Cambridge (CIE) IGCSE Chemistry

Your notes

Extraction of Metals

Contents

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Extraction of Metals

- The Earth's crust contains metals and metal compounds such as gold, copper, iron oxide and aluminium oxide
- Useful metals are often **chemically combined** with other substances forming **ores**:
  - A metal ore is a rock that contains enough of the metal to make it worthwhile extracting
- They have to be extracted from their ores through processes such as **electrolysis**, using a **blast furnace** or by reacting with **more reactive** material
- In many cases the ore is an **oxide** of the metal, therefore the extraction of these metals is a reduction process since oxygen is being removed
- Common examples of oxide ores are **iron** and **aluminium** ores which are called **hematite** and **bauxite** respectively
- Unreactive metals do not have to be extracted chemically as they are often found as the **uncombined** element
- This occurs as they do not easily react with other substances due to their **chemical stability**
- They are known as **native metals** and examples include **gold** and **platinum** which can both be mined directly from the Earth's crust
- The position of the metal on the reactivity series influences the method of extraction
- Those metals placed higher up on the series (above carbon) have to be extracted using electrolysis
- Metals lower down on the series can be extracted by heating with carbon

The Extraction Method Depends on the Position of a Metal in the Reactivity Serie

Metal	Method of Extraction
Most reactive	
Potassium	Extracted by electrolysis of molten chloride or molten oxide Large amount of electricity required so expensive process
Sodium	
Lithium	
Calcium	

Magnesium	
Aluminium	
Carbon	
Zinc	Extracted by heating with reducing agent such as carbon or carbon monoxide
Iron	
Hydrogen	
Copper	Found as pure elements (copper may have to be extracted from it's ore by heating with carbon or hydrogen)
Silver	
Gold	
Least reactive	

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Extraction of iron from hematite

- Iron is extracted in a large container called a blast furnace from its ore, hematite
- Modern blast furnaces produce approximately 10,000 tonnes of iron per day

