

Metals by reactivity and how we extract them

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: The reactivity series ranks metals by how easily they lose electrons. A more reactive metal displaces a less reactive one from its compound, which is a redox reaction. Metals below carbon are extracted by heating their oxides with carbon, and metals above carbon need electrolysis.

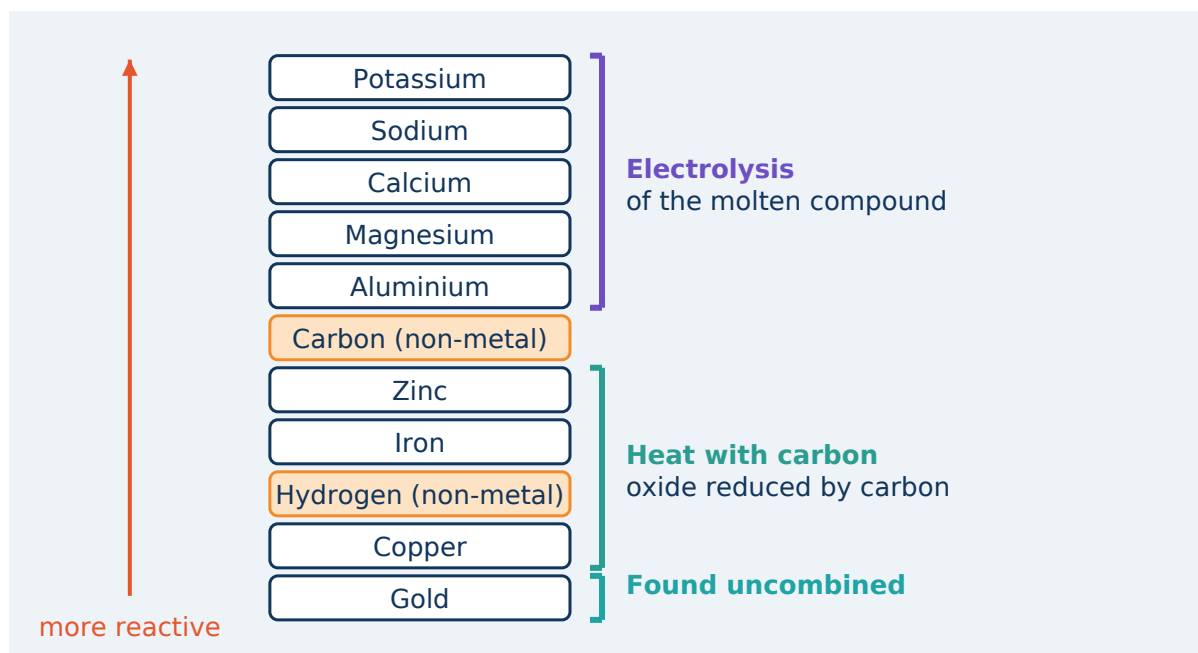
Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C4

What is the reactivity series?

Definition

The **reactivity series** lists metals in order of how readily they form positive ions by losing electrons. The more reactive the metal, the more vigorously it reacts with water, acid and oxygen.

Potassium and sodium sit at the top and react violently with cold water. Magnesium burns brightly in air but reacts slowly with cold water. Zinc and iron react with dilute acid. Copper and gold do not react with dilute acid at all. Carbon and hydrogen are non-metals, but they are placed in the series because they help us decide how to extract metals.



