CAIE IGCSE Chemistry

9.6 Extraction of metals

Notes

Describe the ease in obtaining metals from their ores, related to the position of the metal in the reactivity series

- Most metals are extracted from their ores which are found in the Earth's crust
- An ore can be a rock or mineral that contains metals that are combined with other elements

To extract the pure metal from their ores, it depends on their position in the reactivity series:

- The more unreactive metals such as gold and silver are found in the pure form without any elements combined so don't need to undergo any chemical reaction to be obtained
- Zinc and iron are found bonded to oxygen, i.e. zinc oxide and iron oxide, so are reacted with carbon. Since carbon is higher in the reactivity series, it will displace the metal ions in the compounds.
    - This is known as: reduction with carbon
- The remaining metals above carbon in the reactivity series are extracted using electrolysis. An electric current is passed through the compound, e.g. aluminium oxide, to extract pure aluminium.

Most reactive
Potassium
Sodium
Calcium
Magnesium
Aluminium
(Carbon)
Zinc
Iron
(Hydrogen)
Copper
Silver
Gold
Least reactive

Describe the extraction of iron from hematite in the blast furnace. Symbol equations are not required

- The main ore of iron is known as hematite
  - Hematite contains large amounts of iron(III) oxide.
  - Since iron is lower than carbon in the reactivity series, pure iron is extracted through reduction with carbon.
  - The extraction takes place in a large blast furnace.
- The raw materials needed to do this are hematite, coke, limestone and air.
  - Hematite: made up of iron (III) oxide Fe_2O_3
  - Coke: Coal based fuel with a high carbon content
  - Limestone: Calcium carbonate $CaCO_3$ used to remove any acidic impurities from the iron
- The process in the blast furnace is continuous, meaning reactants are being added constantly without the reaction being stopped. This is to save on costs for energy that would otherwise be too expensive if the process had to be halted and restarted.

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

- The hematite, coke and limestone are added through the top of the blast furnace.
- Hot air enters through the bottom of the furnace and moves to the top.
- At the bottom of the furnace, the coke burns in the hot air producing carbon dioxide. This is an exothermic reaction, the heat released keeping the furnace hot.
- Carbon + Oxygen -> Carbon dioxide

(b) The reduction of carbon dioxide to carbon monoxide

- The carbon dioxide produced reacts with the coke to form carbon monoxide:
- Carbon dioxide + Carbon -> Carbon monoxide

(c) The reduction of iron(III) oxide by carbon monoxide

- The carbon monoxide produced reduces the iron(III) oxide to iron:
- Iron (III) oxide + Carbon monoxide -> Iron + Carbon dioxide
- The iron ions in iron (III) oxide are reduced to iron atoms
- Carbon monoxide is oxidised to carbon dioxide
- This method is most used to extract the pure iron, which flows to the bottom of the furnace and is removed.

(d) The thermal decomposition of calcium carbonate/limestone to produce calcium oxide

- The hematite contains other impurities like sand (silicon (IV) oxide), so limestone is added to helps remove these impurities
- Limestone is chemically calcium carbonate $CaCO_3$
- The heat from the furnace decomposes the $CaCO_3$, in a process known as thermal decomposition, into calcium oxide
- Calcium carbonate -> Calcium oxide + Carbon dioxide

(e) The formation of slag

- The calcium oxide reacts with the silicon (IV) oxide to form a 'slag' :calcium silicate.
- This slag can be used as a building material, e.g. for road building
- Calcium oxide + Silicon (IV) oxide -> Calcium silicate

State that…

- The main ore of aluminium is known as bauxite
- Aluminium is higher in the reactivity series than carbon, so is removed via electrolysis

(Extended only) State the symbol equations for the extraction of iron from hematite (a) C + O2 ⟶ CO2 (b) C + CO2 ⟶ 2CO (c) Fe2O3 + 3CO ⟶ 2Fe + 3CO2 (d) CaCO3 ⟶ CaO + CO2 (e) CaO + SiO2 ⟶ CaSiO3

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

- Carbon + Oxygen -> Carbon dioxide
- $C(s) + O_2(g) \rightarrow CO_2(g)$

(b) The reduction of carbon dioxide to carbon monoxide

- Carbon dioxide + Carbon -> Carbon monoxide
- $CO_2(g) + C(s) \rightarrow 2CO(g)$

(c) The reduction of iron(III) oxide by carbon monoxide

- Iron (III) oxide + Carbon monoxide -> Iron + Carbon dioxide
- $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$

(d) The thermal decomposition of calcium carbonate /limestone to produce calcium oxide

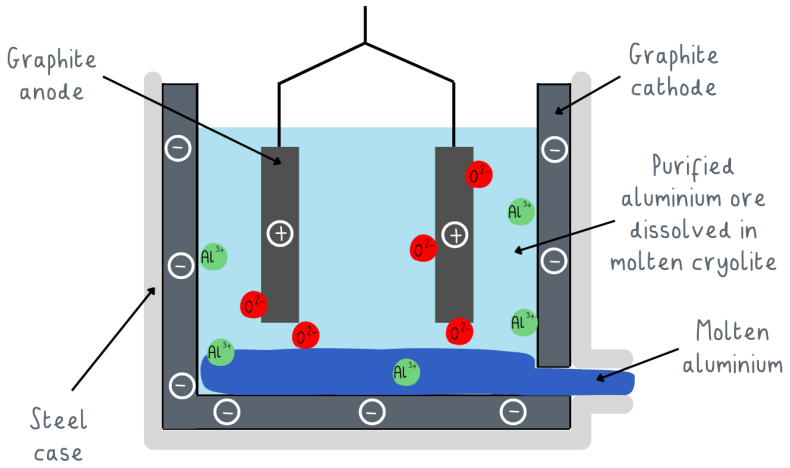
- Calcium carbonate -> Calcium oxide + Carbon dioxide
- $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(e) The formation of slag

- Calcium oxide + Silicon (IV) oxide -> Calcium silicate
- $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

(Extended only) Describe the extraction of aluminium from purified bauxite / aluminium oxide. Details of the purification of bauxite are not required

- The extraction of aluminium from purified bauxite is done by electrolysis.
- Purified bauxite contains aluminium oxide from which pure aluminium can be removed



(a) The role of cryolite

- For electrolysis to occur the ions in the aluminium oxide must be free to move so that electricity can pass through it.
- Molten cryolite is an aluminium compound with a lower melting point than aluminium oxide. The use of cryolite reduces some of the energy costs involved in extracting aluminium.
- Aluminium oxide has a very high melting point. It is dissolved in molten cryolite to reduce the melting point of the electrolyte, reducing energy usage and cost.

(b) Why the carbon anodes need to be regularly replaced

- The cathodes and the anodes involved in the electrolysis of aluminium are made of graphite, a form of carbon.
- During electrolysis oxide ions lose electrons at the anode, become oxidised and form oxygen molecules
- The anodes are eroded as the carbon they are made from reacts with the oxygen to form carbon dioxide, so they must be replaced frequently.

(c) the reactions at the electrodes, including ionic half-equations

- At the cathode: Positively charged aluminium ions are attracted and gain electrons (become reduced) to become aluminium atoms, forming pure molten aluminium.
- The half equation is $Al^{3+} + 3e^- \rightarrow Al$.
- At the anode: Negatively charged oxide ions are attracted and lose electrons (become oxidised) and form oxygen gas.
- The half equation is $2O^{2-} - 4e^- \rightarrow O_2$