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Level 3 Chemistry, 2015

91392 Demonstrate understanding of equilibrium principles in aqueous systems

2.00 p.m. Wednesday 11 November 2015
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.

Not Achieved

TOTAL 7

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QUESTION ONE NOT ACHIEVED

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Methylammonium chloride, CH_3NH_3Cl, dissolves in water to form a weakly acidic solution.

$K_a(CH_3NH_3^+) = 2.29 \times 10^{-11}$

(a) (i) Write an equation to show CH_3NH_3Cl dissolving in water.

$$CH_3NH_3Cl_{(s)} + H_2O_{(\ell)} \rightleftharpoons CH_3NH_{3(aq)}^+ + Cl^-_{(aq)}$$

(ii) Write an equation to show the reaction occurring in an aqueous solution of CH_3NH_3Cl.

$$CH_3NH_3Cl_{(aq)} \overset{water}{\rightleftharpoons} CH_3NH_{2(aq)} + Cl^-_{(aq)} + H_3O^+_{(aq)}$$

(iii) List all the species present in an aqueous solution of CH_3NH_3Cl, in order of decreasing concentration.

Do not include water.

CH_3NH_3Cl, $CH_3NH_3^+$, Cl^-, H_3O^+, OH^-

(iv) Calculate the pH of 0.0152 mol L^{-1} CH_3NH_3Cl solution.

$$[H^+] = \frac{K_w}{[Base]}$$

$$= \frac{10^{-14}}{0.0152}$$

$$H^+ = 6.579 \times 10^{-13}$$

$$pH = -\log[H^+]$$
$$= -\log 6.579 \times 10^{-13}$$

$$pH = 12.2$$

(b) The table shows the pH and electrical conductivity of three solutions. The concentrations of the solutions are the same.

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Solution	NaOH	CH_3NH_2	CH_3COONa
pH	13.2	11.9	8.98
Electrical conductivity	good	poor	good

Compare and contrast the pH and electrical conductivity of these three solutions.

Include appropriate equations in your answer.

pH: pH depends on the concentration of OH^- and H_3O^+ ions. NaOH fully dissociates into it's ions making it a Strong base with a pH of 13.2.

$NaOH \rightarrow Na^+ + OH^-$

CH_3NH_2 partially dissociates into it's ions making it a weak base.

$CH_3NH_2 \xrightarrow{H_2O} CH_3NH_3^+ + OH^-$

because of the increase in OH^- concentration it has a High pH although not as high as NaOH.

$CH_3COONa \xrightarrow{H_2O} CH_3COOH + OH^-$ and it is a weak base also

U

Electrical conductivity:

Electrical conductivity depends on how many free ions that can carry a charge a molecule has.

NaOH is a good conductor since it fully disscociates into it's ions.

CH_3NH_2 has no free ions that carry a charge so is a poor conductor and CH_3COONa partially dissociates into ions so is also a good conductor

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N2

QUESTION TWO

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Sufficient calcium carbonate, $CaCO_3(s)$, is dissolved in water to make a saturated solution.

(a) (i) Write the equation for the equilibrium occurring in a saturated solution of $CaCO_3$.

$$CaCO_{3(s)} \cancel{+ H_2O} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

(ii) Write the expression for $K_s(CaCO_3)$.

$$K_s = [Ca^{2+}_{(aq)}][CO_3^{2-}{}_{(aq)}]$$

(iii) Calculate the solubility product of $CaCO_3$, $K_s(CaCO_3)$.
The solubility of $CaCO_3$ is 5.74×10^{-5} mol L^{-1}.

$$K_s(CaCO_3) = [Ca^{2+}][CO_3^{2-}]$$
$$= (5.74 \times 10^{-5})^2$$
$$= 3.29 \times 10^{-9} \text{ mol } L^{-1}$$

(b) Some marine animals use calcium carbonate to form their shells. Increased acidification of the oceans poses a problem for the survival of these marine animals.

Explain why the solubility of $CaCO_3$ is higher in an acidic solution.
Use an equation to support your explanation.

a higher acidic solution means more H_3O^+ ions are present. an increase in H_3O^+ concentration means that it will affect the equilibrium equation and more $CaCO_3$ will be formed, therefore the solubility of $CaCO_3$ will be higher.

$$CaCO_{3(s)} + H_2O_{(l)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_{2(aq)}^{-} + H_3O^+_{(aq)}$$

(c) Show, by calculation, that a precipitate of lead(II) hydroxide, $Pb(OH)_2$, will form when 25.0 mL of a sodium hydroxide solution, NaOH, at pH 12.6 is added to 25.0 mL of a 0.00421 mol L^{-1} lead(II) nitrate, $Pb(NO_3)_2$, solution.

