4. CHEMICAL, PHYSICAL, AND RADIOLOGICAL INFORMATION

4.1 CHEMICAL IDENTITY

Radon is a naturally occurring radionuclide. The largest source of radon in the environment is due to the ambient levels produced by the widespread distribution of uranium, thorium, and their decay products in the soil (Buttafuoco et al. 2007; Weast 1980). Radon is a decay product of radium and part of the uranium and thorium decay chains (see Figure 4-1) (Buttafuoco et al. 2007; O'Neil et al. 2006). The chemical identity of radon isotopes and identification numbers for several of the radon isotopes (^{218}Rn, ^{219}Rn, ^{220}Rn, ^{222}Rn, ^{226}Rn, ^{229}Rn, and ^{230}Rn) are listed in Table 4-1.

4.2 PHYSICAL, CHEMICAL, AND RADIOLOGICAL PROPERTIES

Radon is the densest of all the gases. Important physical and chemical properties of radon are listed in Table 4-2. The radioactive properties of the important, short-lived daughters of ^{222}Rn are listed in Table 4-3. Figure 4-1 depicts the ^{238}U decay series containing ^{222}Rn. Figure 4-2 depicts the ^{232}Th decay series containing ^{220}Rn (thoron). Figure 4-3 depicts the ^{235}U decay series containing ^{219}Rn (actinon).

Table 4-1. Chemical Identity of Radon

Characteristic	Radon	Reference
Isotope(s)	Recognized isotopes: ^{195}Rn through ^{228}Rn Naturally-occurring isotopes: ^{222}Rn (radon) ^{220}Rn (thoron) ^{219}Rn (actinon)	DOE 2008
Registered trade name(s)	No data	
Chemical formula	Rn	
Chemical structure	Monatomic	
Identification numbers:		
CAS Registry	10043-92-2 Radon 51712-92-6 (^{230}Rn) 51712-91-5 (^{229}Rn) 16369-95-2 (^{226}Rn) 14859-67-7 (^{222}Rn) 22481-48-7 (^{220}Rn) 14835-02-0 (^{219}Rn) 15411-71-9 (^{218}Rn)	ChemIDPlus 2012
NIOSH RTECS	No data	
EPA Hazardous Waste	No data	
OHM/TADS	No data	
DOT/UN/NA/IMDG	No data	
HSDB	6369 (radon radioactive)	HSDB 2008
NCI	No data	

CAS = Chemical Abstracts Services; DOT/UN/NA/IMDG = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; DOE = Department of Energy; Environmental Protection Agency; HSDB = Hazardous Substance Data Bank; NCI = National Cancer Institute; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; RTECS = Registry of Toxic Effects of Chemical Substances

Table 4-2. Physical, Chemical, and Radiological Properties of Radon

Property	Radon	Reference
Molecular weight	222 (radon), 220 (thoron), 219 (actinon)	Cothern 1987a
Color	Colorless	Lewis 2001
Physical state	Gas at 0 °C and 760 mm Hg	Lewis 2001
Melting point	-71 °C	Lide 2005
Boiling point	-61.8 °C	Lewis 2001
Density at -20 °C	$9.96x10^{-3}$ g/cm^3	Cothern 1987a
Odor[b]	Odorless	O'Neil et al. 2006
Odor threshold:		
Water	Odorless	
Air	Odorless	
Solubility:		
Water at 20 °C	230 cm^3/L	O'Neil et al. 2006
Organic solvents	Organic liquid, slightly soluble in alcohol	Weast 1980
Vapor pressure at 25 °C[a]	395.2 mm Hg	Cothern 1987a
Henry's Law constant	No data	
Autoignition temperature	Noble gas; does not autoignite	
Flash point	Noble gas; does not burn	
Flammability limits	Noble gas; is not flammable	
Half-life:		
^{222}Rn	3.8235 days	DOE 2008
^{220}Rn	55.6 seconds	DOE 2008
^{219}Rn	3.96 seconds	DOE 2008
Decay energies (MeV), and intensities (%)		
^{222}Rn	Alpha particles: 4.826 (0.0005%) 4.986 (0.078%) 5.48948 (99.920%) Gamma rays: 0.510 (0.076%)	DOE 2008
^{220}Rn	Alpha particles: 5.747 (0.114%) 6.288 (99.886%) Gamma rays: 0.5497 (0.114%)	DOE 2008

