.4			163.3	5.1
²³¹ Th ↓	25.52 hours			288.1	40	13.3	72
				305.3	33	25.6	14.1
				206.0	12.8	84.2	6.6
				287.2	12		
				142.2	2.8		
²³¹ Pa ↓	32,760 years	5,014	25.4			12.7	36
		4,951	22.8			27.4	10.3
		5,028	20.0			300.0	2.5
		5,059	11.0			302.6	2.2
		4,736	8.4				
²²⁷ Ac ↓ 98+% 1.4%	21.772 years	4,953	0.658	44.8	53	12.0	0.088
				35.5	35		
				20.3	10		
²²⁷ Th ↓	18.68 days	6,038	24.2			12.3	40
		5,978	23.5			236.0	12.9
		5,757	20.4			50.1	8.4
		5,709	8.3			256.2	7.0
		5,713	4.9			329.8	2.9
²²³ Fr ↓	22.00 minutes			1,099.0	70	50.1	34
				1,069.4	15.0	12.3	30
				914.3	10.1	79.7	8.7
						234.8	3.0
						49.8	2.8
²²³ Ra ↓	11.43 days	5,716	51.6			83.8	25.4
		5,607	25.2			11.7	25
		5,747	9.0			81.1	15.3
		5,540	9.0			269.5	13.9
		5,434	2.2			94.9	11.5

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Table 4-5. ²⁴³Am Decay Scheme^a

Nuclide	Half-life	Energies and intensities of emitted radiation					
		Alpha (α)		Beta (β) max		Gamma (γ)	
		keV	%	MeV	%	keV	%
²¹⁹ Rn ↓	3.96 seconds	6,819	79.4			271.2	10.8
		6,553	12.9			401.8	6.6
		6,425	7.5				
²¹⁵ Po ↓	1.781 milli-seconds	7,386	100.0				
²¹¹ Pb ↓	36.1 minutes			1379	91.3	404.9	3.8
				547	6.3	832.0	3.5
²¹¹ Bi ↓	2.14 minutes	6,623	83.5			351.1	12.9
		6,278	16.2				
²⁰⁷ Tl ↓	4.77 minutes			1427	99.7	897.8	0.26
²⁰⁷ Pb	stable						

^a Minimum intensity 2%, up to five energies, with at least one entry per radiation type (DOE 2003)