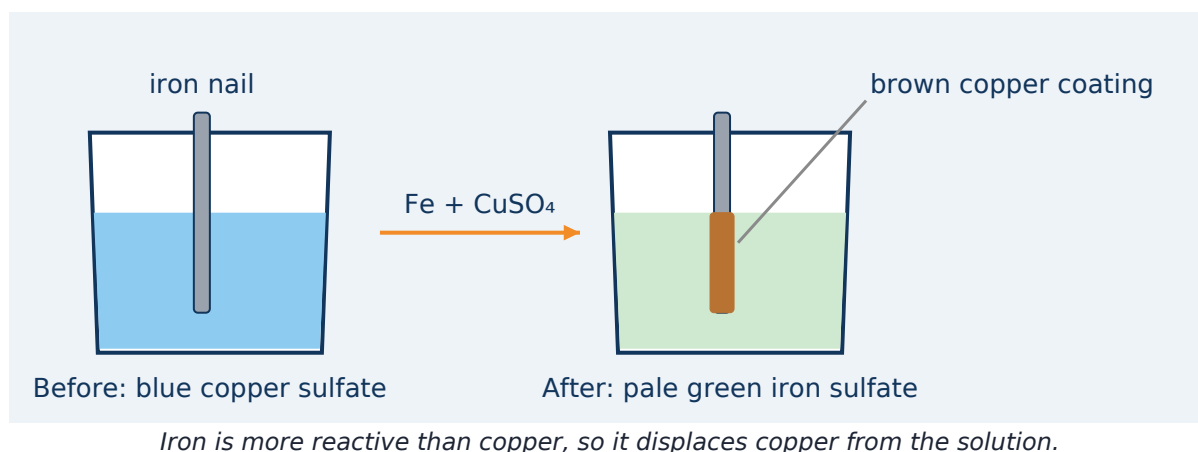
The reactivity series decides how a metal is extracted.

Metal	With cold water	With dilute acid	How it is extracted
Sodium	Vigorous, makes NaOH and H ₂	Violent	Electrolysis

Metal	With cold water	With dilute acid	How it is extracted
Calcium	Steady bubbles of H ₂	Vigorous	Electrolysis
Magnesium	Very slow	Fast bubbles	Electrolysis
Zinc	None	Moderate	Heating with carbon
Iron	None	Slow	Heating with carbon
Copper	None	None	Heating with carbon or other methods

What is a displacement reaction?

A more reactive metal will push a less reactive metal out of its compound. The test is simple: add a metal to a solution of another metal's salt and see whether a new metal appears. If it does, the added metal is more reactive.



Key law

A metal displaces another metal from its compound only if it is **higher** in the reactivity series. $\text{Fe} + \text{CuSO}_4 \rightarrow \text{FeSO}_4 + \text{Cu}$, but $\text{Cu} + \text{FeSO}_4 \rightarrow \text{no reaction}$.

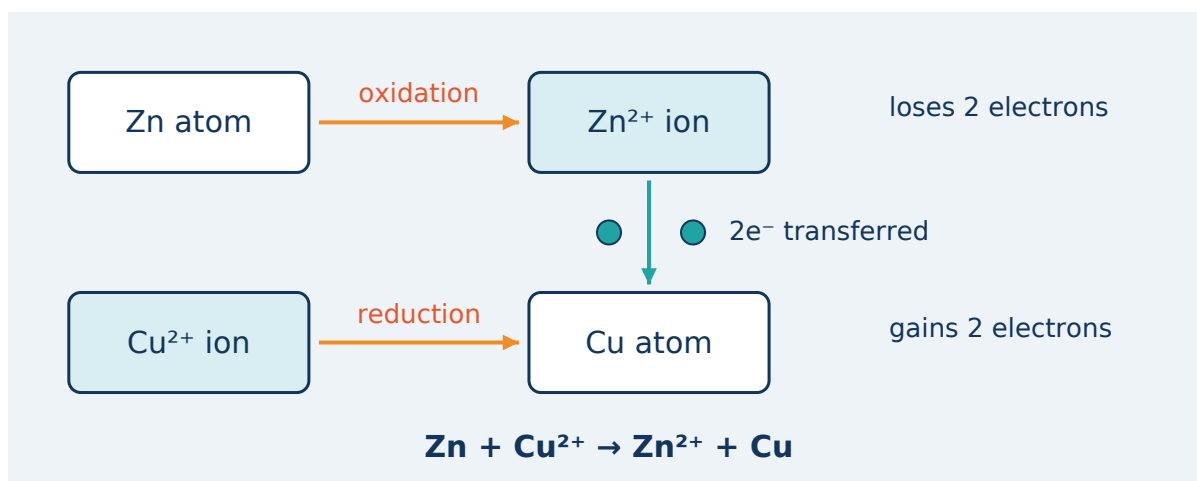
Worked example

Mei in Singapore drops a strip of zinc into copper(II) sulfate solution. Predict what happens and write the ionic equation.

