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SAMPLE PAPER

NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Chemistry

3.6: Demonstrate understanding of equilibrium principles in aqueous systems

Credits: Five

Check that you have completed ALL parts of the box at the top of this page.

Check that you have been supplied with the resource sheet for Chemistry 3.6.

You should answer ALL parts of ALL questions in this booklet.

If you need more room for any answer, use the space provided at the back of this booklet.

Check that this booklet has pages 2–11 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO YOUR TEACHER AT THE END OF THE ALLOTTED TIME.

EXEMPLAR FOR LOW ACHIEVED

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You are advised to spend 60 minutes answering the questions in this booklet.

Assessor's use only

QUESTION ONE

(a) Methanoic acid, HCOOH, is a weak acid. A dilute aqueous solution of this acid has a pH of 2.78.

$$pK_a\,(HCOOH) = 3.74$$

(i) Write an equation for the reaction of methanoic acid with water.

$HCOOH_{(aq)} + H_2O_{(l)} \rightleftharpoons HCOO^-_{(aq)} + H_3O^+_{(aq)}$

Correct equation.

(ii) List all the species in the aqueous solution of methanoic acid in order of decreasing concentration.

$H_2O_{(l)} > HCOO^-_{(aq)} = HCOOH_{(aq)} > H_3O^+_{(aq)}$

Incorrect [$HCOO^-$] > [HCOOH].

Give reasons for you answer.

Waters concentration is very large and also a constant. Next $HCOO^-_{(aq)}$ and it's conjugate acid HCOOH, and then H_3O^+ because it's concentration is always very small

(iii) Calculate the concentration of the methanoic acid solution with a pH of 2.78.

$[H_3O^+] = 10^{-pH}$

$= 10^{-2.78}$

$= 1.66 \times 10^{-3}\ mol\,L^{-1}$

Therefore the concentration of the solution was $1.66 \times 10^{-3}\ mol\,L^{-1}$

Calculates [H_3O^+] correctly.

(b) Justify the variation in the properties (pH and conductivity) for the four dilute aqueous solutions described in the table below.

Assessor's use only

	pH	Conductivity
HCl	1.0	high
NH_4Cl	5.1	high
NH_3	11.1	low
NaOH	13.0	high

- HCl is a strong acid and as such it disosiates fully meaning its aqueous solution is made entirely of ions allowing it to conduct very well.

- NH_4Cl is a salt of a weak acid meaning it also dissociates when put in solution allowing good conductivity.

- NH_3 is a weak base that is molecular and therefore does not have the ability to conduct charge ✓

Reason for lack of conductivity not given.

- NaOH is a strong base that is ionic and therefore dissociates giving the ability to conduct charge. ✓

Identifies the presence of ions in solution is responsible for conductivity.

States HC1 dissociates fully.

Identifies NH_4C1 as a salt.

Three correct statements.

A4

QUESTION TWO

Assessor's use only

(a) Iron(II) sulfide, FeS, is dissolved in water to make a saturated solution.

(i) Write the equation for the equilibrium present in a saturated solution of FeS.

$FeS \rightleftharpoons Fe^{2+}_{(aq)} + S^{2-}_{(aq)}$ (H_2O above the arrow)

(ii) Write the expression for K_s(FeS). **Correct equation and correct K_s expression.**

$K_s(FeS) = [Fe^{2+}][S^{2-}]$

(iii) Calculate the solubility of FeS in a saturated solution, in mol L^{-1}.

$K_s(FeS) = 4.90 \times 10^{-18}$ $K_s = 2s^2$

$K_s(FeS) = 4.90 \times 10^{-18}$ $s = \sqrt{\frac{4.90 \times 10^{-18}}{2}}$

$[Fe^{2+}][S^{2-}] = 4.90 \times 10^{-18}$

$s = 1.57 \times 10^{-9}$ mol L^{-1}

(b) Some sulfides have very low solubility products. When hydrogen sulfide gas is bubbled through solutions of these ions, these ions separate from a mixture of ions.

