[Template:Other uses](/wiki/Template:Other_uses" \o "Template:Other uses) [Template:Pp-move-indef](/wiki/Template:Pp-move-indef) [Template:Pp-vandalism](/wiki/Template:Pp-vandalism) [Template:Use dmy dates](/wiki/Template:Use_dmy_dates)

[Template:Good article](/wiki/Template:Good_article) [Template:Infobox copper](/wiki/Template:Infobox_copper) **Copper** is a [chemical element](/wiki/Chemical_element) with symbol **Cu** (from [Template:Lang-la](/wiki/Template:Lang-la)) and [atomic number](/wiki/Atomic_number) 29. It is a soft, malleable and [ductile](/wiki/Ductility) metal with very high [thermal](/wiki/Thermal_conductivity) and [electrical conductivity](/wiki/Electrical_conductivity). A freshly exposed surface of pure copper has a reddish-orange color. It is used as a conductor of heat and electricity, as a building material and as a constituent of various metal [alloys](/wiki/Alloy), such as [Sterling silver](/wiki/Sterling_silver) used in [jewelry](/wiki/Jewelry), [cupronickel](/wiki/Cupronickel) used to make marine hardware and [coins](/wiki/Coins) and [constantan](/wiki/Constantan) used in [strain gauges](/wiki/Strain_gauge) and [thermocouples](/wiki/Thermocouples) for temperature measurement.

Copper is found as a pure metal in nature, and this was the first source of the metal to be used by humans, ca. 8,000 BC. It was the first metal to be smelted from its ore, ca. 5,000 BC, the first metal to be cast into a shape in a mold, ca. 4,000 BC and the first metal to be purposefully alloyed with another metal, [tin](/wiki/Tin), to create [bronze](/wiki/Bronze), ca. 3,500 BC.[[1]](#cite_note-1) In the Roman era, copper was principally mined on [Cyprus](/wiki/Cyprus), the origin of the name of the metal, from *aes сyprium* (metal of Cyprus), later corrupted to *сuprum*, from which the words *copper* (English), *cuivre* (French), *Koper* (Dutch) and *Kupfer* (German) are all derived.[[2]](#cite_note-2) The commonly encountered compounds are copper(II) salts, which often impart blue or green colors to such minerals as [azurite](/wiki/Azurite), [malachite](/wiki/Malachite), and [turquoise](/wiki/Turquoise), and have been used widely and historically as pigments. Architectural structures built with copper (usually roofing elements) corrode to give green [verdigris](/wiki/Verdigris) (or [patina](/wiki/Patina)). [Decorative art](/wiki/Decorative_art) prominently features copper, both in the elemental metal and in compounds as pigments. Copper compounds are also used as [bacteriostatic agents](/wiki/Bacteriostatic_agent), [fungicides](/wiki/Fungicide), and wood preservatives.

Copper is essential to all living organisms as a trace [dietary mineral](/wiki/Dietary_mineral) because it is a key constituent of the respiratory enzyme complex [cytochrome c oxidase](/wiki/Cytochrome_c_oxidase). In [molluscs](/wiki/Molluscs) and [crustacea](/wiki/Crustacea) copper is a constituent of the blood pigment [hemocyanin](/wiki/Hemocyanin), replaced by the iron-complexed [hemoglobin](/wiki/Hemoglobin) in fish and other [vertebrates](/wiki/Vertebrate). In humans, copper is found mainly in the liver, muscle, and bone.[[3]](#cite_note-3) The adult body contains between 1.4 and 2.1 mg of copper per kilogram of body weight. Hence a healthy human weighing 60 kilogram contains approximately 0.1g of copper. However, this small amount is essential to the overall human well-being.[[4]](#cite_note-4)

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## Characteristics[[edit](/index.php?title=(none)&action=edit&section=1)]

### Physical[[edit](/index.php?title=(none)&action=edit&section=2)]

[thumb|left|150px|A copper disc (99.95% pure) made by](/wiki/File:Cu-Scheibe.JPG) [continuous casting](/wiki/Continuous_casting); [etched](/wiki/Industrial_etching) to reveal [crystallites](/wiki/Crystallite).

