

Design & Technology

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# Metals

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## Ferrous and non-ferrous metals

Metals in their many forms and varieties are vital materials in today's society. They play an integral role in the manufacture of buildings, vehicles and household products, ranging from the Shard in London through to the keys to your house.

Metal is a **naturally occurring material** and is mined from the ground in the form of ore. The raw metal is then extracted from the ore through a combination of crushing, smelting or heating, with the addition of chemicals and huge amounts of electrical energy.

**Most** metals **can be recycled**, saving natural resources and limiting the amount of materials imported from abroad.

Metals can be identified by their properties and characteristics, such as **colour, hardness, toughness, tensile strength, malleability, elasticity and conductivity**.

Metals are readily available in a variety of stock forms such as sheet, rod, bar, tube and angle.

They are categorised into two groups: **ferrous metals** and **non-ferrous metals**

### KEY WORDS

**Ferrous metal** A metal that contains iron.

**Non-ferrous metal**  
A metal that does not contain iron.

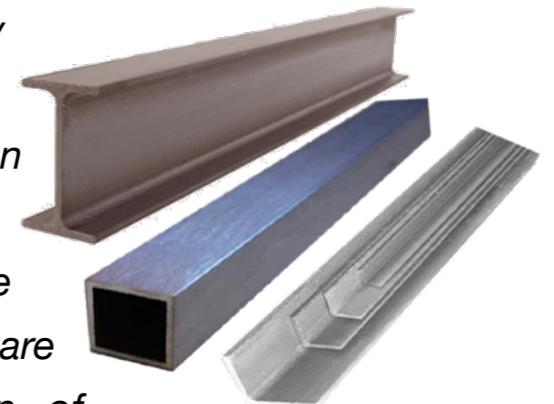
## Properties of ferrous metals

**Ferrous metals** are those that **contain iron**. Most are **magnetic**, which is a useful property when it comes to sorting out metals when recycling. Their carbon content means that most are **prone to corrosion**, in the form of **rust**, when exposed to moisture and oxygen.

A good way of remembering that ferrous metals contain iron is to remember the periodic table symbol for iron. FE = iron = ferrous.

The properties of ferrous metals, such as hardness and malleability, are directly related to their carbon content. For example, the more carbon that is found in steel, the harder and less malleable the steel becomes.

- *Mild steel is one of the most widely used of the ferrous metals. It has excellent tensile strength and, when fabricated into an I-beam cross-section, it can be used to produce rolled steel joists (RSJs). These are widely used in the construction of buildings.*



- *Medium-carbon steel contains more carbon than mild steel and is therefore harder. It is typically used in the manufacture of tools such as spades, trowels and gardening equipment.*

- *High-carbon steel, as the name suggests, contains even more carbon and is used for cutting tools such as saw blades and drill bits.*



- *Cast iron is hard but can be brittle. It is used for intricate castings such as the metalwork vice you use in the workshop.*

### Finishes for ferrous metals

Most ferrous metals require a finish to be applied to prevent rusting. Painting, galvanising, plating and polymer coating are typical ways of protecting ferrous metals and enhancing their appearance.



Galvanised Bolt



Plastic Coated Hook

### Properties of non-ferrous metals

Non-ferrous metals are those that **don't contain iron**. The absence of iron makes nonferrous metals desirable for their malleable properties and for their resistance to corrosion.

The majority of them are also not magnetic, which means that they can be used in electronic devices and wiring.

After steel, aluminium is the most widely used metal. Aluminium is produced from alumina, which is extracted from an ore known as bauxite. In addition to heating, several chemicals are used to help the separation process, including caustic soda and lime. The alumina then goes through an electrolysis process from which liquid aluminium is obtained.

All of this processing takes a huge amount of energy, which is why aluminium is so regularly recycled. It takes around 95 per cent less energy to recycle aluminium than to produce the raw material from bauxite.

Copper is a versatile material due to its wide range of desirable properties. It is commonly found in plumbing fixings and heating systems because it is easy to solder and does not corrode when in contact with moisture.



## Finishes for non-ferrous metals

Non-ferrous metals have the advantage of not rusting. They do, however, oxidise. Oxidation is when the surface of the metal is affected by air and water. The surface of aluminium becomes white, the surface of copper becomes green, and other metals become dull and eventually turn black.

To prevent oxidation occurring, non-ferrous metal should have a finish applied. Processes such as chrome plating and anodising are often used, as well as more conventional finishing techniques such as painting.

## Alloys

Metals in their pure form can be useful for many purposes, but it is often desirable to adjust their mechanical and physical properties in order to produce a more suitable material for a particular use.

