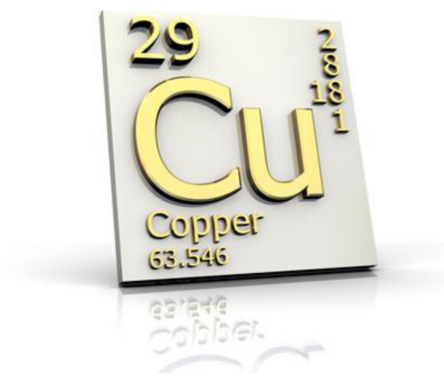
Copper: Properties and Applications

The word copper comes from the Latin word 'cuprum', which means 'ore of Cyprus'. This is why the chemical symbol for copper is Cu.

Copper has many extremely useful properties, including:
- good electrical conductivity
- good thermal conductivity
- corrosion resistance

It is also:
- easy to alloy
- antimicrobial
- easily joined
- ductile
- tough
- non-magnetic
- attractive
- recyclable
- catalytic

See below for more information on each of these properties, and how they benefit us in our daily lives.

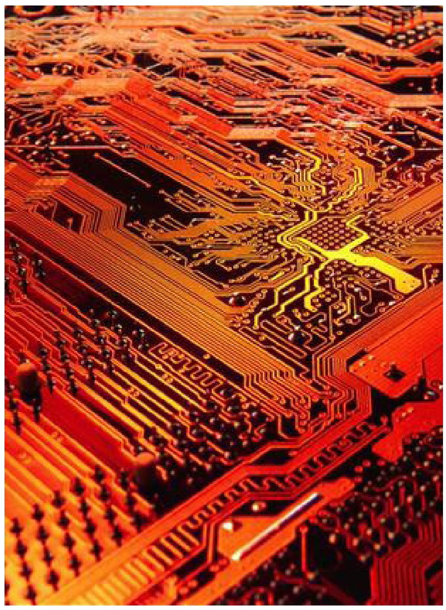


Copper is a metal with symbol Cu, atomic number 29 and atomic mass 63.55.

Good Electrical Conductivity

Copper has the best electrical conductivity of any metal, except silver.

A good electrical conductivity is the same as a small electrical resistance. An electric current will flow through all metals, however they still have some resistance, meaning the current needs to be pushed (by a battery) in order to keep flowing. The bigger the resistance, the harder we have to push (and the smaller the current is). Current flows easily through copper thanks to its small electrical resistance, without much loss of energy. This is why copper wires are used in mains cables in houses and underground (although overhead cables tend be aluminium because it is less dense). However, where size rather than weight is important, copper is the best choice. Thick copper strip is used for lightning conductors on tall buildings like church spires. The copper strip has to be thick so that it can carry a large current without melting.



An electrical circuit board benefiting from copper's good electrical conductivity.

Copper wire can be wound into a coil. The coil will produce a magnetic field and, being made of copper, won't waste much electrical energy. Copper coils can be found in:

Device	Use
Motors	Locks, scrapyard cranes, electric bells. (see Electromagnets) Pumps, domestic appliances (washing machines, dishwashers, fridges, vacuum cleaners), cars (starter motors, windscreen wipers, electric windows), computers (disc drives, fans), entertainment systems (DVD players). (See Electric Motors.)
Dynamos	Bicycles, power stations
Transformers	Mains adaptors, electricity substations, power stations. (See Copper and Electricity: Transformers.)

How copper conducts

Copper is a metal made up of copper atoms closely packed together.

If we could look closely enough, we would see that there are electrons moving about between the copper atoms.

Each copper atom has lost one electron and become a positive ion. So copper is a lattice of positive copper ions with free electrons moving between them. (The electrons are a bit like the particles of a gas that is free to move within the surfaces of the wire).

The electrons can move freely through the metal. For this reason, they are known as free electrons. They are also known as conduction electrons, because they help copper to be a good conductor of heat and electricity.

The copper ions are vibrating (Click on the link to the animated version above Figure 1). Notice that they vibrate around the same place whereas the electrons can move through the lattice. This is very important when we connect the wire to a battery.