[left|150px|thumb|Copper just above its melting point keeps its pink luster color when enough light outshines the orange](/wiki/File:Copper_just_above_its_melting_point.jpg) [incandescence](/wiki/Incandescence) color. Copper, [silver](/wiki/Silver) and [gold](/wiki/Gold) are in [group 11](/wiki/Group_11_element) of the periodic table, and they share certain attributes: they have one s-orbital electron on top of a filled d-[electron shell](/wiki/Electron_shell) and are characterized by high [ductility](/wiki/Ductility) and electrical and thermal conductivity. The filled d-shells in these elements contribute little to interatomic interactions, which are dominated by the s-electrons through [metallic bonds](/wiki/Metallic_bond). Unlike metals with incomplete d-shells, metallic bonds in copper are lacking a [covalent](/wiki/Covalent_bond) character and are relatively weak. This observation explains the low [hardness](/wiki/Hardness) and high ductility of [single crystals](/wiki/Monocrystalline) of copper.<ref name=b1/> At the macroscopic scale, introduction of extended defects to the [crystal lattice](/wiki/Crystal_lattice), such as grain boundaries, hinders flow of the material under applied stress, thereby increasing its hardness. For this reason, copper is usually supplied in a fine-grained [polycrystalline](/wiki/Polycrystalline) form, which has greater strength than monocrystalline forms.[[5]](#cite_note-5) The softness of copper partly explains its high electrical conductivity (59.6×106 [S](/wiki/Siemens_(unit))/m) and high thermal conductivity, the second highest (second only to silver) among pure metals at room temperature.<ref name=CRC>[Template:Cite book](/wiki/Template:Cite_book)</ref> This is because the resistivity to electron transport in metals at room temperature originates primarily from scattering of electrons on thermal vibrations of the lattice, which are relatively weak in a soft metal.<ref name=b1/> The maximum permissible current density of copper in open air is approximately 3.1×106 A/m2 of cross-sectional area, above which it begins to heat excessively.[[6]](#cite_note-6) Copper is one of four metallic elements with a natural color other than gray or silver, the others being [caesium](/wiki/Caesium) (yellow), [gold](/wiki/Gold) (yellow), and [osmium](/wiki/Osmium) (bluish).[[7]](#cite_note-7) Pure copper is orange-red and acquires a reddish [tarnish](/wiki/Tarnish) when exposed to air. The characteristic color of copper results from the electronic transitions between the filled 3d and half-empty 4s atomic shells – the energy difference between these shells corresponds to orange light. The same mechanism causes the yellow color of gold and caesium.<ref name=b1>[Template:Cite book](/wiki/Template:Cite_book)</ref>

As with other metals, if copper is put in contact with another metal, [galvanic corrosion](/wiki/Galvanic_corrosion) will occur.[[8]](#cite_note-8)

### Chemical[[edit](/index.php?title=(none)&action=edit&section=3)]

[left|150px|thumb|Unoxidized copper wire (left) and oxidized copper wire (right).](/wiki/File:Copper_wire_comparison.JPG) [thumb|The East Tower of the](/wiki/File:Royal_Observatory_Edinburgh_East_Tower_2010_cropped.jpg) [Royal Observatory, Edinburgh](/wiki/Royal_Observatory,_Edinburgh). The contrast between the refurbished copper installed in 2010 and the green color of the original 1894 copper is clearly seen. Copper does not react with water but it does slowly react with atmospheric oxygen to form a layer of brown-black copper oxide which, unlike the [rust](/wiki/Rust) that forms on iron in moist air, protects the underlying metal from further corrosion ([passivation](/wiki/Passivation_(chemistry))). A green layer of [verdigris](/wiki/Verdigris) (copper carbonate) can often be seen on old copper structures, such as the roofing of many older buildings[[9]](#cite_note-9) and the [Statue of Liberty](/wiki/Statue_of_Liberty).[[10]](#cite_note-10) Copper [tarnishes](/wiki/Tarnish) when exposed to some [sulfur](/wiki/Sulfur) compounds, with which it reacts to form various [copper sulfides](/wiki/Copper_sulfide).[[11]](#cite_note-11)

### Isotopes[[edit](/index.php?title=(none)&action=edit&section=4)]

[Template:Main article](/wiki/Template:Main_article) There are 29 [isotopes](/wiki/Isotope) of copper. 63Cu and 65Cu are stable, with 63Cu comprising approximately 69% of naturally occurring copper; both have a [spin](/wiki/Spin_(physics)) of [Template:Frac](/wiki/Template:Frac).[[12]](#cite_note-12) The other isotopes are [radioactive](/wiki/Radioactivity), with the most stable being 67Cu with a [half-life](/wiki/Half-life) of 61.83 hours.[[12]](#cite_note-12) Seven [metastable isotopes](/wiki/Nuclear_isomer) have been characterized; 68mCu is the longest-lived with a half-life of 3.8 minutes. Isotopes with a [mass number](/wiki/Mass_number) above 64 decay by [β−](/wiki/Beta_decay), whereas those with a mass number below 64 decay by [β+](/wiki/Positron_emission). [64Cu](/wiki/Copper-64), which has a half-life of 12.7 hours, decays both ways.[[13]](#cite_note-13) 62Cu and 64Cu have significant applications. 62Cu is used in 62Cu-PTSM as a [radioactive tracer](/wiki/Radioactive_tracer) for [positron emission tomography](/wiki/Positron_emission_tomography).[[14]](#cite_note-14)

