Copper(II) sulfate

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Copper (II) sulfate, also known as **cupric sulfate** or copper sulphate, is the inorganic compound with the chemical formula $CuSO_4$.

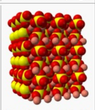
This salt exists as a series of compounds that differ in their degree of hydration. The anhydrous form is a pale green or gray-white powder, whereas the pentahydrate ($CuSO_4 \cdot 5H_2O$), the most commonly encountered salt, is bright blue. Copper (II) sulfate exothermically dissolves in water to give the aquo complex $[Cu(H_2O)_6]^{2+}$, which has octahedral molecular geometry and is paramagnetic. Other names for copper(II) sulfate are "blue vitriol" and "bluestone".[9]

Copper(II) sulfate


Anhydrous $CuSO_4$ powder


Crystals of $CuSO_4 \cdot 5H_2O$


Ball-and-stick model of $CuSO_4$


Space-filling model $CuSO_4$

Names	
IUPAC name	Copper(II) sulfate
Other names	Cupric sulfate Blue vitriol (pentahydrate) Bluestone (pentahydrate) Bonattite (trihydrate mineral) Boothite (heptahydrate mineral) Chalcanthite (pentahydrate mineral) Chalcocyanite (mineral)
Identifiers	
CAS Number	7758-98-7 ✓ 7758-99-8 (pentahydrate) ✗ 16448-28-5 (trihydrate) ✗ 19086-18-1 (heptahydrate) ✗
ChEBI	CHEBI:23414 ✓
ChEMBL	ChEMBL604 ✓
ChemSpider	22870 ✓
EC Number	231-847-6
Jmol 3D image	Interactive graph
KEGG	C18713 ✓
PubChem	24462
RTECS number	GL8800000 (anhydrous) GL8900000 (pentahydrate)
UNII	KUW2Q3U1VV ✓
InChI	[show]
SMILES	[show]
Properties	
Chemical formula	$CuSO_4$ (anhydrous) $CuSO_4 \cdot 5H_2O$ (pentahydrate)
Molar mass	159.609 g/mol (anhydrous)[1] 249.685 g/mol (pentahydrate)[1]
Appearance	gray–white (anhydrous) blue (pentahydrate)
Density	3.60 g/cm³ (anhydrous)[1] 2.286 g/cm³ (pentahydrate)[1]
Melting point	110 °C (230 °F; 383 K) decomposes (−5H₂O)[1] >560 °C decomposes[1]
Solubility in water	1.055 mol/al (10 °C) 1.26 mol/al (20 °C) 1.502 mol/al (30 °C)[2]
Solubility	anhydrous insoluble in ethanol[1] pentahydrate soluble in methanol[1] 10.4 g/L (18 °C) insoluble in ethanol
Refractive index (n_D)	1.724–1.739 (anhydrous)[3] 1.514–1.544 (pentahydrate)[4]
Structure	
Crystal structure	Orthorhombic (anhydrous, chalcocyanite), space group Pnma, oP24, a = 0.839 nm, b = 0.669 nm, c = 0.483 nm,[5] Triclinic (pentahydrate), space group P$\bar{1}$, aP22, a = 0.5986 nm, b = 0.6141 nm, c = 1.0736 nm, α = 77.333°, β = 82.267°, γ = 72.567°[5]
Thermochemistry	
Std molar entropy (S°_{298})	5 J K⁻¹ mol⁻¹
Std enthalpy of formation ($\Delta_f H^{\circ}_{298}$)	−769.98 kJ/mol
Pharmacology	
ATC code	V03AB20 (WHO)
Hazards	
Safety data sheet	anhydrous pentahydrate
GHS pictograms	
EU classification (DSD)	Harmful (**Xn**) Irritant (**Xi**) Dangerous for the environment (**N**)
R-phrases	R22, R36/38, R50/53
S-phrases	(S2), S22, S60, S61
NFPA 704	
Flash point	Non-flammable
Lethal dose or concentration (LD, LC): LD_{50} (Median dose)	300 mg/kg (oral, rat)[6]
US health exposure limits (NIOSH):	
PEL (Permissible)	TWA 1 mg/m³ (as Cu)[7]
REL (Recommended)	TWA 1 mg/m³ (as Cu)[7]
IDLH (Immediate danger)	TWA 100 mg/m³ (as Cu)[7]
Related compounds	
Other cations	Iron(II) sulfate Manganese(II) sulfate Nickel(II) sulfate Zinc sulfate

Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).