Conducting electricity

We can connect a copper wire to a battery and a switch. Normally, the free electrons move about randomly in the metal. When we close the switch, an electric current flows. Now the free electrons flow through the wire (Figure 2) they are moving

CLICK HERE TO SEE ANIMATED VERSIONS OF THESE DIAGRAMS

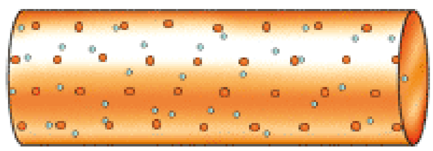


Figure 1: A copper wire is made of a lattice of copper ions. There are free electrons that move through this lattice like a gas

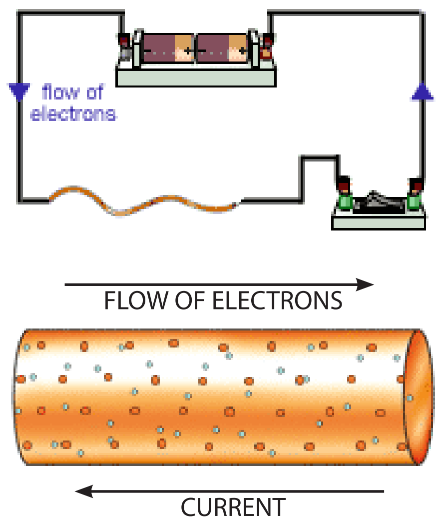


Figure 2: Operating the switch in the circuit (above left) causes electrons to flow from left to right, in the opposite direction of the current.

from left to right (and still move randomly as well). Electrons have a negative charge. They are attracted to the positive end of the battery. The free electrons move through the copper, flowing from the negative to positive terminal of the battery (note that they flow in the opposite direction to conventional current; this is because they have a negative charge).

The copper ions in the wire vibrate. Sometimes an ion blocks the path of a moving electron. The electron collides with the ion and bounces off it. This slows down the electron. Some of its energy has been transferred to the ion, which vibrates faster.

In this way, energy is transferred from the moving electrons to the copper ions. The copper gets hotter. This explains why:

- metals have electrical resistance.
- metals get hot when a current flows through them.

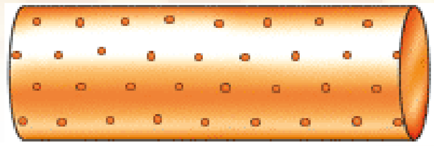


Figure 3: The left hand end of the piece of copper is hotter. The copper ions at the hot end vibrate more. (Note: the electrons have been left out of the picture to keep it clear.)

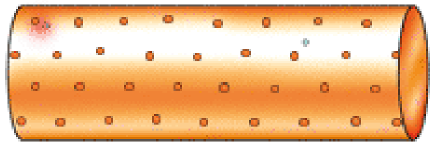


Figure 4: How electrons conduct heat from the left to the right (only a few are shown to make it easier to see).

Good Thermal Conductivity

Copper is a good conductor of heat. This means that if you heat one end of a piece of copper, the other end will quickly reach the same temperature. Most metals are pretty good conductors; however, apart from silver, copper is the best.

It is used in many heating applications because it doesn't corrode and has a high melting point. The only other material that has similar resistance to corrosion is stainless steel. However, its thermal conductivity is 30 times worse than that of copper.

Applications

Copper allows heat to pass through it quickly. It is therefore used in many applications where quick heat transfer is important. These include:

Device	Use
Copper plate	Saucepan bottoms
Copper Pipes	Heat exchangers in hot water tanks, under floor heating systems, all weather football pitches and car radiators.
Heat Sinks	Computers, disk drives, TV sets.

Metal	Relative Conductivity
Copper	394
Silver	418
Aluminium	238
Stainless Steel	13

Thermal conductivity of common metals. When you heat one side of a material, the other side will warm up. The values above are a measure of how quickly the other side gets as hot as the heated side.

Conducting heat

Copper is made from a lattice of ions with free electrons (see Figure 1). The ions are vibrating and the electrons can move through the copper (rather like a gas).

Figure 3 shows what happens when one end of the piece of copper gets hotter. The copper ions at the hot end vibrate more. Note: the electrons have been left out of the picture to keep it clear.

Figure 4 focuses on just a few electrons to see how they conduct heat from the left to the right.

1. A free electron collides with an ion at the hot end, and gains kinetic energy (it speeds up).
2. It moves to the cold end.
3. It collides with a 'cold ion', making the previously cold ion vibrate more. This heats up the cold end.
4. In this way, energy is transferred through copper, from hot to cold.

Non-metals conducting heat

Compare this with how heat is conducted in a non-metal. The vibrating particles pass on the vibrations to their nearest neighbours. This is much slower. That's why metals are the best conductors - their free electrons can carry the energy along their length.