$K_s(Pb(OH)_2) = 8.00 \times 10^{-17}$ at 25°C

$n = \frac{m}{M}$

$c = \frac{n}{V}$

$= 10^{-12.6}$

$= 2.512 \times 10^{-13}$

$n = cV$

$= 0.00421 \times 0.25$

$= 1.05 \times 10^{-3}$

$K_s(Pb(NO_3)_2 = [Pb][NO_3]^2$

$= (0.00421) \times (0.00421^2)$

$= 7.46 \times 10^{-8}$

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

Precipitate will form because $K_s(Pb(NO_3)_2$ is larger than $K_s(Pb(OH)_2)$

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N2

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QUESTION THREE

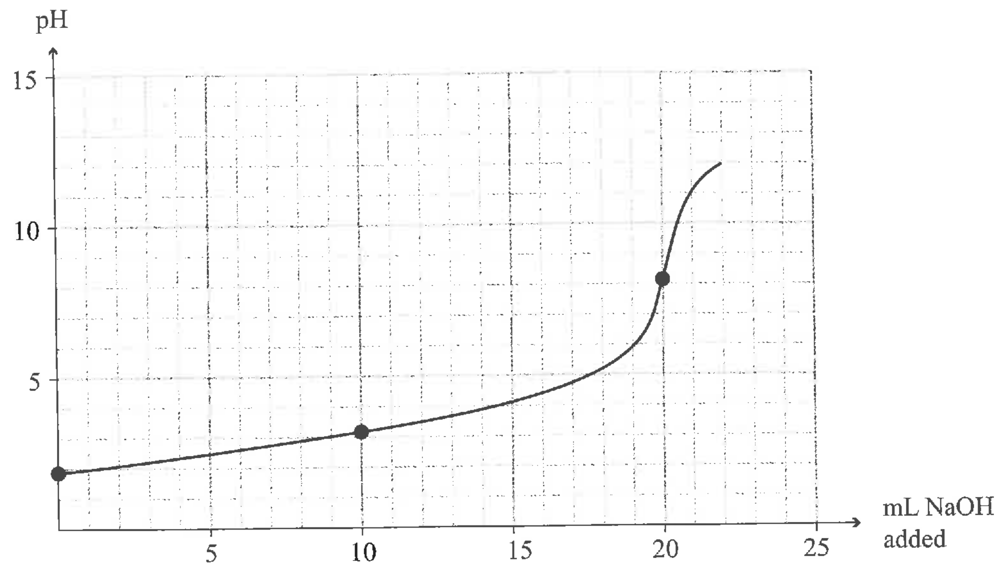
20.0 mL of 0.258 mol L^{-1} hydrofluoric acid, HF, solution is titrated with a sodium hydroxide, NaOH, solution.

The equation for the reaction is:

$$HF + NaOH \rightarrow NaF + H_2O$$

$$pK_a(HF) = 3.17$$

The titration curve is given below:



(a) (i) Identify the species in solution at the equivalence point.

NaOH, NaF, H_2O, HF

(ii) Explain why the pH at the equivalence point is greater than 7.

Include an equation in your answer.

at the equivalence point the weak acid HF has been added to the weak base NaOH the concentration of OH^- ions is still higher than H^+ ions so it is slightly basic with a pH of greater than 7.

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(iii) After a certain volume of NaOH solution has been added, the concentration of HF in the solution will be twice that of the F^-.

Calculate the pH of this solution, and evaluate its ability to function as a buffer.

$pH = pka + \log\left(\frac{base}{acid}\right) = 3.17 + \log\left(\frac{0.129}{0.258}\right)$

$pH = 2.87$

because these conditions are acidic the solution will be able to act as a buffer as the NaOH is added

C

(iv) Determine by calculation, the pH of the solution after 24.0 mL of 0.258 mol L^{-1} NaOH solution has been added.

$n = \frac{c}{v} = \frac{0.258}{0.24}$

base = 1.075

$n = \frac{c}{v} = \frac{0.258}{0.20}$

acid = 0.129

$ka = 10^{-3.17}$

$= 6.76 \times 10^{-4}$

$[H^+] = \sqrt{\frac{ka \times kw}{base}}$

$[H^+] = \sqrt{\frac{6.76 \times 10^{-4} \times 10^{-14}}{1.075}}$

$= 2.51 \times 10^{-9}$

$pH = -\log 2.51 \times 10^{-9}$

$pH = 8.6$

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Question Three continues on the following page.

Strong acid

(b) In a second titration, a 0.258 mol L^{-1} ethanoic acid, CH_3COOH, solution was titrated with the NaOH solution.

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Contrast the expected pH at the equivalence point with the HF titration.

$pK_a(CH_3COOH) = 4.76$

No calculations are necessary.

The Strong acid strong base titration will have a ~~higher~~ lower pH at equivalence point than the weak acid strong base titration, this is due to the higher concentration of H_3O^+ ions that will ~~lower~~ lower the pH of the solution. so CH_3COOH with NaOH has a lower pH at the equivalence point.

A3

Not Achieved exemplar for 91392 2015			Total score	07
Q	**Grade score**	**Annotation**		
1	N2	This provides evidence for N2 because there are no correct equations in part (a)(i), (ii) & (iii) and in (a) (iv) the calculation is incorrect. However in (b) they recognise which substance are strong and weak bases but they are unclear as to which ions are responsible. They do recognise conductivity depends on ions but the explanation is unclear.		
2	N2	This provides evidence for N2 because they correctly calculate the solubility product in (a) (iii).		
3	A3	This provides evidence for A3 because they correctly calculate the pH of the buffer in (a)(iii) and in (a)(iv) they perform one calculation correctly ($[H_3O^+]$ to pH).		