Assessment Schedule – 2013

Chemistry: Demonstrate understanding of equilibrium principles in aqueous systems (91392)

Evidence Statement

Q	Evidence	Achievement	Achievement with Merit	Achievement with Excellence
ONE (a)	$HCl < CH_3NH_3Cl < CH_3NH_2$ HCl, a strong acid, reacts completely with water to form 1 mol L^{-1} H_3O^+ and hence a low pH. **$HCl + H_2O \rightarrow H_3O^+ + Cl^-$** CH_3NH_3Cl dissociates completely in water to form $CH_3NH_3^+$ and Cl^-. $CH_3NH_3^+$, a weak acid, partially reacts with water to form less than 1 mol L^{-1} H_3O^+ and hence a higher pH than HCl. **$CH_3NH_3Cl \rightarrow CH_3NH_3^+ + Cl^-$** **$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$** CH_3NH_2, a weak base, partially reacts with water to form OH^- ions. So there are more OH^- ions than H_3O^+ ions and the pH is thus high. **$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$**	• Correct order. • TWO equations correct. • Recognises that HCl dissociates completely in water. OR Recognises that $CH_3NH_3^+$OR CH_3NH_2 only partially react with water.	• THREE correct equations. • Recognises that HCl dissociate completely in water. AND Recognises that $CH_3NH_3^+$ or CH_3NH_2 only partially react with water.	• Discusses all the reactions correctly including concentrations of OH^- and H_3O^+ ions.
(b)	$HCl = CH_3NH_3Cl > CH_3NH_2$ CH_3NH_3Cl and HCl will dissociate completely in water to produce 2 mol L^{-1} ions. CH_3NH_2 will only partially react with water to produce less than 1 mol L^{-1} of ions.	• CH_3NH_2 written last. • Links concentration of ions to degree of conductivity.	• CH_3NH_2 written last and discusses HCl / CH_3NH_3Cl AND CH_3NH_2. Links concentration of ions to degree of conductivity.	• Correct order with valid discussion. Links concentration of ions to degree of conductivity.

(c)(i)	$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]}$ $[H_3O^+] = \frac{K_a[CH_3NH_3^+]}{[CH_3NH_2]}$ $[CH_3NH_2] = \frac{30\times10^{-3}\times1}{50\times10^{-3}} = 0.600 \text{ mol L}^{-1}$ $[CH_3NH_3^+] = \frac{20\times10^{-3}\times1}{50\times10^{-3}} = 0.400 \text{ mol L}^{-1}$ $[H_3O^+] = 1.52705\times10^{-11} \text{ mol L}^{-1}$ $\text{pH} = 10.8$ Candidates should not be penalised for using ratio of volume and getting correct answer.	• Correct K_a expression. OR • $\text{pH} = \text{p}K_a + \log\frac{[\text{base}]}{[\text{acid}]}$ OR Correct concentrations or number of moles.	• Correct process with minor error.	• Correct answer.
(ii)	When a small amount of acid (H_3O^+) ions are added, they will react with the $CH_3NH_2(aq)$ molecules to form $CH_3NH_3^+(aq)$ ions. $CH_3NH_2(aq) + H_3O^+(aq) \rightarrow CH_3NH_3^+(aq) + H_2O(\ell)$ The added acid (H_3O^+), is mostly consumed, and the pH of the solution changes very little.	• Correct equation. OR Shows understanding that $CH_3NH_2(aq)$ reacts with added acid. OR Discusses minor reaction of $OH^- + H_3O^+$.	• Correct equation. AND Shows understanding that $CH_3NH_2(aq)$ reacts with added acid.	Correct equation and correct discussion of reaction.

Not Achieved	NØ	No response or no relevant evidence
	N1	2a
	N2	3a
Achievement	A3	4a
	A4	5a
Merit	M5	3m
	M6	4m
Excellence	E7	3e with minor error / omission / additional information.
	E8	4e