An **alloy** is a material that is produced by **combining two or more elements together** to produce a new material with refined properties.

Alloys can be categorised as **ferrous alloys** or **non-ferrous alloys**, depending on the main pure metal that they contain.

### KEY WORD

**Alloy** A mixture of two or more different metals.



**Stainless steel** is a ferrous alloy that is regularly used in the manufacture of surgical equipment, catering items and decorative homeware. It has a 13 per cent chromium content, which when combined with the oxygen in the atmosphere produces an oxide that protects it from corrosion. It is extremely hard and corrosion-resistant and can be polished to give a shiny finish.



Brass is a non-ferrous alloy that can be cast into detailed shapes and is used extensively for plumbing fittings such as water taps and pipe connectors. It is an alloy of copper and zinc. The zinc adds hardness to the copper, which retains its resistance to corrosion.

Bronze is also a non-ferrous alloy that is used widely by metal sculptors to produce large pieces of artwork. Its ability to be cast into intricate shapes and its resistance to corrosion make it ideal for outdoor projects.



## Common Ferrous Metals

All ferrous metals contain iron and when alloyed (mixed) with carbon they produce steel. Steel is our most abundant metal and is generally used for its strength. Iron is magnetic, which is a useful property when it comes to sorting out metals when recycling.

The carbon in ferrous metals, however, means that they are prone to corrosion, in the form of rust, when exposed to moisture and oxygen. Their properties, such as hardness and malleability, are directly related to their carbon content.

For example, the more carbon that is found in steel, the harder and less malleable the steel becomes.

Ferrous metal	Composition	Properties	Common uses
<b>Cast iron</b>	Iron and 3.5 per cent carbon	<ul style="list-style-type: none"> <li>• Hard surface but has a brittle soft core</li> <li>• Strong compressive strength</li> <li>• Poor resistance to corrosion</li> <li>• 12,000°C melting point</li> <li>• Good electrical and thermal conductivity</li> <li>• Cheap</li> </ul>	Vices, car brake discs, cylinder blocks, manhole covers
<b>Mild steel</b>	Iron and 0.15–0.35 per cent carbon	<ul style="list-style-type: none"> <li>• Good tensile strength, tough, malleable</li> <li>• Poor resistance to corrosion</li> <li>• 15,000°C melting point</li> <li>• Good electrical and thermal conductivity</li> <li>• Cheap</li> </ul>	Car bodies, nuts, bolts and screws, RSJs and girders
<b>Medium-carbon steel</b>	Iron and 0.35–0.7 per cent carbon	<ul style="list-style-type: none"> <li>• Good tensile strength</li> <li>• Tougher and harder than mild steel</li> <li>• Poor resistance to corrosion</li> <li>• 15,000°C melting point</li> <li>• Good electrical and thermal conductivity</li> </ul>	Gardening tools and springs
<b>High-carbon steel</b>	Iron and 0.70–1.4 per cent carbon	<ul style="list-style-type: none"> <li>• Hard but also brittle</li> <li>• Less tough, malleable or ductile than medium-carbon steel</li> <li>• Poor resistance to corrosion</li> <li>• 15,000°C melting point</li> <li>• Good electrical and thermal conductivity</li> </ul>	Screwdrivers, chisels, taps and wires

## Non-ferrous metals

Non-ferrous metals differ from ferrous metals in that they do not contain iron. The lack of iron means that non-ferrous metals do not rust. Most of them are also not magnetic, which means that they are suitable for electronic devices and wiring.

Non-ferrous metal	Composition	Properties	Common uses
<b>Aluminium</b>	Pure metal	<ul style="list-style-type: none"> <li>• Lightweight, soft, ductile and malleable</li> <li>• A good conductor of heat and electricity</li> <li>• Corrosion-resistant</li> <li>• 6600°C melting point</li> </ul>	Aircraft bodies, high-end car chassis, cans, cooking pans, bike frames
<b>Copper</b>	Pure metal	<ul style="list-style-type: none"> <li>• Extremely ductile and malleable</li> <li>• An excellent conductor of heat and electricity</li> <li>• Easily soldered and corrosion-resistant</li> <li>• 10,840°C melting point</li> </ul>	Plumbing fittings, hot water tanks, electrical wire
<b>Silver</b>	Pure metal	<ul style="list-style-type: none"> <li>• A soft, precious metal that is extremely resistant to corrosion</li> <li>• An excellent conductor of heat and electricity</li> <li>• 9610°C melting point</li> <li>• Expensive</li> </ul>	Often used as jewellery

## Heat treatment of metals

### KEY WORDS

**Annealing** A heat treatment process that softens metal to increase its elasticity.

**Hardening** A heat treatment process that hardens steel.

**Tempering** A heat treatment process that removes the brittleness from hardened steel.

The properties of ferrous metals can be altered by the use of heat.

