

Metals

IGCSE Chemistry 0620 · Topic 9 revision notes

Everything from the 8 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Properties of metals

2. Uses of metals

3. Alloys and their properties

4. The reactivity series

5. Rusting and its prevention

6. Extraction and the reactivity series

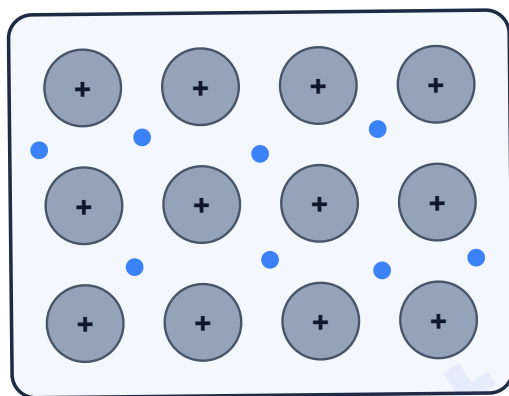
7. Extracting iron in the blast furnace

8. Extracting aluminium by electrolysis

1 Properties of metals

Syllabus 9.1

Metals are good **conductors of heat and electricity**, **malleable** (can be hammered into shape) and **ductile** (can be drawn into wires), and usually have **high melting and boiling points**. Non-metals are generally poor conductors and brittle when solid. Metals react with **dilute acids** to give a salt and hydrogen, with **cold water or steam** to give a hydroxide or oxide and hydrogen, and with **oxygen** to give metal oxides.



positive ions in a sea of
delocalised electrons

conduct electricity

delocalised electrons move

conduct heat

electrons and ions pass energy

malleable and ductile

layers of ions slide

high melting points

strong metallic bonding

Fig. 1: metallic structure and the physical properties it explains

Conduct, bend, react.

- ✓ **Physical:** conductors, malleable, ductile, high melting point.
- ✓ **Acid:** salt + hydrogen.
- ✓ **Cold water:** hydroxide + hydrogen.
Steam: oxide + hydrogen.
- ✓ **Oxygen:** metal oxide.

Watch out!

With **cold water** a reactive metal forms a **hydroxide**; with **steam** a metal forms an **oxide**. Magnesium reacts only very slowly with cold water but burns in steam to give magnesium oxide.

2 Uses of metals

Syllabus 9.2

Choose a metal by matching its properties to the job. **Aluminium** is used in **aircraft** (low density, and strong as an alloy), **overhead power cables** (low density and a good electrical conductor) and **food containers** (resistant to corrosion). **Copper** is used in **electrical wiring** because it is a good conductor of electricity and is ductile.

aluminium

aircraft

low density, strong (as alloy)

overhead power cables

low density, good conductor

food containers

resists corrosion

copper

electrical wiring

good conductor, ductile

water pipes

does not corrode easily

saucepan bases

good conductor of heat

Fig. 1: uses of aluminium and copper and the properties behind them

Match property to use.

- ✓ **Aircraft:** aluminium, low density, strong alloys.
- ✓ **Overhead cables:** aluminium, low density, conducts.
- ✓ **Food containers:** aluminium, resists corrosion.
- ✓ **Wiring:** copper, conducts, ductile.