Corrosion Resistance

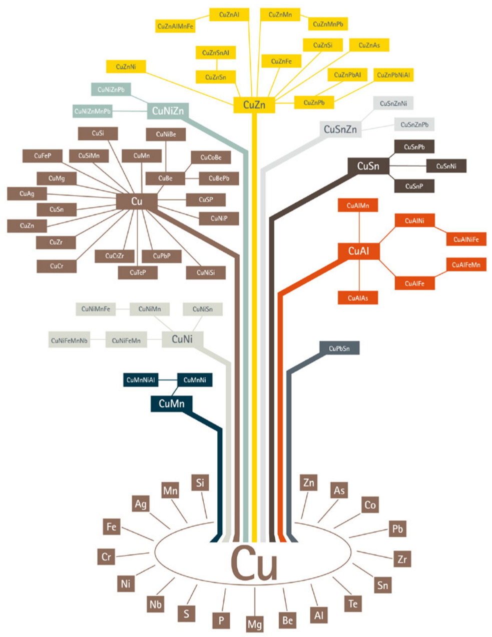
Copper is low in the reactivity series. This means that it doesn't tend to corrode. This is important for its use for pipes, electrical cables, saucepans and radiators.

It also means that it is well suited to decorative use. Jewellery, statues and parts of buildings can be made from copper, brass or bronze and remain attractive for thousands of years.

For more information on the benefits of copper's corrosion resistance for marine applications, see the Copper Alloys in Aquaculture resource.

Alloys Easily Joined

Copper can be combined easily with other metals to make alloys. The first alloy produced was copper melted with tin to



The copper alloy tree shows the options for adding other metals to make different alloys.
Below are some examples.

Click here see a larger version of the diagram.

Copper + tin = tin bronze
Copper + tin + phosphorus = phosphor bronze
Copper + aluminium = aluminium bronze
Copper + zinc = brass
Copper + tin + zinc = gunmetal
Copper + nickel = copper-nickel
Copper + nickel + zinc = nickel silver.

form bronze - a discovery so important that periods in history are called The Bronze Age.

Much later came brass (copper and zinc), and - in the modern age - cupronickel (copper and nickel). The alloys are harder, stronger and tougher than pure copper. They can be made even harder by hammering them - a process called 'work hardening'.

For more information, see the Copper in Coinage resource. You can also view the Copper Development Association pages on Copper and its Alloys.

Copper's inherent antimicrobial properties make it a good choice for the surfaces that staff, patients and visitors touch in hospitals, helping to prevent the spread of infection.

Antimicrobial

Copper is inherently antimicrobial, meaning it will rapidly kill bacteria, viruses and fungi that settle on its surface. This property is leading to the installation of surfaces made from copper and copper alloys in hospitals and other areas where hygiene is a key concern.

For more information, see the Copper, Pathogens and Disease resource.

A tuba made from brass.

Easily Joined

Copper can be joined easily by soldering or brazing. This is useful for pipework and for making sealed copper vessels.

Ductile

Copper is a ductile metal. This means that it can easily be shaped into pipes and drawn into wires.
Copper pipes are lightweight because they can have thin walls. They don't corrode and they can be bent to fit around corners. The pipes can be joined by soldering and they are safe in fires because they don't burn or support combustion.

Tough

Copper and copper alloys are tough. This means that they were well suited to being used for tools and weapons. Imagine the joy of ancient man when he discovered that his carefully formed arrowheads no longer shattered on impact.

The property of toughness is vital for copper and copper alloys in the modern world. They do not shatter when they are dropped or become brittle when cooled below 0°C.

Non-magnetic

Copper is non-magnetic and non-sparking. Because of this, it is used in special tools and military applications.

Attractive Colour

Copper and its alloys, such as brass, are used for jewellery and ornaments. They have an attractive golden colour which varies with the copper content. They have a good resistance to tarnishing making them last a long a time.

Recyclable

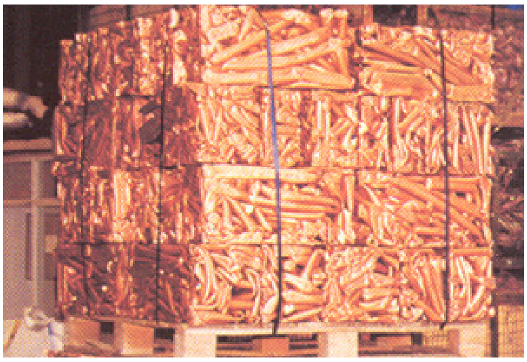
Copper can be recycled without any loss of quality. Around 40% of Europe's demand is met from recycled copper.

For more information, see the Copper Recycling and Sustainability resource.

Catalytic

Copper can act as a catalyst – meaning a substance that can speed up a chemical reaction and improve its efficiency. It does so by reducing the activation energy. Catalysts in biological reactions are called enzymes.

Copper speeds up the reaction between zinc and dilute sulfuric acid. It is found in some enzymes, one of which is involved in respiration. It really is a vital element!



A pallet of recycled copper ready to be reused and helping to preserve natural resources.