IONIC EQUILIBRIA

3 **(a)** In the human body, one important buffer system in the blood involves the hydrogen carbonate ion, HCO_3^-, and carbonic acid, H_2CO_3. The equilibrium involved is

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

(i) Explain how the HCO_3^- / H_2CO_3 buffer system maintains a constant pH in the blood stream.

(ii) In a sample of blood with a pH of 7.41, the concentration of $HCO^-_{3(aq)}$ ions is 2.5×10^{-2} moldm^{-3} and the concentration of $H_2CO_{3(aq)}$ is 1.2×10^{-3} moldm^{-3}.

Calculate the value of the acid dissociation constant for carbonic acid.

[4]

(b) A buffer solution made from mixing ethanoic acid and sodium ethanoate had 0.15 moldm^{-3} ethanoic acid and 0.10 moldm^{-3} sodium ethanoate. The K_a value for ethanoic acid is 1.74×10^{-5} moldm^{-3} at 298 K.

Calculate the

(i) pH of the buffer solution,

(ii) change in pH on addition of a 10 cm^3 portion of 1.0 moldm^{-3} hydrochloric acid to 1 dm^3 of the buffer solution.

[8]

[Total: 12]

IONIC EQUILIBRIA

3 **(a)** Hydrogen carbonate ions provide a buffering action in biological systems.

(i) Define the term *buffer solution*.

(ii) Explain by means of equations, the buffering action of hydrogen carbonate ions.

[3]

(b) A mixture of benzoic acid and sodium benzoate can also act as a buffer.

[K_a of benzoic acid is 6.4×10^{-5} moldm^{-3}]

Calculate the

(i) concentration of H^+ ions in 0.02 moldm^{-3} benzoic acid,

(ii) pH of 0.02 moldm^{-3} benzoic acid,

(iii) pH of a solution containing 7.2 g of sodium benzoate in 1 dm^3 of 0.02 moldm^{-3} benzoic acid,

(iv) pH change, if 1 cm^3 of 1.0 moldm^{-3} NaOH is added to the buffer in **(iii)**.

[7]

(c) Show that at 25 °C, the pH of water is 7. [2]

[Total: 12]

IONIC EQUILIBRIA

4 "Acidity regulators" are food additives that have a *buffering action* on the pH of foodstuffs. Mixtures of citric acid and its sodium salt are often used for this purpose.

$$C_5H_7O_4CO_2H \rightleftharpoons C_5H_7O_4CO_2^- + H^+;\ K_a = 7.4 \times 10^{-4} \text{ mol dm}^{-3} \text{ citric acid}$$

(a) The concentration of citric acid in lemon juice is 0.22 mol dm^{-3}.

Assuming that no other acid is present, calculate the pH of lemon juice. [3]

(b) Write equations to show how the citric acid/sodium citrate buffer system regulates the acidity on the addition of

(i) H^+ ions,

(ii) OH^- ions.

[2]

(c) Calculate the pH of a solution containing 0.10 mol dm^{-3} citric acid and 0.30 mol dm^{-3} sodium citrate. [2]

(d) Define the term K_w and explain why, at 25 °C, water has a pH of 7. [3]

IONIC EQUILIBRIA

2 **(a)** Outline the Bronsted-Lowry theory of acids and bases. [2]

(b) The following is a list of compounds that react with or dissolve in water:

sodium chloride, hydrogen chloride, silicon tetrachloride, ammonia, methanol.

Water can react as either an acid or a base. Choose a compound from the above list with which water acts as

(i) a Bronsted base,

(ii) a Bronsted acid.

Construct a balanced equation for each reaction. [3]

(c) Lactic acid is a monoprotic acid which is an important flavouring component of many foods such as cheese, yoghurt and pickled cabbage. A solution of lactic acid in water containing $0.10\,\text{mol}\,\text{dm}^{-3}$ has a pH of 2.43.

(i) Is lactic acid a strong or a weak acid? Explain your answer.

(ii) Use the data given to calculate the value of K_a for lactic acid.

(iii) Suggest a suitable indicator for the titration of lactic acid with aqueous sodium hydroxide.

(iv) A sample of lactic acid having a mass of 1.00 g was dissolved in water and titrated with $0.500\,\text{mol}\,\text{dm}^{-3}$ sodium hydroxide. It was found that $22.2\,\text{cm}^3$ of hydroxide was required for neutralisation. Calculate the M_r of lactic acid.

