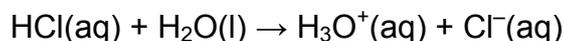


### 3.7 Aqueous Solutions 2005 Answers

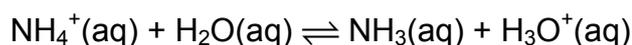
#### QUESTION ONE: ACIDS AND BASES

**Order of increasing pH:** HCl, NH<sub>4</sub>Cl, NaCl, NH<sub>3</sub>, NaOH

**HCl:** strong acid, fully dissociates giving high concentration of H<sub>3</sub>O<sup>+</sup>(aq), i.e. low pH.

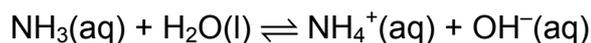


**NH<sub>4</sub>Cl:** dissolves to give a solution of NH<sub>4</sub><sup>+</sup>(aq) and Cl<sup>-</sup>(aq) ions. The NH<sub>4</sub><sup>+</sup>(aq) ions are weakly acidic and partially dissociate in water to give a small increase in [H<sub>3</sub>O<sup>+</sup>(aq)].

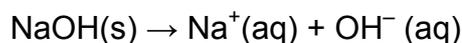


**NaCl:** dissolves to give Na<sup>+</sup>(aq) and Cl<sup>-</sup>(aq) ions, but neither of these have any reaction with water so solution is neutral.

**NH<sub>3</sub>:** is a weak base and reacts with water to give a small increase in OH<sup>-</sup>(aq) ions, making the solution weakly alkaline.



**NaOH:** is a strong base and fully dissociates, giving a high concentration of OH<sup>-</sup>(aq) ions, i.e. high pH.



**A =** Order of substances correct with no justification. **OR** Correct order but reversed pH, with justification of at least one weak and one strong species (may have arrow or equilibrium signs if equation written). **OR** Places four species in order, with correct justification and equations for any two.

**M =** Places ALL the substances in the correct order, with valid discussion for at least three species and at least two equations involving one weak and one strong example.

**E =** Full discussion linking ALL substances with their relative pH and including equations for NH<sub>3</sub>, NH<sub>4</sub>Cl, and one other. *Must use appropriate arrows or equilibrium signs, and CLEARLY state reasons for high or low concentration of H<sub>3</sub>O<sup>+</sup> or OH<sup>-</sup> ions.*

#### QUESTION TWO: PRECIPITATING SILVER CHLORIDE

**a** Solubility is the amount of substance that will dissolve in a given volume to form a saturated solution (at that temperature).

**A =** Definition clearly identifies that it is the maximum amount that will dissolve in the given volume **OR** amount dissolved in a saturated solution **OR** concentration that ions can reach before a precipitate forms.

- b  $K_s$  is an equilibrium constant for the reaction  $\text{AgCl}(s) \rightleftharpoons \text{Ag}^+(aq) + \text{Cl}^-(aq)$   
and  $K_s = [\text{Ag}^+(aq)][\text{Cl}^-(aq)]$

More solid dissolves when the temperature is increased as the equilibrium shifts in the endothermic direction, which means it shifts to the right and increases the concentration of ions in solution. This increases  $K_s$ .

**A = Answer recognises that increased  $K_s$  value means increased solubility or concentration of ions.**  
**M = Answer correctly links increase in  $K_s$  to the shift in equilibrium for the equation they have written, resulting in increased solubility OR discusses shift in endothermic direction and links it to increased concentration of ions / solubility / shift in given equation.**

- c (i)  $[\text{Ag}^+] = [\text{Cl}^-] = \text{solubility}, s$   
 $K_s = s^2$   
so  $s = \sqrt{K_s}$   
 $= 1.25 \times 10^{-5} \text{ mol L}^{-1}$

- (ii)  $K_s = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$   
so  $s = \sqrt[3]{K_s/4}$   
 $= 6.88 \times 10^{-5} \text{ mol L}^{-1}$

**A = Solubility of EITHER  $\text{AgCl}$  OR  $\text{Ag}_2\text{CrO}_4$  calculated correctly.**

**M = Correct process for calculation of solubility of BOTH  $\text{AgCl}$  and  $\text{Ag}_2\text{CrO}_4$ , plus ONE value of solubility correct.**

**E = Calculations correctly show that  $\text{Ag}_2\text{CrO}_4$  is more soluble than  $\text{AgCl}$  with correct units of  $\text{mol L}^{-1}$ .**

- d  $K_s(\text{Ag}_2\text{CrO}_4) = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$   
 $= 1.30 \times 10^{-12}$

$$[\text{Ag}^+]^2 = \frac{1.30 \times 10^{-12}}{6.3 \times 10^{-2}}$$

$$= 2.06 \times 10^{-10}$$

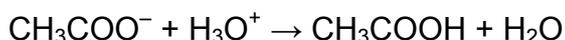
$$[\text{Ag}^+] = 1.44 \times 10^{-5} \text{ mol L}^{-1}$$

**A = Correct process for the calculation OR Calculation to get  $[\text{Ag}^+]^2 = 2.06 \times 10^{-10}$ .**

**M =  $[\text{Ag}^+]$  correctly calculated.**

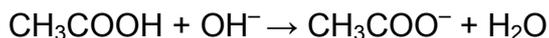
### QUESTION THREE: ETHANOIC ACID SOLUTIONS

- a In a buffer solution the pH hardly changes when acid or base **is added**. In this case addition of **acid** results in the reaction:



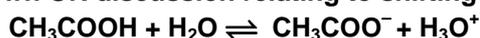
which means there is essentially no change in the concentration of  $\text{H}_3\text{O}^+$ .