The blast furnace

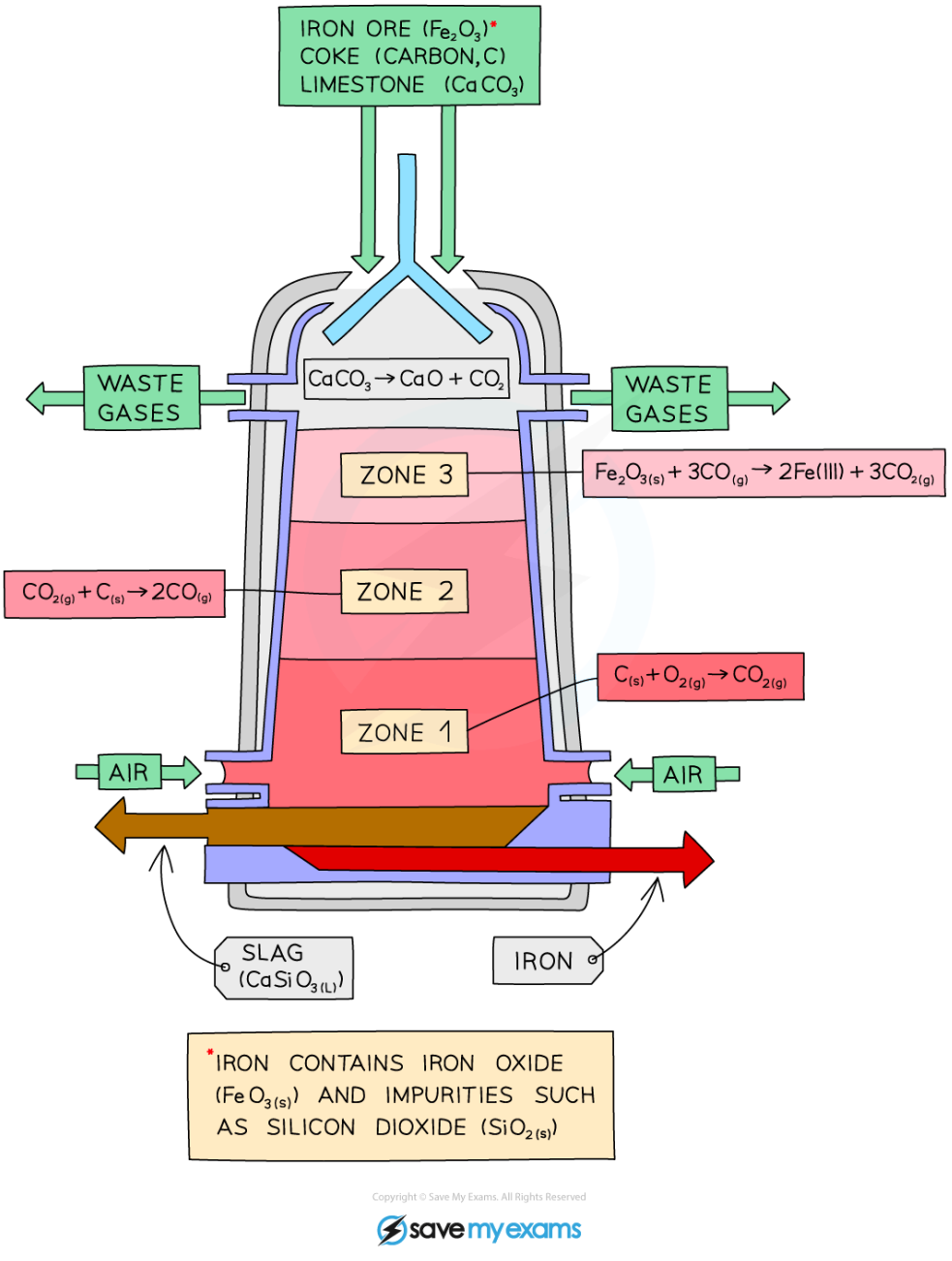

Diagram showing the carbon extraction of iron

- The raw materials: iron ore (hematite), coke (an impure form of carbon), and limestone are added into the top of the blast furnace
- Hot air is blown into the bottom

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Zone 1

- Coke **burns** in the hot air forming **carbon dioxide**
- The reaction is exothermic so it gives off heat, **heating** the furnace

carbon + oxygen → carbon dioxide

Zone 2

- At the high temperatures in the furnace, more coke reacts with carbon dioxide forming carbon monoxide
- Carbon dioxide has been **reduced** to carbon monoxide

carbon + carbon dioxide → carbon monoxide

Zone 3

- Carbon monoxide **reduces** the iron(III) oxide in the iron ore to form iron
- This will melt and collect at the bottom of the furnace, where it is tapped off

iron(III) oxide + carbon monoxide → iron + carbon dioxide

- Limestone (calcium carbonate) is added to the furnace to remove impurities in the ore
  - The calcium carbonate in the limestone **thermally decomposes** to form calcium oxide

calcium carbonate → calcium oxide + carbon dioxide

- The calcium oxide formed reacts with the silicon dioxide, which is an impurity in the iron ore, to form calcium silicate
- This melts and collects as a molten **slag** floating on top of the molten iron, which is tapped off separately

calcium oxide + silicon dioxide → calcium silicate

Examiner Tips and Tricks

For Core students, the symbol equations are **not** needed for the different reactions involved in the extraction of iron from hematite.

Equations for extraction of iron from hematite

Extended tier only

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Zone 1

- The burning of carbon (coke) to provide heat and produce carbon dioxide:

$$C\,(s) + O_2\,(g) \rightarrow CO_2\,(g)$$

Zone 2

- The reduction of carbon dioxide to carbon monoxide:

$$CO_2\,(g) + C\,(s) \rightarrow 2CO\,(g)$$

Zone 3

- The reduction of iron(III) oxide by carbon monoxide:

$$Fe_2O_3\,(s) + 3CO\,(g) \rightarrow 2Fe\,(l) + 3CO_2\,(g)$$

- The thermal decomposition of calcium carbonate (limestone) to produce calcium oxide:

$$CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$$

- The formation of slag:

$$CaO\,(s) + SiO_2\,(s) \rightarrow CaSiO_3\,(l)$$

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Extraction of aluminium from bauxite

