

4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Tungsten is a naturally occurring element found in the earth's surface rocks. Tungsten metal typically does not occur as the free element in nature. Of the more than 20 tungsten-bearing minerals, some of the commonly used commercial ones include feberite (iron tungstate), huebnerite (manganese tungstate), wolframite (iron-manganese tungstate), and scheelite (calcium tungstate). Tungsten appears in Group VIB of the periodic table. Natural tungsten is composed of five stable isotopes: ^{180}W (0.12%), ^{182}W (26.5%), ^{183}W (14.3%), ^{184}W (30.6%), and ^{186}W (28.4%). Twenty-eight radioactive isotopes of tungsten are known; most of these isotopes have short half-lives. Tungsten forms a variety of different compounds, such as tungsten trioxide, tungsten carbide, and ammonium paratungstate (Penrice 1997a). Information regarding the chemical identity of elemental tungsten and tungsten compounds is located in Table 4-1.

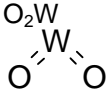
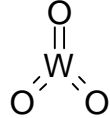
4.2 PHYSICAL AND CHEMICAL PROPERTIES

Tungsten has several common oxidation states (e.g., W[0], W[2+], W[3+], W[4+], W[5+], and W[6+]). However, tungsten alone has not been observed as a cation. Tungsten is stable, and therefore its most common valence state is +6. The naturally occurring isotopes of tungsten are 180 (0.135%), 182 (26.4%), 183 (14.4%), 184 (30.6%), and 186 (28.4%). Artificial radioactive isotopes of tungsten are 173–179, 181, 185, and 187–189 (O'Neil et al. 2001). Elemental tungsten metal is stable in dry air at room temperature. Above 400 °C, tungsten is susceptible to oxidation. Tungsten is resistant to many chemicals and is also a good electrical conductor (Penrice 1997a). Information regarding the physical and chemical properties of elemental tungsten is located in Table 4-2.

Tungsten compounds differ widely in stereochemistry and oxidation states. Tungsten forms binary halide compounds for all oxidation states between +2 and +6. Oxyhalide compounds are only known for oxidation states +5 and +6. In general, tungsten halogen compounds are reactive toward water and oxygen in air. These compounds are all solid, colored compounds at room temperature, except the fluorides, and many decompose on heating before melting. Tungsten oxides form a series of well-defined ordered phases to which precise stoichiometric formulas can be assigned. The composition of the

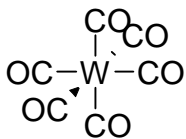
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Table 4-1. Chemical Identity of Tungsten and Tungsten Compounds^a

Characteristic	Tungsten	Tungsten oxide	Tungsten trioxide
Synonyms	Wolfram; VA (tungsten)	Tungsten oxide; tungsten dioxide	Tungsten blue; tungsten oxide (WO ₃); tungsten trioxide; tungsten(VI) oxide; tungstic acid; tungstic acid anhydride; tungstic anhydride; tungstic oxide; wolframic acid, anhydride
Registered trade name(s)	Tungsten; Wolfram	No data	No data
Chemical formula	W	O ₂ W	O ₃ W
Chemical structure	W		
Identification numbers:			
CAS registry	7440-33-7	12036-22-5	1314-35-8
NIOSH RTECS	YO7175000	No data	Y07760000
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/ IMCO shipping	No data	No data	No data
HSDB	5036	No data	5800
NCI	No data	No data	77901

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Table 4-1. Chemical Identity of Tungsten and Tungsten Compounds^a

Characteristic	Tungsten carbide	Ditungsten carbide	Tungsten carbonyl
Synonyms	Tungsten carbide; tungsten monocarbide	Tungsten carbide	Hexacarbonyltungsten; tungsten carbonyl; tungsten hexacarbonyl
Registered trade name(s)	Tungsten carbide	No data	No data
Chemical formula	CW	CW ₂	C ₆ O ₆ W
Chemical structure	WC	W ₂ C	
Identification numbers:			
CAS registry	12070-12-1; 11130-73-7	12070-13-2	14040-11-0
NIOSH RTECS	YO7250000	No data	YO7705000
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/ IMCO shipping	No data	No data	No data
HSDB	2932	No data	No data
NCI	61198	No data	No data

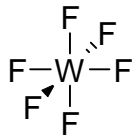
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Table 4-1. Chemical Identity of Tungsten and Tungsten Compounds^a