Zinc is higher than copper, so it displaces copper. The blue colour fades and a brown solid forms. The sulfate ions are spectators: $\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$.

What are oxidation and reduction?

Oxidation is gain of oxygen or loss of electrons. **Reduction** is loss of oxygen or gain of electrons. They always happen together, so the reaction is a **redox reaction**. A memory aid is OIL RIG: oxidation is loss, reduction is gain (of electrons).



In a displacement reaction electrons pass from the more reactive metal to the less reactive metal ion.

Worked example

Magnesium reacts with copper(II) oxide: $\text{Mg} + \text{CuO} \rightarrow \text{MgO} + \text{Cu}$. Identify what is oxidised and what is reduced.

Magnesium gains oxygen (it forms MgO), so it is **oxidised**. Copper oxide loses oxygen, so it is **reduced**. Mg is the reducing agent. In ionic terms, $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$ and $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$.

How are metals extracted from their ores?

Most metals are found as compounds in **ores**. A rock is an ore only if the metal can be extracted from it profitably. The method depends on the position of the metal relative to carbon.

- **Below carbon** (zinc, iron, copper): heat the oxide with carbon. Carbon is more reactive, so it takes the oxygen. In the blast furnace, carbon monoxide does the work: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$.
- **Above carbon** (aluminium and higher): carbon cannot reduce the oxide. Electrolysis of the molten compound is used instead. Aluminium oxide is dissolved in molten cryolite to lower the temperature.
- **Very unreactive metals** (gold): found uncombined in the ground.

Electrolysis needs huge amounts of electricity, so metals extracted this way are more expensive. Low-grade copper ores can be treated by bioleaching, which uses bacteria, or by phytomining, which uses plants, so that less rock is dug up.

Worked example

A furnace in Odisha reduces 80 kg of iron(III) oxide: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$ (Ar: Fe = 56, O = 16). Calculate the mass of iron.

$M(\text{Fe}_2\text{O}_3) = 160 \text{ g/mol}$, so $n = 80\,000 \div 160 = 500 \text{ mol}$. The ratio $\text{Fe}_2\text{O}_3 : \text{Fe}$ is 1 : 2, so $n(\text{Fe}) = 1000 \text{ mol}$ and $m = 1000 \times 56 = 56\,000 \text{ g} = \mathbf{56 \text{ kg}}$.

Common mistake

Carbon cannot extract a metal that is *above* carbon in the series. Many students write that carbon reduces aluminium oxide; it does not, because aluminium is more reactive than carbon.

Lina's tip

Draw the series as a ladder and mark carbon on it. Metals above the carbon rung need electricity; metals below it can be smelted with carbon.

Key points to remember

- Series: K, Na, Ca, Mg, Al, (C), Zn, Fe, (H), Cu, Ag, Au
- More reactive metals displace less reactive ones
- Oxidation is loss of electrons; reduction is gain (OIL RIG)
- $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$ in the blast furnace
- Metals above carbon are extracted by electrolysis

Metals by reactivity and how we extract them: frequently asked questions

How can I remember the order of the reactivity series?

Use a mnemonic for the main metals: potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen), copper, silver, gold. Learn the positions of carbon and hydrogen.

Why does a more reactive metal displace a less reactive one?

The more reactive metal loses electrons more easily. It gives its electrons to the ions of the less reactive metal, which become atoms and form a solid.

What is the difference between oxidation and reduction?

Oxidation is gain of oxygen or loss of electrons. Reduction is loss of oxygen or gain of electrons. Both always occur together in a redox reaction.

Why is aluminium extracted by electrolysis?

Aluminium is more reactive than carbon, so carbon cannot remove the oxygen from aluminium oxide. Electricity passes through the molten oxide to separate the metal.

Why do some metals not need extraction?

Very unreactive metals such as gold do not form compounds easily, so they are found as the metal itself. They can be collected by physical methods.