(i) In a saturated solution of hydrogen sulfide $[H_3O^+]^2[S^{2-}] = 1.10 \times 10^{-23}$

Calculate the sulfide ion concentration when the pH of the solution is 4.20.

$[H_3O^+] = 10^{-pH}$

$= 10^{-4.20}$

$= 6.31 \times 10^{-5}$ **Correct [H_3O^+].**

$[S^{2-}] = 1.74 \times 10^{-19}$

(ii) Calculate the solubility of FeS in this solution, in mol L^{-1}.

Assessor's use only

(c) A solution contains a mixture of the two metal ions Cu^{2+} and Zn^{2+}, both of the same concentration. The solution is saturated with hydrogen sulfide and adding hydrochloric acid lowers the pH of the solution.

$K_s(CuS) = 6.30 \times 10^{-36}$ $K_s(ZnS) = 1.6 \times 10^{-24}$

Account for the fact that at a pH close to 7 all the metal sulfides will precipitate whereas only the most insoluble sulfides precipitate out at a lower pH.

In your answer, you should use equilibrium principles and both Cu^{2+} and Zn^{2+} as examples. **(No calculations are required.)**

Two statements correct.

A3

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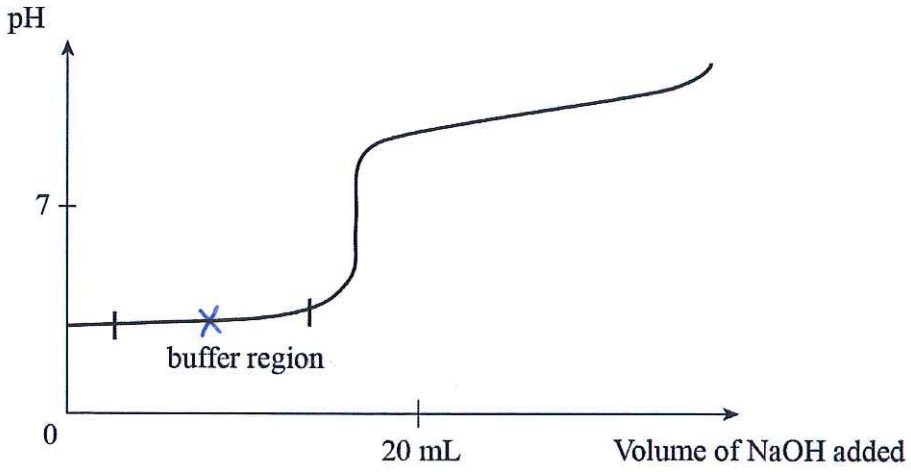
QUESTION THREE

Assessor's use only

20.00 mL of 0.125 mol L^{-1} ethanoic acid is titrated with 0.125 mol L^{-1} sodium hydroxide solution. The equation for this reaction is:

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O\ (l)$$

The titration curve for the reaction is given below and the buffer region is marked on the graph.



(a) (i) Explain why the solution in the titration flask can act as a buffer in this marked region. Use an equation in your answer.

Because at this point the adition of the base is only effecting the pH very slightly which is the function of a buffer solution //

(ii) Put an **X** on the graph to show at which point the buffering action is the most efficient. Give reasons for your answer.

Correct position identified but no reason given.

(b) (i) Show that the pH at the equivalence point for this titration is 8.78.

Assessor's use only

$$pK_a(CH_3COOH) = \cancel{9.24}\ 4.76$$

(ii) Explain why methyl orange is not a suitable indicator for this titration and why phenolphthalein is a suitable indicator for this titration.

Indicator	pK_a
Methyl orange	3.70
Phenolphthalein	9.30

Because Methyl orange will indicate much before the equivalence point and therefore will invalidate all readings

(iii) Phenolphthalein is an acid-base indicator. It is a weak acid and its formula can be represented as HIn. Phenolphthalein is colourless in acidic solutions and purple in basic solutions.

Assessor's use only

$$pK_a\ (HIn) = 9.60$$

Discuss the effect of adding ethanoic acid and sodium hydroxide in turn to a solution containing phenolphthalein. In your answer, you should refer to:

- equilibrium principles
- the species responsible for the colours seen
- the pH range within which this indicator is effective.

