Equilibria - 2022 Nov A2 Chemistry 9701

1. Nov/2022/Paper_41/No.4

(a) A sample of butanoic acid, $CH_3(CH_2)_2COOH$, is shaken with a mixture of two immiscible solvents, ethoxyethane and water. The solvents form two layers. The butanoic acid is distributed between the two layers, its concentration in ethoxyethane being higher than its concentration in water.

(i) State what is meant by partition coefficient.

Is the ratio of concentration of the solute in two solvents at equilibrium. [1]

(ii) The partition coefficient, K_{pc}, for butanoic acid between ethoxyethane and water is 3.50.

A solution of 2.00 g of butanoic acid in 100 cm³ ethoxyethane is added to water. This mixture is left until there is no further change in the concentration of butanoic acid in either solvent. The mass of butanoic acid dissolved in the ethoxyethane layer is now 1.62 g.

Calculate the volume of water used.

$$3.50 = \left(\frac{1.62}{100}\right) \div \left(\frac{0.38}{x}\right)$$

$$x = 82.097$$

volume of water used = 82 cm³ cm³ [2]

(b) An aqueous solution of butanoic acid can be used to make a buffer solution.

(i) Define buffer solution.

A solution that has no change in pH when small amounts of acid or base are added. [1]

(ii) Suggest one organic compound, and one inorganic compound, that can be added to two different samples of aqueous butanoic acid to produce buffer solutions.

organic compound Propanoic acid and sodium propanoate.

inorganic compound NaOH

[1]

(c) The solubility of aluminium hydroxide, $Al(OH)_3$, in water is 2.47×10^{-9} mol dm^{-3}.

(i) Give the expression for the solubility product, K_{sp}, of aluminium hydroxide.

$Al(OH)_3 \rightleftharpoons Al^{3+} + 3OH^-$

K_{sp} =

$K_{sp} = [Al^{3+}][OH^-]^3$

[1]

(ii) Calculate the numerical value of the K_{sp} of aluminium hydroxide. Include the units of K_{sp} in your answer.

$K_{sp} = 2.47 \times 10^{-9}$ mol/dm^3 $(Al(OH)_3)$

$[OH^-] = 3 \times 2.47 \times 10^{-9}$

$K_{sp} = [2.47 \times 10^{-9}][7.41 \times 10^{-9}]^3$

$= 1.01 \times 10^{-33}$ mol^4/dm^{12}

K_{sp} = 1.01×10^{-33}

units = mol^4 dm^{-12}

[3]

[Total: 9]

2. Nov/2022/Paper_42/No.4

(a) The value of the solubility product, K_{sp}, of iron(III) hydroxide, $Fe(OH)_3$, is given by the following expression.

$$K_{sp} = [Fe^{3+}][OH^-]^3 = 2.0 \times 10^{-39}\ mol^4\ dm^{-12}$$

(i) Calculate the solubility of $Fe(OH)_3$ in water.

$Fe(OH)_{3(s)} \rightleftharpoons Fe^{3+} + 3OH^-$ (x, x, $3x$)

$\frac{3^3x^4}{27} = \sqrt[4]{\frac{2.0\times10^{-39}}{27}}$

$3^3x^4 = 2\times10^{-39}$

$x = 9.28\times10^{-11}$

solubility = 9.28×10^{-11} $mol\ dm^{-3}$ [1]

(ii) Calculate the solubility of $Fe(OH)_3$ in 0.010 $mol\ dm^{-3}$ barium hydroxide, $Ba(OH)_2(aq)$.

(i) $Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$

(ii) $Fe(OH)_3 \rightarrow Fe^{3+} + 3OH^-$

$[Fe^{3+}][0.02]^3 = 2\times10^{-39}$

$[Fe^{3+}] = \frac{2\times10^{-39}}{[0.02]^3}$

solubility = 2.5×10^{-34} $mol\ dm^{-3}$ [2]

(iii) $Fe(OH)_3$ is less soluble in $Ba(OH)_2(aq)$ than it is in pure water.

Name this effect.

Common Ion effect. [1]

(b) The numerical value of the K_a of HBrO is 2.00×10^{-9}.

X is a solution of HBrO which contains 4.00×10^{-3} mol of HBrO in 100 cm^3 of solution. In this solution the following equilibrium is established in which there are two conjugate acid-base pairs.

$$HBrO + H_2O \rightleftharpoons BrO^- + H_3O^+$$

(i) Define conjugate acid-base pair.

Two species that differ by an H^+ ion. [1]

(ii) Identify the two conjugate acid-base pairs shown in the equation above.

	acid	base
pair one	HBrO	BrO^-
pair two	H_3O^+	H_2O

[1]

(iii) Calculate the pH of solution **X**. Show all your working.

$H^+ = \sqrt{K_a \times [HA]}$

$[acid] = 4 \times 10^{-2}$

$[H^+]^2 = 8.0 \times 10^{-11} \Rightarrow H^+ = \sqrt{8.0 \times 10^{-11}}$

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

pH = 5.05 [2]

(iv) A solution containing 2.00×10^{-3} mol of NaOH is added to solution **X**. A buffer solution is formed.

Calculate the pH of this buffer solution.

pH of buffer = $pK_a + \log \frac{[salt]}{[acid]}$

$HBrO + NaOH \rightarrow NaBrO + H_2O$

4.0×10^{-3} 2.0×10^{-3} 2.0×10^{-3}

2.0×10^{-3}

$pH = -\log(2.00 \times 10^{-9}) + \log \frac{[1]}{0}$

$pH = -\log K_a$

$= 8.69$

pH = 8.70 [1]

[Total: 9]