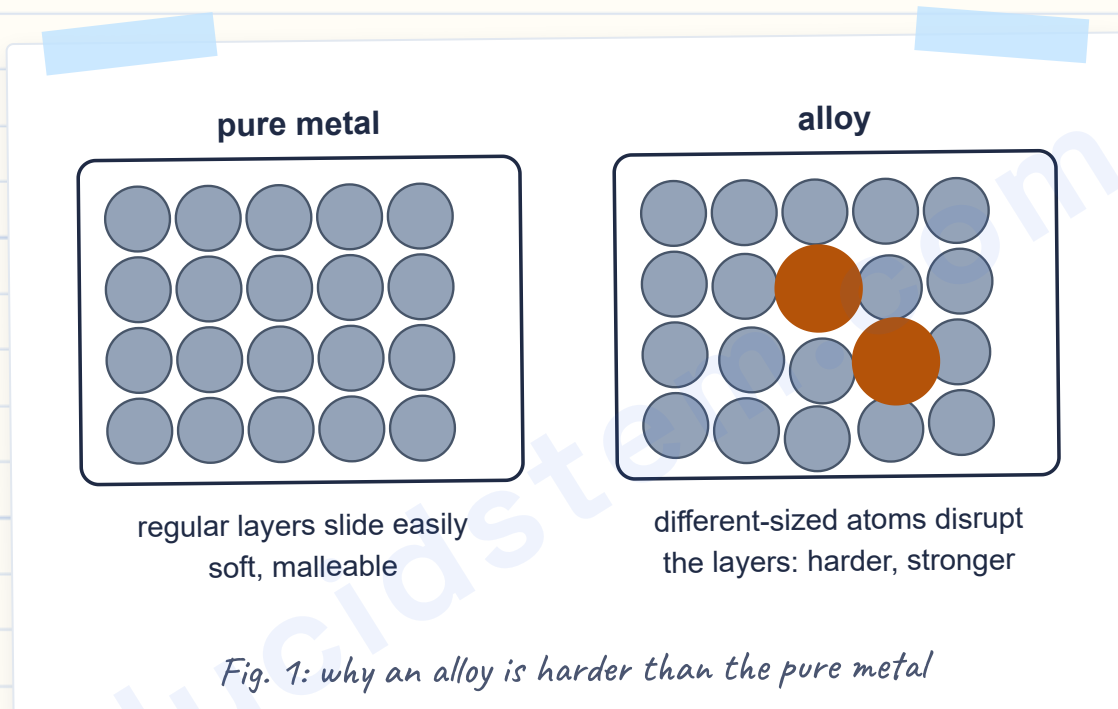
Watch out!

Aluminium resists corrosion not because it is unreactive (it is high in the reactivity series) but because of a thin, tough layer of **aluminium oxide** that seals the surface. Say "resists corrosion", not "is unreactive".

3 Alloys and their properties

Syllabus 9.3

An **alloy** is a **mixture** of a metal with other elements. Examples: **brass** is copper and zinc; **stainless steel** is iron with other elements such as chromium, nickel and carbon. Alloys can be **harder and stronger** than the pure metals and are used for that reason: stainless steel for cutlery because it is hard and resists rusting. **Extended:** in an alloy, atoms of different sizes disrupt the regular layers, so the layers cannot slide over each other as easily.



Mixture, harder, disrupted layers.

- ✓ **Alloy:** a mixture of a metal with other elements.
- ✓ **Brass:** copper + zinc. **Stainless steel:** iron + Cr, Ni, C.
- ✓ **Harder and stronger** than the pure metal.
- ✓ **Extended:** different-sized atoms stop layers sliding.

Watch out!

An alloy is a **mixture**, not a compound: the elements are not chemically combined and there is no fixed formula. And the added element need not be a metal: steel contains carbon, a non-metal.

4 The reactivity series

Syllabus 9.4

The **reactivity series**, from most to least reactive, is: potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen), copper, silver, gold. It is worked out from reactions with **cold water, steam and dilute acids**. A more reactive metal **displaces** a less reactive metal from a solution of its salt. **Extended:** the more reactive the metal, the more easily it **loses electrons to form positive ions**. Aluminium appears unreactive because of its protective oxide layer.