✗ verify (what is ✓/✗ ?)
Infobox references

Contents [hide]

Preparation and occurrence [edit]


Preparation of copper (II) sulfate by electrolyzing sulfuric acid, using copper electrodes

Copper sulfate is produced industrially by treating copper metal with hot concentrated sulfuric acid or its oxides with dilute sulfuric acid. For laboratory use, copper sulfate is usually purchased. Copper sulfate can also be produced by slowly leaching low grade copper ore in air; bacteria may be used to hasten the process.[10]

Commercial copper sulfate is usually about 98% pure copper sulfate, and may contain traces of water. Anhydrous Copper sulfate is 39.81 percent copper and 60.19 percent sulfate by mass, and in its blue, hydrous form, it is 25.47% copper, 38.47% sulfate (12.82% sulfur) and 36.06% water by mass. Four types of crystal size are provided based on its usage: large crystals (10-40mm), small crystals (2-10 mm), snow crystals (less than 2 mm), and windswept powder (less than 0.15 mm).[11]

The anhydrous form occurs as a rare mineral known as chalcocyanite. The hydrated copper sulfate occurs in nature as chalcanthite (pentahydrate), and two more rare ones: bonattite (trihydrate) and boothite (heptahydrate).


The rare mineral boothite ($CuSO_4 \cdot 7H_2O$)

Chemical properties [edit]

Copper (II) sulfate pentahydrate decomposes before melting at 150 °C (302 °F), losing two water molecules at 63 °C (145 °F), followed by two more at 109 °C (228 °F) and the final water molecule at 200 °C (392 °F).[12][13] Dehydration proceeds by decomposition of the tetraaquacopper(2+) moiety, two opposing aqua groups are lost to give a diaquacopper(2+) moiety. The second dehydration step occurs with the final two aqua groups are lost. Complete dehydration occurs when the only unbound water molecule is lost. At 650 °C (1,202 °F), copper (II) sulfate decomposes into copper (II) oxide (CuO) and sulfur trioxide (SO_3).

Copper sulfate reacts with concentrated hydrochloric acid to give tetrachlorocuprate(II):

$$Cu^{2+} + 4\ Cl^- \rightarrow CuCl_4^{2-}$$

It also reacts with more reducing metals to give copper metal and the corresponding oxidized metal, e.g.

$$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$$

Uses [edit]

As a herbicide, fungicide and pesticide [edit]

Copper sulfate pentahydrate is a fungicide.[14] However, some fungi are capable of adapting to elevated levels of copper ions.[15] Mixed with lime it is called Bordeaux mixture and used to control fungus on grapes, melons, and other berries.[16]

$$Cu^{2+} + SO_4^{2-} + Ca^{2+} + 2(OH)^- \rightarrow Cu(OH)_2 + CaSO_4$$

Another application is Cheshunt compound, a mixture of copper sulfate and ammonium carbonate used in horticulture to prevent damping off in seedlings. Its use as a herbicide is not agricultural, but instead for control of invasive aquatic plants and the roots of plants near pipes containing water. It is used in swimming pools as an algicide. A dilute solution of copper sulfate is used to treat aquarium fish for parasitic infections,[17] and is also used to remove snails from aquariums. Copper ions are highly toxic to fish, so care must be taken with the dosage. Most species of algae can be controlled with very low concentrations of copper sulfate. Copper sulfate inhibits growth of bacteria such as *Escherichia coli*.

Niche uses [edit]

Copper(II) sulfate has attracted many niche applications over the centuries. In industry copper sulfate has multiple applications. In printing it is an additive to book binding pastes and glues to protect paper from insect bites; in building it is an additive to concrete to provide water resistance and to make it antiseptic. Copper sulfate can also be used as a coloring ingredient in artworks, especially glasses and potteries.[18] Copper sulfate is also used in firework manufacture as a blue coloring agent, but it is not safe to mix copper sulfate with chlorates when mixing firework powders.[19]

Analytical reagent [edit]

Several chemical tests utilize copper sulfate. It is used in Fehling's solution and Benedict's solution to test for reducing sugars, which reduce the soluble blue copper(II) sulfate to insoluble red copper(I) oxide. Copper(II) sulfate is also used in the Biuret reagent to test for proteins.

Copper sulfate is also used to test blood for anemia. The blood is tested by dropping it into a solution of copper sulfate of known specific gravity – blood which contains sufficient hemoglobin sinks rapidly due to its density, whereas blood which does not sink or sinks slowly has insufficient amount of hemoglobin.[20]

In a flame test, its copper ions emit a deep green light, a much deeper green than the flame test for barium.

