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Level 3 Chemistry 2021

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 – 11 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

QUESTION ONE

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

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

(iii) Calculate the solubility of $Mg(OH)_2$ in water at 25 °C, and give $[Mg^{2+}]$ and $[OH^-]$.

$K_s(Mg(OH)_2) = 7.10 \times 10^{-12}$

(b) When dilute sodium hydroxide, NaOH, is added to a saturated solution of $Mg(OH)_2$, the concentration of Mg^{2+} ions in the saturated solution decreases.

(i) Explain, using equilibrium principles, why the concentration of Mg^{2+} ions in the saturated solution decreases upon the addition of NaOH.

(ii) Calculate the concentration of Mg^{2+} ions in a solution after 30.0 mL of 0.120 mol L^{-1} NaOH is added to 20.0 mL of a saturated $Mg(OH)_2$ solution.

Assume the concentration of OH^- ions in the original saturated solution of $Mg(OH)_2$ is insignificant.

(c) Determine whether a precipitate of $Mg(OH)_2$ will form when 65.0 mL of 0.240 mol L^{-1} magnesium nitrate, $Mg(NO_3)_2$, is added to 40.0 mL of NaOH solution of pH 12.8.

QUESTION TWO

(a) A buffer solution is made by mixing appropriate amounts of methanoic acid, HCOOH, and sodium methanoate, HCOONa.

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

(i) When a small volume of dilute sodium hydroxide, NaOH, is added to the buffer, the following reaction occurs:

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

Describe the function of a buffer solution and explain the significance of this equation in terms of the function of the buffer solution.

(ii) Explain why the pH remains unchanged when water is added to a buffer solution.

(iii) A buffer solution of pH 2.93 is made by dissolving 1.65 g HCOONa in 250 mL of a HCOOH solution.

Calculate the concentration of the HCOOH solution used to make this buffer solution.

M(HCOONa) = 68.0 g mol^{-1}

Assume there is no change in the total volume.

(b) HCOOH has a pK_a of 3.74, whereas the methylammonium ion, $CH_3NH_3^+$, has a pK_a of 10.6.

Compare the pH and electrical conductivity of HCOOH and methylammonium chloride, CH_3NH_3Cl, solutions of equal concentration. Your answer should include relevant equation(s).

No calculations are necessary.

QUESTION THREE

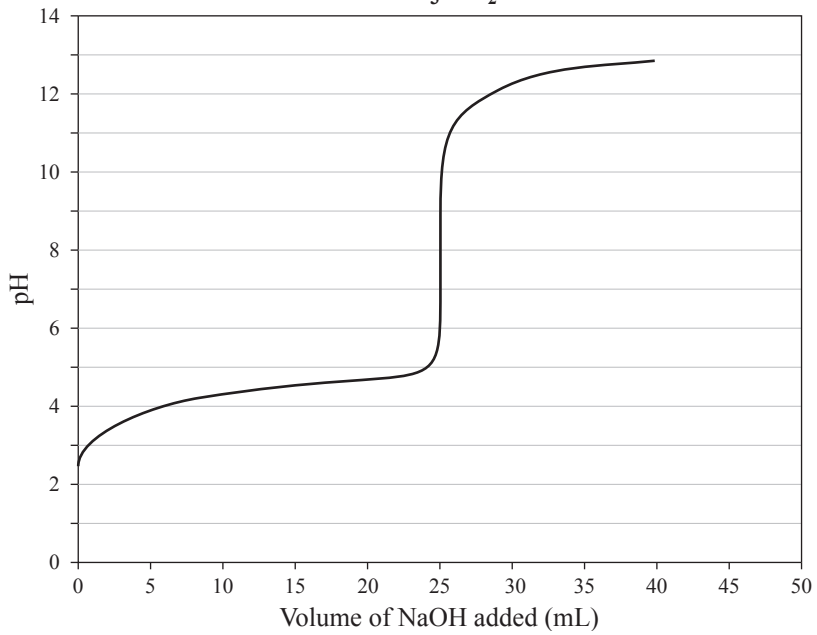
A titration was carried out by adding 0.163 mol L^{-1} sodium hydroxide, NaOH, to 20.0 mL of propanoic acid solution, CH_3CH_2COOH, in a conical flask.

The equation for the reaction is:

$$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$$

$K_a(CH_3CH_2COOH) = 1.35 \times 10^{-5}$ $\quad$ $pK_a(CH_3CH_2COOH) = 4.87$

Titration curve for CH_3CH_2COOH with NaOH



(a) (i) Fill in the boxes below to show all the species present in a solution of propanoic acid in order of decreasing concentration.

Do not include water.

	>		=	H_3O^+	>	

(ii) The propanoic acid solution has a pH of 2.78 before any NaOH is added.

Show, by calculation, that the initial concentration of the propanoic acid is 0.204 mol L^{-1}.

(b) (i) Put a cross at the equivalence point on the titration curve on the facing page.

(ii) Put ONE tick in the table below to choose the most suitable indicator for the titration.

Indicator	pK_a	TICK (✔) most suitable indicator
Thymol blue	1.70	
Methyl yellow	3.10	
Nile blue	9.70	

Explain your choice, including the consequences of choosing the other indicators.

(iii) Calculate the pH at the equivalence point.

Question Three continues on the next page.

(c) (i) Calculate the pH of the solution in the conical flask after 29.0 mL of the NaOH solution has been added.

(ii) The original 0.163 mol L^{-1} NaOH solution in the burette has a pH of 13.2.

Explain why this is different from the pH calculated in part (i) above.

No calculations are necessary.

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

QUESTION NUMBER

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