

CHEMICAL EQUILIBRIUM PART 1

DYNAMIC EQUILIBRIUM

Many reactions are **reversible** – they can go backwards and forwards. Reversible reactions are indicated by a special arrow like this:



When a reversible reaction is set up in a **closed system** (so no chemicals can enter or leave), the rates of the forward and reverse reactions can become equal.

In this situation, the concentrations of product and reactant do not change (even though the reaction is still happening) – this is called **dynamic equilibrium**.

C is made as fast as it turns back into A and B – it looks as if nothing is happening, but it is!

MEASURING THE POSITION OF EQUILIBRIUM

Coloured compounds

You can see changes in the position of equilibrium if some (or all) of the chemicals are coloured.

e.g. $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$: since N_2O_4 is colourless and NO_2 is brown, the further the position of equilibrium is to the right, the darker brown the mixture appears.

Acid-base reactions

In equilibria involving acids or bases, pH will change as the position of equilibrium changes. A pH meter or indicator can be used to investigate such equilibria, e.g. $\text{HCOOH}(aq) \rightleftharpoons \text{HCOO}^-(aq) + \text{H}^+(aq)$.

LE CHATELIER'S PRINCIPLE

The **term position of equilibrium** refers to how much product and how much reactant there is when a reaction reaches a state of dynamic equilibrium. If there is a lot of product but not much reactant, you say the position of equilibrium lies to the right. If there is little product but a lot of reactant, you say the position of equilibrium lies to the left.

Changes in temperature, pressure or concentration can cause the position of equilibrium to change. Le Chatelier's principle is a way of predicting the **direction of change** – it says the position of equilibrium moves to **minimise the change**.

Effect of changing pressure

Which way will this equilibrium move if the pressure is increased? $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$

- 1 What is the change in condition? **Pressure increases**
- 2 What is the reverse of this? **Pressure decreases, i.e. less gas in same volume**
- 3 Which direction causes this? **Move to where there are fewer moles of gas, i.e. left**

Effect of changing temperature

Which way will this equilibrium move if the temperature is increased? $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$ $\Delta H = +ve$

- 1 What is the change in condition? **Temperature increases**
- 2 What is the reverse of this? **Temperature decreases**
- 3 Which direction causes this? **Move in the endothermic direction, i.e. right**

INDUSTRIAL EQUILIBRIA

Understanding how temperature and pressure affect the position of an equilibrium allows chemical engineers to maximise the amount of product made in a process.

Rate of reaction must be balanced against the **yield** (position of equilibrium), e.g. in the Haber process for making ammonia, high temperature increases the rate, but moves the position of equilibrium to the left, lowering yield.

Compromise conditions are used – a fairly low yield is produced, but quite quickly.

Unreacted N_2 and H_2 are reused – by making low yields frequently, more NH_3 is produced in total than waiting a long time for a high yield.

Effect of changing concentration

Which way will this equilibrium move if HCOONa is added? $\text{HCOOH}(aq) \rightleftharpoons \text{HCOO}^-(aq) + \text{H}^+(aq)$

- 1 What is the change in condition? **Adding HCOONa increases the concentration of HCOO^-**
- 2 What is the reverse of this? **Decrease the amount of HCOO^- in the solution**
- 3 Which direction causes this? **React HCOO^- with H^+ to form HCOOH – move left**

Effect of adding a catalyst

Which way will this equilibrium move if a vanadium oxide catalyst is added? $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$

A catalyst lowers the activation energy for a reaction – making **both forward and backward reactions faster** by the same amount. This **does not change** the position of equilibrium.

THE HABER PROCESS

hot = fast, low yield cold = slow, high yield



low pressure = slow, low yield high pressure = fast, high yield

A catalyst (iron) is added – this does not affect the yield but speeds up the reaction