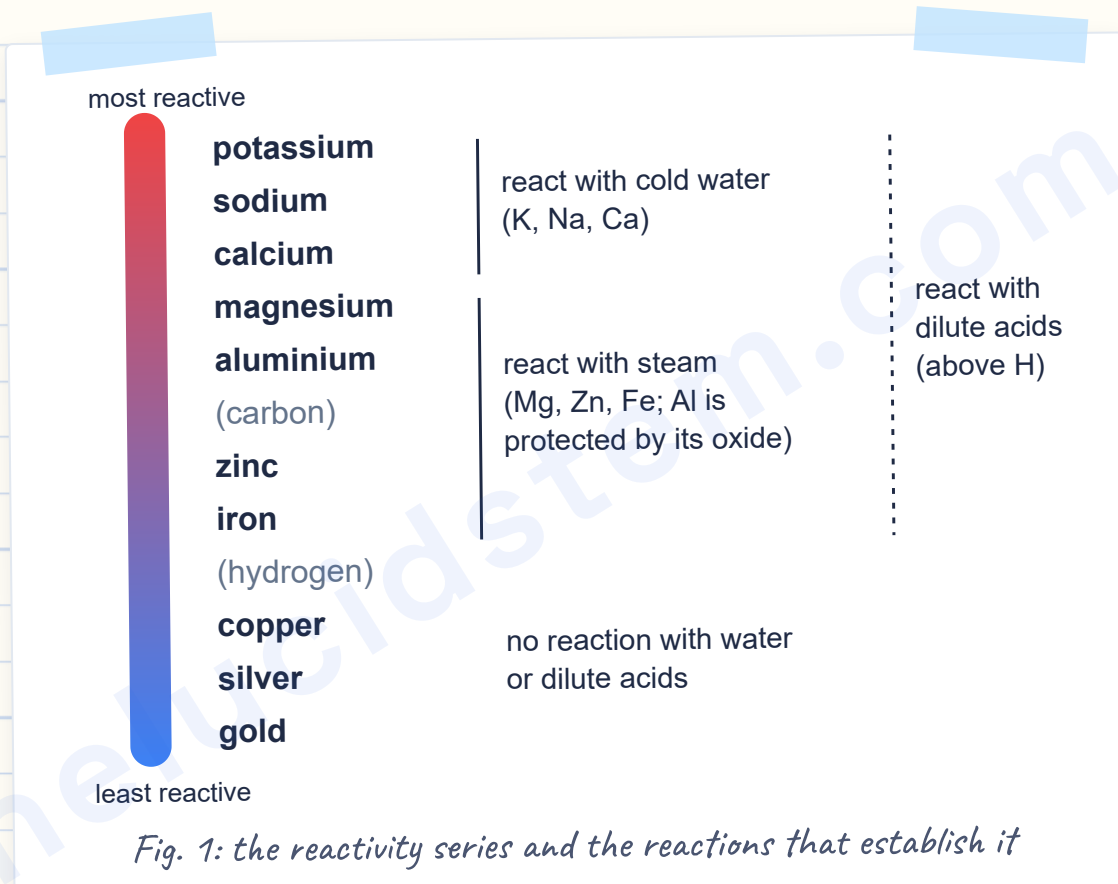


Fig. 1: the reactivity series and the reactions that establish it

Higher displaces lower.

- ✓ **Order:** K, Na, Ca, Mg, Al, (C), Zn, Fe, (H), Cu, Ag, Au.
- ✓ **Displacement:** a more reactive metal pushes out a less reactive one.
- ✓ **Extended:** more reactive = forms positive ions more readily.
- ✓ **Aluminium:** protected by its oxide layer.

Watch out!

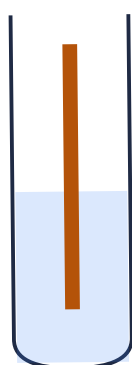
Aluminium is **high** in the series but often seems unreactive, for example it does not react with water. That is because its surface is sealed by a layer of aluminium oxide, not because it is low in the series. Remove the layer and it reacts vigorously.

5 Rusting and its prevention

Syllabus 9.5

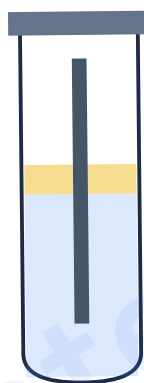
Iron and steel **rust** only when both **water and oxygen** are present; rust is **hydrated iron(III) oxide**. **Barrier methods** (painting, greasing, coating with plastic) stop rusting by keeping out water and oxygen. **Galvanising** coats iron with zinc. **Extended:** zinc, or a block of magnesium, gives **sacrificial protection**: being more reactive, it loses electrons and corrodes instead of the iron, even if the surface is scratched.

air and water



rusts

boiled water, oil layer



no rust (no oxygen)

dry air



no rust (no water)

iron rusts only when both oxygen and water are present

Fig. 1: the experiment showing that rusting needs both oxygen and water

Water and oxygen, both.

- ✓ **Rust** = hydrated iron(III) oxide.
- ✓ **Barriers:** paint, grease, plastic keep out water and oxygen.
- ✓ **Galvanising:** zinc coating.
- ✓ **Extended:** sacrificial metal is more reactive and corrodes instead.

Watch out!

A barrier only works while it is **unbroken**: once paint is scratched, iron underneath rusts. Galvanising protects even when scratched because zinc is **more reactive** than iron and corrodes in its place. Tin-plating does the opposite: tin is less reactive, so a scratched tin can rust faster.