[7]

IONIC EQUILIBRIA

3 (a) At a given temperature, solubility of barium phosphate, $Ba_3(PO_4)_2$, is x moldm^{-3} and its solubility product is y.

(i) Derive a relationship between x and y.

(ii) A saturated solution of barium phosphate was found to contain 3×10^{-5}moldm^{-3} of PO_4^{3-} ions.
Calculate the concentration of Ba^{2+} ions in the solution and hence determine the value of y and its units.

(iii) Solubility of barium phosphate in a sodium phosphate, Na_3PO_4, solution at this temperature is less than x.
Explain this observation. [7]

(b) (i) What is a buffer solution?

(ii) Explain how a solution containing both sodium ethanoate, CH_3CO_2Na, and ethanoic acid, CH_3CO_2H, can act as a buffer solution. [5]

Total [12]

IONIC EQUILIBRIA

2 **(a)** **(i)** Define the term *dynamic equilibrium*.

(ii) State **two** factors that would affect a system in dynamic equilibrium indicating the effect.

(iii) Why would a catalyst not cause any effect on such a system?

[4]

(b) An excess of a sparingly soluble solid, $M(OH)_3$, was added to 200 cm^3 of 0.1 $moldm^{-3}$ KOH. The mixture was shaken, allowed to reach equilibrium at r.t.p and then filtered.

25.0 cm^3 of the filtrate was titrated with 0.2 $moldm^{-3}$ HC*l* of which 18.0 cm^3 were required to reach the end point.

(i) Calculate the number of moles of hydroxide ions in the filtrate.

(ii) Find the concentration of hydroxide ions in the filtrate which are from $M(OH)_3$.

(iii) Hence, deduce the concentration of M^{3+} ions.

(iv) State what is meant by *solubility* of substance and hence give the solubility of $M(OH)_3$ in 0.1 $moldm^{-3}$ KOH.

(iv) Use your answer to **(iv)** to deduce the K_{sp} value of $M(OH)_3$.

[8]

[Total: 12]

IONIC EQUILIBRIA

2 **(a)** Liquid ammonia and aqueous ammonia dissociate to give ammonium ions, the dissociations reaching equilibrium.

(i) Construct equations for the dissociation of each of the two substances.

(ii) Write the equilibrium constant expression, K_b, for the dissociation of aqueous ammonia.

(iii) Calculate the K_b value of aqueous ammonia given that 0.01 $moldm^{-3}$ of the solution yield equilibrium concentration of 4.30×10^{-4} $moldm^{-3}$ for each product, stating any assumption you have made. [5]

(b) Mixtures of aqueous solutions of ammonia and ammonium chloride act as buffers.

(i) Name the type of buffer made by these solutions.

(ii) Write equations to show how the ammonia/ ammonium chloride buffer system works.

(iii) Use your K_b value in **(a) (iii)** to calculate the pH of the buffer solution that would be formed when 1.0 g of ammonium chloride is added to 1.0 dm^3 of 0.01 $moldm^{-3}$ ammonia solution. [7]

[Total: 12]

IONIC EQUILIBRIA

2 **(a)** Define an *acid-base indicator*. [1]

(b) If an indicator can be conveniently represented as Hln and its equilibrium dissociation constant as Kln, write

(i) the equation for the dissociation of Hln in aqueous solution,

(ii) an expression for Kln.

[2]

(c) Congo red, an acid base indicator, is blue in acidic conditions and red in alkaline conditions. It has a Kln value of 1.2×10^{-4} moldm^{-3}.

(i) Given that colour change begins when $[ln^-] = [Hln]$, calculate the pH at which Congo red begins to change colour.

(ii) State the acid-base titrations for which Congo red would be most suitable.

(iii) Calculate the pH of a 0.2 moldm^{-3} solution of Congo red.

(iv) If an Indicator contributes to the pH of a solution, suggest a reason why the pH of a titration mixture is not affected by the Indicator used.

[5]

(d) The pH changes during the titration of acid **HA** against base **HB** are shown in **Table 1**.

Table 1

Volume of base **HB**/cm^3	0	5	10	15	20	22	25	30
pH	0.8	1.0	1.6	2.4	3.6	8.0	9.0	9.6

(i) Plot a graph of pH against volume of base **HB**.

(ii) Use your graph to deduce the pH at end point.

[4]
[Total: 12]

IONIC EQUILIBRIA

1 (a) State what is meant by a *buffer solution*.

.....

.....