### Occurrence[[edit](/index.php?title=(none)&action=edit&section=5)]

[thumb|right|150px|Native copper from the Keweenaw Peninsula Michigan about 2.5 inches (6.4 cm) long](/wiki/File:Native_Copper_from_the_Keweenaw_Peninsula_Michigan.jpg) Copper is produced in massive stars[[15]](#cite_note-15) and is present in the Earth's crust in a proportion of about 50 parts per million (ppm).<ref name=emsley>[Template:Cite book](/wiki/Template:Cite_book)</ref> It occurs as [native copper](/wiki/Native_copper), in the copper sulfides [chalcopyrite](/wiki/Chalcopyrite) and [chalcocite](/wiki/Chalcocite), in the copper carbonates [azurite](/wiki/Azurite) and [malachite](/wiki/Malachite), and in the [copper(I) oxide](/wiki/Copper(I)_oxide) mineral [cuprite](/wiki/Cuprite).<ref name=CRC/> The largest mass of elemental copper discovered weighed 420 tonnes and was found in 1857 on the [Keweenaw Peninsula](/wiki/Keweenaw_Peninsula) in [Michigan](/wiki/Michigan), US.<ref name=emsley/> Native copper is a [polycrystal](/wiki/Polycrystal), with the largest single crystal ever described measuring 4.4×3.2×3.2 cm.[[16]](#cite_note-16)

## Production[[edit](/index.php?title=(none)&action=edit&section=6)]

[thumb|left|](/wiki/File:Chuquicamata-002.jpg)[Chuquicamata](/wiki/Chuquicamata) in Chile is one of the world's largest [open pit](/wiki/Open-pit_mining) copper [mines](/wiki/Mining). [thumb|World production trend](/wiki/File:Copper_-_world_production_trend.svg)

[thumb|Copper prices 2003–2011 in USD per tonne](/wiki/File:Copper_Price_History_USD.png)

[Template:See also](/wiki/Template:See_also)

Most copper is mined or [extracted](/wiki/Copper_extraction_techniques) as copper sulfides from large [open pit mines](/wiki/Open_pit_mine) in [porphyry copper](/wiki/Porphyry_copper) deposits that contain 0.4 to 1.0% copper. Sites include [Chuquicamata](/wiki/Chuquicamata) in Chile, [Bingham Canyon Mine](/wiki/Bingham_Canyon_Mine) in Utah, United States and [El Chino Mine](/wiki/El_Chino_Mine) in New Mexico, United States. According to the [British Geological Survey](/wiki/British_Geological_Survey) in 2005, Chile was the top producer of copper with at least one-third world share followed by the United States, Indonesia and Peru.<ref name=CRC/> Copper can also be recovered through the [in-situ leach](/wiki/In-situ_leach) process. Several sites in the state of Arizona are considered prime candidates for this method.[[17]](#cite_note-17) The amount of copper in use is increasing and the quantity available is barely sufficient to allow all countries to reach developed world levels of usage.[[18]](#cite_note-18)

### Reserves[[edit](/index.php?title=(none)&action=edit&section=7)]

[Template:See also](/wiki/Template:See_also) Copper has been in use at least 10,000 years, but more than 95% of all copper ever mined and [smelted](/wiki/Smelting) has been extracted since 1900,<ref name=Leonard2006/> and more than half was extracted the last 24 years. As with many natural resources, the total amount of copper on Earth is vast, with around 1014 tons in the top kilometer of Earth's crust, which is about 5 million years' worth at the current rate of extraction. However, only a tiny fraction of these reserves is economically viable with present-day prices and technologies. Estimates of copper reserves available for mining vary from 25 years to 60 years, depending on core assumptions such as the growth rate.[[19]](#cite_note-19) Recycling is a major source of copper in the modern world.<ref name=Leonard2006>[Template:Cite web](/wiki/Template:Cite_web)</ref> Because of these and other factors, the future of copper production and supply is the subject of much debate, including the concept of [peak copper](/wiki/Peak_copper), analogous to [peak oil](/wiki/Peak_oil).

The price of copper has historically been unstable,[[20]](#cite_note-20) and it sextupled from the 60-year low of US$0.60/lb (US$1.32/kg) in June 1999 to US$3.75 per pound (US$8.27/kg) in May 2006. It dropped to US$2.40/lb (US$5.29/kg) in February 2007, then rebounded to US$3.50/lb (US$7.71/kg) in April 2007.[[21]](#cite_note-21)[Template:Better source](/wiki/Template:Better_source) In February 2009, weakening global demand and a steep fall in commodity prices since the previous year's highs left copper prices at US$1.51/lb (US$3.32/kg).[[22]](#cite_note-22)

### Methods[[edit](/index.php?title=(none)&action=edit&section=8)]

[Template:Main article](/wiki/Template:Main_article) [left|thumb|Scheme of flash smelting process](/wiki/File:Copper_Flash_Smelting_Process_(EN).svg) The concentration of copper in ores averages only 0.6%, and most commercial ores are sulfides, especially chalcopyrite (CuFeS2) and to a lesser extent chalcocite (Cu2S).<ref name=G&E/> These minerals are concentrated from [crushed](/wiki/Comminution) ores to the level of 10–15% copper by [froth flotation](/wiki/Froth_flotation) or [bioleaching](/wiki/Bioleaching).[[23]](#cite_note-23) Heating this material with [silica](/wiki/Silica) in [flash smelting](/wiki/Flash_smelting) removes much of the iron as [slag](/wiki/Slag). The process exploits the greater ease of converting iron sulfides into oxides, which in turn react with the silica to form the [silicate](/wiki/Silicate) slag that floats on top of the heated mass. The resulting *copper matte,* consisting of Cu2S, is [roasted](/wiki/Roasting_(metallurgy)) to convert all sulfides into oxides:<ref name=G&E>[Template:Greenwood&Earnshaw2nd](/wiki/Template:Greenwood&Earnshaw2nd)</ref>

