

CHAPTER 4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Molybdenum (Mo) is a naturally occurring metallic trace element found in natural minerals, but not as the free metal. Biologically, it is an important micronutrient in plants and animals, including humans. It is used widely in industry for metallurgical applications (EPA 1979).

Molybdenum metal is a dark-gray or black powder with a metallic luster (NLM 2020a). It is a transition element in Group 6 of the Periodic Table. It has oxidation states from -2 to +6. Commonly encountered compounds are those of molybdenum in oxidation state +6 (Mo(VI), MoO₃, molybdates) and +4 (Mo(IV), MoS₂). It does not occur naturally in the pure metallic form; it more commonly occurs in the mineral, molybdenite (Sebenik et al. 2012). Other naturally occurring molybdenum-containing minerals are powellite, wulfenite, ferrimolybdate, and ilsemannite; however, molybdenite is the primary commercial source of molybdenum. Molybdenum (VI) anions include molybdate (MoO₄²⁻) with molybdenum at the center of a tetrahedron of four oxygen atoms, and polymeric anions ('isopolymolybdates') of which the most common are heptamolybdate (Mo₇O₂₄⁶⁻) and octamolybdate (Mo₈O₂₆⁴⁻) (EPA 1979). These anions occur in sodium and ammonium salts, often hydrated, which are the common sources of molybdenum in commerce and industrial applications.

There are 33 known isotopes of molybdenum. Seven isotopes occur naturally: mass numbers 92, 94, 95, 96, 97, 98, and 100. ⁹⁸Mo is the most abundant isomer, comprising approximately 24.3% (Rumble et al. 2018). Radioisotopes of masses 83–91, 93, 99, and 101–115 have been reported. The only one of major worldwide importance is Mo-99 (⁹⁹Mo), a 100% beta-emitting isotope with a 65.976-hour radioactive half-life that is used to produce technetium-99m (Tc-99^m or ^{99m}Tc) for medical scans (Doll et al. 2014; Parma 2009; Richards 1989).

Under physiological conditions (pH >6.5), the molybdate anion, [MoO₄]²⁻, is the sole molybdenum species in aqueous media (Cruywagen 2000; Cruywagen et al. 2002). Molybdenum compounds (e.g., molybdenum trioxide and polymolybdates) transform rapidly to the [MoO₄]²⁻ ion under environmentally relevant test conditions (Deltombe et al. 1974; Greenwood and Earnshaw 1997). Protonated forms, such as [HMoO₄]⁻ and H₂MoO₄, are found at pH <5 (Smedley and Kinniburgh 2017). Molybdenum tends to be more mobile under alkaline conditions, but adsorption increases with decreasing pH (Goldberg et al. 2002).

4. CHEMICAL AND PHYSICAL INFORMATION

Information regarding the chemical identity of molybdenum and molybdenum compounds is provided in Table 4-1.

Table 4-1. Chemical Identity of Molybdenum and Compounds

Characteristic	Information		
Chemical name	Molybdenum ^a	Molybdenum disulfide ^b	Molybdenum trioxide ^c
Synonym(s) and registered trade names ^d	MChVL; TsM1; Amperit 105.054; Amperit 106.2; Metco 63	Molybdenite (natural mineral); molybdenum(IV) sulfide; DAG 325; Molykote	Molybdenum(VI) oxide; molybdic acid anhydride; molybdic anhydride; molybdic oxide
Chemical formula	Mo	MoS ₂	MoO ₃
CAS Registry Number	7439-98-7	1309-56-4/1317-33-5 (natural mineral form) ^e ; 12612-50-9 (synthetic form)	1313-27-5
Chemical name	Sodium molybdate ^f	Ammonium dimolybdate	Ammonium heptamolybdate tetrahydrate ^g
Synonym(s) and registered trade names ^d	Disodium molybdate; molybdic acid, disodium salt ^e	Ammonium molybdenum oxide ^e	Ammonium paramolybdate tetrahydrate; hexammonium molybdate
Chemical formula	Na ₂ MoO ₄	(NH ₄) ₂ Mo ₂ O ₇	(NH ₄) ₆ Mo ₇ O ₂₄ ·4H ₂ O
CAS Registry Number	7631-95-0	27546-07-2	12054-85-2/12027-67-7 (anhydrous) ^h
Chemical name	Diammonium molybdate	Ammonium tetrathiomolybdate	
Synonym(s) and registered trade names ^d	Ammonium molybdate; molybdic acid, diammonium salt ⁱ	Tiomolibdate diammonium; ammonium molybdenum sulfide; ammonium tetrathiomolybdate; thiomolybdic acid, diammonium salt; Coprexa; TM; ATTM ^j	
Chemical formula	(NH ₄) ₂ MoO ₄	(NH ₄) ₂ MoS ₄	
CAS Registry Number	13106-76-8	15060-55-6	

^aAll information in this column obtained from NLM (2020a), unless otherwise noted.

^bAll information in this column obtained from NLM (2020b), unless otherwise noted.

^cAll information in this column obtained from NLM (2020c), unless otherwise noted.

^dAdditional synonyms and trade names may be queried using the Common Chemistry service from Chemical Abstracts Service (<http://www.commonchemistry.org/>).

^eEPA 2019a.

^fAll information in this column obtained from NLM (2020d), unless otherwise noted.

^gAll information in this column obtained from NLM (2020e), unless otherwise noted.

^hOECD 2013.

ⁱEPA 2019b.

^jNLM 2019.

CAS = Chemical Abstracts Service

4. CHEMICAL AND PHYSICAL INFORMATION

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Metallic molybdenum, in the form of fine molybdenum powder, is considered nonflammable.

