Assessment Schedule – 2012

Chemistry: Describe properties of aqueous systems (90700)

Evidence Statement

Q	Evidence	Achievement	Achievement with Merit	Achievement with Excellence
ONE (a)(i) (ii) (iii)	$HCl(aq) + H_2O(\ell) \rightarrow Cl^-(aq) + H_3O^+(aq)$ $CH_3NH_2(\ell) + H_2O \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$ $NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$ $NH_4^+(aq) + H_2O \rightleftharpoons NH_3(aq) + H_3O^+(aq)$ Note: Do not accept H^+, states are not required, equation may be in part (c).	Any TWO of: • Any TWO equations correct.	• Either: All FOUR equations correct. OR ALL species and order correct for TWO solutions.	• ONE answer to merit level.
(b)(i) (ii) (iii)	$H_3O^+ = Cl^- > OH^-$ $CH_3NH_2 > OH^- = CH_3NH_3^+ > H_3O^+$ $Cl^- > NH_4^+ > H_3O^+ = NH_3 > OH^-$ (allow inclusion of H_2O and commas in place of >)	• All species correct for TWO solutions identified.	AND	AND
(c)	HCl is a strong acid, so fully reacts with water to produce a high $[H_3O^+]$. pH < 7. NH_4Cl is an acidic salt that completely dissociates into its ions producing NH_4^+ and Cl^-. NH_4^+ is a weak acid, so only partially reacts with water to produce H_3O^+. pH < 7, but higher than HCl since NH_4^+ has a lower $[H_3O^+]$ than HCl. CH_3NH_2 is a weak base, so only partially reacts with water to produce OH^- ions. pH > 7. Electrical conductivity relates to the concentration of mobile charged particles present. In the case of solutions, conductivity relates to the number of ions present. Both HCl and NH_4Cl completely react with water to produce a high concentration of ions, so their conductivity will be high (and equal). Since CH_3NH_2 is a weak base, it partially reacts with water to produce only a few ions in the solution, making it a poor electrical conductor.	• Either: Recognises reasons for pH variation are due to production of H_3O^+ / OH^- OR Recognises conductivity is related to the number of ions in solution.	• Either: Recognises reasons for variations in pH and conductivity AND makes a valid comparison between one pair. OR Difference in pH correctly discussed for ALL 3 solutions. OR Difference in conductivity correctly discussed for ALL 3 solutions.	• Discussion addresses variation in BOTH pH (including whether acidic or basic) and conductivity using correct reasons for ALL 3 solutions.

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TWO (a)(i)	$Fe(OH)_2(s) \rightarrow Fe^{2+}(aq) + 2OH^-(aq)$ (states not required, allow $\rightleftharpoons$)	Any TWO of: • (a) (i) and (ii) correct.		
(ii)	$K_s = [Fe^{2+}]\,[OH^-]^2$			
(b)	Let s be the solubility: $[Fe^{2+}] = s$ $[OH^-] = 2s$ $K_s = s \times (2s)^2$ $4.10 \times 10^{-15} = 4s^3$ $s = 1.01 \times 10^{-5}$ mol L^{-1} Solubility of $Fe(OH)_2(s) = 1.01 \times 10^{-5}$ mol L^{-1}	• Method correct but error in calculation.	• Either: Correct answer (3 significant figures). OR Method uses correct IP expression but has one calculation error AND Compares IP and K_s to make a valid conclusion (3 significant figures).	
(c) (i)	$Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$ Ion Product (IP) = $[Fe^{3+}]\,[OH^-]^3$ At pH 7, $[OH^-] = 1 \times 10^{-7}$ mol L^{-1} IP = $[1.05 \times 10^{-4}]\,[1 \times 10^{-7}]^3 = 1.05 \times 10^{-25}$ Since IP > K_s, $Fe(OH)_3$ will form a precipitate	• Either: Correct IP expression OR Compares IP and K_s to make a valid conclusion.	AND	• Answer correct with supporting calculation (3 significant figures). AND
(ii)	When the pH is decreased, $[H_3O^+]$ will increase. The H_3O^+ will react with the OH^- and therefore remove them from the equilibrium. This will cause the reaction to replace some of the removed OH^-. As a result more $Fe(OH)_3$ will dissolve, so decreasing the pH will increase the solubility of $Fe(OH)_3$.	• Either: Writes an equilibrium expression AND identifies direction it shifts in. OR States $[OH^-]$ decreases / $[H_3O^+]$ increases causing $Fe(OH)_3$ to be more soluble.	• Either: States the change in $[OH^-]$, its impact on the equilibrium position and therefore more $Fe(OH)_3$ dissolves. OR Discussion of effect of decreasing pH on $Fe(OH)_3$ dissolving in terms of $[H_3O^+]$ / $[OH^-]$ changing.	• Complete discussion of effect of decreasing pH on $Fe(OH)_3$ solubility, including role of H_3O^+ (reacting with OH^-).