6 Extraction and the reactivity series

Syllabus 9.6

An **ore** is a rock that contains enough of a metal compound to make extraction worthwhile. The **method of extraction** depends on the metal's position in the **reactivity series**: metals **below carbon** (such as zinc, iron and copper) can be extracted by **reduction** of their oxides with carbon or carbon monoxide; metals **above carbon** (such as aluminium and sodium) must be extracted by **electrolysis** of a molten compound. Very unreactive metals such as gold are found **uncombined**.

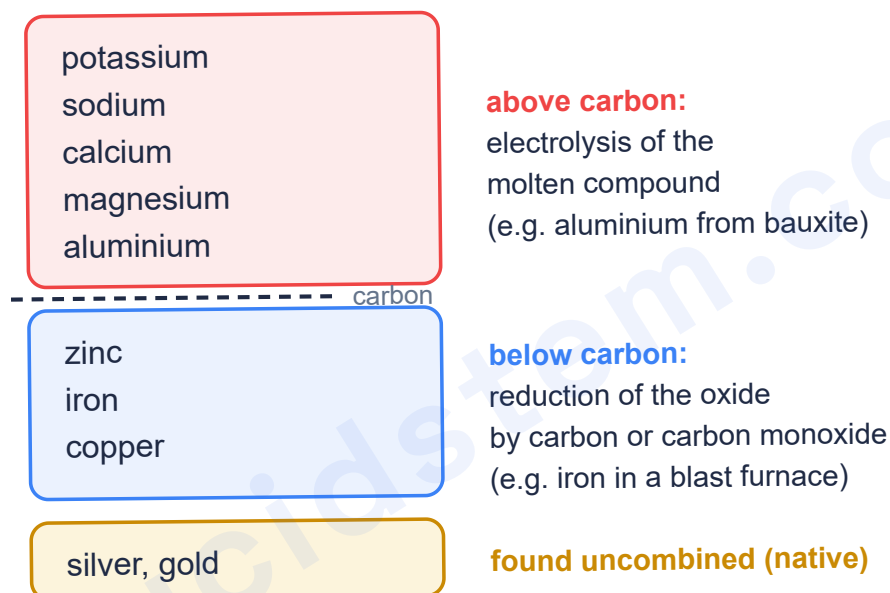


Fig. 1: the reactivity series decides the extraction method

Above carbon: electrolysis.
Below: carbon.

- ✓ **Ore:** rock with enough metal compound to extract.
- ✓ **Below carbon:** reduce the oxide with carbon or CO.
- ✓ **Above carbon:** electrolysis of a molten compound.
- ✓ **Gold, silver:** found uncombined.

Watch out!

Aluminium is **not** extracted with carbon, because aluminium is above carbon in the reactivity series. And the metal is **reduced** during extraction: whether by carbon or at the cathode, the metal ion gains electrons or the oxide loses oxygen.

7 Extracting iron in the blast furnace

Syllabus 9.6

The raw materials are **hematite** (iron ore, Fe_2O_3), **coke** (carbon), **limestone** (CaCO_3) and **hot air**. Coke burns: $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$, giving heat. Carbon dioxide reacts with more coke: $\text{CO}_2 + \text{C} \rightarrow 2\text{CO}$. Carbon monoxide **reduces** the ore: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$. Limestone decomposes, $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$, and the calcium oxide removes sand: $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$ (**slag**).

