Topic 13 – Metal Extraction
Revision Notes

1) Introduction

- Rocks that contain a high enough percentage of a metal for commercial extraction are known as ores
- Ores usually contain metal compounds, mainly oxides and sulphides
- Sulphide ores are usually converted into oxides by roasting in air. This produces SO_2 that would cause acid rain if released into the atmosphere. However, the SO_2 can be captured and used to make sulphuric acid, H_2SO_4
- Extraction of metals involves reduction of metal ions e.g.

$$\mathbf{Fe^{3+} + 3e^- \rightarrow Fe}$$

2) Reduction with carbon & carbon monoxide

- C and CO are cheap and effective reducing agents. They can be made from coke, which is purified coal. They are used in the extraction of iron, manganese and copper from their oxides

a) Iron, Fe

- Fe is extracted by heating Fe_2O_3 with carbon in a blast furnace
- This is a continuous process that needs a high temperature. The high temperature is produced by burning the carbon in a blast of hot air

$$\mathbf{C + O_2 \rightarrow CO_2}$$
$$\mathbf{CO_2 + C \rightarrow 2CO}$$

- The Fe_2O_3 is reduced by both C and CO

$$\mathbf{Fe_2O_3 + 3C \rightarrow 2Fe + 3CO}$$
$$\mathbf{Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2}$$

- Limestone (calcium carbonate) is added to the blast furnace to remove sandy impurities (SiO_2)
- Calcium silicate (slag) is produced which can be used in the construction industry (for road building, to make breeze blocks)

$$\mathbf{CaCO_3 \rightarrow CaO + CO_2}$$
$$\mathbf{CaO + SiO_2 \rightarrow CaSiO_3}$$

b) Manganese, Mn

- Manganese is extracted by the reduction of manganese dioxide

$$\mathbf{MnO_2 + 2C \rightarrow Mn + 2CO}$$

c) Copper, Cu

- Cu is extracted from the ore chalcopyrite, $CuFeS_2$, in a three stage process
- In the first stage chalcopyrite is heated with silicon dioxide and oxygen

$$\mathbf{2CuFeS_2 + + 2SiO_2 + 4O_2 \rightarrow Cu_2S + 2FeSiO_3 + 3SO_2}$$

- The SO_2 produced would cause acid rain if released into the atmosphere. However, the SO_2 can be captured and used to make sulphuric acid, H_2SO_4
- In stage 2, the copper(I) sulphide is roasted with oxygen at a high temperature

$$\mathbf{Cu_2S + 2O_2 \rightarrow 2CuO + SO_2}$$

- In stage 3, the copper(II) oxide is reduced by heating with carbon

$$\mathbf{CuO + C \rightarrow Cu + CO}$$

d) Ti, Al and W

- Titanium and tungsten are not extracted by heating their oxides with carbon because the carbide would be formed as well as the metal. The carbide (e.g. TiC) makes the metal brittle and useless
- Aluminium is not extracted by heating with carbon because the temperature required is too high

3) <u>Reduction by electrolysis</u>

- Aluminium is useful because it resists corrosion and has a low density
- Al is extracted from purified bauxite (aluminium oxide) by electrolysis
- Electrolysis is more expensive than heating with carbon because electricity is expensive
- Al_2O_3 is dissolved in molten cryolite. The cryolite needs to be molten so that ions are free to move
- A high temperature is needed to keep the cryolite molten but the temperature is less than that required to melt Al_2O_3 thus saving energy costs
- The electrode equations are as follows:

$$\mathbf{Al^{3+} + 3e^- \rightarrow Al}$$
$$\mathbf{2O^{2-} \rightarrow O_2 + 4e^-}$$

- Carbon electrodes are used which have to be replaced from time to time. The positive electrode burns away as the carbon reacts with the oxygen produced there

$$\mathbf{C + O_2 \rightarrow CO_2}$$

4) <u>Reduction with reactive metals</u>

- Ti is extracted from TiO_2 by conversion to $TiCl_4$ then displacement by a more reactive metal (Na or Mg) which acts as the reducing agent
- This is a batch process (which involves stopping and starting)

$$\mathbf{TiO_2 + C + 2Cl_2 \rightarrow TiCl_4 + CO_2}$$
$$\mathbf{TiCl_4 + 4Na \rightarrow Ti + 4NaCl}$$

- Both stages need a high temperature to increase the reaction rate
- The second stage needs an atmosphere of argon (which is unreactive). This prevents Ti and Na reacting with air and prevents $TiCl_4$ and Na reacting with water
- Extracting Ti by this process is expensive because: Na and Cl_2 are expensive because they have to be made by electrolysis, it is a batch process (inefficient), an argon atmosphere is needed, both stages need a high temperature

5) Reduction with hydrogen

- Tungsten is extracted from its oxide using hydrogen gas as the reducing agent

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

- Tungsten is heated to around 700°C in a stream of hydrogen
- Air has to be exclude from the system as there is a risk of explosion using hydrogen at this sort of temperature

6) Recycling

- In economic terms, recycling uses less energy than extraction from an ore. In environmental terms, recycling reduces landfill, reduces mining, reduces acid rain and reduces greenhouse gas emission
- Recycling aluminium is viable because expensive electricity is needed to produce the new aluminium by electrolysis
- There are costs involved with recycling: collection of scrap and separation of the pure metal

7) Extraction of copper from low grade ores

- Aqueous solutions of copper compounds can be made by leaching from low grade ores
- The copper can then be extracted by displacement using scrap iron as the reducing agent

$$Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$$

- This is a low cost method of extracting copper because it uses scrap iron as the reducing agent and it has a low energy requirement