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
- $2CuO + C \rightarrow 2Cu + CO_2$
- Gold is found as the uncombined metal
- More reactive than carbon → extract by electrolysis
- $2ZnO + C \rightarrow 2Zn + CO_2$
- $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

Notes

Where metals are found

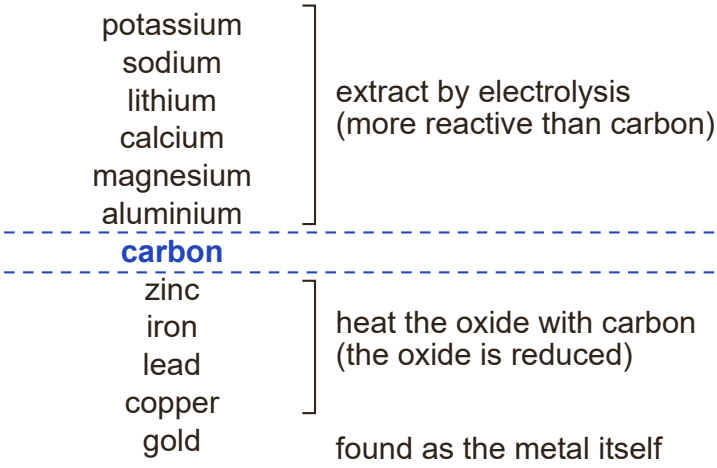
- Very unreactive metals such as **gold** are found in the Earth as the metal itself (uncombined).
- Most metals are found as **compounds**, often oxides, in rocks. A rock that contains enough of a metal compound to make extraction worthwhile is called an **ore**.
- Chemical reactions are needed to extract 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; $2ZnO + C \rightarrow 2Zn + CO_2$.
- Example: $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$.
- 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.



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.
- Compare methods using the data given: energy needed, cost of raw materials, how much metal is produced, waste products and effects on the environment (e.g. carbon dioxide released). End with a conclusion.

How to answer each type of question

Explain the choice of extraction method 2 marks **Grade 5**

1. Find the metal and carbon in the reactivity series.
2. Below carbon: carbon is more reactive, so it can remove the oxygen from (reduce) the metal oxide.
3. 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)

Balance the equation and identify what is oxidised 3 marks **Grade 6**

1. Balance one element at a time, then count atoms on both sides.
2. The substance that gains oxygen is oxidised; the one that loses oxygen is reduced.
3. Give the reason in terms of oxygen.

Example. Copper can be extracted by heating copper(II) oxide with carbon.
(a) Balance the equation: ....CuO + C → ....Cu + CO_2
(b) Which substance is oxidised? Give a reason for your answer.

Model answer.

(a) $2CuO + C \rightarrow 2Cu + CO_2$ (1)

(b) Carbon (1) because it gains oxygen (to form carbon dioxide) (1)

Evaluate an extraction process from given information 4 to 6 marks **Grade 5**

1. Pick out the facts in the information: temperature, energy, cost of reactants, speed, waste.
2. Turn each fact into an advantage or a disadvantage and say why.
3. Use the reactivity series to explain why the reaction works.
4. Finish with a conclusion if the question asks for a judgement.

Example. Titanium cannot be extracted by heating its oxide with carbon. In one process, titanium chloride is heated with sodium at a high temperature in an atmosphere of argon:
$TiCl_4 + 4Na \rightarrow Ti + 4NaCl$
Sodium is extracted by electrolysis of molten sodium chloride. The process is done in batches.
Evaluate this method of producing titanium. [4 marks]

Model answer.

Any four from:

sodium is more reactive than titanium, so it displaces titanium from titanium chloride (1)

heating to a high temperature needs a lot of energy, which is expensive (1)

sodium is expensive because electrolysis uses a lot of electrical energy (1)

argon (an unreactive gas) is needed to stop the hot metals reacting with oxygen in the air, which adds to the cost (1)

a batch process is slow, so less titanium is made in a given time (1)

conclusion: the method works, but it makes titanium an expensive metal (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, $2ZnO + C \rightarrow 2Zn + CO_2$.

Grade 5 — **Identify what is oxidised and reduced**
The metal oxide loses oxygen so it is reduced; carbon gains oxygen so it is oxidised.

Grade 5 — **Evaluate an unfamiliar extraction method**
Use the information given and the reactivity series to judge a method on energy, cost, raw materials and waste.

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