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 $Am(OH)_3$ 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 maleable, non-magnetic metal. Americium melts at 1,176 ºC, boils at 2,011 ºC, 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, ^{242m}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 ($t_{½}$=2.14x10^6 years) and ^{239}Np ($t_{½}$=2.355 days) as the respective products. ^{239}Np subsequently decays to ^{239}Pu ($t_{½}$=2.411x10^4 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. ^{242m}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 ^{242m}Am undergoes an isomeric transition to ^{242}Am ($t_{½}$=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) ($t_{½}$=162.8 days), which decays to ^{238}Pu ($t_{½}$=87.74 years) and then to ^{234}U ($t_{½}$=2.45x10^5 years) (another naturally-occurring uranium isotope); 17% undergoes electron capture to ^{242}Pu ($t_{½}$=3.76x10^5 years).

^{241}Am has a high specific activity of 3.428 Ci/g (0.1268 TBq/g), emitting ~7x10^9 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).

Table 4-1. Principal Americium Isotopes

Isotope[a]	CAS Registry No.	Decay mode/ percent (product)	Decay mode energy(MeV)	Particle energy		Half-life (years)	Specific activity[b] (Ci/g)	Gamma energy (keV)
				Energy (MeV)	Intensity (percent)			
^{241}Am	14596-10-2 86954-36-1[c]	" ($^{237}_{93}$Np)	5.637	5.4431 5.4857 5.3884 Others	12.8 85.2 1.4 <1	432.2	3.43	26.34 33.192 59.536
^{242m}Am	13981-54-9	I.T./95.5 (^{242}Am)	0.048			141	10.5	48.63
		" /0.5($^{238}_{93}$Np)	5.62	5.141 5.2070	0.026 0.4			86.48 109.44 163.04
^{242}Am	13981-54-9	β^-/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 5.2343 5.2766 Others	1.1 11 88 <1	7,370	0.199	43.54 74.67 86.57 117.70 141.97

[a]An m after the atomic mass indicates one of multiple isomers of a given atomic mass.
[b]LANL 1999 (1 Ci=0.037 TBq)
[c]CAS Registry Number for $^{241}Am^{3+}$ ion

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

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.

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

	Value			
Property	Americium	Americium(II) oxide	Americium(III) oxide	Americium(III) chloride
Atomic/molecular weight[a]	243	275	534	349
Chemical formula	Am	AmO_2	Am_2O_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

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

	Value		
Property	Americium(III) fluoride	Americium nitrate	Americium citrate
Atomic/molecular weight[a]	300	429	432
Chemical formula	AmF_3	$Am(NO_3)_3$	$AmC_6H_5O_7$
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

[a]Calculated for ^{243}Am
[b]This is also a generic CAS Registry Number for americium (unspecified form).

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

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

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

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

Table 4-5. ^{243}Am 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	21.772 years	4,953	0.658	44.8	53	12.0	0.088
↓				35.5	35		
98+% 1.4%				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

Table 4-5. ^{243}Am 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)