- Aluminium is a reactive metal, above carbon in the reactivity series
- Its main ore, is **bauxite**, which contains aluminium oxide
- Aluminium is higher in the reactivity series than carbon, so it cannot be extracted by reduction using carbon
- Instead, aluminium is extracted by **electrolysis**

The electrolysis of aluminium

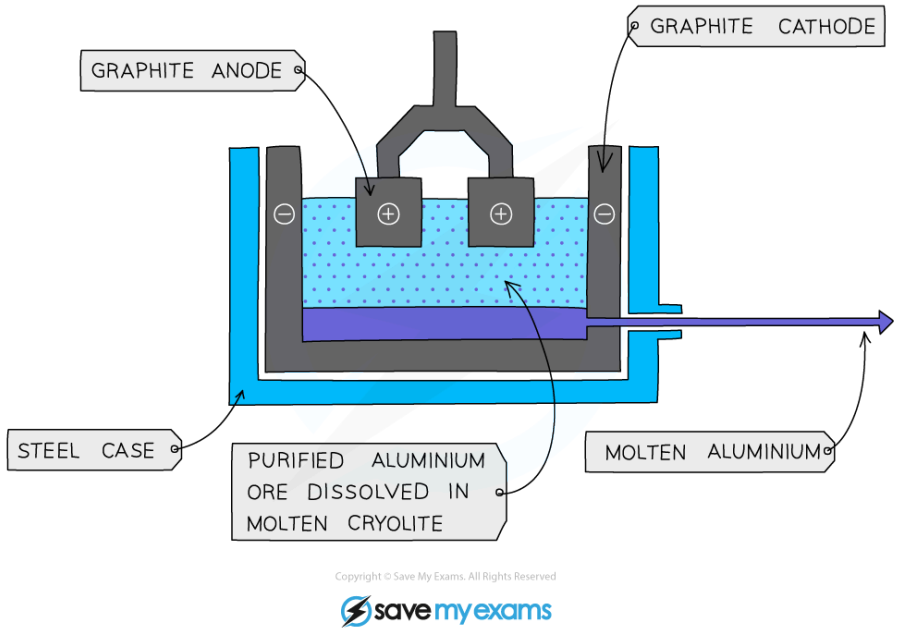

Diagram showing the extraction of aluminium by electrolysis

Examiner Tips and Tricks

If you are a Core student, you do **not** need to explain the process of extraction of aluminium by electrolysis.

The process of aluminium extraction by electrolysis

Extended tier only

- Bauxite is first **purified** to produce aluminium oxide, Al_2O_3
- Aluminium oxide is then dissolved in **molten cryolite**
  - This is because aluminium oxide has a melting point of over 2000 °C which would use a lot of energy and be very expensive
  - The resulting mixture has a lower melting point without interfering with the reaction
- The mixture is placed in an electrolysis cell, made from steel, lined with graphite
- The **graphite** lining acts as the negative electrode, with several large graphite blocks as the positive electrodes
- At the **cathode** (negative electrode):
  - Aluminium ions gain electrons (reduction)
  - Molten aluminium forms at the bottom of the cell
  - The molten aluminium is siphoned off from time to time and fresh aluminium oxide is added to the cell

$$Al^{3+} + 3e^- \rightarrow Al$$

- At the **anode** (positive electrode):
  - Oxide ions lose electrons (oxidation)
  - Oxygen is produced at the anode:

$$2O^{2-} \rightarrow O_2 + 4e^-$$

- The overall equation for the reaction is:

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

- The carbon in the **graphite** anodes reacts with the oxygen produced to produce **CO_2**

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

- As a result the anode wears away and has to be replaced regularly
- A lot of **electricity** is required for this process of extraction, this is a major **expense**

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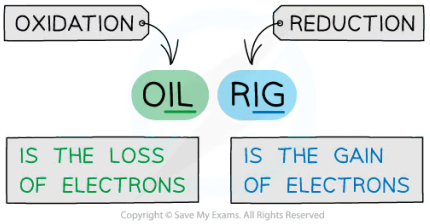
Examiner Tips and Tricks

Use OIL RIG to remember whether oxidation or reduction has occurred at the electrodes:



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