Equilibrium

What is a *Reversible Reaction*?
Give 2 examples.

Explain what is meant by *Equilibrium*.

Explain how the equilibrium position is affected by changes in *Concentration*, *Temperature* and *Pressure*.

How is yield related to equilibrium position?

Reversible Reaction:

A reaction that can take place in both directions, e.g.

$$CuSO_4 \cdot 5H_2O_{(s)} \underset{\text{Water}}{\overset{\text{Heat}}{\rightleftharpoons}} CuSO_{4\,(s)} + 5H_2O_{(l)}$$

$$CoCl_{2\,(s)} + 6H_2O_{(l)} \underset{\text{Heat}}{\overset{\text{Water}}{\rightleftharpoons}} CoCl_2 \cdot 6H_2O_{(s)}$$

Equilibrium:

- The **forward** and **backward** reactions take place at the **same rate**
- There is no overall change in the concentration of reactants and products

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Effect of Change in Concentration:

The equilibrium position moves to the **products** side if:

- the reactant concentration increases (e.g. more reactant is added)
- the product concentration decreases (e.g. product is removed)

Effect of Temperature Change:

Temperature **increase**: equilibrium position moves in the **endothermic** direction

Temperature **decrease**: equilibrium position moves in the **exothermic** direction

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Effect of Pressure Change:

Pressure **increase**: equilibrium position moves to side with **fewer gas molecules**

Pressure **decrease**: equilibrium position moves to side with **most gas molecules**

Yield & Equilibrium Position:

The yield will be higher if the equilibrium position is further towards the products side

Sulfur

Name 3 natural sources of sulfur.

What is produced in the *Contact Process*?
List the raw materials.
State the 4 steps in the Contact Process, with equations.

Describe the properties of both *Dilute Sulfuric Acid* & *Concentrated Sulfuric Acid*.

Give uses of *Sulfuric Acid* & *Sulfur Dioxide*.

Sources:

- As the element (underground and near volcanoes)
- As a compound in metal ores, e.g. galena (lead(II) sulfide, PbS)
- In fossil fuels, e.g. coal, crude oil & natural gas

Contact Process:

Product: Sulfuric acid (H_2SO_4)

Raw materials: Sulfur (or sulfur dioxide), air, water

Step 1: Sulfur is burned in air to make sulfur dioxide:

$$S_{(g)} + O_{2\,(g)} \longrightarrow SO_{2\,(g)}$$

Step 2: SO_2 is mixed with more air and passed over a vanadium(V) oxide catalyst at 450°C, 1–5 atmospheres pressure to make sulfur trioxide:

$$2SO_{2\,(g)} + O_{2\,(g)} \underset{450°C,\ 1-5\ atm}{\overset{\text{Vanadium(V) oxide}}{\rightleftharpoons}} 2SO_{3\,(g)}$$

Step 3: SO_3 is dissolved in concentrated sulfuric acid to make oleum:

$$H_2SO_{4\,(l)} + SO_{3\,(g)} \longrightarrow H_2S_2O_{7\,(l)}$$

Step 4: Oleum is mixed with water to produce concentrated sulfuric acid:

$$H_2S_2O_{7\,(l)} + H_2O_{(l)} \longrightarrow 2H_2SO_{4\,(l)}$$

Properties of Sulfuric Acid:

- Dilute sulfuric acid shows the usual reactions of acids, e.g. it reacts with metals, metal oxides, hydroxides and carbonates forming salts called sulfates.
- Concentrated sulfuric acid is a dehydrating/drying agent – it removes water.

Uses of Sulfuric Acid:

- Fertilisers, e.g. ammonium sulphate
- Paints, pigments, dyes
- Fibres, plastics
- Soaps, detergents
- Car batteries

Uses of Sulfur Dioxide:

- As a bleach in the manufacture of wood pulp for paper
- As a food preservative (it kills bacteria)

Haber Process & Fertilisers

What is the *Haber Process*? Give an equation.
Where are the *Raw Materials* obtained from?
What *Temperature*, *Pressure* & *Catalyst* are required?
How can the equilibrium be forced to make more ammonia?

Give uses of ammonia.

Why are fertilisers necessary? Give 4 examples of fertilisers, including formulae.

Haber Process:

An industrial process for the production of ammonia (NH_3) from nitrogen and hydrogen

Equation: $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons^{\text{Iron catalyst}} 2NH_{3\,(g)}$

Raw Materials:

- Nitrogen – extracted from the air (by fractional distillation – *see card **Pink 16***)
- Hydrogen – from reacting methane with steam or from cracking alkanes

Temperature: 450°C

Pressure: 200 atmospheres

Catalyst: Iron

Increasing the yield:

The ammonia is cooled, so that it condenses into a liquid and can be removed

This makes the equilibrium move to the products side, increasing the yield

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Uses of Ammonia:

- Fertilisers
- Explosives
- Cleaning products

Fertilisers:

Fertilisers make crops grow bigger and faster

e.g. Ammonium nitrate, NH_4NO_3

Ammonium sulfate, $(NH_4)_2SO_4$

Ammonium phosphate, $(NH_4)_3PO_4$

Potassium sulfate, K_2SO_4

*Fertilisers contain **N** (Nitrogen), **P** (Phosphorus) and **K** (Potassium) which are essential for healthy plant growth*