Characteristic	Tungsten chloride	Sodium tungstate, dihydride	Sodium phosphotungstate
Synonyms	Hexa-chlorotungsten; (2-) tungsten hexachloride; wolfram hexa-chloride	Disodium tetraoxatungstate (2-); disodium tungstate, dihydrate; sodium tungsten oxide, dihydrate; sodium wolframate, dihydrate; tungstic acid, disodium salt, dihydrate	Sodium tungstophosphate; tungstophosphoric acid, sodium salt; sodium-12-tungstophosphate
Registered trade name(s)	No data	No data	No data
Chemical formula	Cl ₆ W	O ₄ NaW ₂ • 2H ₂ O (dihydrate)	ca. 2Na ₂ OP ₂ O ₅ • 12WO ₃ • 18H ₂ O
Chemical structure			
Identification numbers:			
CAS registry	13283-01-7	10213-10-2 (dihydrate); 13472-45-2 (anhydrous)	51312-42-6
NIOSH RTECS	YO7710000	YO7900000; YO7875000	TH5775000
EPA hazardous waste	No data	No data	No data
OHM/TADS	No data	No data	No data
DOT/UN/NA/ IMCO shipping	No data	No data	No data
HSDB	No data	No data	No data
NCI	No data	No data	No data

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Table 4-1. Chemical Identity of Tungsten and Tungsten Compounds^a

Characteristic	Ammonium paratungstate	Tungstate hexafluoride
Synonyms	APT	Tungsten hexafluoride; tungsten fluoride
Registered trade name(s)	No data	No data
Chemical formula	H ₂₄ N ₆ O ₂₄ W ₇	F ₆ W
Chemical structure	(NH ₄) ₆ W ₇ O ₂₄	
Identification numbers:		
CAS registry	12028-06-7 (anhydrous); 12208-54-7 (hexahydrate)	7783-82-6
NIOSH RTECS	No data; BS0480000	YO7720000
EPA hazardous waste	No data	No data
OHM/TADS	No data	No data
DOT/UN/NA/IMCO shipping	No data	UN 2196
HSDB	No data	No data
NCI	No data	No data

^aSources: Chemfinder 2004; ChemID 2004; HSDB 2004; NIOSH 1990; RTECS 2004

CAS = Chemical Abstracts Service; DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances 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

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Table 4-2. Physical and Chemical Properties of Tungsten and Tungsten Compounds^a

Property	Tungsten	Tungsten oxide	Tungsten trioxide
Molecular weight	183.85	215.84 ^b	231.85
Color	Steel-gray to tin-white	Blue ^b	Canary yellow; dark orange when heated ^c
Physical state	Solid metal	Solid ^b	Solid
Melting point	3,410 °C	1,500–1,700 °C (decomposes)	1,472 °C
Boiling point	5,900 °C at 760 mm Hg	Not applicable	No data
Density (g/cm ³)	18.7–19.3 at 20 °C/4 °C	10.82 (theoretical)	7.2
Odor	No data	No data	No data
Odor threshold:			
Water (mL/g)	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	No data	Insoluble ^b	Insoluble
Other solvent(s)	Soluble in mixture of nitric acid and hydrofluoric acid	Insoluble in organic solvents ^b	Caustic alkalies; very slightly soluble in acids; slightly soluble in hydrofluoric acid
Partition coefficients:			
K _d (mL/g)	Not applicable	Not applicable	Not applicable
K _{ow}	Not applicable	Not applicable	Not applicable
K _{oc}	Not applicable	Not applicable	Not applicable
Vapor pressure	1.97×10 ⁻⁷ mm Hg at 2,327 °C	No data	No data
Henry's law constant	No data	No data	No data
Autoignition temperature	Not applicable	Not applicable	Not applicable
Flashpoint	Not applicable	Not applicable	Not applicable
Flammability limits	Not applicable	Not applicable	Not applicable
Conversion factor	Not applicable	Not applicable	Not applicable
Explosive limits	Not applicable	Not applicable	Not applicable

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Table 4-2. Physical and Chemical Properties of Tungsten and Tungsten Compounds^a

Property	Tungsten carbide	Ditungsten carbide	Tungsten carbonyl
Molecular weight	195.85	379.69 ^b	351.90 ^b
Color	Gray	No data	White ^b
Physical state	Solid	Solid ^b	Solid ^b
Melting point	2,785 °C	~2,800 °C ^b	170 °C (decomposes) ^b
Boiling point	6,000 °C	No data ^b	Sublimes in vacuo ^{b,d}
Density (g/cm ³)	15.6	14.8 ^b	2.65 ^b
Odor	No data	No data	No data
Odor threshold:			
Water (mL/g)	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	Insoluble	Insoluble ^b	Insoluble ^b
Other solvent(s)	Soluble in nitric acid/ hydrogen fluoride; aqua regia	No data	Soluble in organic solvents ^b
Partition coefficients:			
K _d (mL/g)	Not applicable	Not applicable	No data
K _{ow}	Not applicable	Not applicable	No data
K _{oc}	Not applicable	Not applicable	No data
Vapor pressure	7.5x10 ⁻³ mm Hg at 3,204 °C ^b	No data	0.1 mm Hg at 20 °C ^c 1.20 mm Hg at 67 °C ^c
Henry's law constant	No data	No data	No data
Autoignition temperature	Not applicable	Not applicable	No data
Flashpoint	Not applicable	Not applicable	No data
Flammability limits	Not applicable	Not applicable	No data
Conversion factor	Not applicable	Not applicable	No data
Explosive limits	Not applicable	Not applicable	No data

