Equilibria

Reversible Reactions

- In a reversible reaction the products can react to form the reactants back
- the reaction can proceed in both the forward and backward directions

- Reversible reactions are represented by a double arrow $\rightleftharpoons$

Dynamic Equilibrium

- When the rate of the forward reaction is equal to the rate of the backward direction in a closed system

Le Chatelier's principle

When any dynamic equilibrium is disturbed, it will shift the equilibrium in the forward or backward direction to undo the disturbance and restore the equilibrium.

1. Temperature: Increasing temperature shifts the equilibrium towards the endothermic reaction, decreasing shifts towards exothermic

2. Pressure: Increasing pressure shifts equilibrium towards lesser number of moles of gas

3. Concentration: Increasing concentration of reactants or decreasing concentration of products will shift equilibrium towards forward reaction. Decreasing concentration of reactants or increasing concentration of products shifts equilibrium towards backward reaction.

Equilibrium Constant - Concentrations

- The equilibrium constant K_c is the ratio of concentrations of products in a reaction to the concentrations of the reactants
- Square brackets [ ] represent concentration
- K_c = [products] / [reactants]
- The concentrations of different products and reactants are multiplied with each other, the moles of each substance are taken as a power in the calculation
- The unit of K_c is deduced from its calculation
- Only a change in temperature affects the value of K_c

K_c calculation example

$$2SO_2(g) + O_2 \rightleftharpoons 2SO_3\ (g)$$

$$K_c = \frac{[SO_3]^2}{[SO_2]^3[O_2]}$$

Mole fraction

it is the number of moles of one gas divided by the total number of moles of gas at equilibrium

Partial Pressure

It is the pressure exerted by one gas in a mixture of gases
Sum of partial pressures = total pressure

Partial pressure = mole fraction x total pressure

Equilibrium Constant - Partial Pressures

- The equilibrium constant K_p is the ratio of the partial pressures of the products to the partial pressure of the reactants
- K_p = partial pressure of products/partial pressure of reactants
- Only a change in temperature affects the value of K_p

$$2SO_2(g) + O_2 \rightleftharpoons 2SO_3\ (g)$$

$$K_c = \frac{p(SO_3)^2}{p(SO_2)^3 p(O_2)}$$

Conditions used in Haber's process

$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$

- The Haber's process is carried out under the conditions of 450 - 500 degrees temperature, 200 - 250 atm, and Fe or Fe_2O_3 as catalyst
- Although temperature increases the rate of reaction, it shifts equilibrium backward since the backward reaction is endothermic which decreases the yield of ammonia. Therefore, a compromising temperature of 450-500 degrees is used.
- Increasing pressure increases both the rate of reaction but also shifts equilibrium forward and increases yield. Thus, pressure is kept at 200-250 atm, however, maintaining higher pressures is expensive.

Conditions used in the Contact Process

$2SO_2$ (g) + O_2(g) ⇌ $2SO_3$ (g)

- Increasing pressure shifts equilibrium forward
- However the reaction is carried out at 1 atm
- This is because the K_p is already high, higher pressures are expensive and unnecessary
- Although temperature increases the rate of reaction, it shifts equilibrium backward since the backward reaction is endothermic which decreases the yield of ammonia. Therefore, a compromising temperature of 450 degrees is used.

Lowry-Bronsted acid-base theory

- According to this theory, acids are proton donors (H^+ ions) and bases are protons accepters
- A lowry-bronsted acid is a substance that gives away H^+ ions
- A Lowry-Bronsted base is a substance that accepts H^+ ions

CH_3CO_2H	+	H_2O	⇌	H_3O^+	+	$CH_3CO_2^-$
Bronsted Acid		Conjugate Acid		Conjugate Acid		Conjugate Base

pH Scale

- it is a scale that shows how acidic or alkaline a substance is
- Acids have pH below 7
- Alkalis have pH above 7
- pH 7 is neutral, water has ph7
- the lower the pH, the more acidic a substance is
- the higher the pH, the more alkaline a substance is
- the most accurate way to measure pH is with a pH metre
- it can also be measured using a universal indicator which changes colour according to the pH of the solution; acids are red/orange, neutral solutions are green, bases are blue/purple

Strong & Weak Acids

- Strong acids fully dissociate H^+ ion in water
- The greater the concentration of the H^+ ions, the more acidic the substance
- Weaker acids only partially dissociate H^+ ions
- Stronger acids conduct electricity better due to the concentration of H^+ ions
- Stronger acids are more reactive

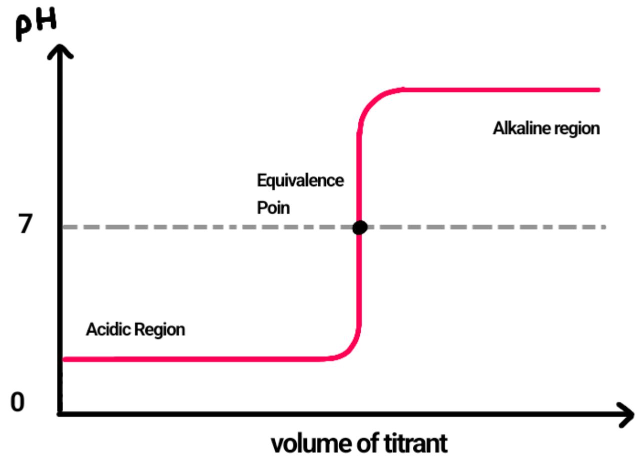
Neutralisation Reaction

- A reaction between an acid and an alkali to produce a salt and water
- The ionic equation of any neutralisation reaction is the same

H^+(aq) + OH^-(aq) → H_2O (l)

pH Titration Curve

- Titration is a technique used to carry out neutralisation reactions
- It involves adding a titrant from a burette to a solution in a conical flask with an indicator
- The titrant is added till the end point, which is when solution changes colour
- Neutralisation takes place at the end point
- It is also known as the equivalence point



- The curve is drawn with the volume of titrant in cm^3 at the x axis and pH on y axis
- It starts from the pH of the solution in the conical flask and goes to the pH of the titrant
- At the equivalence point, the line is vertical
- The shape of the curve changes according the pH of the solution and titrant