

4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

Copper is the first element of Group IB of the periodic table and displays four oxidation states: Cu(O), Cu(I), Cu(II), and Cu(III). Along with silver and gold, it is classified as a noble metal and, like them, can be found in nature in the elemental form. Copper's unique chemical and physical properties have made it one of the most important metals. These properties include high thermal conductivity, high electrical conductivity, malleability, low corrosion, alloying ability, and pleasing appearance. Properties of metallic copper such as electrical conductivity and fabricability vary markedly with purity. Standard classifications have been defined according to processing method. For example, ASTM B5-74 is >99.90% pure and is the accepted basic standard for electrolyte copper wire bars, etc. (Tuddenham and Dougall 1978). Data on the chemical identity of copper are shown in Table 4-1. Data on the chemical identity of copper sulfate, the most important commercial compound of copper, are shown in Table 4-2.

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Copper is positioned below hydrogen in the electromotive-force series, so it will not displace hydrogen ions from dilute acid. Accordingly, copper will not dissolve in acid unless an oxidizing agent is present. Therefore, while it readily dissolves in nitric and hot concentrated sulfuric acid, it only dissolves slowly in hydrochloric and dilute sulfuric acid, and then only when exposed to the atmosphere (Hawley 1981). It is also attacked by acetic acid and other organic acids. When exposed to moist air, a characteristic green layer of the basic copper carbonate slowly forms (Windholz 1983). This tightly adherent coating protects the underlying metal from further attack and is also prized for its appearance. Copper dissolves in ammonia in the presence of air, forming the cupric ammonium complex ion $\text{Cu}(\text{NH}_3)_4^{2+}$ (Cotton and Wilkinson 1980).

Cu(I) or the cuprous ion disproportionates rapidly (<1 second) in aqueous solution to form Cu(II) and Cu(0) (Cotton and Wilkinson 1980). The only Cu(I) compounds that are stable in water are extremely insoluble ones such as CuCl. It has been shown that Cu(I) complexes may be formed in seawater by photochemical processes and may persist for several hours (Moffett and Zika 1987). Cuprous compounds are generally colorless.

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Table 4-1. Chemical Identity of Copper

Characteristic	Information	Reference
Chemical name	Copper	
Synonym(s)	Not reported	
Registered trade names(s)	Not reported	
Chemical formula	Cu	HSDB 2004
Chemical structure	Face-centered cubic	Budavari 2001
Identification numbers:		
CAS registry	7440-50-8	HSDB 2004
NIOSH RTECS	GL5324000	HSDB 2004
EPA hazardous waste	Not reported	
OHM/TADS	Not reported	
DOT/UN/NA/IMCO shipping	Not reported	
HSDB	1622	HSDB 2004
NCI	Not reported	

CAS = Chemical Abstracts Services; 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. Chemical Identity of Copper Sulfate

Characteristic	Information	Reference
Chemical name	Copper sulfate	
Synonym(s)	Cupric sulfate; blue stone; blue vitriol; cupric sulphate; Roman vitriol; Salzburg vitriol; blue copperas; copper(II) sulfate	Budavari 2001; Hawley 1997; HSDB 2004
Registered trade names(s)	Not reported	
Chemical formula	CuO ₄ S	Budavari 2001
Chemical structure	CuSO ₄	Budavari 2001
Identification numbers:		
CAS registry	7758-98-7	HSDB 2004
NIOSH RTECS	GL8800000	HSDB 2004
EPA hazardous waste	Not reported	
OHM/TADS	Not reported	
DOT/UN/NA/IMCO shipping	Not reported	
HSDB	916	HSDB 2004
NCI	Not reported	

CAS = Chemical Abstracts Services; 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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Cu(II) or the cupric ion is the most important oxidation state of copper. Cu(II) is the oxidation state of copper generally encountered in water (Cotton and Wilkinson 1980). Cupric ions are coordinated with six water molecules in solution; the arrangement of the water molecules is distorted in that there are four molecules bound closely to the copper in a planar array while the other two are more loosely bound in polar position (Cotton and Wilkinson 1980). Addition of ligands such as NH_3 to the solution will successively displace only the four planar water molecules. Most cupric compounds and complexes are blue or green in color. They are frequently soluble in water.

When Cu(II) is introduced into the environment, the cupric ion typically binds to inorganic and organic materials contained within water, soil, and sediments. In water, Cu(II) binds to dissolved organics (e.g., humic or fulvic acids). The Cu(II) ion forms stable complexes with $-\text{NH}_2$, $-\text{SH}$ and, to a lesser extent, $-\text{OH}$ groups of these organic acids. Cu(II) will also bind to inorganic and organic components in sediments and soils with varying affinities. For example, Cu(II) binds strongly to hydrous manganese and iron oxides in clay and to humic acids in organic matter, but much less strongly to aluminosilicates in sand. As in water, the binding affinities of Cu(II) with inorganic and organic matter in sediments and soils is dependent on pH, the oxidation-reduction potential in the local environment, and the presence of competing metal ions and inorganic anions.

Cu(III) is strongly oxidizing and only occurs in a few compounds (Kust 1978). At this time, none of these compounds are industrially important or environmentally significant.

Data on the physical and chemical properties of copper and copper sulfate are shown in Table 4-3.

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Table 4-3. Physical and Chemical Properties of Copper and Copper Sulfate

Property	Copper	Copper sulfate
Molecular weight	63.546 ^a	159.61 ^a
Color	Reddish ^b	Blue crystals, white dehydrated ^b
Physical state	Solid ^b	Solid ^b
Melting point	1,083 ^c	Decomposes at 560 ^a
Boiling point	2,595 ^c	No data
Specific gravity (20/4 °C)	8.94 ^c	3.60 ^a 2.286 (pentahydrate) ^a
Odor	No data	None ^d
Odor threshold		
Air	No data	No data
Water	No data	No data
Taste	No data	No data
Taste threshold	No data	No data
pK _a		
Solubility:		
Water	Insoluble ^e	32.0g/100g (20 °C) ^f
Organic solvent(s)		Soluble in methanol, slightly soluble in ethanol ^b
Partition coefficients:		
Log K _{ow}	No data	No data
Log K _{oc}	No data	No data
Vapor pressure:	1 (1,628 °C) ^g	No data
Henry's law constant at 25 °C	No data	No data
Autoignition temperature	No data	No data
Flashpoint	No data	No data
Flammability limits	No data	No data
Conversion factors at 25 °C ppm to mg/m ³	Since these substances exist in the atmosphere in the particulate state, the concentration is expressed as mg/m ³ .	
Explosive limits	No data	No data

^aLide 2000^bLewis 1997^cBudavari et al. 2001^dMeister et al. 2001^eStewart and Lassiter 2001^fDean 1985^gLewis 2000pK_a = The dissociation constant of the conjugate acid