# CHEM 9.4.2 HABER PROCESS

## Chemical processes in industry require monitoring and management to maximise production

### 2.1 Identify and describe the **industrial uses of ammonia**

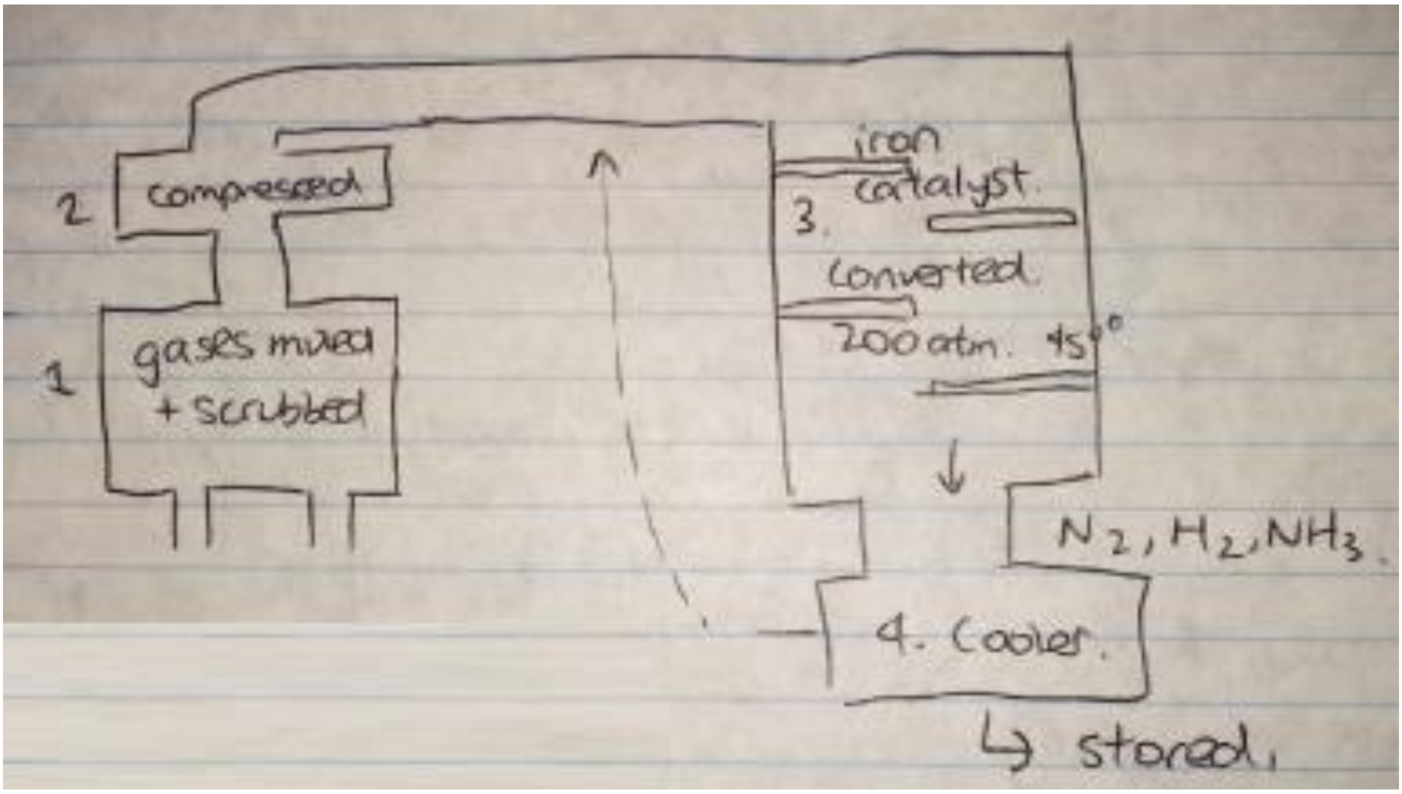
- **Fertilisers** – reaction with sulfuric acid to form ammonium sulfate fertiliser
- **Nitric acid** – through **Ostwald Process** to make **ammonium nitrate** fertiliser, explosives
- Detergents, pharmaceuticals, household cleaners, fibres and plastics (rayon, acrylics, nylon)

### 2.2 Identify that ammonia can be **synthesised from its component gases**, nitrogen and hydrogen

- Both gases, **$N_2$ and $H_2$ synthesise** as $NH_3$ is made up of nitrogen and hydrogen atoms
  - Therefore can be synthesised from $N_2$ and $H_2$