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THREE (a)	$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ $K_a = 10^{-9.24} = 5.75 \times 10^{-10}$ $K_b = [OH^-]^2 / [NH_3] = K_w / K_a = 1.74 \times 10^{-5}$ $[OH^-] = \sqrt{(1.74 \times 10^{-5} \times 0.150)} = 1.61 \times 10^{-3}$ mol L^{-1} $[H_3O^+] = K_w/[OH^-] = 6.19 \times 10^{-12}$ mol L^{-1} pH = 11.2	Any TWO of: • Either: K_a correctly calculated OR Correct equilibrium equation and K_a (or K_b) expression for the equation written.	Any TWO of: • Method correct with minor arithmetic error.	• Either: pH correct (3 s.f.).
(b)	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ $[NH_4^+] = [NH_3]\,[H_3O^+] / K_a$ $[NH_4^+] = 0.150 \times 10^{-8.60} / 10^{-9.24}$ $[NH_4^+] = 0.655$ mol L^{-1} n (NH_4^+) = 0.655 mol L^{-1} × 0.250 L = 0.164 mol m (NH_4Cl) = 0.164 mol × 53.5 g mol^{-1} = 8.76 g Note: allow use of pH = pK_a + log $[NH_3]$ / $[NH_4^+]$	• K_a expression or pH = pK_a + log$[NH_3]$ / $[NH_4^+]$ rearranged for $[NH_4^+]$.	• Either: Correct method but error in calculation / units missing / unit incorrect OR $[NH_4^+]$ calculated.	OR Correct answer with units (3 s.f.). AND
(c)	A buffer is a solution that undergoes a minimal change of pH when small amounts of acid or base are added. Added acid will react with NH_3 so that there is almost no change in $[H_3O^+]$: $NH_3 + H_3O^+ \rightarrow NH_4^+ + H_2O$ Added base will react with NH_4^+ so that there is almost no change in $[OH^-]$: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ (These equations show that the ratio of NH_3: NH_4^+ changes slightly, but this does not significantly affect the pH.) Since the pH of the buffer is lower than the pK_a of NH_4^+, the $[NH_4^+]$ will be higher than the $[NH_3]$. This means the buffer will be more effective against added base.	• Either: Recognises acid will react with added base and base will react with added acid OR Describes the function of a buffer.	• Explains buffer action, writes appropriate equations and refers to the fact that there is almost no change in $[H_3O^+]$ / $[OH^-]$.	• Complete discussion of buffer action and its effectiveness at pH 8.60.

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FOUR (a)(i) (ii)	n (NaOH) = 0.180 mol L^{-1} × 0.04 L = 0.0072 mol 1NaOH : 1HCOOH c (HCOOH) = 0.0072 mol / 0.025 L = 0.288 mol L^{-1} $HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$ $K_a = [HCOO^-][H_3O^+] / [HCOOH]$ $[H_3O^+] = \sqrt{(0.288 \text{ mol L}^{-1} \times 1.82 \times 10^{-4})} = 7.24 \times 10^{-3}$ mol L^{-1} pH = 2.14	Any TWO of: • Shows [HCOOH] = 0.288 molL^{-1} • Method to find pH correct with minor arithmetic error. • EITHER: States [HCOOH] = [$HCOO^-$] OR pH = pK_a • EITHER: Identifies correct or incorrect indicator(s) with limited reasoning. OR Identifies that the endpoint needs to be close to the equivalence point.	Any TWO of: • Correct pH. • States [HCOOH] = [$HCOO^-$] so pH = pK_a when half-way to the equivalence point / in buffer zone. • Identifies the correct indicator and an incorrect indicator, including consequences of wrong choice, but gaps in discussion (i.e. have talked in general terms about an incorrect choice).	• 1 answer to merit level AND • Discussion of indicators links the equivalence point pH to the effective pK_a over which each indicator will change colour (range may be for either the indicator colour change occurring over a range OR for it's pK_a falling within the range of the vertical part of graph).
(b)	Half way to the equivalence point (20 mL), the NaOH has reacted with half the HCOOH, so [HCOOH] = [$HCOO^-$]. $K_a = [HCOO^-]\ [H_3O^+] / [HCOOH]$ Since [HCOOH] = [$HCOO^-$], substitution into K_a gives: $K_a = [H_3O^+]$ Taking –log of each side: pK_a = pH So the pH half way to the equivalence point = pK_a of HCOOH = 3.74			
(c)	According to the titration curve, the pH at the equivalence point is approximately 8.4. Indicators change colour at their pK_a +/–1. So bromocresol green changes colour over a pH range of 3.7-5.7 and alizarin yellow will change colour over a pH range of 10.0 – 12.0. This means bromocresol green would therefore change colour before the equivalence point and alizarin yellow would change colour after the equivalence point. Both of these indicators would therefore be unsuitable for this titration. Cresol red will change colour over a pH range of 7.3 – 9.3. This includes the pH at the equivalence point. Cresol red would therefore be a suitable indicator to detect the endpoint since it changes colour at the equivalence point.			

Judgement Statement

Achievement	Achievement with Merit	Achievement with Excellence
3 × A or 2 × M	3 × M	2 × E + 1 × M