1. Nov/2023/Paper_9701/41/No.2

(a) Define K_w mathematically by completing the expression.

K_w = ...

[1]

(b) Two solutions, **V** and **W**, are described.

- **V** is HC*l*(aq).
- **W** is NaOH(aq).
- The concentration of HC*l* in **V** is the same as the concentration of NaOH in **W**.
- The pH values of **V** and **W** differ by exactly 11.00 at 298 K.

(i) Calculate the concentration of HC*l* in **V**.

concentration of HC*l* in **V** = ... $mol\,dm^{-3}$ [2]

(ii) Equal volumes of the two solutions **V** and **W** are mixed, giving solution **X**.

Name solution **X** and state its pH.

solution **X** ..... pH .....

[1]

(iii) A 1 cm^3 sample of 1.0 $mol\,dm^{-3}$ HNO_3 is added to 100 cm^3 of solution **X**, forming mixture **Y**.

A 1 cm^3 sample of 1.0 $mol\,dm^{-3}$ KOH is added to 100 cm^3 of solution **X**, forming mixture **Z**.

Estimate the pH of mixtures **Y** and **Z**. No calculations are required.

mixture **Y** ..... mixture **Z** .....

[1]

(c) **(i)** CH_3CH_2COOH, CH_3CCl_2COOH and H_2SO_4 are all acidic.

Suggest the trend in the relative acid strength of these three compounds.

Explain your answer.

....
strongest acid weakest acid

explanation .....

.....

.....

.....

.....

[3]

(ii) When concentrated H_2SO_4 is added to water a series of acid-base reactions occurs.

There are three conjugate acid-base pairs that can be identified during this series of reactions.

Write the formulae of these three conjugate acid-base pairs.

conjugate acid 1 ..... conjugate base 1 .....

conjugate acid 2 ..... conjugate base 2 .....

conjugate acid 3 ..... conjugate base 3 .....

[2]

(d) The partition coefficient, K_{pc}, of a substance, **Q**, between hexane and water is 7.84 at 298 K.

Q is more soluble in hexane than it is in water.

(i) Define partition coefficient, K_{pc}.

.....

..... [1]

(ii) 5.00 g of **Q** is shaken with a mixture of 100.0 cm^3 of water and 100.0 cm^3 of hexane at 298 K and left until there is no further change in concentrations.

Calculate the mass of **Q** dissolved in the water.

mass of **Q** = ... g [1]

(iii) A sample of **Q** is shaken with a different mixture of water and hexane and left until there is no further change in concentrations.

It is found that the mass of **Q** dissolved in each solvent is the same.

Use the K_{pc} value to suggest possible values for the volume of water used and the volume of hexane used.

volume of water = ... cm^3

volume of hexane = ... cm^3

[1]

(iv) **Q** is more soluble in hexane than it is in water.

It is suggested that **Q** is one of KC*l*, $CH_3(CH_2)_4OH$ or HCOOH.

Identify **Q**. Explain your answer.

.....

..... [1]

[Total: 14]

2. Nov/2023/Paper_9701/42/No.2

Benzoic acid, C_6H_5COOH, is a weak acid. The K_a of benzoic acid is 6.31×10^{-5} mol dm^{-3} at 298 K.

A 1.00 dm^3 buffer solution is made at 298 K containing 1.00 g of C_6H_5COOH and a slightly greater mass of sodium benzoate, $C_6H_5COO^-Na^+$.

This buffer solution has a pH of 4.15.

(a) Define buffer solution.

.....

..... [1]

(b) Write equations to show how this solution acts as a buffer solution when the named substances are added to it:

(i) dilute aqueous sodium hydroxide

..... [1]

(ii) dilute aqueous nitric acid.

..... [1]

(c) Calculate the H^+ concentration and the C_6H_5COOH concentration in the buffer solution described. Use the expression for the K_a of C_6H_5COOH to calculate the concentration of $C_6H_5COO^-Na^+$ in the buffer solution.

Show your working and give each answer to a minimum of **three** significant figures.

$[H^+]$ = ... mol dm^{-3}

$[C_6H_5COOH]$ = ... mol dm^{-3}

$[C_6H_5COO^-Na^+]$ = ... mol dm^{-3}

[3]

(d) A 10.0 cm^3 sample of the buffer solution is mixed with 10.0 cm^3 of 1.00 mol dm^{-3} KOH. Both solutions are at 298 K. A reaction is allowed to occur without stirring.

Two observations are recorded:

- the temperature, after the reaction is complete, is fractionally above 298 K
- the pH, after the reaction, is greater than 13.

Explain these two observations.

.....

.....