Organic synthesis [edit]

Copper sulfate is employed at a limited level in organic synthesis.[21] The anhydrous salt is used as a dehydrating agent for forming and manipulating acetal groups.[22] The hydrated salt can be intimately mingled with potassium permanganate to give an oxidant for the conversion of primary alcohols.[23]

Chemistry education [edit]

Copper sulfate is commonly included in children's chemistry sets. It is often used to grow crystals in schools and in copper plating experiments, despite its toxicity. Copper sulfate is often used to demonstrate an exothermic reaction, in which steel wool or magnesium ribbon is placed in an aqueous solution of $CuSO_4$. It is used to demonstrate the principle of mineral hydration. The pentahydrate form, which is blue, is heated, turning the copper sulfate into the anhydrous form which is white, while the water that was present in the pentahydrate form evaporates. When water is then added to the anhydrous compound, it turns back into the pentahydrate form, regaining its blue color, and is known as blue vitriol.[24] Copper(II) sulfate pentahydrate can easily be produced by crystallization from solution as copper(II) sulfate is quite hygroscopic.

In an illustration of a "single metal replacement reaction", iron is submerged in a solution of copper sulfate. Upon standing, iron reacts, producing iron(II) sulfate, and copper precipitates.

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

In high school and general chemistry education, copper sulfate is used as electrolyte for galvanic cells, usually as a cathode solution. For example, in a zinc/copper cell, copper ion in copper sulfate solution absorbs electron from zinc and forms metallic copper. [25]

$$Cu^{2+} + 2e^- \rightarrow Cu \text{ (cathode) } E^{\circ}\text{cell} = 0.34V$$

Medical and public health [edit]

Copper sulfate was also used in the past as an emetic.[26] It is now considered too toxic for this use.[27] It is still listed as an antidote in the World Health Organization's Anatomical Therapeutic Chemical Classification System.[28] Copper sulfate was once used to fight malaria. For example, during the 1940s in Trinidad, a malaria epidemic was caused by an increase of mosquito habitat in bromeliads growing on newly-imported immortelle (*Erythrina micropteryx*) trees. The epidemic was controlled by spraying dilute copper sulfate solution into these epiphytes, killing them and removing the mosquito breeding grounds.[29] Copper sulfate is also used as a molluscicide to treat bilharzia in tropical countries.[30] Cupric sulfate is also used to assist with the treatment of cutaneous phosphorus burns; however, it is not recommended for this purpose due to its toxicity.[31]

Art [edit]

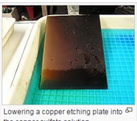
In 2008, the artist Roger Hiorns filled an abandoned waterproofed council flat in London with 75,000 liters of copper sulfate solution. The solution was left to crystallize for several weeks before the flat was drained, leaving crystal-covered walls, floors and ceilings. The work is titled *Seizure*.[32] Since 2011, it has been on exhibition at the Yorkshire Sculpture Park.[33]

Etching [edit]

Copper sulfate is also used to etch zinc or copper plates for intaglio printmaking.[34][35] It is also used to etch designs into copper for jewelry, such as for Champlevé.[36]

Dyeing [edit]

Copper sulfate can also be used as a mordant in vegetable dyeing. It often highlights the green tints of the specific dyes.


Lowering a copper etching plate into the copper sulfate solution.

Toxicological effects [edit]

Copper sulfate is an irritant.[37] The usual routes by which humans can receive toxic exposure to copper sulfate are through eye or skin contact, as well as by inhaling powders and dusts.[38] Skin contact may result in itching or eczema.[39] Eye contact with copper sulfate can cause conjunctivitis, inflammation of the eyelid lining, ulceration, and clouding of the cornea.[40]

Upon oral exposure, copper sulfate is moderately toxic;[26] According to studies, the lowest dose of copper sulfate that had a toxic impact on humans is 11 mg/kg.[41] Because of its irritating effect on the gastrointestinal tract, vomiting is automatically triggered in case of the ingestion of copper sulfate. However, if copper sulfate is retained in the stomach, the symptoms can be severe. After 1–12 grams of copper sulfate are swallowed, such poisoning signs may occur as a metallic taste in the mouth, burning pain in the chest, nausea, diarrhea, vomiting, headache, discontinued urination, which leads to yellowing of the skin. In cases of copper sulfate poisoning, injury to the brain, stomach, liver, or kidneys may also occur.[40]

Environmental toxicity [edit]

Copper sulfate is highly soluble in water and therefore is easy to distribute in the environment. Copper in the soil may be from industry, motor vehicle and architectural materials.[42] According to studies,[citation needed] copper sulfate exists mainly in the surface soil and tends to bind organic matter. The more acidic the soil is, the less binding occurs.

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External links [edit]

- International Chemical Safety Card 0751
- International Chemical Safety Card 1416
- National Pollutant Inventory – Copper and compounds fact sheet

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V · T · E **Copper compounds** [show]

V · T · E **Salts and the ester of the sulfate ion** [show]

V · T · E **Antidotes (V03AB)** [show]

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Categories: Copper compounds | Sulfates | Desiccants | Herbicides