3

91392

913920

SUPERVISOR'S USE ONLY

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Level 3 Chemistry, 2017

91392 Demonstrate understanding of equilibrium principles in aqueous systems

2.00 p.m. Wednesday 15 November 2017
Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of equilibrium principles in aqueous systems.	Demonstrate in-depth understanding of equilibrium principles in aqueous systems.	Demonstrate comprehensive understanding of equilibrium principles in aqueous systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table is provided on the Resource Sheet L3–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

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 THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 21

ASSESSOR'S USE ONLY

ASSESSOR'S USE ONLY

QUESTION ONE

(a) Hydrogen fluoride, HF, and hydrogen bromide, HBr, both form acidic solutions when added to water.

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

Hydrogen fluoride, HF, with water:

$HF + H_2O \rightleftharpoons F^- + H_3O^+$

Hydrogen bromide, HBr, with water:

$HBr + H_2O \rightleftharpoons Br^- + H_3O^+$

(ii) Compare and contrast the electrical conductivity of 0.150 mol L^{-1} solutions of hydrofluoric acid, HF, and hydrobromic acid, HBr.

In your answer, you should:

- include the requirements for a solution to conduct electricity
- identify the species present AND their relative concentrations.

No calculations are necessary.

Electrical conductivity depends upon the amount of ions in solution that are able to carry charge. HF and HBr are both weak acids as they f.o. partially dissociate to form F^- and H_3O^+ in the case of HF and Br^- and H_3O^+ in the case of HBr. The equilibrium lies to the left. Each weak acid forms two ionic products which are able to carry charge, and in equal concentrations, so will have similar conductivity.

(b) 40.0 mL of 0.150 mol L^{-1} HBr solution was added to 25.0 mL of a saturated silver bromide, AgBr, solution.

ASSESSOR'S USE ONLY

(i) Write an equation for the equilibrium occurring in a saturated solution of AgBr.

$AgBr \rightleftharpoons Ag^+ + Br^-$

(ii) Explain the changes that occur to the concentrations of the species in the saturated solution of AgBr on the addition of the HBr solution.

On addition, HBr dissociates to form H_3O^+ and Br^- ions ($HBr + H_2O \rightleftharpoons Br^- + H_3O^+$). According to le chatelier's principle, the excess of Br^- ions will cause the AgBr equilibrium to favour the reverse reaction to reduce the concentration of Br^- ions. Thus the concentration of Ag^+ and Br^- decreases and concentration of AgBr increases. //

(iii) Calculate the concentration of the silver ions, Ag^+, after the HBr solution has been added.

$K_s(AgBr) = 5.00 \times 10^{-13}$

Assume the concentration of Br^- in the original saturated solution of AgBr is insignificant.

$[Ag^+][Br^-] = 5.00 \times 10^{-13}$

$c(Br^-) = \frac{n(Br^-)}{0.065}$

$n(\text{old } Br^-) = 0.150 \times 0.04 = 6 \times 10^{-3}$ mol

$c(\text{new } Br^-) = \frac{6 \times 10^{-3}}{0.065} = 0.0923$

$[Ag^+][0.0923] = 5.00 \times 10^{-13}$

$[Ag^+] = 5.42 \times 10^{-12}$ mol L^{-1}

E7

ASSESSOR'S USE ONLY

QUESTION TWO

(a) Ammonia, NH_3, is a weak base.

$pK_a(NH_4^+) = 9.24$ $K_a(NH_4^+) = 5.75 \times 10^{-10}$

(i) Calculate the pH of a 0.105 mol L^{-1} NH_3 solution.

$[H_3O^+] = \sqrt{\frac{Ka \times Kw}{C(base)}}$

$= \sqrt{\frac{5.75 \times 10^{-10} \times 10^{-14}}{0.105}}$

$= 7.40 \times 10^{-12}$

$-\log[7.40 \times 10^{-12}] = pH$

$= 11.13$ //

(ii) Dilute hydrochloric acid, HCl, is added to the NH_3 solution until the ratio of NH_3 to NH_4^+ in the solution is 5:1.

Determine the pH of this solution, and evaluate its ability to resist a change in pH when small volumes of strong acid or base are added.