Q	Evidence	Achievement	Achievement with Merit	Achievement with Excellence
TWO (a)	$K_s = [Ag^+]^2[CrO_4^{2-}]$	• Correct K_s expression.		
(b)(i)	$n(Ag_2CrO_4) = \frac{1.44\times10^{-3}}{332}$ $= 4.33\times10^{-6}$ mol in 50 mL $[Ag_2CrO_4] = \frac{4.33\times10^{-6}}{50\times10^{-3}}$ $= 8.67\times10^{-5}$ mol L^{-1} $[Ag^+] = 8.67\times10^{-5}\times2 = 1.73\times10^{-4}$ mol L^{-1} $[CrO_4^{2-}] = 8.67\times10^{-5}$ mol L^{-1}	• Correct process OR Correct answer with limited working • Correct ratio of $[Ag^+]$: $[CrO_4^{2-}]$	• Correct concentration of silver chromate calculated.	• Correct solubility concentration values for each ion and *K*s value.
(ii)	$K_s = (1.73\times10^{-4})^2\ (8.67\times10^{-5})$ $= 2.61\times10^{-12}$	• Uses $4s^3$ with incorrect answer.		
(c)	Dissolving 0.0100g of silver chromate in 50 mL water will result in solid being present, as the required amount to make a saturated solution is 1.44×10^{-3} g in 50 mL, so any more than this will form a solid. If the same mass is added to 50 mL of ammonia, more will dissolve and less solid will be present due to the formation of a complex ion. The Ag_2CrO_4 will dissociate completely and form an equilibrium. $Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{2-}$ $Ag^+ + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+$ The silver ion will then react further with NH_3, removing it from the above equilibrium. Thus, more Ag_2CrO_4 will dissolve to re-establish equilibrium.	• Recognises that more dissolves in B. • Recognises that a complex ion forms.	• Recognises that more dissolves in beaker B with link to an equation. • Recognises that in ammonia a silver complex ion will form.	• Links equilibrium of silver chromate with silver & ammonium complex ion removal and hence more dissolves. • Recognises $0.0100\text{ g} > 1.44\times10^{-3}$, therefore solid Ag_2CrO_4 is present. • Correct equation of formation of complex ion.

Not Achieved	NØ	No response; no relevant evidence.
	N1	1a
	N2	2a
Achievement	A3	3a
	A4	4a
Merit	M5	2m
	M6	3m
Excellence	E7	2e
	E8	3e

Q	Evidence	Achievement	Achievement with Merit	Achievement with Excellence
THREE (a)	$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$ • $pH = pK_a + \log\frac{[base]}{[acid]}$ $[H_3O^+] = \sqrt{1.74\times10^{-5}\times0.0896}$ mol L^{-1} $= 1.25\times10^{-3}$ mol L^{-1} $pH = -\log[H_3O^+] = 2.90$	• Correct process.	• Correct pH.	(a) & (b) correct.
(b)	Halfway to equivalence point, half of the ethanoic acid has been used up. There are now equimolar quantities of ethanoic acid and sodium ethanoate. As $K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$ According to the equation when $[CH_3COOH] = [CH_3COO^-]$ then $K_a = [H_3O^+]$ So pK_a = pH.	• Recognises that there are equimolar quantities of ethanoic acid and sodium ethanoate.	• Relates equation correctly to explanation.	
(c)(i)	$NaOH(aq) + CH_3COOH(aq) \rightarrow NaCH_3COO(aq) + H_2O(l)$ (1) $[CH_3COO^-]$ increases as it is formed in reaction (1). $[Na^+]$ increases as NaOH is added (1). $[CH_3COOH]$ decreases as it reacts with NaOH (1). $[H_3O^+]$ decreases because $[CH_3COO^-]$ / $[CH_3COOH]$ increases and K_a is a constant. $[OH^-]$ increases because $[H_3O^+]$ decreases and $[H_3O^+]$ $[OH^-]$ is constant.	• Correct equation *minor error.* • Correct statement relating to change in concentration of 1 species.	Correct equation and correctly describes the change in concentration of 2 species.	• Correct equation. AND Correctly describes the change in concentration of the 4 species.

(c)(ii)	$n(CH_3COOH \text{ at start}) = 0.0896 \times 20 \times 10^{-3}$ $= 1.79 \times 10^{-3}$ mol $n(NaOH \text{ added}) = 0.1 \times 5 \times 10^{-3}$ $= 5 \times 10^{-4}$ mol After 5 mL NaOH added: $n(CH_3COOH) = 1.29 \times 10^{-3}$ mol $n(CH_3COO^-) = 5 \times 10^{-4}$ mol $[CH_3COOH] = 0.0516$ mol L^{-1} $[CH_3COO^-] = 0.0200$ mol L^{-1} $[H_3O^+] = 4.48 \times 10^{-5}$ mol L^{-1} pH = 4.35 Candidates will not be penalised for not calculating concentrations.	• Correct n for CH_3COOH OR NaOH at the start.	• Correct process to identify either of the species after 5 mL has been added (mol or mol L^{-1}).	• Correct answer.

Not Achieved	NØ	No response; no relevant evidence.
	N1	1a
	N2	2a
Achievement	A3	3a
	A4	4a
Merit	M5	2m
	M6	3m
Excellence	E7	2e
	E8	3e with one minor error

Judgement Statement

	Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
Score range	0 – 6	7 – 12	13 – 18	19 – 24