2.6 Reversible Reactions, Industrial Processes and Important Chemicals

Reversible Reactions:

- **Reversible Reaction** - a reaction that happens in **both directions**. This means the **products** of the reaction can **react together** to produce the **original reactants**.
- ⇌ - the **symbol** used to represent a reversible reaction.
- If the **forward** reaction is **exothermic**, the reverse reaction is **endothermic**.

The Haber Process:

- The **Haber process** is used in the industrial production of **ammonia**.
- **Ammonia** is a **pungent** smelling **alkaline** gas with the chemical formula **NH_3**.
- **Nitrogen** gas (from the air) and **hydrogen** gas (from natural gas) react together to **produce ammonia**.

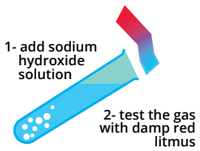
Nitrogen	+	Hydrogen	⇌	Ammonia
$N_{2(g)}$		$3H_{2(g)}$	⇌	$2NH_{3(g)}$

- The ammonia is collected by **cooling** the reaction mixture so the **ammonia condenses** into a liquid.
- The **unreacted nitrogen and hydrogen** are **recycled** back through the process, so there is no waste.

Tests for ammonia gas and ammonium ions

Ammonia gas (NH_3) — Ammonia gas will change damp red litmus paper blue.

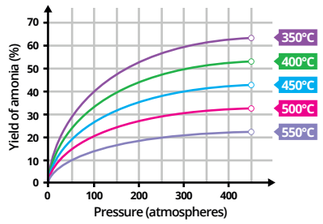
Ammonium ion (NH_4^+)



The ammonium ions convert into ammonia gas which turns the damp red litmus paper blue.

The Chosen Reaction Conditions:

- The reaction conditions for the process are a **compromise** between the **yield** of production, **rate** of production, **cost** and **safety**.



*The graph shows that a **lower temperature** and **higher pressure** would produce the **best theoretical yield***

  - » The **rate** of production is **too slow** at a **lower temperature**. A higher temperature is a compromise between yield and rate.
  - » Operating at **higher pressures is expensive**. There is also **more risk** of **explosions**. A lower pressure is a compromise between yield and cost/safety.

- The **catalyst** works like any catalyst - speeding up the rate of production, without getting used up. However, over time, it does get poisoned and needs replacing.

Fertilisers:

- The majority of **ammonia** and **sulfuric acid** produced is used to **make fertilisers**.
- **Ammonium sulfate** – common fertiliser made by **neutralising** the sulfuric acid* with ammonia or ammonium hydroxide.

ammonia	+	sulfuric acid	→	ammonium sulfate
$2NH_3$		H_2SO_4	→	$(NH_4)_2SO_4$

ammonium hydroxide	+	sulfuric acid	→	ammonium sulfate	+	water
$2NH_4OH$	+	H_2SO_4	→	$(NH_4)_2SO_4$	+	$2H_2O$

* Other acids can be used – e.g. **nitric acid** produces ammonium **nitrate**.

Advantages and disadvantages of fertilisers:

Advantages	Disadvantages
• Increases crop yield	• Eutrophication
• Healthier crops	• Risk of stomach cancer
• Improves soil quality	• *Blue baby syndrome*

The Contact Process:

- The **Contact process** is used in the industrial production of **sulfuric acid**, **H_2SO_4**.
- The process is in **3 stages**. The **raw materials** are **sulfur** (stage 1), **air** (stages 1 + 2) and **water** (stage 3).

Stage 1: Sulfur buns in air to form **sulfur dioxide** gas.

sulfur	+	oxygen	→	sulfur dioxide
$S_{(s)}$	+	$O_{2(g)}$	→	$SO_{2(g)}$

Stage 2: Sulfur dioxide reacts with more oxygen to form **sulfur trioxide** gas:

sulfur dioxide	+	oxygen	⇌	sulfur trioxide
$2SO_{2(g)}$	+	$O_{2(g)}$	⇌	$2SO_{3(g)}$

- The reaction in this stage is reversible. The conditions used are:
  - » 400 – 500°C
  - » Atmospheric pressure
  - » Vanadium(V) oxide catalyst

Stage 3: Sulfur trioxide is dissolved in concentrated sulfuric acid to produce **oleum**.

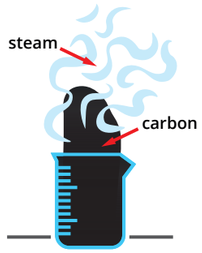
sulfur trioxide	+	sulfuric acid	→	oleum
$SO_{3(g)}$	+	$H_2SO_{4(l)}$	→	$H_2S_2O_{7(l)}$

The oleum is then **diluted with water** to produce sulfuric acid.

oleum	+	Water	→	sulfuric acid
$H_2S_2O_{7(l)}$	+	$H_2O_{(l)}$	→	$2H_2SO_{4(l)}$

Note - adding sulfur trioxide directly to water is too violent!!!

Sulfuric acid as a dehydrating agent:



Concentrated sulfuric acid is a dehydrating agent – it **removes water** from a substance.

*In **glucose** - the concentrated sulfuric acid takes away the elements of water leaving **only carbon**.*

glucose	→	carbon	+	water
$C_6H_{12}O_6$	→	$6C_{(s)}$	+	$H_2O_{(g)}$

*The water is removed as **steam** because the reaction is **exothermic.***