$pH = pKa + \log\frac{[base]}{[acid]}$

$= 9.24 + \log\frac{5}{1}$

$= 9.93$

The pH of the Solution is 9.93 meaning there is a higher concentration of conjugate base NH_3, than NH_4^+. Thus, the Solution will be more effective at maintaining pH when small volumes of strong acid are added as the excess NH_3 reacts with it to form NH_4^+ and water.

$NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + H_2O$

ASSESSOR'S USE ONLY

(b) (i) Write the equation for the equilibrium occurring in a saturated solution of copper(II) hydroxide, $Cu(OH)_2$.

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

(ii) Write the expression for $K_s(Cu(OH)_2)$.

$K_s(Cu(OH)_2) = [Cu^{2+}][OH^-]^2$

(iii) Calculate the solubility of $Cu(OH)_2$ in water at 25°C.

$K_s(Cu(OH)_2) = 4.80 \times 10^{-20}$

$[Cu^{2+}][OH^-]^2 = 4.80 \times 10^{-20}$

$4s^3 = 4.80 \times 10^{-20}$

$s = 2.29 \times 10^{-7}$ mol L^{-1}

(c) Explain why the solubility of $Cu(OH)_2$ increases when dilute hydrochloric acid is added.

$Cu(OH)_2$ dissociates to form Cu^{2+} and OH^- ions (($Cu(OH)_2$) $\rightleftharpoons Cu^{2+} + 2OH^-$). When dilute hydrochloric acid is added it forms H_3O^+ and Cl^- ions ($HCl + H_2O \rightleftharpoons Cl^- + H_3O^+$). These H_3O^+ ions neutralise OH^- ions to form H_2O ($OH^- + H_3O^+ \rightleftharpoons H_2O$), which decreases the concentration of OH^- ions in the solution. Thus the $Cu(OH)_2$ equilibrium favours the forward reaction to replenish OH^- ions, increasing the solubility as more $Cu(OH)_2$ dissolves.

E7

ASSESSOR'S USE ONLY

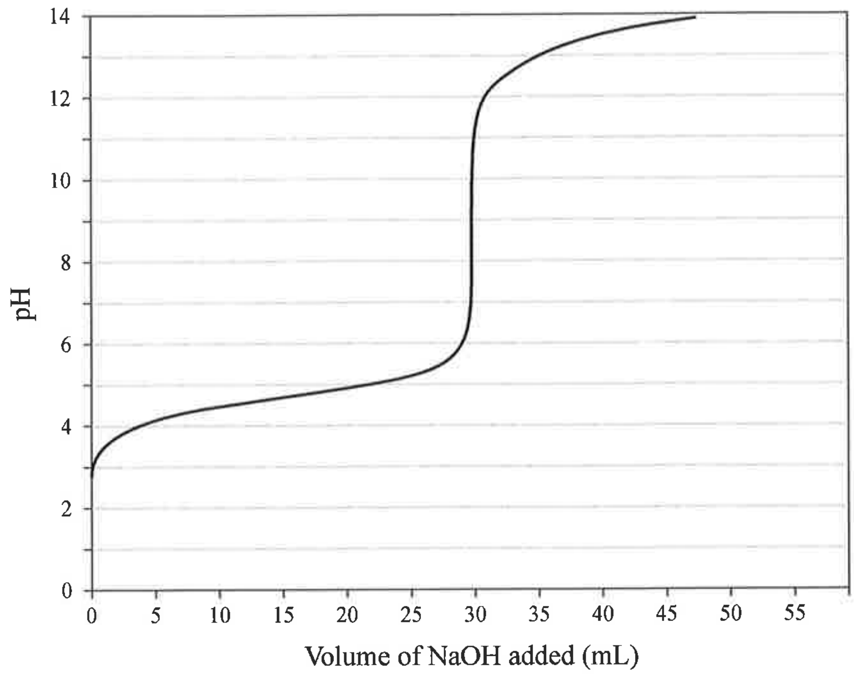
QUESTION THREE

A titration was carried out by adding 0.112 mol L^{-1} sodium hydroxide solution, NaOH(*aq*), to 20.0 mL of ethanoic acid solution, $CH_3COOH(aq)$.

The equation for the reaction is:

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$ $\qquad K_a(CH_3COOH) = 1.74 \times 10^{-5}$

Titration curve for CH_3COOH versus NaOH



(a) With reference to the titration curve above, put a tick next to the indicator most suited to identify the equivalence point.