Information regarding the physical and chemical properties of molybdenum and molybdenum compounds is provided in Table 4-2. Much of the information presented was obtained from the chapter, Molybdenum and Molybdenum Compounds, in the Ullmann's Encyclopedia of Industrial Chemistry (Sebenik et al. 2012), or handbooks such as the CRC Handbook of Chemistry and Physics or the European Chemicals Agency (ECHA) registration dossiers.

4. CHEMICAL AND PHYSICAL INFORMATION

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

Property	Information		
Chemical name	Molybdenum	Molybdenite (natural mineral)/molybdenum disulfide	Molybdenum trioxide
Molecular weight	95.94	160.07	143.95
Color	Dull gray	Black	White, turns slightly blue in light
Physical state	Powder	Crystalline solid	Crystalline solid
Melting point	2,617°C	>1,600°C (rhombohedral crystal); did not melt at 1,800°C ^b	801°C
Boiling point	4,612°C	No data	1,155°C
Density/specific gravity	10.22 g/cm ³	5.05 g/cm ³	4.692 g/cm ³ (21°C)
Odor	No data	Odorless	Odorless ^c
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water at 25°C	Insoluble; 5.5–12 mg/L at 20°C and pH 3.5–4.3 ^d	Insoluble	490 mg/L (28°C)
Organic solvents	No data	Insoluble	Insoluble
Inorganic solvents	Dissolved by a mixture of concentrated nitric and concentrated hydrofluoric acids	Dissolves only in strongly oxidizing acids (e.g., aqua regia)	Soluble in aqueous alkali and ammonia; 14,000 mg/L in nitric acid (4 mol/L, 20°C)
Partition coefficients:			
Log K _{ow}	NA	NA	NA
Log K _{oc}	NA	NA	NA
Vapor pressure ^e :			
at 20°C	No data	No data	No data
at 2,469°C	7.5x10 ⁻³ mm Hg		
at 2,721°C	7.5x10 ⁻² mm Hg		
at 3,039°C	0.75 mm Hg		
at 3,434°C	7.5 mm Hg		
at 3,939°C	75 mm Hg		
at 4,606°C	750 mm Hg		
Henry's law constant at 25°C	NA	NA	NA
Autoignition temperature	NA	NA	NA
Flashpoint	NA	NA	NA
Flammability limits	Not flammable	Not flammable	Not flammable ^c
Explosive limits	NA	NA	NA
Conversion factors	NA	NA	NA

4. CHEMICAL AND PHYSICAL INFORMATION

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

Property	Information		
Chemical name	Sodium molybdate	Ammonium dimolybdate	Ammonium heptamolybdate tetrahydrate
Molecular weight	205.92	339.95	1,235.8
Color	White		White
Physical state	Crystalline powder ^f	Solid, powder ^g	Crystalline solid ^f
Melting point	687°C ^f	Decomposes from ca. 150°C ^g	Decomposition at 90°C ^h
Boiling point	Not applicable	Decomposes from ca. 150°C ^f	Decomposition at 90°C ^h
Density/specific gravity	3.5 g/cm ^h	2.97 at 20°C ^g	2.86 (20°C) ^f
Odor	Odorless ^f	Odorless ^f	Odorless ^f
Odor threshold:			
Water	No data	No data	No data
Air	No data	No data	No data
Solubility:			
Water	40 wt% (anhydrous salt in 100 g saturated solution, 25°C)	228.4 g/L (20°C, pH 6.8) ^g	206.5 g/L (20°C, tetrahydrate) ^f
Organic solvents	No data	No data	No data
Inorganic solvents	No data	No data	No data
Partition coefficients:			
Log K _{ow}	NA	NA	NA
Log K _{oc}	NA	NA	NA
Vapor pressure at 20°C	No data	No data	No data
Henry's law constant at 25°C	NA	NA	NA
Autoignition temperature	NA	No data	NA
Flashpoint	No data	No data	No data
Flammability limits	No data	Non flammable ^g	No data
Explosive limits	NA	NA	NA
Conversion factors	NA	NA	NA

4. CHEMICAL AND PHYSICAL INFORMATION

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

Property	Information	
Chemical name	Diammonium molybdate	Ammonium tetrathiomolybdate
Molecular weight	196.01	260.28
Color	Colorless, white, or slightly greenish-yellowish ⁱ	Deep red ^h
Physical state	Crystalline solid ^h	Crystalline solid ^h
Melting point	No data	>300°C ⁱ
Boiling point	No data	No data
Density	1.4 ⁱ	No data
Odor	Odorless ⁱ	No data
Odor threshold:		
Water	No data	No data
Air	No data	No data
Solubility:		
Water	>10,000 mg/L ^k ; 39 wt% (in 100 g saturated solution, 25°C)	Insoluble (hygroscopic) ^l
Organic solvents	No data	No data
Inorganic solvents	No data	No data
Partition coefficients:		
Log K _{ow}	NA	No data
Log K _{oc}	No data	No data
Vapor pressure at 25°C	No data	NA
Henry's law constant at 25°C	NA	No data
Autoignition temperature	NA	NA
Flashpoint	NA	NA
Flammability limits	Not flammable ⁱ	No data
Explosive limits	NA	NA
Conversion factors	NA	NA

^aAll information was obtained from Sebenik et al. (2012) unless otherwise noted.

^bCannon 1959.

^cNOAA 2015.

^dECHA 2019a.

^eLide 2005.

^fOECD 2013.

^gECHA 2019b.

^hHaynes et al. 2014.

ⁱNJDOH 2009.

^jSigma-Aldrich 2015.

^kECHA 2019c.

^lAlfa Aesar 2015.

NA = not applicable