.....[2]

(b) Explain, using equations, why an aqueous mixture of ethanoic acid (represented as H*A*) and sodium ethanoate (Na^+A^-) can act as a buffer solution

(i) on the addition of acid,

.....

.....

(ii) on the addition of alkali.

.....

.....

[2]

(c) (i) Explain what is meant by the *acid dissociation constant*, K_a, as applied to ethanoic acid (H*A*).

(ii) What is meant by pK_a?

.....

(iii) Use the relationship

$$pH = pK_a - \log_{10}\frac{[acid]}{[salt]}$$

to calculate the pH of a solution which is 0.40 mol dm^{-3} with respect to ethanoic acid and 0.20 mol dm^{-3} with respect to sodium ethanoate.

[Take K_a for ethanoic acid as 1.80×10^{-5} mol dm^{-3}.]

(iv) Calculate the change of pH of 1.0 dm^3 of the solution in **(c) (iii)** when 0.050 mol of solid sodium hydroxide is added (assume no change in volume).

(v) What is the change of pH when 0.050 mol of sodium hydroxide is added to 1.0 dm^3 of water?

[6]

(d) State a buffer system which helps to control the pH of blood.

.....[1]

[Total : 11]

IONIC EQUILIBRIA

1 The solubility of barium hydroxide, $Ba(OH)_2$, at 25°C is 0.24 g dm^{-3}.

(a) **(i)** Calculate the molar concentration of the aqueous solution.

molar concentration of solution = _____ [1]

(ii) The solute is completely ionised, calculate the hydroxide ion concentration of the solution.

hydroxide ion concentration = _____ [1]

(iii) Calculate the pH of the saturated aqueous barium hydroxide.

pH = _____ [2]

(b) **(i)** Write an expression for the solubility product of barium hydroxide.

[1]

(ii) Calculate the solubility product of $Ba(OH)_2$ stating the units.

Solubility product of $Ba(OH)_2$ = _____ [2]

(c) Bottles containing aqueous barium hydroxide need to be kept firmly stoppered or a white deposit forms on the surface.

(i) Name the white deposit.

_____ [1]

(ii) Write an equation to show how the white deposit is formed.

_____

_____ [1]

(iii) Explain how a solution of calcium hydroxide behaves in moist air.

_____

_____

_____

_____

_____ [2]

[Total: 11]

IONIC EQUILIBRIA

(b) **(i)** Write an expression for the solubility product, K_{sp}, of calcium sulphate.

(ii) The solubility product of calcium sulphate is 2×10^{-5} mol^2dm^{-6} at 25 °C.

Predict whether precipitation would occur if equal volumes of 1×10^{-2} $moldm^{-3}$ $CaCl_2$ and 1×10^{-2} $moldm^{-3}$ Na_2SO_4 are mixed.

IONIC EQUILIBRIA

(a) What do you understand by

(i) pH _____

(ii) buffer solution?

_____

_____

[2

(b) During a titration, 20.00 cm^3 of ammonia solution of pH 11.20 required 20.00 cm^3 of 0.1 M hydrochloric acid solution for complete neutralisation.

(i) Write a balanced equation for the reaction.

_____

(ii) Calculate the concentration of the ammonia solution.

concentration = _____ [3]

(c) **(i)** Calculate the pH of the solution halfway to the end point

$\left(K_{a(NH_4^+)} = 5.6 \times 10^{-10}\ moldm^{-3}\right)$

(ii) Sketch the pH curve for this reaction.

(iii) How does the pH calculated in **(c)(i)** compare with the initial pH of the ammonia solution?
Explain your answer.

[6]

IONIC EQUILIBRIA

2 **(a)** The dissociation constant, K_a, of propanoic acid has a value of 1.35×10^{-5} mol dm^{-3}.

(i) Write an expression for the K_a of propanoic acid.

_____ [1]

(ii) Calculate the pK_a value of propanoic acid.

$pK_a =$ _____ [2]

(iii) Calculate the pH of a solution in which the concentrations of propanoic acid and sodium propanoate are 0.20 and 0.10 moldm^{-3} respectively.

$pH =$ _____ [2]

(b) A sparingly soluble salt, X_aY_b, dissolves in water and the following equilibrium is established:

$$X_aY_{b(s)} \rightleftharpoons aX^{b+}_{(aq)} + bY^{a-}_{(aq)}$$

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

_____ [1]

(ii) State and explain the effect of adding X^{b+} ions to the solution.