Indicator	pK_a	Tick ONE box below
Methyl yellow	3.1	
Bromocresol purple	6.3	✓
Phenolphthalein	9.6	

(b) (i) The ethanoic acid solution, $CH_3COOH(aq)$, has a pH of 2.77 before any NaOH is added.

Show by calculation that the concentration of the CH_3COOH solution is 0.166 mol L^{-1}.

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

$1.74 \times 10^{-5} = \frac{[H_3O^+]^2}{[CH_3COOH]}$

$10^{-2.77} = [H_3O^+]$
$= 1.698 \times 10^{-3}$

$[CH_3COOH] = \frac{(1.698 \times 10^{-3})^2}{1.74 \times 10^{-5}}$

$= 0.166$ mol L^{-1}

(ii) Calculate the pH of the solution in the flask after 10.0 mL of 0.112 mol L^{-1} NaOH has been added to 20.0 mL of ethanoic acid solution, $CH_3COOH(aq)$.

$n(CH_3COOH) = n(CH_3COOH) - n(NaOH\ added)$
$= (0.166 \times 0.02) - (0.112 \times 0.01)$
$= 2.2 \times 10^{-3}$

$C(CH_3COOH) = \frac{2.2 \times 10^{-3}}{0.03} = 0.0733$ mol L^{-1}

$C(NaOH) = \frac{n(NaOH\ added)}{0.03} = \frac{(0.112 \times 0.01)}{0.03} = 0.0373$ mol L^{-1}

$pH = pKa + \log \frac{[base]}{[acid]}$
$= 4.76 + \log \frac{0.0373}{0.0733}$

$= 4.47$

Question Three continues on the following page.

(c) The equivalence point pH for the titration of ethanoic acid with sodium hydroxide is 8.79.

ASSESSOR'S USE ONLY

(i) Identify the chemical species present at the equivalence point, other than water.

CH_3COONa, CH_3COO^-, Na^+, CH_3COOH, OH^-

(ii) In a second titration, a 0.166 mol L^{-1} methanoic acid solution, HCOOH(*aq*), is titrated with the NaOH solution. The equivalence point pH for this titration is 8.28.

The equivalence point pH for the CH_3COOH titration is 8.79.

Compare and contrast the pH values at the equivalence point for both titrations.

$K_a(HCOOH) = 1.82 \times 10^{-4}$ $K_a(CH_3COOH) = 1.74 \times 10^{-5}$

No calculations are necessary.

HCOOH has a higher Ka value than CH_3COOH. This means that HCOOH will dissociate more than CH_3COOH ie. the equilibrium lies further to the right ($HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$). Thus there will be more H_3O^+ ions in the solution, giving it a lower pH than CH_3COOH.

E7

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

ASSESSOR'S USE ONLY

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

ASSESSOR'S USE ONLY

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

ASSESSOR'S USE ONLY

91392

Excellence exemplar for 91392 2017		Total score	21
Q	**Grade score**	**Annotation**	
1	E7	The candidate was awarded E7 for the following reasons: In part (a)(i), the correct arrow was used for hydrogen fluoride, but not for hydrogen bromide. In part (a)(ii), the candidate had the correct ideas on both conductivity and strength. In part (b), the candidate wrote the correct equation; had a full discussion on solubility – justifying their response using Le Chatelier's Principle; correctly used K_s expression to correctly calculate the concentration of the silver ions present in the dilution.	
2	E7	The candidate was awarded E7 for the following reasons: In part (a), the candidate calculated the pH correctly, but the answer did not reflect the appropriate number of significant figures. The correct buffer pH and evaluation were given. In part (b), the correct equation and expression were given which were used to correctly calculate the solubility of $Cu(OH)_2$, with the correct unit. In part (c), a full discussion on solubility relating to both equilibrium and acid-base reaction was given.	
3	E7	The candidate was awarded E7 for the following reasons: In part (a), an incorrect indicator was chosen. In part (b), the calculation of both concentration and pH were correct, with justification. In part (c), four correct species were given; the pH related to acid strength, however, to gain E8, the candidate's response need to relate to all species present, e.g. the conjugate base strengths.	