### 2.3 Describe that synthesis of ammonia occurs as a **reversible reaction** that will reach **equilibrium**

- Industrially known as **Haber process**: $\mathbf{N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}}$ $\Delta H = -92\ \text{kJ/mol}$
- **Does not go to completion**, instead reaches equilibrium (at ordinary pressures and temperatures, lies to left)
- **Synthesis** (Haber process) occurs by reacting nitrogen from air and hydrogen from natural gas ($C_2H_4$ + $H_2O$)
  - Gas is **optimally synthesised** (see below) and passed through catalyst
  - Gas then cooled and **ammonia becomes a liquid**, unreacted gases recycled




### 2.4 Identify the reaction of hydrogen with nitrogen as **exothermic**

- The equation is $\Delta H = \mathbf{-92\ kJ}/\text{mol}$, meaning that it is exothermic as **ΔH is negative**

## 2.5 Explain why the **rate of reaction is increased** by **higher temperatures**

- Increased temperature in reaction, causing **increased movement in the particles** ($N_2$ and $H_2$)
  - Therefore **more particles collide** and allows **reaction speed** to be **increased**
  - **Equilibrium reached faster**

## 2.6 Explain why the **yield of product** in the Haber process is **reduced** at **higher temperatures** using Le Chatelier's principle

- Le Chatelier's principle states that when an equilibrium is disturbed, it will move to minimise the disturbance
  - Reaction is **exothermic**: $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}\ (+\,\text{heat})$
  - Therefore higher temperatures will **reduce products** and equilibrium **moves to the left**

## 2.7 Explain why the Haber process is based on a **delicate balancing act** involving **reaction energy, reaction rate and equilibrium**

- **Compromise conditions** (balancing act) used to produce highest yield quickly
  - **Reaction energy** increased through **higher temperatures**, but affects equilibrium
  - **Reaction rate** increased by **increasing temperature** (faster), **catalyst** (iron) and **higher pressure**
  - **Equilibrium** to the right by **lower temperatures**, **higher pressure, removal of ammonia** continuously
    - **Removal** by liquefaction – lowers concentration of $NH_3$ so shifts right
- Therefore:
  - Temperature at **400°C, 250 atm with iron catalyst**

## 2.8 Explain that the **use of a catalyst** will **lower the reaction temperature** required and identify the catalyst(s) used in the Haber Process

- Catalyst used to **increase reaction rate** by reducing energy required for reaction to occur
- Catalyst is **magnetite** (iron oxide) – $Fe_3O_4$
  - Surface is **reduced to iron** and **finely ground** – **large surface area**
- Reaction rate can be increased through higher temperatures, but due to **compromise**, **catalyst retains rate**

## 2.9 Analyse the impact of **increased pressure** on the system involved in the **Haber process**

- Le Chatelier's principle – increasing pressure will **favour the side with less moles** of gas
  - Gas ratio of 4:2 – favours **products** – **increases yield of $NH_3$**

## 2.10 Explain why **monitoring of the reaction vessel** used in the Haber process is **crucial** and discuss the **monitoring required**

- In **reaction vessel**, temperature (400°C) and pressure (250 atm)
  - **High temperatures** can damage catalyst, for optimal conversion
  - **High pressures** may cause explosion
- In monitoring **reactants**
  - **Ratio 1:3** for $N_1$:$H_2$ – build-up of gas increases pressure
  - **Contaminants removed** – **oxygen removed** (explosive with $H_2$), **low CO, $CO_2$ and** S (poisons catalyst)
- In monitoring **products** – ammonia should be pure – contaminates product

2.P1 Gather and process information from secondary sources to describe the **conditions** under which Haber developed the **industrial synthesis** of ammonia and evaluate its **significance at that time** in world history

- **Fritz Haber 1908** developed method of synthesising ammonia
- **Carl Bosch 1914** converted into industrial process (therefore **Haber-Bosch process**)
- Nitrates for fertilisers and explosives from **saltpetre** (sodium nitrate) from **Chile/South America**
  - Ammonium nitrate, TNT and dynamite explosives
- British cut off supplies of saltpetre in **World War I** to Germany
- Haber process introduced, meaning a **cheap source of nitrates**
  - $NH_3$ converted to nitric acid and nitrates through Ostwald process
  - Therefore Germany **continued war**