2 Cu2S + 3 O2 → 2 Cu2O + 2 SO2

The cuprous oxide is converted to *blister* copper upon heating:

2 Cu2O → 4 Cu + O2

The Sudbury [matte](/wiki/Matte_(metallurgy)) process converted only half the sulfide to oxide and then used this oxide to remove the rest of the sulfur as oxide. It was then electrolytically refined and the anode mud exploited for the [platinum](/wiki/Platinum) and gold it contained. This step exploits the relatively easy reduction of copper oxides to copper metal. [Natural gas](/wiki/Natural_gas) is blown across the blister to remove most of the remaining oxygen and [electrorefining](/wiki/Electrorefining) is performed on the resulting material to produce pure copper:[[24]](#cite_note-24):Cu2+ + 2 e− → Cu

### Recycling[[edit](/index.php?title=(none)&action=edit&section=9)]

Like [aluminium](/wiki/Aluminium), copper is 100% recyclable without any loss of quality, both from raw state and from manufactured products. In volume, copper is the third most recycled metal after iron and aluminium.[Template:Citation needed](/wiki/Template:Citation_needed) An estimated 80% of all copper ever mined is still in use today.[[25]](#cite_note-25) According to the [International Resource Panel's](/wiki/International_Resource_Panel) [Metal Stocks in Society report](/wiki/Metal_Stocks_in_Society_report), the global per capita stock of copper in use in society is 35–55 kg. Much of this is in more-developed countries (140–300 kg per capita) rather than less-developed countries (30–40 kg per capita).

The process of recycling copper is roughly the same as is used to extract copper but requires fewer steps. High-purity scrap copper is melted in a [furnace](/wiki/Furnace#Metallurgical_furnace) and then [reduced](/wiki/Redox) and cast into [billets](/wiki/Billet_(semi-finished_product)) and [ingots](/wiki/Ingot); lower-purity scrap is refined by [electroplating](/wiki/Electroplating) in a bath of [sulfuric acid](/wiki/Sulfuric_acid).[[26]](#cite_note-26)

## Alloys[[edit](/index.php?title=(none)&action=edit&section=10)]

[Template:See also](/wiki/Template:See_also) Numerous copper [alloys](/wiki/Alloy) have been formulated, many with important uses. [Brass](/wiki/Brass) is an alloy of copper and [zinc](/wiki/Zinc). [Bronze](/wiki/Bronze) usually refers to copper-[tin](/wiki/Tin) alloys, but can refer to any alloy of copper such as [aluminium bronze](/wiki/Aluminium_bronze). Copper is one of the most important constituents of silver and [carat](/wiki/Carat_(purity)) gold and carat solders used in the jewelry industry, modifying the color, hardness and melting point of the resulting alloys.<ref name=goldalloys>[Template:Cite web](/wiki/Template:Cite_web)</ref> Some lead-free [solders](/wiki/Solder#Solder_alloys) consist of tin alloyed with a small proportion of copper and other metals.[[27]](#cite_note-27) The alloy of copper and [nickel](/wiki/Nickel), called [cupronickel](/wiki/Cupronickel), is used in low-denomination coins, often for the outer cladding. The US 5-cent coin (currently called a *nickel*) consists of 75% copper and 25% nickel in homogeneous composition. The alloy of 90% copper and 10% nickel, remarkable for its resistance to corrosion, is used for various objects exposed to seawater, though it is vulnerable to the sulfides sometimes found in polluted harbors and estuaries.[[28]](#cite_note-28) Alloys of copper with aluminium (about 7%) have a pleasant golden color and are used in decorations.<ref name=emsley/> [Shakudō](/wiki/Shakudō) is a Japanese decorative alloy of copper containing a low percentage of gold, typically 4-10%, that can be [patinated](/wiki/Patina) to a dark blue or black colour.<ref name=Shakudō>[Template:Cite journal](/wiki/Template:Cite_journal)</ref>

## Compounds[[edit](/index.php?title=(none)&action=edit&section=11)]

[thumb|A sample of](/wiki/File:CopperIoxide.jpg) [copper(I) oxide](/wiki/Copper(I)_oxide). [Template:See also](/wiki/Template:See_also)

Copper forms a rich variety of compounds, usually with [oxidation states](/wiki/Oxidation_state) +1 and +2, which are often called *cuprous* and *cupric*, respectively.[[29]](#cite_note-29)

### Binary compounds[[edit](/index.php?title=(none)&action=edit&section=12)]

As with other elements, the simplest compounds of copper are binary compounds, i.e. those containing only two elements, the principal examples being oxides, sulfides, and [halides](/wiki/Halide). Both [cuprous](/wiki/Copper(I)_oxide) and [cupric oxides](/wiki/Copper(II)_oxide) are known. Among the numerous [copper sulfides](/wiki/Copper_sulfide), important examples include [copper(I) sulfide](/wiki/Copper(I)_sulfide) and [copper(II) sulfide](/wiki/Copper_monosulfide).

