CAIE Chemistry A-level

Topic 25 - Equilibria

(A level only)

Flashcards

What is a conjugate acid-base pair?

Label the conjugate acid-base pairs in the equation below:

$$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

What is a conjugate acid-base pair? Label the conjugate acid-base pairs in the equation below:

$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$

A conjugate acid-base pair is two species that differ from each other by a proton (H^+ ion)

- HCl and Cl^- are a conjugate acid-base pair.
- H_2O and H_3O^+ are a conjugate acid-base pair.

What is the acid dissociation constant, K_a? Write the general equation for K_a

What is the acid dissociation constant, K_a? Write the general equation for K_a

A quantitative measure of the strength of an an acid.

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Write a general equation for pK_a. Why might pK_a be used instead of K_a?

Write a general equation for pK_a. Why might pK_a be used instead of K_a?

$$pK_a = -\log K_a$$

pK_a values make it easier to compare relative acidic strengths of substances.

What is pH?

What is pH?

pH is a measure of hydrogen ion concentration.

The pH scale ranges from 0-14 and can be measured using universal indicator or a pH probe.

How do you calculate the pH of a strong acid?

How do you calculate the pH of a strong acid?

Strong acid: $HA \rightarrow H^+ + A^-$

Concentration of acid = concentration of H^+ ions.

$$pH = -\log[H^+]$$

What is K_w?

What is K_w?

K_w is the ionic product of water.

- $K_w = [H^+][OH^-] = 1 \times 10^{-14}\ mol^2\ dm^{-6}$ at RTP
- So little water is ionised at any moment that the concentration of H_2O remains almost constant, and thus does not appear in the K_w expression.
- Water molecules can function as acids and bases.

  $H_2O \rightarrow H^+ + OH^-$

How do you calculate the pH of a strong base?

How do you calculate the pH of a strong base?

Strong base: $XOH \rightarrow X^+ + OH^-$

Concentration of base = concentration of OH^- ions.

$$K_w = [H^+][OH^-] \quad \text{so} \quad [H^+] = K_w/[OH^-]$$

$$pH = -\log[H^+]$$

How do you calculate the pH of a weak acid?

How do you calculate the pH of a weak acid?

Weak acid: $HA \rightleftharpoons H^+ + A^-$

Write K_a expression: $$K_a = \frac{[H^+][A^-]}{[HA]}$$

We can assume $[H^+] = [A^-]$ so: $$K_a = \frac{[H^+]^2}{[HA]}$$

Rearrange to make $[H^+]$ the subject: $$[H^+] = \sqrt{K_a \times [HA]}$$

$pH = -\log[H^+]$

Write an equation that can be used to calculate the concentration of hydrogen ions from pH

Write an equation that can be used to calculate the concentration of hydrogen ions from pH

$$[H^+] = 10^{-pH}$$

What is a buffer?

What is a buffer?

A system that minimises pH changes on the addition of small amounts of an acid or base.

Describe how the system below can act as a buffer:

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

Describe how the system below can act as a buffer:

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

- Upon addition of acid, the concentration of H^+ ions increases. H^+ ions combine with $CH_3COO^-_{(aq)}$ to form CH_3COOH. The reverse reaction is favoured and the position of equilibrium shifts to the left.
- Upon addition of base, the concentration of OH^- ions increases. OH^- ions combine with H^+ to form H_2O. The forward reaction is favoured and the position of equilibrium shifts to the right.

What is a weak acid buffer?

What is a weak acid buffer?

A mixture of a weak acid and its conjugate base (usually in the form of one of its salts, e.g. $CH_3COO^-Na^+$).

How would you calculate the pH of the weak acid buffer solution shown below?

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

How would you calculate the pH of the weak acid buffer solution shown below?

$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$

- Write K_a expression: $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$
- Make $[H^+]$ the subject: $[H^+] = \frac{K_a \times [CH_3COOH]}{[CH_3COO^-]}$
- Calculate $[H^+]$ and substitute into

$$pH = -\log[H^+]$$

How do buffers control the pH of blood?

How do buffers control the pH of blood?

- It is important that blood remains within a specific pH range to prevent disastrous effects on enzymes and proteins in the blood that could put our life at risk.
- One way that blood pH is maintained is with the carbonic acid-hydrogen carbonate buffer system:

$$H_2CO_{3(aq)} \rightleftharpoons H^+_{(aq)} + HCO_3^-{}_{(aq)}$$

- If small amounts of acid or base are added, the position of equilibrium shifts to minimise this pH change.

Explain how to calculate the pH of a buffer

Explain how to calculate the pH of a buffer

General equation for a buffer: $HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

- Do not assume that $[H^+] = [A^-]$ like other weak acids.
- Assume that [HA] at equilibrium = [HA] at start.
- Rearrange K_a to find $[H^+]$ and then substitute $[H^+]$ into:

$$pH = -\log_{10}[H^+]$$

What is the solubility product?

What is the solubility product?

- The solubility product constant, K_{sp}, is an equilibrium constant for a solid dissolving in (aqueous) solution.
- The higher the K_{sp}, the more soluble a substance is and hence the more solute that dissolves.

How do you calculate K_{sp}?

How do you calculate K_{sp}?

For reaction: $aA_{(s)} \rightleftharpoons cC_{(aq)} + dD_{(aq)}$

$$K_{sp} = [C]^c[D]^d$$

Solids are not included as their concentrations do not affect the expression, and hence are insignificant.

How does K_{sp} affect whether a precipitate will form?

How does K_{sp} affect whether a precipitate will form?

A precipitate will only form if the ionic concentrations give a value that is greater than the solubility product.

What is the common ion effect?

What is the common ion effect?

- The extent of which a solute dissolves in solution is affected by the presence of a common ion.
- This prevents dissociation due to shifting the position of equilibrium towards the solid reactant.

What is meant by the partition coefficient? Write an equation for K_{pc}.

What is meant by the partition coefficient? Write an equation for K_{pc}.

A dynamic equilibrium is established between two immiscible layers in a separating funnel when a substance (X) is dissolved in the liquids:

$$X(\text{in more dense liquid}) \rightleftharpoons X(\text{in less dense liquid})$$

$$K_{pc} = \frac{[X \text{ in less dense liquid}]}{[X \text{ in more dense liquid}]}$$

1.00g of X is in 100cm^3 of water and 5cm^3 of ether. K_{pc} is 40. Calculate the mass of X dissolved in ether.

1.00g of X is in 100cm^3 of water and 5cm^3 of ether. K_{pc} is 40. Calculate the mass of X dissolved in ether.

Concentration of X in ether:

m/5 g cm^{-3}

Concentration of X in water:

(1.00 - m)/100 g cm^{-3}

$$K_{pc} = \frac{\text{[X in less dense liquid]}}{\text{[X in more dense liquid]}}$$

$$40 = \frac{m/5}{(1.00 - m)/100}$$

$$\frac{40(1.00 - m)}{100} = \frac{m}{5}$$

$$200 - 200m = 100m$$

$$300m = 200$$

$$m = 0.67g$$