3. CHEMICAL AND PHYSICAL INFORMATIONS

3.1 CHEMICAL IDENTITY

Data pertaining to the chemical identity (that is, the common terms or smbols used for the identification of the element) of thorium are listed in Table 3-1.

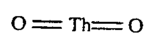
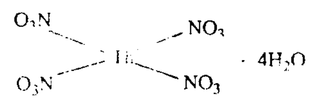
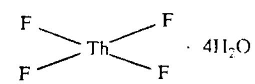
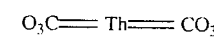
3.2 PHYSICAL AND CHEMICAL PROPERTIES

The physical and chemical properties of elemental thorium and a few rpresentative water soluble and insoluble thorium componds are presented in Table 3-2. Water soluble thorium compounds include the chloride, fluoride, nitrate, and sulfate salts (Weast 1983). These compounds dissolve fairly readily in water. Soluble thorium compounds, as a class, have greater bioavailability than the insoluble thorium compounds. Water Insoluble thorium compounds include the dioxide, carbonate, hydroxide, oxalate, and phosphate salts. Thorium carbonate is soluble in concentrated sodium carbonate (West 1983). Thorium metal and several of its compounds are commercially available. No general specifications for commercially prepared thorium metal or compounds have been established. Manufactures prepare thorium products according to contractual specifications (Hedrick 1985)

Thorium is a metallic element of the actinide series. It exists in several isotopic forms. The isotope thorium-232 is a naturally occuring element that is radioactive. Ti decays through the emission of a series of alpha and beta particles, gamma radiation, and the formation of daughter products, finally yielding the stable isotope of lead, lead-208. The decay series of thorium-232, together with that of uranium-238 and uranium-235, are shown in Figure 3-1. It can be seen from Figure 3-1 that the isotopes thorium-234 and thorium-230 are produced during the decay of naturally occuring uranium-238, the isotope thorium-228 diring the decay of thorium-232, and the isotopes thorium-231 and thorium-227 during the decay of naturally occuring uranium-235. Of these naturally produced isotopes of thorium, only thorium-232, thorium-230, and thorium-228 have long enough half-lives to be environmentally significant. More than 99.99% of natural thorium is thorium-232; the rest is thorium-230 and thorium-228.

Including artifically produced isotopes, there are 12 isotopes of Thorium with atomic masses ranging from 223 to 234. All are radioactive and Decay with the emission of alpha or beta particles and/or gamma radiation (West 1983). The percent occurrence and the energies of the major alpha and beta particles emitted by these isotopes are shown in Table 3-3. In general, the alpha particles are more intensely ionizing and less penetrating than the beta particles. The gamma radiation is the most penetrating of the three, but it has the least ionizing intensity. Alpha particles do not penetrate external skin to a sufficient depth to produce biological damage due to the protective effect of the epidermis. However, alpha particles emitted from thorium deposited in the lung are able to penetrate lung tissue and produce adverse biological damage since the

TABLE 3-1. Chemical Identity of Thorium and Compounds[a]

Characteristic	Thorium	Thorium dioxide	Thorium nitrate (tetrahydrate)	Thorium fluoride (tetrahydrate)	Thorium carbonate
Synonym(s)[b]	Thorium-232, thorium metal, pyrophoric	Thoria Thorotrast	No data	No data	No data
Registered trade name(s)	No data	No data	No data	No data	No data
Chemical formula	Th	ThO_2	$Th(NO_3)_4{\bullet}4H_2O$	$ThF_4{\bullet}4H$	$Th(CO_3)_2$
Chemical structure[c]	Th[e]				
Identification numbers:					
CAS registry	7440-29-1[c]	1314-20-1[c]	110140-69-7[c]	No data	No data
NIOSH RTECS	X0640000[d]	X06950000[d]	No data	No data	No data
EPA hazardous waste	No data	No data	No data	No data	No data
OHM/TADS	No data	No data	No data	No data	No data
DOT/UN/NA/IMCO shipping	NA9170, UN2975[c]	No data	No data	No data	No data
HSDB	864	6364	No data	No data	No data
NCI	No data	No data	No data	No data	No data