_____

_____

_____ [2]

(c) Explain why magnesium sulphate and barium sulphate have different solubilities in water at the same temperature.

_____

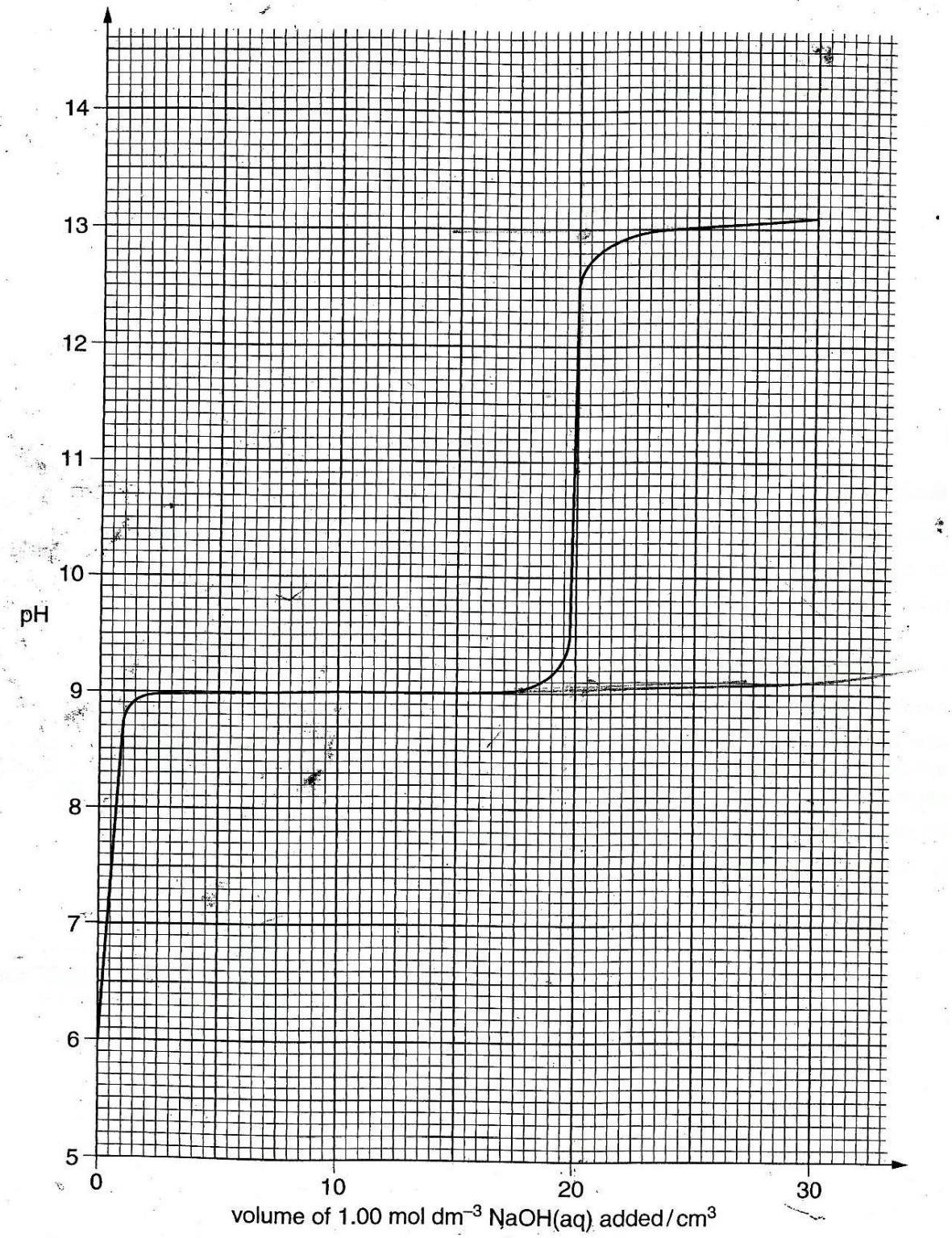
_____

_____

_____ [3]

IONIC EQUILIBRIA

1 In an experiment, 50.0 cm^3 of aqueous magnesium chloride were titrated with 1.00 mol dm^{-3} sodium hydroxide. The pH of the solution changed as in the diagram.



(a) Write an equation (ionic or molecular) for the reaction between aqueous $MgCl_2$ and aqueous NaOH. Include state symbols so that any precipitation is clearly indicated.

