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Level 3 Chemistry, 2016

91392 Demonstrate understanding of equilibrium principles in aqueous systems

2.00 p.m. Monday 21 November 2016
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 in 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 2–8 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.

Achievement

TOTAL 11

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QUESTION ONE

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Silver carbonate, Ag_2CO_3, is a sparingly soluble salt.

$K_s(Ag_2CO_3) = 8.10 \times 10^{-12}$ at 25°C $M(Ag_2CO_3) = 276$ g mol^{-1}

(a) Write the solubility product expression, K_s, for silver carbonate (Ag_2CO_3).

$Ks = [Ag^+]^2 + [CO_3^{2-}]$

(b) Calculate the mass of Ag_2CO_3 that will dissolve in 50 mL of water to make a saturated solution at 25°C.

$\frac{1000}{50} = 20$ $Ks = 4s^3$ $\sqrt[3]{\frac{4s}{4}} = s$

$\sqrt[3]{\frac{8.10\times10^{-12}}{4}} = s = 1.265148998 \times 10^{-4}$ molL^{-1}

$20 \times \frac{1.265...\times10^{-4}}{~~ma~~}$ = in 50ml = ~~6.325744499×10^{-6}~~

2.530297996×10^{-3}

~~$n = 6.325...\times10^{-6}$~~ $n = \frac{m}{Mr}$ ~~$6.325...\times10^{-6}\times276$~~ m

$2.53029766\times10^{-3} \times 276 = m = 0.6983622$

$= 0.698$ grams.

(c) Explain how the solubility of Ag_2CO_3 will change if added to 50 mL of a 1.00 mol L^{-1} ammonia, NH_3, solution.

Support your answer with balanced equations.

No calculations are necessary.

~~$Ag_2CO_3 + NH_3 \rightleftharpoons$~~ Solubility will decrease because the addition of the base will interfere with the pH.

(d) Show by calculation whether a precipitate of Ag_2CO_3 will form when 20.0 mL of 0.105 mol L^{-1} silver nitrate, $AgNO_3$, solution is added to 35.0 mL of a 0.221 mol L^{-1} sodium carbonate, Na_2CO_3, solution.

NO_3^{2-}

$K_s(Ag_2CO_3) = 8.10 \times 10^{-12}$ at 25°C

$0.105 = [Ag][NO_3^-]$

$[Ag] = \cancel{7.735 \times 10^{-3}\ mol\ L^{-1}}$

$= 2.1 \times 10^{-3}$

$0.221 = 2[Na_2]^2[CO_3]$

$CO_3^{2-} = 7.735 \times 10^{-3}$

ks

$Ag_2CO_3 = \frac{[Ag^+]^2[CO_3^{2-}]}{\cancel{Ag_2CO_3}} = 3.411134 \times 10^{-8}$

$IP < ks$ so No precipitate.

It will not precipitate.

$\frac{0.105}{50} = [Ag^+]$

$\frac{0.221}{\left(\frac{1000}{35}\right)} = [CO_3^{2-}]$

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N2

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QUESTION TWO

Ethanamine, $CH_3CH_2NH_2$, is a weak base.

$pK_a(CH_3CH_2NH_3^+) = 10.6$ $K_a(CH_3CH_2NH_3^+) = 2.51 \times 10^{-11}$

(a) Write an equation to show the reaction of ethanamine with water.

$CH_3CH_2NH_2 + H_2O \rightleftharpoons NH_3 + OH^- + CH_3CH_2^+$

(b) Calculate the pH of a 0.109 mol L^{-1} solution of ethanamine.

$ka = \frac{[NH_3][OH^-]}{[CH_3CH_2NH_2]}$ $2.51\times10^{-11} = \frac{[OH^-]^2}{0.109}$

$\sqrt{2.51\times10^{-11}\times0.109} = OH^- = 1.6540556\times10^{-6}$

$-\log[OH^-] = 5.7814989$

$14 - 5.7814... = pH = 8.2185501$

(c) Ethyl ammonium chloride, $CH_3CH_2NH_3Cl$, is a weak acid that will also react with water.

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List all the species present in a solution of $CH_3CH_2NH_3Cl$, in order of decreasing concentration.

Do not include water.

Cl^-, $CH_3CH_2NH_3^+$, H_3O^+, $CH_3CH_2NH_2$, OH^-

Justify the order you have given.

Include equations, where necessary.

$CH_3CH_2NH_3Cl \rightarrow Cl^- + CH_3CH_2NH_3^+$ This shows the complete dissociation of $CH_3CH_2NH_3Cl$. The Cl^- & $CH_3CH_2NH_3^+$ are therefor the highest in concentration, however the $CH_3CH_2NH_3^+$ undergoes an equilibrium reaction with H_2O (water) so some is used, making this concentration less than Cl^-.