[a]All information obtained from HSDB 1990 except where noted
[b]Structures are based on tetra valency of thorium unless otherwise stated
[c]CAS 1990
[d]RTECS 1989
[e]SANSS 1988

TABLE 3-2. Physical and Chemical Properties of Thorium and Compounds

Property	Thorium (Th)	Thorium Dioxide (ThO_2)	Thorium Nitrate, Tetrahydrate ($Th(NO_3)_4 \cdot 4H_2O$)	Thorium Fluoride Tetrahydrate ($ThF_4 \cdot 4H_2O$)	Thorium Carbonate ($Th(CO_3)_2$)
Molecular weight	232.04[a]	264.04[a]	552.12[a]	380.09[a]	352.06[a]
Color	Gray[a]	White[b]	Colorless[a]	Not known	Not known
Physical state	Solid[a]	Powdery solid[b]	Crystalline solid[a]	Crystalline solid[a]	Not known
Odor	Not known	Not known	Not known	Not known	Not known
Melting point, °C	≈1700[b]	3220 ± 50[a]	500 (decomposes)	100 (-H_2O)[a]	Not known
Boiling point, °C	≈4500[b]	4400[b]	Not applicable	140-100 (-$2H_2O$)[a]	Not known
Autoignition temperature	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Solubility:					
Water	Insoluble[a]	Insoluble[b]	Very soluble[b]	0.017 g/100 cc H_2O (25°C)[a]	Insoluble in cold water
Other solvents and organics	Soluble in HCl, H_2SO_4, slightly soluble in HNO_3[a]	Soluble in hot H_2SO_4; insoluble in dilute acid, alkali[a]	Very soluble in alcohol; slightly soluble in acetone[a]	Insoluble in HF[a]	Soluble in concentrated Na_2CO_3
Density (g/cm^3)	11.7[a]	9.7[b]	Not known	Not known	Not known
Partition coefficients	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Vapor presure	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Henry's law constant	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Refractive index	Not applicable	2.20 (liquid)[a]	Not applicable	Not applicable	Not applicable
Flash point	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Flammability limits	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Conversion factors:	1 pCi = 1.2 fg[c] of Th-228 1 pci = 9.1 μg of Th-232 1 pCi = 48 fg[c] of Th-230	1 pCi = 1.2 fg[c] of Th-228 1 pci = 9.1 μg of Th-232 1 pCi = 48 fg[c] of Th-230	1 pCi = 1.2 fg[c] of Th-228 1 pci = 9.1 μg of Th-232 1 pCi = 48 fg[c] of Th-230	1 pCi = 1.2 fg[c] of Th-228 1 pci = 9.1 μg of Th-232 1 pCi = 48 fg[c] of Th-230	1 pCi = 1.2 fg[c] of Th-228 1 pci = 9.1 μg of Th-232 1 pCi = 48 fg[c] of Th-230

[a]Weast 1983
[b]Hawley 1981

[c]1 fg = 10^{-9} μg; 1 pCi = 10^{-12} Ci.

	Uranium-238 Series						
Np							
U	^{238}U 4.5E9 y		^{234}U 2.5E5 y				
Pa	↓	^{234}Pa 1.2 m	↓				
Th	^{234}Th 24 d		^{230}Th 8.0E4 y				
Ac			↓				
Ra			^{226}Ra 1600 y				
Fi			↓				
Rn			^{222}Rn 3.82 d				
Ai			↓				
Po			^{218}Po 3.05 m		^{214}Po 1.6E-4 s		^{210}Po 138 d
Bi			↓	^{214}Bi 19.7 m	↓	^{210}Bi 5.0 d	↓
Pb			^{214}Pb 26.8 m		^{210}Pb 21 y		^{206}Pb stable
Ti							