Table 4-2. Physical, Chemical, and Radiological Properties of Radon

Property	Radon	Reference
^{219}Rn	Alpha particles (15 reported): 6.425 (7.5%) 6.530 (0.12%) 6.553 (12.9%) 6.819 (79.4%) Gamma rays (dozens reported): 0.0111 (9.6% 0.0769 (5.0%) 0.0793 (8.4%) 0.2712 (10.8%)	U.S. DHEW 1970
Specific activity, nλ/mass (Ci/g):		
^{222}Rn	1.538×10^{5}	Based on DOE 2008
^{220}Rn	9.135×10^{8}	Based on DOE 2008
^{219}Rn	1.301×10^{10}	Based on DOE 2008
Decay products:	Radon progeny (daughters)	
^{222}Rn (see Figure 4-1)	^{218}Po ^{214}Pb ^{214}Bi ^{214}Po ^{210}Tl ^{210}Pb ^{210}Bi ^{210}Po ^{206}Tl ^{206}Pb	DOE 2008
^{220}Rn (see Figure 4-2)	^{216}Po ^{212}Pb ^{212}Bi ^{212}Po ^{208}Tl ^{208}Pb	DOE 2008
^{219}Rn (see Figure 4-3)	^{215}Po ^{215}At ^{211}Pb ^{211}Bi ^{211}Po ^{207}Tl ^{207}Pb	DOE 2008

MeV = million electron volts

Table 4-3. Radioactive Properties of ^{222}Rn and Its Short-lived Progeny

Isotope	Historical symbol	Principal radiation(s)	Q-Value of principal decay mode (MeV)	Half-life	Specific activity (Ci/g)
^{222}Rn	Rn	α	5.5903	3.8235 days	$1.54x10^{5}$
^{218}Po[a]	RaA	α	6.1147	3.098 minutes	$2.78x10^{8}$
^{218}At	At	α	6.874	1.5 seconds	$3.45x10^{10}$
^{214}Pb	RaB	β,γ	1.023	26.8 minutes	$3.28x10^{7}$
^{214}Bi	RaC	β,γ	5.6168	19.9 minutes	$4.41x10^{7}$
^{214}Po[a]	RaC'	α	7.8335	164.3 μseconds	$3.21x10^{14}$
^{210}Tl	RaC"	β	5.489	1.30 minutes	$6.89x10^{8}$

[a]Isotopes of primary radiological interest due to the potential for retention in the lung and subsequent alpha decay.