.....[1]

(c) When 10 cm^3 of aqueous NaOH were added,

(i) calculate the hydroxide ion concentration from the pH of the mixture,

.....

(ii) estimate the hydrated magnesium ion concentration, assuming that it is half the original concentration.

.....

[2]

(d) **(i)** Write an expression for the solubility product, K_{sp}, of magnesium hydroxide.

(ii) Use your values from **(c)** to calculate this K_{sp}, including the units.

[2]

(e) Show by calculation why the pH after the addition of 30 cm^3 of aqueous NaOH should be 13.1.

[1]

[Total : 7]

IONIC EQUILIBRIA

1 (a) (i) Define a *Bronsted –Lowry acid.*

_____

_____

(ii) Indicate the conjugate acid-base pairs for the reaction of

1 ethanoic acid and water,

_____

_____

2 hydrogen chloride and ammonia.

_____

_____ [3]

(b) (i) Write the K_a expression for chloroethanoic acid, $CH_2ClCOOH$.

_____

_____

(ii) Name the term used to describe a solution obtained by mixing chloroethanoic acid and sodium chloroethanoate.

_____

_____

(iii) 0.01 moldm^{-3} chloroethanoic acid and 0.0002 moldm^{-3} sodium chloroethanoate were mixed. Given that K_a for chloroethanoic acid is 1. 4 x 10^{-3} moldm^{-3}, calculate the pH of the mixture.

pH = _____.

[5]

(b) The pH of 0.1 M hydrochloric acid is 1 and that of 0.1 M ethanoic acid is approximately 3.

(i) Write the equation for the dissociation of ethanoic acid.

_____

(ii) Explain the difference in pH of the two acids.

_____

_____

_____

[3]

(c) 0.1 M ammonia and 0.1 M ammonium chloride are mixed to give a buffer solution of pH 10.0

[K_a for ammonium chloride is 6×10^{-10} moldm^3]

(i) Define the term *buffer solution*.

_____

_____

(ii) Calculate the ratio $\frac{[NH_4^+]}{[NH_3]}$ in the buffer solution.

[4]
[Total: 10]

IONIC EQUILIBRIA

(b) **(i)** Define the term

1. *weak acid*,

2. *buffer solution*.

(ii) Calculate the pH of a buffer solution prepared by adding 20.00 cm^3 of 0.40 $moldm^{-3}$ $HCl_{(aq)}$ to 30.00 cm^3 of 0.65 $moldm^{-3}$ $NH_{3(aq)}$, given that $K_b(NH_3) = 1.81 \times 10^{-5}$ $moldm^{-3}$.

(iii) Give any **two** applications of buffers.

[9]

(b) **(i)** Define the term

1. *solubility*,

2. *ionic product*. [1]

(ii) Deduce whether a precipitate will form or not when 100 cm^3 of 0.001 $moldm^{-3}$ solution of magnesium chloride is mixed with 300 cm^3 of a 0.001 $moldm^{-3}$ sodium hydroxide solution.

[Ksp $(Mg(OH)_2) = 7.16 \times 10^{-11}$ mol^3dm^{-9}]

[8]

(b) **(i)** Define the term *ionic product of water*, K_w.

(ii) Explain, using K_w, why at 25°C water has a pH of 7. [4]

(c) An aqueous buffer solution containing 0.055 moles of weak acid, HA, and 0.025 moles of NaA in 100 cm^3 of solution has a pH of 4.20.
[K_a of the acid, HA, is 2.87×10^{-5} $moldm^{-3}$ at 25°C]

Calculate the pH of the solution formed when 10 cm^3 of 0.130 $moldm^{-3}$ sodium hydroxide are added to 100 cm^3 of the buffer solution. [5]

IONIC EQUILIBRIA

2 **(a)** During respiration in humans, carbon dioxide produced diffuses into the blood to form a mixture of H_2CO_3 and HCO_3^-. The mixture acts as a buffer in the blood.

(i) Explain the importance of the H_2CO_3 and HCO_3^- mixture in the blood.

(ii) Write equations to show the buffering action of the mixture.

(iii) Calculate the mass of $NaHCO_3^-$ present in a 250 cm^3 sample of the buffer given that the pH of the buffer is 5.94 and the concentration of H_2CO_3 is 0.5 $moldm^{-3}$.
[$K_a(H_2CO_3) = 4.6 \times 10^{-7}$ $moldm^{-3}$] [7]