	Thorium-232 Series				
Np					
U					
Pa					
Th	^{232}Th 1.4E10 y		^{228}Th 1.91 y		
Ac	↓	^{228}Ac 6.13 h	↓		
Ra	^{228}Ra 5.8 y		^{224}Ra 3.64 d		
Fi			↓		
Rn			^{220}Rn 55 s		
Ai			↓		
Po			^{216}Po 0.15 s		^{212}Po 3.0E-7 s
Bi			↓	^{212}Bi 60.6 m	↓
Pb			^{212}Pb 10.6 h	↓	^{208}Pb stable
Ti				^{208}Ti 3.1 m	

	Uranium - 235 Series				
Np					
U	^{235}U 7.1E8 y				
Pa	↓	^{231}Pa 3.2E4 y			
Th	^{231}Th 25.5 h	↓	^{227}Th 18.2 d		
Ac		^{227}Ac 21.6 y	↓		
Ra			^{223}Ra 11.4 d		
Fi			↓		
Rn			^{219}Rn 4.0 s		
Ai			↓		
Po			^{215}Po 1.8E-3 s		
Bi			↓	^{211}Bi 2.15 m	
Pb			^{211}Pb 36.1 m	↓	^{207}Pb stable
Ti				^{207}Ti 4.79 m	

↓ alpha decay; ↗ beta decay; d = days; m = minutes; s = seconds; y = years

FIGURE 3-1. Uranium and Thorium Isotope Decay Series Showing the Sources and Decay Products of the Two Naturally-Occurring Isotopes of Thorium

Source: NCRP 1975

TABLE 3-3. Percent Occurrence and the Energies of the Major Alpha and Beta Particles Emitted by Thorium Isotopes With Atomic Masses Ranging from 223 to 234[a]

Isotope	% in Natural Thorium	Major Alpha Energies[b] Mev[c] (abundances)	Half-Life
Thorium-223	0	7.287 (60%) 7.317 (40%)	0.66 seconds
Thorium-224	0	6.997 (19%) 7.170 (79%)	1.04 seconds
Thorium-225	0	6.441 (>15%) 6.479 (43%) 6.501 (14%) 6.796 (9%)	8.0 minutes
Thorium-226	0	6.228 (23%) 6.338 (75%)	31.0 minutes
Thorium-227	0	5.72 (14%) 5.76 (21%) 5.98 (24%) 6.04 (23%)	18.72 days
Thorium-228	Very small	5.341 (26.7%) 5.423 (73.0%)	1.91 years
Thorium-229	0	4.814 (9.3%) 4.845 (56.0%) 4.901 (10.2%)	7.3×10^3 years
Thorium-230	Very small	4.621 (23.4%) 4.688 (76.3%)	7.54×10^4 years
Thorium-231	0	beta-active[d] (0.389 Mev)	25.2 hours
Thorium-232	>99.99%	3.952 (23%) 4.010 (77%)	1.4×10^{10} years

TABLE 3-3. (Continued)

Isotope	% in Natural Thorium	Major Alpha Energies[b] Mev (abundances)	Half-Life
Thorium-233	0	beta-active (1.243 Mev)	22.3 minutes
Thorium-234	0	beta-active (0.270 Mev)	24.1 days

[a]Source: Weast 1983.
[b]All but a few of these isotopes also emit gamma radiation.
[c]MEV = Million electron volt.
[d]The values in parentheses are the decay energies for the beta particles.

protective coating of the lung tissue is very thin. In turn, beta particles are able to penetrate the skin to a sufficient depth to cause biological effects in the skin just below the epidermis. Likewise, they penetrate lung tissues to a greater depth. Gamma rays can generally pass through all tissue and interact with tissue at any depth.

Alpha particles give up all of their energy in a very short distance and, hence, produce ionization. Beta particles produce less dense ionization, and gamma rays produce less yet. In general, the severity of biological effects of exposures to ionizing radiations is proportional to the density of the ionization produced by their passage through tissue.

Finely divided thorium metal is pyrophoric in air, and thorium ribbon burns in air to give the oxide. The metal also reacts vigorously with hydrogen, nitrogen, the halogens, and sulfur. Thorium compounds are stable in +4 oxidation state (Katzin 1983). Details of thorium chemistry are given by Katzin (1983).