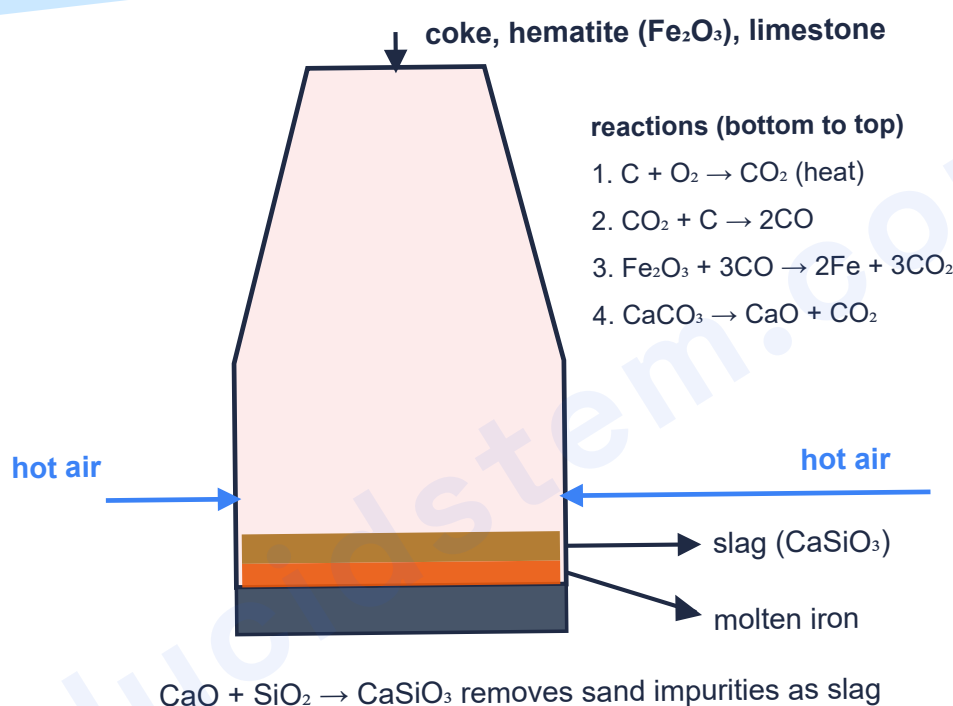


Fig. 1: the blast furnace

Burn, form CO, reduce, remove sand.

- ✓ **Raw materials:** hematite, coke, limestone, hot air.
- ✓ **Heat:** $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$. **CO:** $\text{CO}_2 + \text{C} \rightarrow 2\text{CO}$.
- ✓ **Reduction:** $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$.
- ✓ **Slag:** $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$.

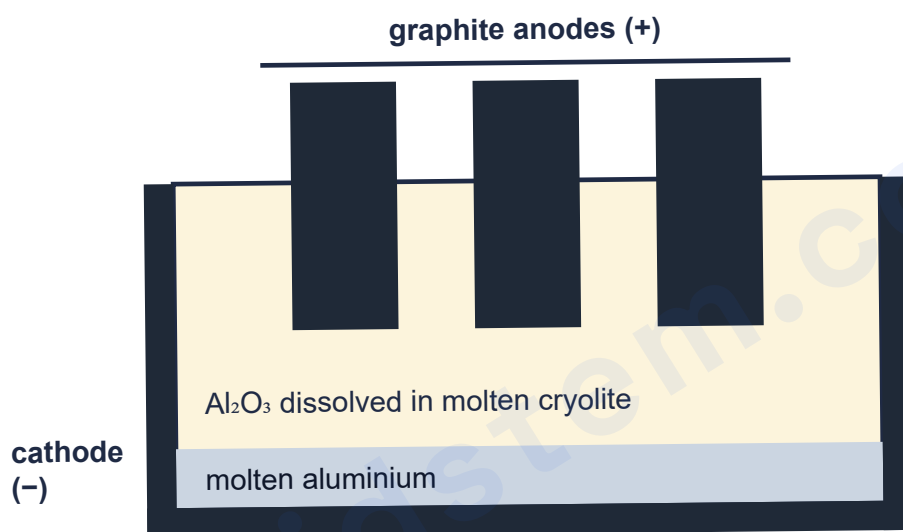
Watch out!

The main reducing agent is **carbon monoxide**, not carbon: it is a gas that reaches every part of the ore. And limestone does not reduce anything; its job is to remove the sandy impurities as slag.

8 Extracting aluminium by electrolysis

Syllabus 9.6

The ore is **bauxite**, purified to **aluminium oxide**, Al_2O_3 . It is dissolved in **molten cryolite**, which lowers the operating temperature and improves conductivity, and electrolysed with **carbon (graphite) electrodes**. **Aluminium** forms at the **cathode** and **oxygen** at the **anode**. The oxygen reacts with the hot carbon anodes to form carbon dioxide, so the anodes must be replaced regularly. **Extended:** $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ and $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$.



cathode: $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ anode: $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$
oxygen reacts with the hot carbon anodes, so they burn away and are replaced

Fig. 1: the electrolysis cell for aluminium

Aluminium down, oxygen up.

- ✓ **Electrolyte:** Al_2O_3 in molten cryolite (lower temperature).
- ✓ **Cathode:** aluminium. **Anode:** oxygen.
- ✓ **Anodes burn:** $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$; replaced often.
- ✓ **Extended:** $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$; $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$.

Watch out!

Cryolite is **not** a catalyst and not the source of aluminium; it is a solvent that lowers the temperature needed, saving energy. And it is the **anodes**, not the cathode, that must be replaced, because oxygen forms there and burns the carbon.