Cuprous halides (with [chlorine](/wiki/Copper(I)_chloride), [bromine](/wiki/Copper(I)_bromide), and [iodine](/wiki/Copper(I)_iodide)) are known, as are cupric halides with [fluorine](/wiki/Copper(II)_fluoride), [chlorine](/wiki/Copper(II)_chloride), and [bromine](/wiki/Copper(II)_bromide). Attempts to prepare copper(II) iodide yield only cuprous iodide and iodine.[[29]](#cite_note-29):2 Cu2+ + 4 I− → 2 CuI + I2

### Coordination chemistry[[edit](/index.php?title=(none)&action=edit&section=13)]

[thumb|left|Copper(II) gives a deep blue coloration in the presence of ammonia ligands. The one used here is](/wiki/File:Tetramminkupfer(II)-sulfat-Monohydrat_Kristalle.png) [tetramminecopper(II) sulfate](/wiki/Tetraamminecopper(II)_sulfate). Copper forms [coordination complexes](/wiki/Coordination_complex) with [ligands](/wiki/Ligand). In aqueous solution, copper(II) exists as [Cu(H2O)6]2+. This complex exhibits the fastest water exchange rate (speed of water ligands attaching and detaching) for any transition [metal aquo complex](/wiki/Metal_aquo_complex). Adding aqueous [sodium hydroxide](/wiki/Sodium_hydroxide) causes the precipitation of light blue solid [copper(II) hydroxide](/wiki/Copper(II)_hydroxide). A simplified equation is: [thumbnail|Pourbaix diagram for copper in uncomplexed media (anions not other than OH- considered). Ion concentration 0.001 m (mol/kg water). Temperature 25°C.](/wiki/File:Cu-pourbaix-diagram.svg)

Cu2+ + 2 OH− → Cu(OH)2

[Aqueous ammonia](/wiki/Ammonia_solution) results in the same precipitate. Upon adding excess ammonia, the precipitate dissolves, forming [tetraamminecopper(II)](/wiki/Schweizer's_reagent):

Cu(H2O)4(OH)2 + 4 NH3 → [Cu(H2O)2(NH3)4]2+ + 2 H2O + 2 OH−

Many other [oxyanions](/wiki/Oxyanion) form complexes; these include [copper(II) acetate](/wiki/Copper(II)_acetate), [copper(II) nitrate](/wiki/Copper(II)_nitrate), and [copper(II) carbonate](/wiki/Copper(II)_carbonate). [Copper(II) sulfate](/wiki/Copper(II)_sulfate) forms a blue crystalline penta[hydrate](/wiki/Hydrate), the most familiar copper compound in the laboratory. It is used in a [fungicide](/wiki/Fungicide) called the [Bordeaux mixture](/wiki/Bordeaux_mixture).[[30]](#cite_note-30)[thumb|right|200px|](/wiki/File:Tetraamminediaquacopper(II)-3D-balls.png)[Ball-and-stick model](/wiki/Ball-and-stick_model) of the complex [Cu(NH3)4(H2O)2]2+, illustrating the [octahedral coordination geometry](/wiki/Octahedral_coordination_geometry) common for copper(II).

[Polyols](/wiki/Polyol), compounds containing more than one alcohol [functional group](/wiki/Functional_group), generally interact with cupric salts. For example, copper salts are used to test for [reducing sugars](/wiki/Reducing_sugars). Specifically, using [Benedict's reagent](/wiki/Benedict's_reagent) and [Fehling's solution](/wiki/Fehling's_solution) the presence of the sugar is signaled by a color change from blue Cu(II) to reddish copper(I) oxide.[[31]](#cite_note-31) Schweizer's reagent and related complexes with [ethylenediamine](/wiki/Ethylenediamine) and other [amines](/wiki/Amine) dissolve [cellulose](/wiki/Cellulose).[[32]](#cite_note-32) [Amino acids](/wiki/Amino_acid) form very stable [chelate complexes](/wiki/Chelate_complex) with copper(II). Many wet-chemical tests for copper ions exist, one involving [potassium ferrocyanide](/wiki/Potassium_ferrocyanide), which gives a brown precipitate with copper(II) salts.

