

Extraction of metals and reduction

4.4.1.3 · Chemical changes · revision notes

Where metals come from, and how metals less reactive than carbon are extracted by heating their oxides with carbon (reduction). Questions often give information about an unfamiliar extraction and ask you to explain or evaluate it using the reactivity series.

Key facts

- Ore = rock containing enough metal compound to make extraction worthwhile
- Less reactive than carbon → extract by heating the oxide with carbon
- Reduction = loss of oxygen; oxidation = gain of oxygen
- $2\text{CuO} + \text{C} \rightarrow 2\text{Cu} + \text{CO}_2$
- Gold is found as the uncombined metal
- More reactive than carbon → extract by electrolysis
- $2\text{ZnO} + \text{C} \rightarrow 2\text{Zn} + \text{CO}_2$
- $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$

Notes

Where metals are found

- Very unreactive metals such as **gold** are found in the Earth as the metal itself (uncombined).
- Most metals are found as **compounds**, often oxides, in rocks. A rock that contains enough of a metal compound to make extraction worthwhile is called an **ore**.
- Chemical reactions are needed to extract a metal from its compound.

Reduction with carbon

- Metals **less reactive than carbon** can be extracted by heating their oxides with carbon.
- Carbon removes the oxygen from the metal oxide. The metal oxide is **reduced** (loses oxygen) and the carbon is **oxidised** (gains oxygen).
- Example: zinc oxide + carbon → zinc + carbon dioxide; $2\text{ZnO} + \text{C} \rightarrow 2\text{Zn} + \text{CO}_2$.
- Example: $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$.
- Carbon is used because it is cheap and it is more reactive than these metals.

Metals more reactive than carbon

- Metals **more reactive than carbon** (potassium, sodium, lithium, calcium, magnesium and aluminium) cannot be extracted by heating with carbon. They are extracted by **electrolysis** of their molten compounds.
- Electrolysis needs a lot of energy, so it is more expensive than reduction with carbon.
- Rule: find the metal in the reactivity series. Below carbon → reduce with carbon. Above carbon → electrolysis.

potassium	}	extract by electrolysis (more reactive than carbon)
sodium		
lithium		
calcium		
magnesium		
aluminium		
----- carbon -----		
zinc	}	heat the oxide with carbon (the oxide is reduced)
iron		
lead		
lead	}	found as the metal itself
copper		
gold		

Find the metal, then look at which side of carbon it is on.

Evaluating an extraction process

- You may be given information about a process you have not met. You do not need to learn the details of any industrial process.
- Use the reactivity series to explain the choice of reactant, e.g. scrap iron can be added to copper sulfate solution to obtain copper, because iron is more reactive and displaces it.

How to answer each type of question

Explain the choice of extraction method

2 marks

Grade 5

- Find the metal and carbon in the reactivity series.
- Below carbon: carbon is more reactive, so it can remove the oxygen from (reduce) the metal oxide.
- Above carbon: carbon cannot reduce the oxide, so electrolysis is needed.

Example. Tin is extracted by heating tin oxide with carbon. Magnesium cannot be extracted in this way.

Explain why.

Model answer. Tin is less reactive than carbon, so carbon can remove the oxygen from / reduce tin oxide (1)

Magnesium is more reactive than carbon, so carbon cannot reduce magnesium oxide (1)

Don't lose marks

- ✗ Saying carbon is used because it is 'more reactive' without saying it removes oxygen from the metal oxide.
- ✗ Saying the metal is oxidised during extraction: the metal oxide is reduced.
- ✗ Thinking carbon can extract aluminium or magnesium: both are more reactive than carbon.
- ✗ Writing only general points in an evaluation instead of using the information given.

More tips

Memory tricks

- Draw a line at carbon in the reactivity series: above the line → electrolysis, below the line → heat with carbon.
- A metal oxide is 'reduced' down to the bare metal: it loses oxygen.
- In a carbon reduction equation, carbon always ends up as carbon dioxide (or carbon monoxide) on the right.

Exam technique

- In 'evaluate' questions, give advantages and disadvantages and finish with a conclusion supported by the information.
- Use the phrase 'more reactive than carbon' or 'less reactive than carbon' whenever you explain a method.
- You do not need to learn industrial details (such as the blast furnace): the question gives you what you need.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Explain why gold is found as the metal

Gold is so unreactive that it is found in the Earth as the metal itself, not as a compound.

Grade 4

State which metals carbon can extract

Metals below carbon in the reactivity series, such as zinc, iron and copper, can be extracted by heating their oxides with carbon.

Grade 5

Write equations for reduction with carbon

For example, $2\text{ZnO} + \text{C} \rightarrow 2\text{Zn} + \text{CO}_2$.

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