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Table 4-2. Physical and Chemical Properties of Tungsten and Tungsten Compounds^a

Property	Tungsten chloride	Sodium tungstate, dihydrate	Sodium phosphotungstate
Molecular weight	396.56 ^b	329.85 ^b	No data
Color	Purple ^b	White ^b ; colorless ^e	White ^c
Physical state	Solid ^b	Solid ^b	Solid ^d
Melting point	275 °C	Decomposes at 100 °C with loss of water ^d and then melts at 692 °C ^f	No data
Boiling point	346.75 °C	Not applicable	No data
Density (g/cm ³)	3.52	3.25 ^b	No data
Odor	No data	Odorless	Odorless
Odor threshold:			
Water (mL/g)	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	Decomposes ^d	Very soluble ^b ; about 1.1 parts water (ca. 1x10 ⁶ mg/L) ^c	Very soluble ^e
Other solvent(s)	Soluble in ethanol, organic solvents ^b , lingroin ^e	Insoluble in alcohol and acids ^e	Very soluble in alcohols ^e
Partition coefficients:			
K _d (mL/g)	No data	No data	No data
K _{ow}	No data	No data	No data
K _{oc}	No data	No data	No data
Vapor pressure	43 mm Hg at 215 °C ^e	No data	No data
Henry's law constant	No data	No data	No data
Autoignition temperature	No data	Not applicable	No data
Flashpoint	No data	Not applicable	No data
Flammability limits	No data	Not applicable	No data
Conversion factor	No data	Not applicable	No data
Explosive limits	No data	Not applicable	No data

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Table 4-2. Physical and Chemical Properties of Tungsten and Tungsten Compounds^a

Property	Ammonium paratungstate	Tungstate hexafluoride
Molecular weight	1779.16 ^f	297.83 ^b
Color	White ^e	Colorless ^b ; Pale yellow (liquid) ^c
Physical state	Solid ^e	Gas at room temperature ^b
Melting point	No data	2.3 °C ^b
Boiling point	No data	17 °C ^b
Density (g/cm ³)	No data	12.173 ^b
Odor	No data	No data
Odor threshold:		
Water	No data	No data
Air	No data	No data
Solubility:		
Water	Soluble ^e	Reacts with water ^b
Other solvent(s)	Insoluble in alcohol ^e	Dissolves in benzene, cyclohexane, or dioxane; soluble in anhydrous hydrogen fluoride ^e
Partition coefficients:		
K _d (mL/g)	No data	No data
K _{ow}	No data	No data
K _{oc}	No data	No data
Vapor pressure (mm Hg)	No data	Gas at room temperature ^b
Henry's law constant	No data	No data
Autoignition temperature	No data	No data
Flashpoint	No data	No data
Flammability limits	No data	No data
Conversion factor	No data	No data
Explosive limits	No data	No data

^aInformation obtained from HSDB 2004, except where noted.

^bLide 2000

^cO'Neil et al. 2001

^dPenrice 1997b

^eLewis 1997

^fAshford 1994

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tungsten oxide may also vary over a fixed range without change in crystalline structure (Penrice 1997b). A unique characteristic of tungsten is its ability to form condensed complex ions of polytungstates in acid solution (e.g., ammonium paratungstate, $[\text{NH}_4]_{10}[\text{H}_2\text{W}_{12}\text{O}_{42}] \cdot 4\text{H}_2\text{O}$). The tungstate anion (WO_4^{2-}) exists in monomeric form only in strongly alkaline solutions. In mildly alkaline solution, the tungstate anions begin to polymerize, and this progresses with decreasing pH (Lassner et al. 1996). Tungstate complexes (WO_4^{2-}) of the alkali metals and magnesium are soluble in water. Tungsten forms hard, refractory, and chemically stable interstitial compounds with nonmetals, particularly carbon, nitrogen, boron, and silicon (Penrice 1997b). Information regarding the physical and chemical properties of tungsten compounds is located in Table 4-2.