MeV = million electron volts

Source: DOE 2008

Figure 4-1. ^{238}U Decay Series Showing Sources and Decay Products*

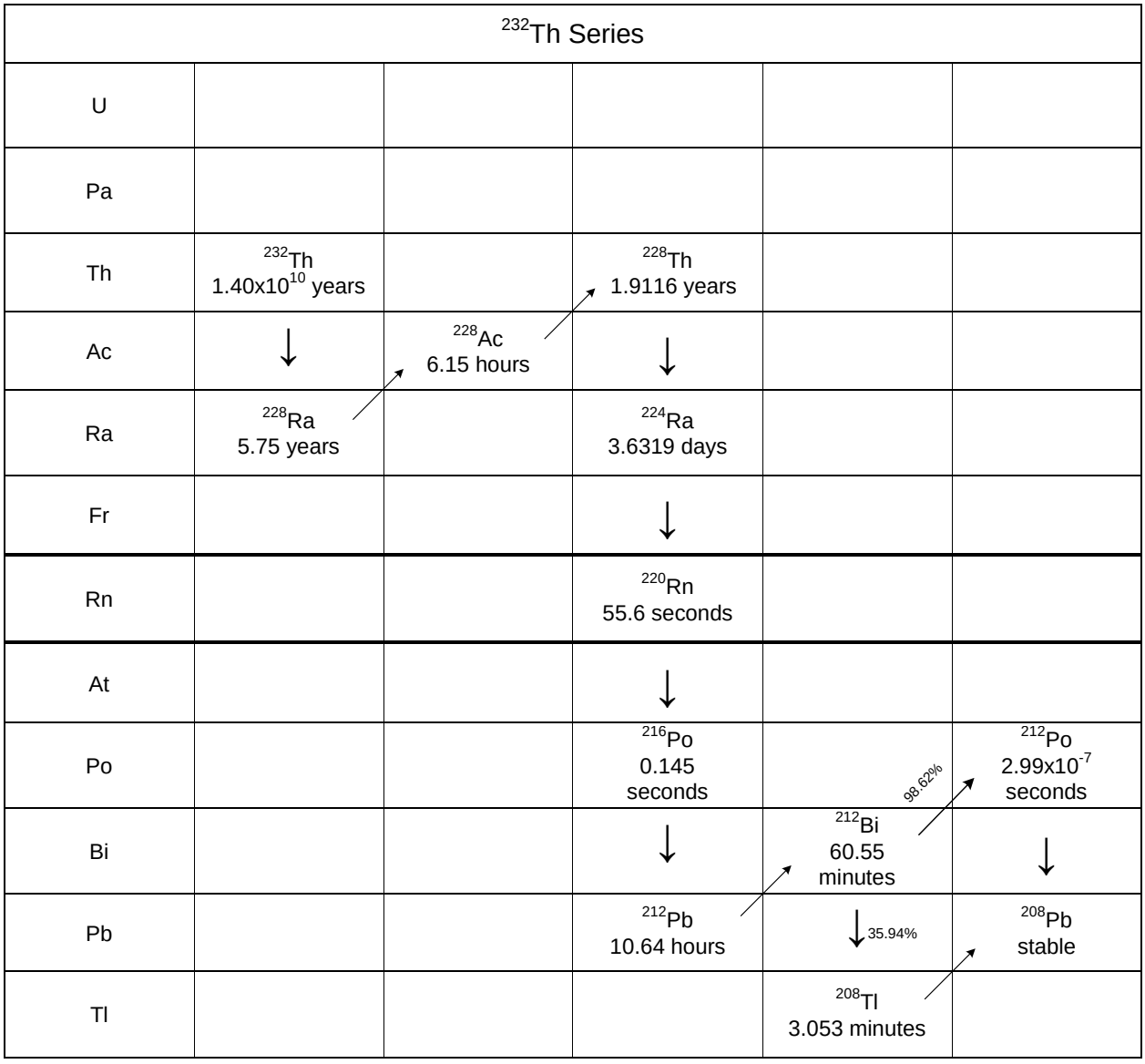
^{238}U Series							
U	^{238}U 4.468×10^{9} years		^{234}U 2.455×10^{5} years				
Pa	↓	^{234m}Pa 1.159 minutes ^{234}Pa 6.70 hours	↓				
Th	^{234}Th 24.10 days		^{230}Th 7.54×10^{4} years				
Ac			↓				
Ra			^{226}Ra 1,600 years				
Fr			↓				
Rn			^{222}Rn 3.8235 days	0.1%	^{218}Rn 0.035 seconds		
At			↓ 0.02%	^{218}At 1.5 seconds	↓		
Po			^{218}Po 3.098 minutes	↓ 99.90%	^{214}Po 1.643×10^{-4} seconds	99.9999%	^{210}Po 138.4376 days
Bi			↓ 99.98%	^{214}Bi 19.9 minutes	99.98% ↓	^{210}Bi 5.012 days	↓
Pb			^{214}Pb 26.8 minutes	↓ 0.02%	^{210}Pb 22.20 years	↓ 1.3×10^{-4}%	^{206}Pb stable
Tl				^{210}Tl 1.30 minutes		^{206}Tl 4.202 minutes	

*All of the single transitions are 100%; other branching ratios are shown in the decay series.