Some accurate statements.

N1

3

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EXEMPLAR FOR HIGH ACHIEVED

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(a) Methanoic acid, HCOOH, is a weak acid. A dilute aqueous solution of this acid has a pH of 2.78.

$$pK_a\ (HCOOH) = 3.74$$

(i) Write an equation for the reaction of methanoic acid with water.

$HCOOH + H_2O \rightarrow H_3O^+ + HCOO^-$

Correct equation.

(ii) List all the species in the aqueous solution of methanoic acid in order of decreasing concentration.

H_3O^+, $HCOOH$, $HCOO^-$, H_2O

Give reasons for you answer.

because methanoic acid is a weak acid.

(iii) Calculate the concentration of the methanoic acid solution with a pH of 2.78.

$PH = 2.78$ $\quad ka = 1.8197 \times 10^{-4}$

$Ka = \frac{[H_3O^+]^2}{[HCOOH]}$

$PH = -\log [H_3O^+]$

$2.78 = -\log [H_3O^+]$

$[H_3O^+] = 1.6596 \times 10^{-3}$

$[H_3O^+] = 1.66 \times 10^{-3}\ mol\,L^{-1}$ 1

Correct concentration of $[H_3O^+]$.

(b) Justify the variation in the properties (pH and conductivity) for the four dilute aqueous solutions described in the table below.

Assessor's use only

	pH	Conductivity
HCl	1.0	high
NH_4Cl	5.1	high
NH_3	11.1	low
NaOH	13.0	high

HCl is a very strong acid
NH4Cl is a weak acid
NH3 is a weak base
NaOH is a strong base

Two correct statements,

A3

QUESTION TWO

Assessor's use only

(a) Iron(II) sulfide, FeS, is dissolved in water to make a saturated solution.

(i) Write the equation for the equilibrium present in a saturated solution of FeS.

$FeS \rightleftharpoons Fe^{2+} + S^{2-}$

Correct equation and K_s expression.

(ii) Write the expression for K_s(FeS).

$Ks = [S^{2-}][Fe^{2+}]$

(iii) Calculate the solubility of FeS in a saturated solution, in mol L^{-1}.

$K_s(FeS) = 4.90 \times 10^{-18}$

$Ks = S \times S$

$Ks = S^2$

$4.90 \times 10^{-18} = S^2$

$S = 2.2135 \times 10^{-9}$

$S = 2.21 \times 10^{-9}\ mol\,L^{-1}$

Correct answer.

(b) Some sulfides have very low solubility products. When hydrogen sulfide gas is bubbled through solutions of these ions, these ions separate from a mixture of ions.

(i) In a saturated solution of hydrogen sulfide $[H_3O^+]^2[S^{2-}] = 1.10 \times 10^{-23}$

Calculate the sulfide ion concentration when the pH of the solution is 4.20.

$Ks = 1.10 \times 10^{-23}$

(ii) Calculate the solubility of FeS in this solution, in mol L^{-1}.

Assessor's use only

$FeS \rightarrow Fe^{2+} + 2S^{2-}$

$Ks = 4.90 \times 10^{-18}$ $Ks = [Fe^{2+}][S^{2-}]^2$

$Ks = S \times (2S)^2$ $Ks = 4S^3$

$4.90 \times 10^{-18} = 4S^3$ $S = 1.06499 \times 10^{-6}$

$S = 1.070 \times 10^{-6}$

(c) A solution contains a mixture of the two metal ions Cu^{2+} and Zn^{2+}, both of the same concentration. The solution is saturated with hydrogen sulfide and adding hydrochloric acid lowers the pH of the solution.

$K_s(CuS) = 6.30 \times 10^{-36}$ $K_s(ZnS) = 1.6 \times 10^{-24}$

Account for the fact that at a pH close to 7 all the metal sulfides will precipitate whereas only the most insoluble sulfides precipitate out at a lower pH.