### Organocopper chemistry[[edit](/index.php?title=(none)&action=edit&section=14)]

[Template:Main article](/wiki/Template:Main_article) Compounds that contain a carbon-copper bond are known as organocopper compounds. They are very reactive towards oxygen to form copper(I) oxide and have [many uses in chemistry](/wiki/Reactions_of_organocopper_reagents). They are synthesized by treating copper(I) compounds with [Grignard reagents](/wiki/Grignard_reaction), [terminal alkynes](/wiki/Terminal_alkyne) or [organolithium reagents](/wiki/Organolithium_compound);[[33]](#cite_note-33) in particular, the last reaction described produces a [Gilman reagent](/wiki/Gilman_reagent). These can undergo [substitution](/wiki/Substitution_reaction) with [alkyl halides](/wiki/Alkyl_halides) to form [coupling products](/wiki/Coupling_reaction); as such, they are important in the field of [organic synthesis](/wiki/Organic_synthesis). [Copper(I) acetylide](/wiki/Copper(I)_acetylide) is highly shock-sensitive but is an intermediate in reactions such as the [Cadiot-Chodkiewicz coupling](/wiki/Cadiot-Chodkiewicz_coupling)[[34]](#cite_note-34) and the [Sonogashira coupling](/wiki/Sonogashira_coupling).[[35]](#cite_note-35) [Conjugate addition](/wiki/Nucleophilic_conjugate_addition) to [enones](/wiki/Enone)[[36]](#cite_note-36) and [carbocupration](/wiki/Carbometalation) of alkynes[[37]](#cite_note-37) can also be achieved with organocopper compounds. Copper(I) forms a variety of weak complexes with [alkenes](/wiki/Alkene) and [carbon monoxide](/wiki/Carbon_monoxide), especially in the presence of amine ligands.[[38]](#cite_note-38)

### Copper(III) and copper(IV)[[edit](/index.php?title=(none)&action=edit&section=15)]

Copper(III) is most often found in oxides. A simple example is potassium [cuprate](/wiki/Cuprate), KCuO2, a blue-black solid.[[39]](#cite_note-39) The most extensively studied copper(III) compounds are the [cuprate superconductors](/wiki/Cuprate_superconductor). [Yttrium barium copper oxide](/wiki/Yttrium_barium_copper_oxide) (YBa2Cu3O7) consists of both Cu(II) and Cu(III) centres. Like oxide, [fluoride](/wiki/Fluoride) is a highly [basic](/wiki/Base_(chemistry)) [anion](/wiki/Anion)[[40]](#cite_note-40) and is known to stabilize metal ions in high oxidation states. Both copper(III) and even copper(IV) fluorides are known, [K3CuF6](/wiki/Potassium_hexafluorocuprate(III)) and [Cs2CuF6](/wiki/Caesium_hexafluorocuprate(IV)), respectively.<ref name=Holleman/>

Some copper proteins form [oxo complexes](/wiki/Oxo_complex), which also feature copper(III).[[41]](#cite_note-41) With [tetrapeptides](/wiki/Tetrapeptide), purple-colored copper(III) complexes are stabilized by the deprotonated [amide](/wiki/Amide) ligands.[[42]](#cite_note-42) Complexes of copper(III) are also found as intermediates in reactions of organocopper compounds.

## History[[edit](/index.php?title=(none)&action=edit&section=16)]

### Copper Age[[edit](/index.php?title=(none)&action=edit&section=17)]

[Template:Main article](/wiki/Template:Main_article) [left|thumb|A corroded copper](/wiki/File:Copper_Ingot_Crete.jpg) [ingot](/wiki/Ingot) from [Zakros](/wiki/Zakros), [Crete](/wiki/Crete), shaped in the form of an animal skin typical in that era. [thumb|Many tools during the](/wiki/File:ReconstructedOetziAxe.jpg) [Chalcolithic](/wiki/Chalcolithic) Era included copper, such as the blade of this replica of [Ötzi's](/wiki/Ötzi) axe [left|thumb|Copper ore (](/wiki/File:Chrysocolla_Timna_070613.jpg)[chrysocolla](/wiki/Chrysocolla)) in [Cambrian](/wiki/Cambrian) sandstone from [Chalcolithic](/wiki/Chalcolithic) mines in the [Timna Valley](/wiki/Timna_Valley), southern [Israel](/wiki/Israel). Copper occurs naturally as [native metallic copper](/wiki/Native_copper) and was known to some of the oldest civilizations on record. The history of copper use is at least 11,000 years old, estimated to have begun in 9000 BC in the Middle East;<ref name=discovery>[Template:Cite web](/wiki/Template:Cite_web)</ref> a copper pendant was found in northern Iraq that dates to 8700 BC.[[43]](#cite_note-43) Evidence suggests that gold and [meteoric iron](/wiki/Meteoric_iron) (but not iron smelting) were the only metals used by humans before copper.<ref name=vander>[Template:Cite web](/wiki/Template:Cite_web)</ref> The history of copper metallurgy is thought to follow this sequence: 1) [cold working](/wiki/Work_hardening) of native copper, 2) [annealing](/wiki/Annealing_(metallurgy)), 3) [smelting](/wiki/Smelting), and 4) the [lost wax casting](/wiki/Lost-wax_casting). In southeastern [Anatolia](/wiki/Anatolia), all four of these techniques appear more or less simultaneously at the beginning of the [Neolithic](/wiki/Neolithic) c. 7500 BC.[[44]](#cite_note-44) Just as agriculture was independently invented in several parts of the world, copper smelting was independently invented in different places. It was probably discovered in China before 2800 BC, in Central America perhaps around 600 AD, and in West Africa about the 9th or 10th century AD.[[45]](#cite_note-45) [Investment casting](/wiki/Investment_casting) was invented in 4500–4000 BC in Southeast Asia[[46]](#cite_note-46) and [carbon dating](/wiki/Carbon_dating) has established mining at [Alderley Edge](/wiki/Alderley_Edge) in [Cheshire](/wiki/Cheshire), UK at 2280 to 1890 BC.[[47]](#cite_note-47) [Ötzi the Iceman](/wiki/Ötzi_the_Iceman), a male dated from 3300–3200 BC, was found with an axe with a copper head 99.7% pure; high levels of [arsenic](/wiki/Arsenic) in his hair suggest his involvement in copper smelting.[[48]](#cite_note-48) Experience with copper has assisted the development of other metals; in particular, copper smelting led to the discovery of [iron smelting](/wiki/Bloomery).[[48]](#cite_note-48) Production in the [Old Copper Complex](/wiki/Old_Copper_Complex) in [Michigan](/wiki/Michigan) and [Wisconsin](/wiki/Wisconsin) is dated between 6000 and 3000 BC.[[49]](#cite_note-49)[[50]](#cite_note-50) Natural bronze, a type of copper made from ores rich in silicon, arsenic, and (rarely) tin, came into general use in the Balkans around 5500 BC.[Template:Citation needed](/wiki/Template:Citation_needed)