• Annealing involves heating the metal to red heat (red heat is when the metal turns red in colour) and then allowing it to cool very slowly. Burying it in sand is good way to slow down the cooling time, which makes the metal as soft as possible.

- To harden ferrous metal you must heat it to red heat and then cool it as quickly as possible. This is normally done by quenching it in water.

- Hardened ferrous metals become brittle. The brittleness is reduced by tempering the steel. This involves heating the steel to a known temperature and then allowing it to cool naturally.
- Case hardening is one way of hardening just the surface of the ferrous metal. The metals first heated to red heat and then placed in a high-carbon compound where it soaks up some of the carbon. This carbon-rich coating can then be hardened by heat treatment.



The properties of non-ferrous metals can also be altered by the use of heat, for example by annealing and hardening in a similar way to ferrous metals. The main difference is that the hardening and annealing of non-ferrous metals happens at a much lower temperature.

### Aesthetics of Metal

Metal	Aesthetics	Functionality
<b>Aluminium (Duralumin)</b>	Easily cast into unique shapes; can be polished to a mirror-like finish or be coloured with a vivid finish known as anodising	Excellent strength-to-weight ratio; easy to cut, weld and join by various methods; good resistance to corrosion
<b>Copper</b>	Easy to shape by beating; has a reddish-brown finish that can be highly polished; has the unique feature of going green when left outdoors and unprotected	Easily worked; good conductor of heat and electricity; malleable, ductile and easily joined by soldering
<b>Brass</b>	Easily cast into unique shapes; has a yellowy-brown colour that can be highly polished	A harder, more durable material than copper; a good conductor of heat and electricity
<b>Pewter</b>	Very easily cast into shape due to its low melting point	A soft metal with a relatively low strength
<b>Mild steel</b>	Can easily be worked into shape; rusts if left unprotected; can receive a wide variety of finishes/platings/coatings	Tough, durable, strong and malleable; relatively easy to work

### Environmental factors

Metals can be considered environmentally friendly as they are durable. This means that they are less likely to break and will last longer so there will be less need to use raw materials.

Metals are reusable; when it has finished its life as one product the metal can be reused as something else. Metals are infinitely recyclable and can be collected and melted down to be used again.

Metals are a finite resource, however, and when we have used this natural resource there will be no more. The processing and manufacturing of metals uses further natural resources and leads to pollution of the atmosphere, which will lead to the formation of greenhouse gases and contribute to global warming.



The sourcing of metal ore can have a major impact on the environment, for example opencast mining can leave scars on the landscape and strip the land of fertile soil. The processing of metals uses large amounts of power and causes air pollution, leading to the build-up of greenhouse gases and contributing to global warming.

Designers and manufacturers must aim to reduce the negative impact of processing metals.

## Cost of materials

The cost of metals varies quite considerably.

- Common ferrous metals such as mild steel are relatively inexpensive as they are produced in very high quantities and there is a plentiful supply of the raw material.
- Non-ferrous metals such as aluminium are more expensive as they require a more complex process to extract the metal from its ore.
- Semi-precious metals such as copper and brass are more expensive as they require further processing and are not produced in such high volumes.
- Precious metals such as gold and silver are very expensive as they are much rarer and require even more sophisticated processing.

The production of metal products is a major cost. Producing metal products requires factories to be built, machinery to be purchased and a labour force to be trained and employed. Metal products are suitable for high volume production, however, which reduces the individual unit cost.

## KEY POINTS

- *Metals are generally selected for their strength.*
- *Metals can be joined by a variety of different methods and can also be cast into intricate shapes.*
- *The appearance of metals can be altered in a number of ways: by painting, polishing and anodising (aluminium).*
- *Metals vary in cost. Mild steels are relatively inexpensive when compared to precious metals such as gold and silver.*
- *Metals are found embedded in rock within the Earth's crust. This rock is known as ore.*
- *Metals are divided into three categories: ferrous metals, non-ferrous metals and alloys.*
- *Increasing the carbon content of steel changes its properties. The more carbon there is, the harder the steel.*
- *Ferrous metals have the disadvantage of rusting but the advantage of being magnetic.*
- *Non-ferrous metals do not rust but are not magnetic.*
- *The surface of steel can be hardened by a process known as case hardening.*
- *Ferrous metals contain iron; they are generally strong but are prone to rusting and must have a protective finish applied.*
- *Non-ferrous metals do not rust.*