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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Chemistry 2023

91392 Demonstrate understanding of equilibrium principles in aqueous systems

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 and other reference material are provided in the Resource Booklet L3–CHEMR.

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

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (DO NOT WRITE IN THIS AREA). This area will be cut off when the booklet is marked.

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QUESTION ONE

(a) (i) Write the equation for the equilibrium occurring in a saturated solution of lead hydroxide, $Pb(OH)_2$.

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

(iii) Calculate the solubility of $Pb(OH)_2$ in a solution of pH 9.55 at 25 °C.

$K_s(Pb(OH)_2) = 8.00 \times 10^{-17}$

(iv) Explain, using equilibrium principles, what would happen to the solubility of $Pb(OH)_2$ in solution when the pH is decreased below 3.

Include relevant equation(s) in your answer.

No calculations are necessary.

(b) (i) Show, by calculation, that a precipitate of lead iodide, PbI_2, will form when 25.0 mL of 0.00741 mol L^{-1} lead nitrate, $Pb(NO_3)_2$, is added to 35.0 mL of 0.00613 mol L^{-1} potassium iodide, KI.

$K_s(PbI_2) = 8.00 \times 10^{-9}$

(ii) One of the following solutions could be added to the mixture in part (i) to cause the PbI_2 to further precipitate.

sodium iodide, NaI **sodium chloride, NaCl**

Circle the correct solution and explain why more solid PbI_2 would form.

QUESTION TWO

(a) An aqueous solution containing a mixture of hydrogen carbonate ions, HCO_3^-, and carbonate ions, CO_3^{2-}, can act as a buffer solution.

$$K_a(HCO_3^-) = 5.01 \times 10^{-11} \qquad pK_a(HCO_3^-) = 10.3$$

(i) Calculate the pH of a buffer solution made by mixing 50.0 mL of 0.211 mol L^{-1} sodium carbonate and 35.0 mL of 0.861 mol L^{-1} sodium hydrogen carbonate.

(ii) A student prepared a solution of HCO_3^- ions and CO_3^{2-} ions with a pH of 8.50.

Explain why this solution would not function effectively as a buffer.

(iii) Elaborate on how the student could adjust the ratio of HCO_3^- : CO_3^{2-} and the pH to make the solution in part (ii) equally effective at neutralising either strong acid or strong base.

(b) Solid ammonium chloride, NH_4Cl, can be dissolved in water to make a solution of ammonium chloride.

(i) List all the species present in a solution of NH_4Cl in order of decreasing concentration.

Do not include water.

	>		>	NH_3	=		>	OH^-

Space for equations if necessary:
No calculations required.

(ii) Calculate the mass of NH_4Cl required to dissolve in 500 mL of water to form a solution of pH 5.25.

Assume the volume of water does not change.

$M(NH_4Cl) = 53.5\ g\ mol^{-1}$ $K_a(NH_4^+) = 5.75 \times 10^{-10}$ $pK_a(NH_4^+) = 9.24$

(iii) Solutions of ammonium chloride, NH_4Cl, and hydrobromic acid, HBr, of equal concentration have the following properties:

Solution	pH	Electrical conductivity
NH_4Cl	5.61	good
HBr	1.98	good

Compare the pH and electrical conductivity of the NH_4Cl and HBr solutions.

Include relevant equation(s) in your answer.

No calculations are necessary.

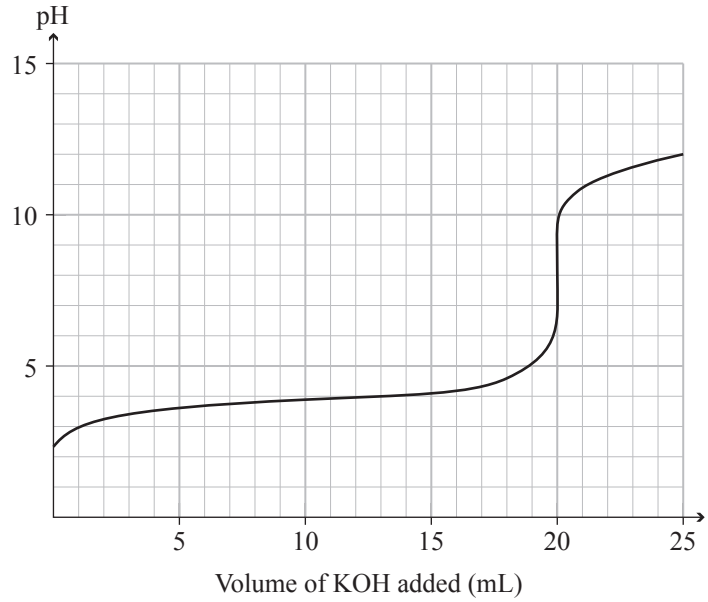
QUESTION THREE

A titration was carried out by adding 0.0893 mol L^{-1} potassium hydroxide, KOH, to 15.0 mL of 0.119 mol L^{-1} methanoic acid, HCOOH, in a conical flask.

The equation for the reaction is:

$$HCOOH + KOH \rightarrow HCOOK + H_2O$$

$$K_a(HCOOH) = 1.82 \times 10^{-4} \qquad pK_a(HCOOH) = 3.74$$



(a) Calculate the pH of the methanoic acid before any potassium hydroxide is added.

(b) (i) Estimate the pH at the equivalence point from the curve.

(ii) Calculate the pH at the equivalence point.

(iii) Explain how to choose a suitable indicator for this titration.

Question Three continues on the next page.

(c) (i) From the titration curve, the pH in the conical flask only gradually increases between approximately 8 and 12 mL of KOH being added.

Explain this observation, using relevant equation(s) to support your answer.

No calculations are necessary.

(ii) After the equivalence point has been reached, the pH rapidly increases as excess KOH is added.

Calculate the pH in the conical flask after 23.0 mL of the KOH solution has been added.

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

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