Metals
IGCSE Chemistry

Properties of metals

Physical properties

Metals 金属 and **non-metals** 非金属 behave very differently:

Property	Metals	Non-metals
thermal conductivity 导热性 (conducting heat)	good	poor
electrical conductivity 导电性	good	poor (except graphite)
malleability 展性 and **ductility** 延性	malleable and ductile	**brittle** 易碎 (they snap)
melting point 熔点 and **boiling point** 沸点	usually high	usually low

Chemical properties

Metals react in three main ways:

- with dilute **acids** 酸 → a **salt** 盐 + **hydrogen** 氢气
- with cold water or **steam** 蒸汽 → a metal hydroxide (or oxide) + hydrogen
- with **oxygen** 氧气 → a metal **oxide** 氧化物

Native copper: metals are shiny, dense, malleable conductors of heat and electricity

Uses of metals

A metal is chosen for a job because of its physical properties.

- **Aluminium** 铝 is used to make aircraft because of its low **density** 密度 (it is light).
- Aluminium is used for overhead electrical cables because of its low density and good electrical conductivity.
- Aluminium is used for food containers because it resists **corrosion** 腐蚀.
- **Copper** 铜 is used for electrical wiring because of its good electrical conductivity and its ductility (it can be drawn into wires).

Aircraft bodies use a lot of aluminium: it is strong but has a low density, so the plane stays light

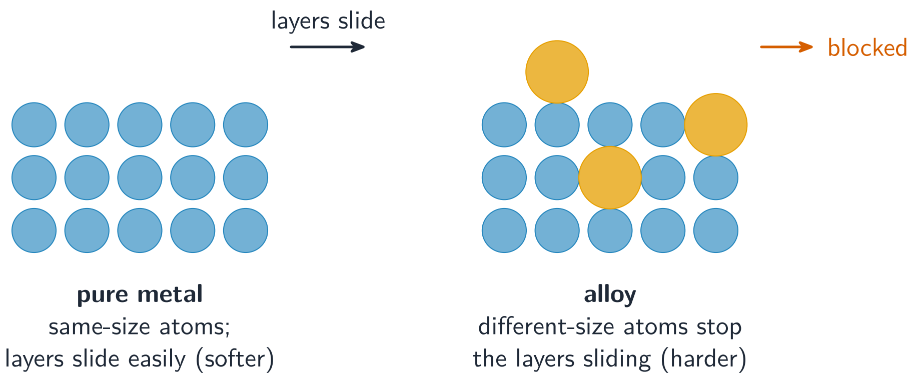
Alloys

An **alloy** 合金 is a **mixture** 混合物 of a metal with one or more other elements.

- **Brass** 黄铜 is a mixture of copper and **zinc** 锌.
- **Stainless steel** 不锈钢 is a mixture of **iron** 铁 with other elements such as **chromium** 铬, **nickel** 镍 and **carbon** 碳.

Alloys are usually harder and stronger than the pure metals, which makes them more useful. For example, stainless steel is used for cutlery because it is hard and does not rust.

Why alloys are harder. In a pure metal, the **atoms** 原子 are all the same size, so the **layers** 层 can slide over each other easily. In an alloy, the different-sized atoms stop the layers from sliding, so the alloy is harder and stronger.



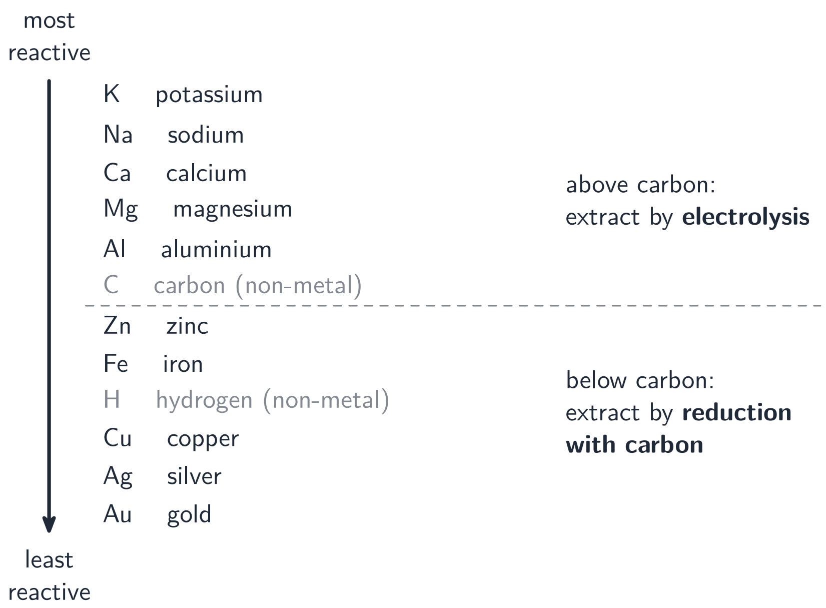
In an alloy, different-sized atoms stop the layers sliding past each other, so the alloy is harder than the pure metal