$CH_3CH_2NH_3^+ + H_2O \rightleftharpoons CH_3CH_2NH_2 + H_3O^+$. As this is an equilibrium reaction, the reactant is favoured most, while product concentration is less. The H_3O^+ ~~and H_2O~~ reacts with excess water however producing both H_3O^+ & OH^-, so the H_3O^+ is of higher concentration than the $CH_3CH_2NH_2$. OH^- is the lowest as it only ~~reacts~~ is formed by the excess water in small quantities

M5

QUESTION THREE

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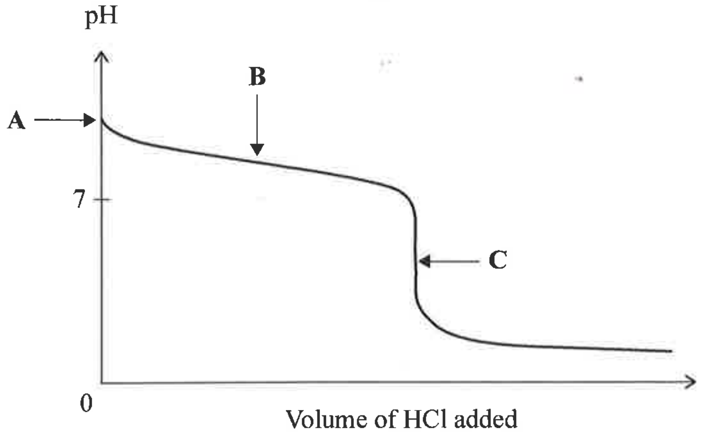
20.00 mL of 0.320 mol L^{-1} ammonia, NH_3, is titrated with 0.640 mol L^{-1} hydrochloric acid, HCl.

The equation for this reaction is:

$$NH_3 + HCl \rightarrow NH_4^+ + Cl^- \qquad pK_a(NH_4^+) = 9.24$$

The curve for this titration is given below.



(a) Explain why the pH at the equivalence point (point C) is not 7.

At equivalence point, all of the NH_3 & HCl have reacted to form NH_4^+ & Cl^-. The NH_4^+ product when reacted with water forms H_3O^+;
$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ this H_3O^+ is what contributes towards pH & so having a higher concentration means more contribution. This contribution is in favour of acid so the increased $[H_3O^+]$ will decrease pH. The equivalence point Pg 8.

SEEN

(b) Show, by calculation, that the pH at the equivalence point (point C) is 4.96.

pka = 9.24 ka = shift $\log^{-}$ pka = $5.754...\times10^{-10}$.

$ka = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$ $= 5.754399373\times10^{-10}$

$5.754...\times10^{-10} \times [NH_4^+] = [H_3O^+]^2$

$[NH_4^+] = \frac{0.32}{5} + \frac{0.64}{5} = 0.208929 \text{ mol } L^{-1}$

$\sqrt{5.754\times10^{-10} \times 0.2089...} = [H_3O^+] = 1.096478196\times10^{-5}$

$-\log[H_3O^+] = pH = 4.9567$
$= 4.96$ (3sf).

(c) Explain, in terms of the species present, why the pH at B (half way to the equivalence point) is 9.24.

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At halfway to the equivalence point, ~~the~~ point C, the concentration of NH_3 is equal to its congugate NH_4^+, so base concentration is equal to its conjugate acid. the effect this has is that H_3O^+ concentration is the same as ka, so pH = pka. ~~ka~~ $pH = pka + \log\left[\frac{acid}{base}\right]$ $\log\left[\frac{acid}{base}\right] = 0$

pg 8. Seen.

(d) Explain, in terms of the species present, why the pH of the solution at point C is 4.96.

No calculations are necessary.

Because HCl is a strong acid, it will completely dissociate with the weak base NH_3. The ~~H3O+~~ NH_4^+ & Cl^- formed, $NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$ means that the pH will be acidic. The strong acid donates all of its H_3O^+ towards the pH while the $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH$, NH_3 only donates some of its OH^-. The pH is therefore very acidic, but not completely due to the OH^- being contributed. 4

1

A4

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

QUESTION NUMBER

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3a. will therefore have a pH below 0, at the acidic ~~end~~ side of the scale

3c. As the acid & base concentrations are equal therefor pH = pka & as the pka of the solution is 9.24, the pH will therefore be the same.

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Achievment exemplar 2016

Subject:	Chemistry	Standard:	91392	Total score:	11

Q	Grade score	Annotation
1	N2	The candidate incorrectly used a + sign in the solubility product expression, K_s in part (a). In part (b), the candidate correctly calculated the solubility, but has an incorrect number of moles. This error is carried through to give the final mass. Nothing of relevance is given in part (c). Both dilutions are incorrectly calculated in part (d), however, these values are carried through using the correct method to calculate K_s.
2	M5	The candidate has given the wrong products in part (a), and has incorrectly calculated pOH in part (b). In part (c), the candidate has given the correct species and a good discussion as to why they form in the quantities that they do. A fuller justification is required as to the reason for the formation of hydroxide ions in lowest concentration.
3	A4	This candidate made no reference to the concentration of hydronium ions being greater than the concentration of hydroxide ions in part (a). In part (b), the concentration of ammonium ions is incorrectly calculated. In part (c), the concepts were correctly used, however, for full marks the candidate needed to refer to a correct mathematical formula.