When  $\text{OH}^-$  is added it reacts as follows:



and there is therefore almost no change in concentration of  $\text{OH}^-$  in the solution.

**A = Answer recognises that  $\text{CH}_3\text{COOH}$  reacts with added base, and  $\text{CH}_3\text{COO}^-$  reacts with added acid. OR correctly justified buffering action in one direction with equation (added acid or added base only).**  
**M = Explanation of how this mixture acts as a buffer includes balanced equations for both reactions shown OR discussion relating to shifting the equilibrium on a single equation,**



$$\begin{aligned} \text{b } K_a &= 1.76 \times 10^{-5} \\ &= \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} \end{aligned}$$

$$\begin{aligned} [\text{H}_3\text{O}^+] &= \text{inv log } (-5.00) \\ &= 1 \times 10^{-5} \end{aligned}$$

$$[\text{CH}_3\text{COOH}] = 0.0500 \text{ mol L}^{-1}$$

$$\begin{aligned} [\text{CH}_3\text{COO}^-] &= \frac{K_a [\text{CH}_3\text{COOH}]}{[\text{H}_3\text{O}^+]} \\ &= 0.0880 \text{ mol L}^{-1} \end{aligned}$$

**A = Correct process for calculation.**

**M = Correct answer for concentration of  $\text{CH}_3\text{COO}^-$ .**

#### QUESTION FOUR: ANALYSIS OF A WEAK ACID



$$\text{b } K_a = \frac{[\text{H}_3\text{O}^+][\text{Pab}^-]}{[\text{HPab}]}$$

**A = Correct equilibrium equation OR equation for  $K_a$ .**

$$\text{c } [\text{H}_3\text{O}^+] = 6.03 \times 10^{-4} \text{ mol L}^{-1}$$

**A = Correct answer.**

4

$$\text{d i } n(\text{OH}^-) = 0.0120 \text{ L} \times 0.050 \text{ mol L}^{-1} \\ = 6.00 \times 10^{-4} \text{ mol}$$

$$[\text{HPab}] = \frac{n}{V} \\ = \frac{6.00 \times 10^{-4} \text{ mol}}{0.0200 \text{ mol L}^{-1}} \\ = 3.00 \times 10^{-2} \text{ mol L}^{-1} \\ = 0.0300 \text{ mol L}^{-1}$$

$$\text{ii } K_a = \frac{[\text{H}_3\text{O}^+][\text{Pab}^-]}{[\text{HPab}]}$$

$$[\text{H}_3\text{O}^+] = [\text{Pab}^-] \text{ and } [\text{HPab}] = 0.0300 \text{ mol L}^{-1}$$

$$K_a = \frac{(6.03 \times 10^{-4})^2}{0.0300} \\ = 1.21 \times 10^{-5}$$

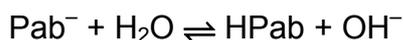
$$\text{p}K_a = -\log(1.21 \times 10^{-5}) \\ = 4.92$$

**A** = Correct concentration of HPab OR  $K_a$  is correctly calculated from the given  $\text{p}K_a$ .

**M** = Correct concentration of HPab AND correct process for part (ii), with clearly stated and valid expression for  $K_a$  or  $\text{p}K_a$ .

**E** = Clearly shows the correct method using the correct data to determine the value of  $\text{p}K_a(\text{HPab})$ . It clearly states what species are involved, and identifies that  $[\text{H}_3\text{O}^+] = [\text{Pab}^-]$ .

- e** The equivalence point would be pH greater than 7 as at this point it is a solution of NaPab and the  $\text{Pab}^-$  ion is weakly basic. It reacts with water to produce an excess of  $\text{OH}^-$  ions.



**A** = Recognises pH greater than 7 due to solution being basic OR  $\text{OH}^-$  greater than  $\text{H}^+$

OR because titration is weak acid with strong base OR halfway between initial and 'final' pH.

**M** = Links pH greater than 7 to reaction of  $\text{Pab}^-$  with  $\text{H}_2\text{O}$  to produce excess of  $\text{OH}^-$  ions.

**MUST** include equation for reaction of  $\text{Pab}^-$  with  $\text{H}_2\text{O}$  OR Correctly calculated pH of weakly basic solution.

- f** Sketch of graph with valid shape, showing:

- initial pH at 3.22,
- half-equivalence point at pH = 4.92
- equivalence point at pH greater than 7 (in range 8–10) and volume of 12 mL.

**A** = General shape of curve correct, with at least TWO of the following points correct:

- starting at pH about 3.2
- midpoint of buffer region at about 4.9
- equivalence point at 12 mL which is given on x axis

**M** = ALL correct as per stated evidence.

**Judgement Statement****Achievement**

SIX opportunities answered at Achievement level or higher.

$6 \times A$

**Achievement with Merit**

EIGHT opportunities answered with at least FIVE at Merit level or higher.

$5 \times M$  plus  $3 \times A$

**Achievement with Excellence**

TEN opportunities answered with at least TWO at Excellence level and FIVE at Merit level.

$2 \times E$  plus  $5 \times M$  plus  $3 \times A$