The reactivity series

The **reactivity series** 金属活动性顺序 lists metals in order of how reactive they are. Carbon and hydrogen are included for comparison:

> **potassium** 钾, **sodium** 钠, **calcium** 钙, **magnesium** 镁, aluminium, carbon, zinc, iron, hydrogen, copper, silver, gold

(most reactive at the top, least reactive at the bottom)



Metals above carbon are extracted by electrolysis; those below carbon can be extracted by heating with carbon

The higher a metal is, the more easily it forms positive **ions** 离子. This explains its reactions:

- potassium, sodium and calcium react with cold water.
- magnesium reacts with steam (but only very slowly with cold water).
- magnesium, zinc and iron react with dilute hydrochloric acid; copper, silver and gold do not.

Displacement reactions

A more reactive metal will displace a less reactive metal from a solution of its ions (a **displacement reaction** 置换反应). For example, zinc displaces copper from copper(II) sulfate solution, because zinc is more reactive than copper:

$$\mathrm{Zn + CuSO_4 \rightarrow ZnSO_4 + Cu}$$

Be ready to say what you would **see**, because those are separate marks:

- the **blue** colour of the solution **fades** - the blue Cu^{2+} ions are being used up (zinc sulfate is colourless).
- a **pink-brown solid** coats the zinc - that is the displaced copper.
- the grey zinc **dissolves** and gets smaller.
- the mixture **warms up** - displacement is exothermic.

Metal-and-acid reactions have their own list: **effervescence** 泡腾 (the hydrogen escaping) and the **solid dissolves**. With copper(II) oxide or carbonate and acid, add that the solution **turns blue**. Never write "hydrogen is given off" as an observation - you cannot see the gas, only the bubbles, so write **effervescence**.

Worked example. Zinc and aluminium are both found as oxides. Which can be extracted by heating with carbon, and why? Find each metal's place relative to **carbon** in the reactivity series. Zinc sits **below** carbon, so carbon is the more reactive of the two and can take the oxygen away from it: zinc oxide is reduced by heating with carbon. Aluminium sits **above** carbon, so carbon is not reactive enough to displace it, and aluminium must be extracted by **electrolysis** instead - which is why aluminium costs far more to extract. The line in the series that decides the method is carbon's, not the top of the list.

The special case of aluminium

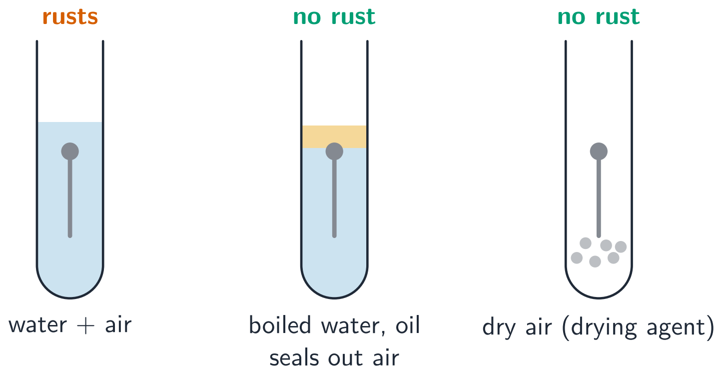
Aluminium seems less reactive than its position suggests. This is because it is covered by a thin, strong **oxide layer** 氧化层 that stops other substances reaching the metal underneath.

Corrosion of metals

Corrosion slowly eats away unprotected metal.

Rusting 生锈 is the corrosion of iron and steel. Two things are needed for rusting: **oxygen** (from the air) and water. The **rust** 铁锈 formed is hydrated iron(III) oxide.

Sea water and air have badly rusted this iron chain — the rust is hydrated iron(III) oxide



Rusting needs both water and oxygen — the nail only rusts in the tube that has both

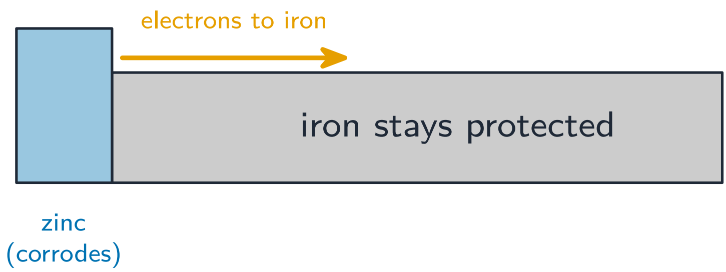
Stopping rust

Barrier methods 隔离法 keep oxygen and water away from the iron:

- painting, **greasing** (covering with oil), and coating with plastic.