### Bronze Age[[edit](/index.php?title=(none)&action=edit&section=18)]

[Template:Main article](/wiki/Template:Main_article) Alloying copper with tin to make bronze was first practiced about 4000 years after the discovery of copper smelting, and about 2000 years after "natural bronze" had come into general use.[Template:Citation needed](/wiki/Template:Citation_needed) Bronze artifacts from the [Vinča culture](/wiki/Vinča_culture) date to 4500 BC.<ref name=antiquity1312>[Template:Cite web](/wiki/Template:Cite_web)</ref> [Sumerian](/wiki/Sumer) and [Egyptian](/wiki/Ancient_Egypt) artifacts of copper and bronze alloys date to 3000 BC.<ref name=hist>[Template:Cite book](/wiki/Template:Cite_book)</ref> The [Bronze Age](/wiki/Bronze_Age) began in Southeastern Europe around 3700–3300 BC, in Northwestern Europe about 2500 BC. It ended with the beginning of the Iron Age, 2000–1000 BC in the Near East, and 600 BC in Northern Europe. The transition between the [Neolithic](/wiki/Neolithic) period and the Bronze Age was formerly termed the [Chalcolithic](/wiki/Chalcolithic) period (copper-stone), when copper tools were used with stone tools. The term has gradually fallen out of favor because in some parts of the world, the Chalcolithic and Neolithic are coterminous at both ends. Brass, an alloy of copper and zinc, is of much more recent origin. It was known to the Greeks, but became a significant supplement to bronze during the Roman Empire.<ref name=hist/>

### Antiquity and Middle Ages[[edit](/index.php?title=(none)&action=edit&section=19)]

[thumb|left|100px|In](/wiki/File:Venus_symbol.svg) [alchemy](/wiki/Alchemy) the symbol for copper was also the symbol for the goddess and planet [Venus](/wiki/Venus). [thumb|Chalcolithic copper mine in](/wiki/File:TimnaChalcolithicMine.JPG) [Timna Valley](/wiki/Timna_Valley), [Negev Desert](/wiki/Negev_Desert), Israel.

In Greece, copper was known by the name *chalkos* (χαλκός). It was an important resource for the Romans, Greeks and other ancient peoples. In Roman times, it was known as *aes Cyprium*, *aes* being the generic Latin term for copper alloys and *Cyprium* from [Cyprus](/wiki/Cyprus), where much copper was mined. The phrase was simplified to *cuprum*, hence the English *copper*. [Aphrodite](/wiki/Aphrodite) ([Venus](/wiki/Venus_(goddess)) in Rome) represented copper in mythology and alchemy because of its lustrous beauty and its ancient use in producing mirrors; Cyprus was sacred to the goddess. The seven heavenly bodies known to the ancients were associated with the seven metals known in antiquity, and Venus was assigned to copper.[[51]](#cite_note-51) Britain first used brass in about the 3rd or 2nd Century BC. In North America, copper mining began with marginal workings by Native Americans. Native copper is known to have been extracted from sites on [Isle Royale](/wiki/Isle_Royale) with primitive stone tools between 800 and 1600.[[52]](#cite_note-52) Copper metallurgy was flourishing in South America, particularly in Peru around 1000 AD. Copper burial ornamentals from the 15th century have been uncovered, but the metal's commercial production did not start until the early 20th century.

