

## Obtaining Metals and Equilibria

### 5.19—The Haber process

The Haber process is a **reversible** reaction between **nitrogen** gas (fractionally distilled from air) and **hydrogen** gas (made from natural gas) to produce **ammonia** gas.

### 5.20—Rate of attainment of equilibrium (HT only)

#### 5.20a—Change in temperature

Increasing the temperature will lead to all molecules having more **energy**, and so they will collide more **frequently**. Both the **forward and backward** reactions will occur faster, and therefore equilibrium will be reached **faster**.

#### 5.20b—Change in pressure

Increasing the pressure will lead to all gaseous molecules being **closer** together, and so they will collide more **frequently**. Both the **forward and backward** reactions will occur faster (if there are gases on both sides), and therefore equilibrium will be reached **faster**.

#### 5.20c—Change in concentration

Increasing the concentration will lead to there being more **particles** per litre, and so they will collide more **frequently**. Both the **forward and backward** reactions will occur faster, and therefore equilibrium will be reached **faster**.

#### 5.20a—Use of a catalyst

Adding a catalyst reduces the **activation** energy of both the **forward and backward** reactions, which will therefore occur faster, and therefore equilibrium will be reached **faster**.

### 5.22—Fertilisers

Fertilisers are chemicals which promote plant growth. They contain significant quantities of the elements **nitrogen**, **phosphorus** and **potassium**. The elements aren't soluble for the roots to absorb, so fertilisers tend to contain salts, especially ammonium ( $\text{NH}_4^+$ ), **phosphate** ( $\text{PO}_4^{3-}$ ) and nitrate ( $\text{NO}_3^-$ ) salts.

### 5.21—Managing industrial reactions

#### 5.21a—Raw materials and energy

The **cost** and **availability** of raw materials determines whether a process is feasible. The process used will depend on these factors. Generally, processes are preferred where the energy costs are **lower**, and raw materials are **renewable**.

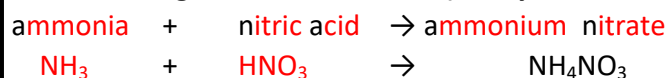
#### 5.21b—Compromise conditions\*

Increasing the **temperature** or **pressure** (of a reaction involving gases) will increase the **rate** of the reaction. However, they also affect the **position** of equilibrium. Where this 'shifts left', reducing the quantity of **products** made, a compromise must be reached.

For example, if the forward reaction of a dynamic equilibrium is **exothermic** (gives out energy), increasing temperature will **reduce** the yield of product. A compromise between **rate** and **yield** must be reached, so enough product is made quickly enough.

Increasing pressure will shift the equilibrium to the side with **fewer** moles of gas. There is also the consideration of the **costs** of using high pressure—both in terms of the initial cost of the reaction vessel and generating the pressures. The pressure used is determined by these factors. Using a **catalyst** has no downsides, as the **rate** is increased whilst the **yield** is unaffected.

### 5.23—Making ammonium nitrate (a very useful fertiliser)



### 5.24—Making ammonium sulfate (another useful fertiliser)

#### 5.24a—Making ammonium sulfate on a small scale (in a laboratory)

In a laboratory, **ammonia** solution is reacted with dilute **sulfuric** acid (via a titration reaction). The neutral salt solution ( $(\text{NH}_4)_2\text{SO}_4$ ) is then left to **crystallise**.

This is a **batch** process, meaning small amounts are made relatively **small**.

#### 5.24b—Making ammonium sulfate in industry

In industry, ammonium sulfate is made in several stages. The **ammonia** and **sulfuric** acid are manufactured in situ, from the raw materials, rather than purchasing **ammonia** and **sulfuric** acid in. This process is **continuous**, meaning  $(\text{NH}_4)_2\text{SO}_4$  can **always** be made if the raw materials are available.