↓ alpha (α) decay; ↗ beta (β^-) decay or internal transition (IT)

Source: NNDC 2012b

Figure 4-2. ^{232}Th Decay Series Showing Sources and Decay Products

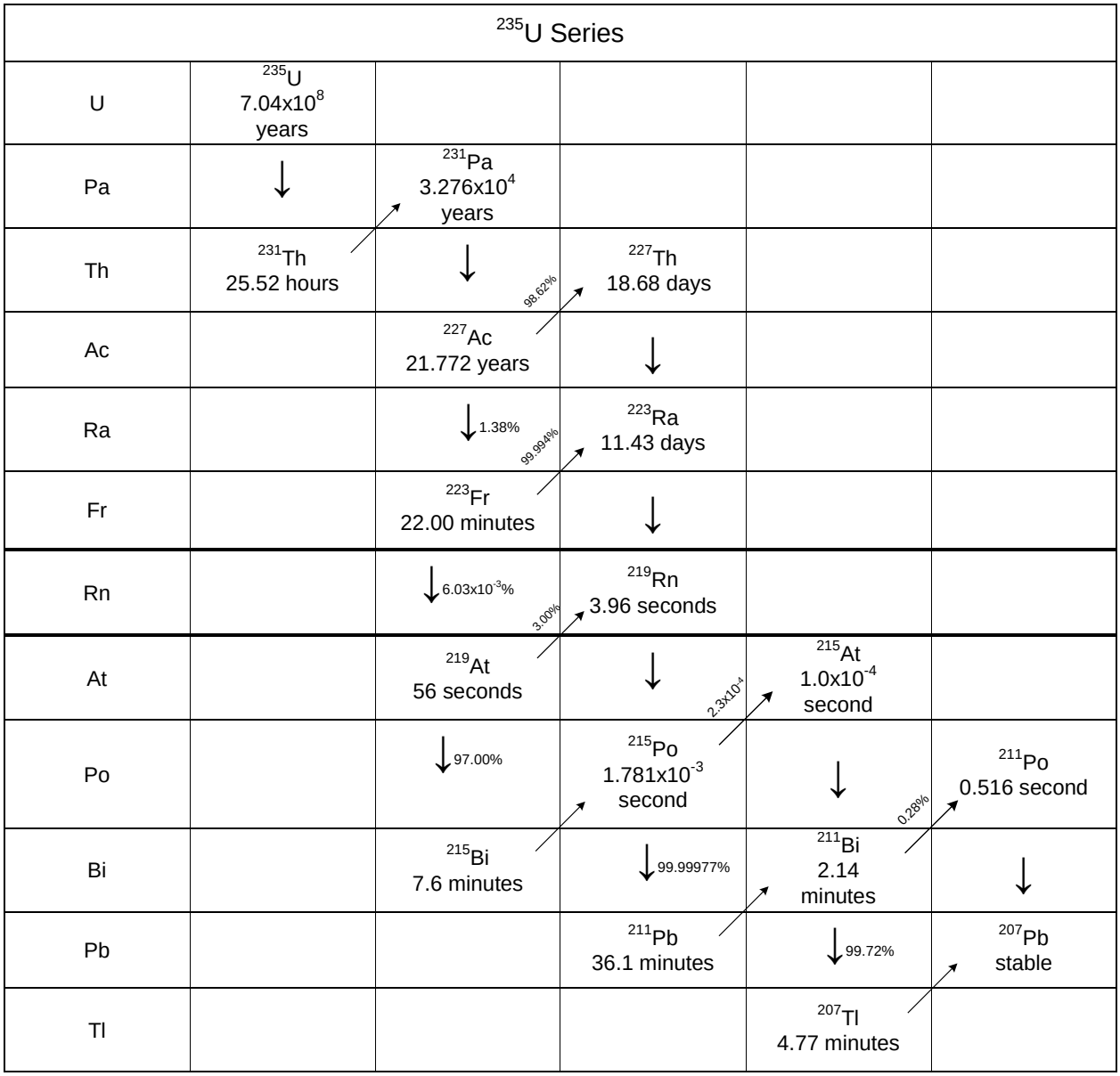


*All of the single transitions are 100%; other branching ratios are shown in the decay series.

↓ alpha (α) decay; ↗ beta (β^-) decay or internal transition (IT)

Source: NNDC 2012b

Figure 4-3. ^{235}U Decay Series Showing Sources and Decay Products



*All of the single transitions are 100%; other branching ratios are shown in the decay series.

↓ alpha (α) decay; ↗ beta (β^-) decay or internal transition (IT)

Source: NNDC 2012b