..... [2]

(e) Magnesium benzoate, $Mg(C_6H_5COO)_2$, has a solubility in water of less than 1.00 g dm^{-3} at 298 K.

$$K_{sp} = [Mg^{2+}][C_6H_5COO^-]^2 = 1.76 \times 10^{-7} \text{ at } 298\,K$$

(i) Calculate the solubility of $Mg(C_6H_5COO)_2$ in water at 298 K. Give your answer in g dm^{-3}.

Show your working.

[M_r: $Mg(C_6H_5COO)_2$, 266.3]

solubility = ... g dm^{-3} [2]

(ii) An excess of $Mg(C_6H_5COO)_2$ is added to a sample of 0.50 mol dm^{-3} $MgSO_4$ at 298 K.

State whether the equilibrium concentration of $Mg(C_6H_5COO)_2$ is higher than, the same as, or lower than your answer to **(i)**. Explain your answer.

The concentration is ..... the concentration in **(i)**.

explanation .....

.....

[1]

[Total: 11]

3. June/2023/Paper_9701/41/No.5(d, e)

(d) Isocyanic acid, HNCO, can form cyanuric acid, $C_3H_3N_3O_3$, under certain conditions.

$C_3H_3N_3O_3$ has a cyclic structure containing alternating carbon and nitrogen atoms in the ring system.

Suggest a structure for cyanuric acid.

[1]

(e) Isocyanic acid, HNCO, is a weak acid.

$$HNCO + H_2O \rightleftharpoons H_3O^+ + NCO^- \qquad pK_a = 3.70 \text{ at } 25\,^\circ C$$

(i) Write the mathematical expressions for pK_a and pH.

pK_a = ...

pH = ...

[1]

(ii) Calculate the pH of 0.120 mol dm^{-3} HNCO(aq).
Give your answer to **three** significant figures.

pH = ... [2]

(iii) Calculate the percentage of HNCO molecules that are ionised in 0.120 mol dm^{-3} HNCO.

percentage ionisation of HNCO = ... [1]

4. June/2023/Paper_9701/42/No.3(e)

(e) Silver sulfite, $Ag_2SO_3(s)$, is sparingly soluble in water.

(i) Give an expression for the solubility product, K_{sp}, of Ag_2SO_3.

K_{sp} =

[1]

(ii) Calculate the equilibrium concentration of Ag^+ in a saturated solution of Ag_2SO_3 at 298 K.

[K_{sp}: Ag_2SO_3, 1.50×10^{-14} mol^3 dm^{-9} at 298 K]

$[Ag^+]$ = ... mol dm^{-3} [1]

5. March/2023/Paper_9701/42/No.6(d)

A student uses thin-layer chromatography (TLC) to analyse a mixture containing different metal cations. The student repeats the experiment using different solvents.

Fig. 6.1 shows the chromatogram obtained by the student using water as a solvent.

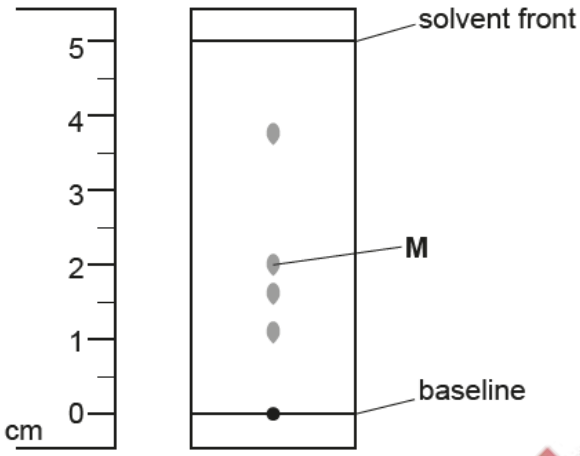

Fig. 6.1

(d) In a third experiment, the pH of the mixture of metal ions is kept constant using a buffer solution.

The student prepares the buffer solution by mixing 20.0 cm^3 of 0.150 mol dm^{-3} KOH(aq) and 50.0 cm^3 of 0.100 mol dm^{-3} $C_8H_5O_4K$(aq).

$C_8H_5O_4K$ is a weak carboxylic acid that has pK_a = 5.40.

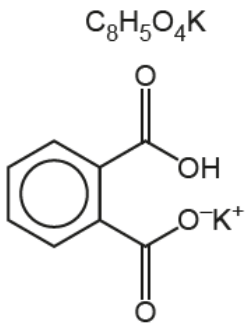

Fig. 6.2

(i) Complete the equation for the reaction of $C_8H_5O_4K$(aq) with KOH(aq).

$C_8H_5O_4K$ + ... [1]

(ii) Calculate the pH of the buffer solution. Show all your working.

pH = ... [4]