

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

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).

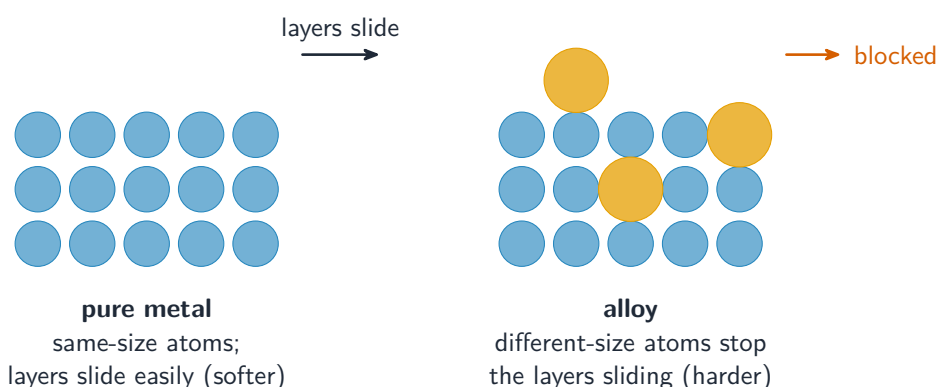
Alloys

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)

most reactive	K potassium	
	Na sodium	
	Ca calcium	
	Mg magnesium	above carbon: extract by electrolysis
	Al aluminium	
	C carbon (non-metal)	
	Zn zinc	
	Fe iron	below carbon: extract by reduction with carbon
	H hydrogen (non-metal)	
	Cu copper	
	Ag silver	
least reactive	Au gold	

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.

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.

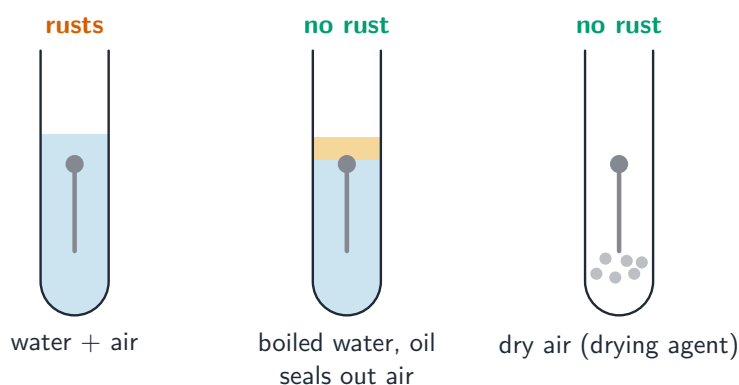
Image: Beta Engineering, Public domain (commons.wikimedia.org)

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

Image: MX1996, CC BY-SA 4.0 (commons.wikimedia.org)



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.

Extraction of metals

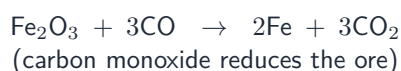
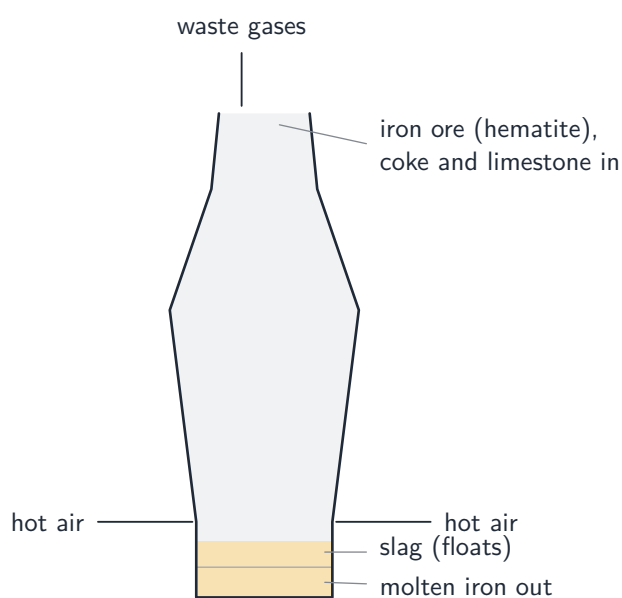
How a metal is taken from its **ore** 矿石 depends on its place in the reactivity series. Metals below carbon can be extracted by heating with carbon (which removes the oxygen).

Metals above carbon are too reactive for this and must be extracted by **electrolysis** 电解.

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.



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.