Galvanising 镀锌 means coating iron with a layer of zinc. This works in two ways:

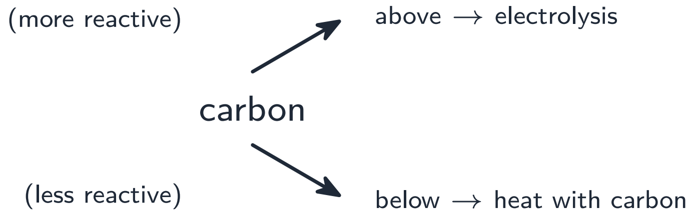
- it is a barrier (the zinc keeps out air and water);
- it gives **sacrificial protection** 牺牲保护. Because zinc is more reactive than iron, the zinc loses **electrons** 电子 and corrodes instead of the iron — even if the surface is scratched.



The more reactive zinc corrodes and gives its electrons to the iron, so the iron is protected even where the surface is scratched

Extraction of metals

How a metal is taken from its **ore** 矿石 depends on its place in the reactivity series. Metals below carbon can be extracted by heating with carbon (which removes the oxygen). Metals above carbon are too reactive for this and must be extracted by **electrolysis** 电解.

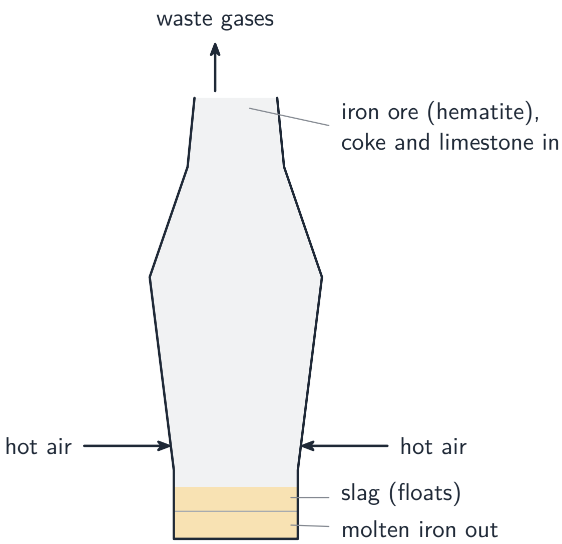


Metals above carbon need electrolysis; those below are heated with carbon

Iron from the blast furnace

Iron is extracted from its ore **hematite** 赤铁矿 (iron(III) oxide) in a **blast furnace** 高炉:

- Carbon (coke) burns in hot air to give carbon dioxide and lots of heat.
- This **carbon dioxide** 二氧化碳 reacts with more carbon to form **carbon monoxide** 一氧化碳.
- The carbon monoxide **reduces** the iron(III) oxide to iron (this is **reduction** 还原).
- **Limestone** 石灰石 (calcium carbonate) breaks down in the heat to form **calcium oxide** 氧化钙.
- The calcium oxide reacts with sandy impurities to form **slag** 炉渣, which is removed.



$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

(carbon monoxide reduces the ore)

In the blast furnace, carbon monoxide reduces the iron ore, and limestone removes sandy impurities as slag

Aluminium by electrolysis

Aluminium is extracted from its ore **bauxite** 铝土矿 (purified to aluminium oxide) by electrolysis:

- The aluminium oxide is dissolved in molten **cryolite** 冰晶石 to lower its melting point and save energy.

- At the **cathode** 阴极, aluminium ions gain electrons to form aluminium metal.
- At the **anode** 阳极, oxygen is formed. This oxygen reacts with the hot carbon anodes and burns them away, so they must be replaced regularly.

Exam tips

- Learn the **reactivity series** (potassium → gold). A more reactive metal displaces a less reactive one from a solution of its ions.
- Metals *above* carbon are extracted by **electrolysis**; those *below* carbon (like iron) can be extracted by heating with carbon.
- **Rusting** needs *both* water and oxygen. Barrier methods (paint, oil) keep them out; **galvanising** also gives sacrificial protection, because the more reactive zinc corrodes instead of the iron.
- **Alloys** are harder than pure metals because the different-sized atoms stop the layers of ions sliding over each other.