In your answer, you should use equilibrium principles and both Cu^{2+} and Zn^{2+} as examples. **(No calculations are required.)**

Two correct statements,

A3

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QUESTION THREE

Assessor's use only

20.00 mL of 0.125 mol L^{-1} ethanoic acid is titrated with 0.125 mol L^{-1} sodium hydroxide solution. The equation for this reaction is:

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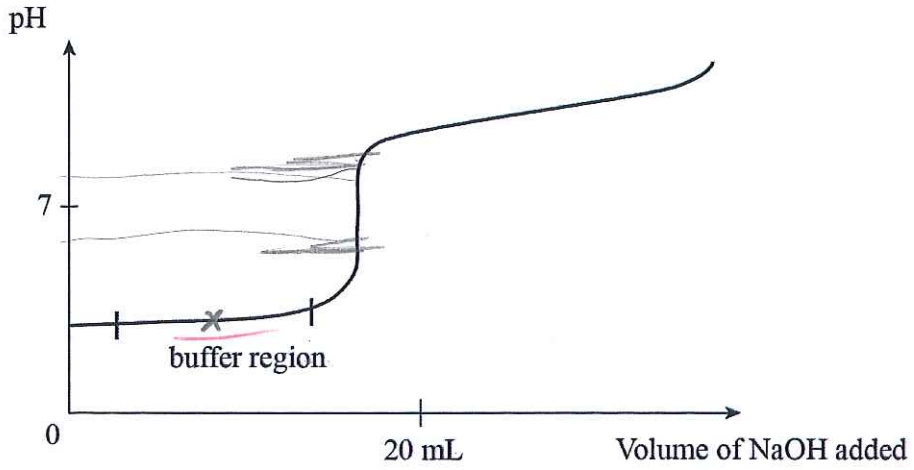
The titration curve for the reaction is given below and the buffer region is marked on the graph.



Correct identification of a buffer made of conjugate base and its acid.

(a) (i) Explain why the solution in the titration flask can act as a buffer in this marked region. Use an equation in your answer.

A buffer solution keeps pH constant when acid and base are added. because it has a conjugate acid and its conjugate base, therefore can work as a buffer.
eg $CH_3COOH + OH^- \rightarrow CH_3COO^-$
ethanoic acid can act as a proton donor
$CH_3COO^- + H^+ \rightarrow CH_3COOH$
sodium ethanoate can act as a proton acceptor
these conjugate pairs therefore are a buffer solution

Correct equations showing how buffer absorbs H^+ or OH^-.

(ii) Put an **X** on the graph to show at which point the buffering action is the most efficient. Give reasons for your answer.

because the ~~amounts~~ concentration of the conjugate acid/base pairs is varied, therefore the buffer solution can operate.

Correct identification of most efficient buffer and attempt at a reason.

Assessor's use only

(b) (i) Show that the pH at the equivalence point for this titration is 8.78.

$pK_a(CH_3COOH) = 9.24$

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

$K_b = \frac{[CH_3COO^-]}{[OH^-]^2}$ $1.738 \times 10^{-5} = 0.125$

(ii) Explain why methyl orange is not a suitable indicator for this titration and why phenolphthalein is a suitable indicator for this titration.

Indicator	pK_a
Methyl orange	3.70
Phenolphthalein	9.30

because methyl orange indicator opperates best at a pH of about 3-4, whereas phenolphthalein opperates best at a pH of about 8-10. In this titration the equivilance point shows us that this sits approx at a pH of 8-9, therefore phenolphthalein would be much more suitable.

Matches equivalence point to range 8–10 for phenolphthalein.

Assessor's use only

(iii) Phenolphthalein is an acid-base indicator. It is a weak acid and its formula can be represented as HIn. Phenolphthalein is colourless in acidic solutions and purple in basic solutions.

$$pK_a\ (HIn) = 9.60$$

Discuss the effect of adding ethanoic acid and sodium hydroxide in turn to a solution containing phenolphthalein. In your answer, you should refer to:

- equilibrium principles
- the species responsible for the colours seen
- the pH range within which this indicator is effective.

One correct Merit answer.

M5