The cultural role of copper has been important, particularly in currency. Romans in the 6th through 3rd centuries BC used copper lumps as money. At first, the copper itself was valued, but gradually the shape and look of the copper became more important. [Julius Caesar](/wiki/Julius_Caesar) had his own coins made from brass, while [Octavianus Augustus Caesar's](/wiki/Augustus) coins were made from Cu-Pb-Sn alloys. With an estimated annual output of around 15,000 t, [Roman copper mining and smelting activities](/wiki/Roman_metallurgy) reached a scale unsurpassed until the time of the [Industrial Revolution](/wiki/Industrial_Revolution); the [provinces](/wiki/Roman_province) most intensely mined were those of [Hispania](/wiki/Hispania), [Cyprus](/wiki/Cyprus) and in Central Europe.[[53]](#cite_note-53)[[54]](#cite_note-54) The gates of the [Temple of Jerusalem](/wiki/Temple_of_Jerusalem) used [Corinthian bronze](/wiki/Corinthian_bronze) treated with [depletion gilding](/wiki/Depletion_gilding).[Template:Clarify](/wiki/Template:Clarify)[Template:Citation needed](/wiki/Template:Citation_needed) The process was most prevalent in [Alexandria](/wiki/Alexandria), where alchemy is thought to have begun.[[55]](#cite_note-55) In ancient [India](/wiki/India), copper was used in the [holistic](/wiki/Holistic) medical science [Ayurveda](/wiki/Ayurveda) for [surgical](/wiki/Surgical) instruments and other medical equipment. Ancient [Egyptians](/wiki/Egyptians) (~2400 BC) used copper for sterilizing wounds and drinking water, and later to treat headaches, burns, and itching.

### Modern period[[edit](/index.php?title=(none)&action=edit&section=20)]

[right|thumb|](/wiki/File:AngleseyCopperStream.jpg)[Acid mine drainage](/wiki/Acid_mine_drainage) affecting the stream running from the disused [Parys Mountain](/wiki/Parys_Mountain) copper mines The [Great Copper Mountain](/wiki/Great_Copper_Mountain) was a mine in Falun, Sweden, that operated from the 10th century to 1992. It satisfied two thirds of Europe's copper consumption in the 17th century and helped fund many of Sweden's wars during that time.[[56]](#cite_note-56) It was referred to as the nation's treasury; Sweden had a [copper backed currency](/wiki/History_of_copper_currency_in_Sweden).[[57]](#cite_note-57) Copper was used in roofing,[[9]](#cite_note-9) currency, [Renaissance](/wiki/Renaissance) sculpture, photographic technology known as the [daguerreotype](/wiki/Daguerreotype), the [Statue of Liberty](/wiki/Statue_of_Liberty), and other structures. [Copper plating](/wiki/Copper_plating) and [copper sheathing](/wiki/Copper_sheathing) was widely used in the hulls of ships, of which the ships of Christopher Columbus were among the earliest.[[58]](#cite_note-58) The [Norddeutsche Affinerie](/wiki/Norddeutsche_Affinerie) in Hamburg was the first modern [electroplating](/wiki/Electroplating) plant starting its production in 1876.[[59]](#cite_note-59) The German scientist [Gottfried Osann](/wiki/Gottfried_Osann) invented [powder metallurgy](/wiki/Powder_metallurgy) in 1830 while determining the metal's atomic mass; around then it was discovered that the amount and type of alloying element (e.g., tin) to copper would affect bell tones. [Flash smelting](/wiki/Flash_smelting) was developed by [Outokumpu](/wiki/Outokumpu) in Finland and first applied at [Harjavalta](/wiki/Harjavalta) in 1949; the energy-efficient process accounts for 50% of the world's primary copper production.[[60]](#cite_note-60) The [Intergovernmental Council of Copper Exporting Countries](/wiki/Intergovernmental_Council_of_Copper_Exporting_Countries), formed in 1967 by Chile, Peru, Zaire and Zambia, operated in the copper market as [OPEC](/wiki/OPEC) does in oil, though it never achieved the same influence, particularly because the second-largest producer, the United States, was never a member; it was dissolved in 1988.[[61]](#cite_note-61)

## Applications[[edit](/index.php?title=(none)&action=edit&section=21)]

[Template:See also](/wiki/Template:See_also) [thumb|Assorted copper fittings](/wiki/File:Kupferfittings_4062.jpg) The major applications of copper are electrical wire (60%), roofing and plumbing (20%), and industrial machinery (15%). Copper is used mostly as a pure metal, but when greater hardness is required, it is put into such alloys as [brass](/wiki/Brass) and [bronze](/wiki/Bronze) (5% of total use).<ref name=emsley/> For more than two centuries, copper paint has been used on boat hulls to control the growth of plants and shellfish.[[62]](#cite_note-62) A small part of the copper supply is used for nutritional supplements and fungicides in agriculture.[[30]](#cite_note-30)[[63]](#cite_note-63) [Machining](/wiki/Machining) of copper is possible, although alloys are preferred for good [machinability](/wiki/Machinability) in creating intricate parts.

### Wire and cable[[edit](/index.php?title=(none)&action=edit&section=22)]

[Template:Main article](/wiki/Template:Main_article)

Despite competition from other materials, copper remains the preferred [electrical conductor](/wiki/Electrical_conductor) in nearly all categories of electrical wiring except overhead [electric power transmission](/wiki/Electric_power_transmission) where [aluminium](/wiki/Aluminium) is often preferred.[[64]](#cite_note-64)[[65]](#cite_note-65)