### Assessment Schedule – 2019

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

#### Evidence Statement

Q	Evidence	Achievement	Merit	Excellence
ONE (a)(i) (ii) (iii) (iv)	$Zn(OH)_{2} \rightleftharpoons Zn^{2+} + 2OH^{-}$ $K_{s} = [Zn^{2+}][OH^{-}]^{2}$ Let solubility be 's': $[Zn^{2+}] = s$ $[OH^{-}] = 2s$ $K_{s} = 4s^{3}$ $4s^{3} = 3.80 \times 10^{-17}$ $s = 2.12 \times 10^{-6} \text{ mol } L^{-1}$ $[Zn^{2+}] = 2.12 \times 10^{-6} \text{ mol } L^{-1}$ $[OH^{-}] = 4.24 \times 10^{-6} \text{ mol } L^{-1}$ $K_{s} = [Zn^{2+}][OH^{-}]^{2}$ $3.80 \times 10^{-17} = \left(\frac{0.210}{2}\right) \times [OH^{-}]^{2}$ $[OH^{-}] = 1.90 \times 10^{-8} \text{ mol } L^{-1}$ Note: $\frac{0.210}{2}$ due to dilution factor from adding two solutions together.	Correct equilibrium equation and $K_s$ expression. Method correct for determining solubility. Recognises $Zn^{2+}$ is the common ion. OR ONE step correct. E.g. correct substitution into $K_s$ excluding dilution / 0.105.	Correct solubility of Zn(OH) <sub>2</sub> calculated, including [Zn <sup>2+</sup> ] and [OH <sup>-</sup> ]. Calculates [OH <sup>-</sup> ], but does not take into account the dilution factor.	Calculates correct [OH <sup>-</sup> ]. Including sig fig and units
(b)	$Zn(OH)_2 \rightleftharpoons Zn^{2+} + 2OH^-$ When the OH <sup>-</sup> ions are in excess, the $Zn^{2+}$ ions can form a complex ion: $Zn^{2+} + 4OH^- \rightarrow [Zn(OH)_4]^{2-}$ A decrease in $[Zn^{2+}]$ will result in the forward reaction being favoured, to restore equilibrium / minimise the change. This causes more solid $Zn(OH)_2$ to dissolve / the solubility of $Zn(OH)_2$ increases / so that $[Zn^{2+}][OH^-]$ will again equal $K_s$ .	Recognises solubility increases due to formation of complex ion.	Explains that formation of a complex ion will decrease [Zn <sup>2+</sup> ].	Fully explains, using equilibrium principles, how the solubility of the Zn(OH) <sub>2</sub> increases when excess NaOH is added. Must include complex ion equation.

(c)	$[Zn^{2+}] = \frac{20}{50} \times 0.0242 = 9.68 \times 10^{-3} \text{ mol } L^{-1}$ $[OH^{-}] = \frac{30}{50} \times 1 \times 10^{-14} / 10^{-13.1} = 0.0755 \text{ mol } L^{-1}$	Correct substitution into $Q_s$ (IP) expression. OR Correct [Zn <sup>2+</sup> ] or [ OH <sup>-</sup> ].	Correct process to determine $Q_s$ and compare with $K_s$ .	Correct calculation and comparison with $K_s$ to determine whether $Zn(OH)_2$ will form a precipitate.
	IP = $[Zn^{2+}][OH^{-}]^2 = 9.68 \times 10^{-3} \times (0.0755)^2$ = 5.52 × 10 <sup>-5</sup> (5.53 × 10 <sup>-5</sup> ) Since IP > K <sub>s</sub> , a precipitate of Zn(OH) <sub>2</sub> will form.			

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	la	2a	3a	4a	2m	3m	1e	2e

Q	Evidence	Achievement	Merit	Excellence
TWO (a)(i) (ii)	Na <sup>+</sup> , HCOO <sup>-</sup> , HCOOH, OH <sup>-</sup> , H <sub>3</sub> O <sup>+</sup> After 12.5 mL NaOH has been added, it is halfway to the equivalence point. This means that [HCOOH] = [HCOO <sup>-</sup> ]. Therefore pH equals $pK_a$ .	THREE species identified. [HCOOH] = [HCOO <sup>-</sup> ] OR $pH = pK_a$	[HCOOH] = [HCOO-] Therefore pH = pK <sub>a</sub> .	
(b)(i) (ii)	Tick cresol red. Indicators change colour at a pH ±1 of the pK <sub>a</sub> / near the pK <sub>a</sub> . Therefore, cresol red should be used as it will change near the equivalence point/steepest part of the curve, whereas thymol blue and bromocresol green will change before the equivalence point/steepest part of the curve. $\begin{bmatrix}H_{3}O^{+}\end{bmatrix} = \sqrt{\frac{K_{a} \times K_{w}}{\begin{bmatrix}CH_{3}CH_{2}NH_{2}\end{bmatrix}}}$ $\begin{bmatrix}H_{3}O^{+}\end{bmatrix} = \sqrt{\frac{1.82 \times 10^{-4} \times 1 \times 10^{-14}}{0.0778}}$ $\begin{bmatrix}H_{3}O^{+}\end{bmatrix} = 4.84 \times 10^{-9} \text{ mol } L^{-1}$ $pH = -\log \begin{bmatrix}H_{3}O^{+}\end{bmatrix} = 8.32$ OR For this solution, $HCOO^{-} + H_{2}O \rightleftharpoons HCOOH + OH^{-1}$	Identifies cresol red. OR Recognises an indicator is chosen to change colour over the vertical section of the curve / at the equivalence point. Correct process for determining pH at equivalence point. OR One correct step.	Explanation with reference to the p <i>K</i> <sub>a</sub> of why cresol red is the appropriate indicator whereas the other two indicators are not.	Full explanation for indicator choice . AND pH at equivalence point.
(c)	After 28 mL NaOH added: $n(\text{unreacted NaOH}) = cV = 0.140 \times 0.003 = 4.2 \times 10^{-4} \text{ mol}$ $c(\text{NaOH}) = \frac{n}{V} = \frac{4.2 \times 10^{-4}}{0.048} = 8.75 \times 10^{-3} \text{ mol L}^{-1}$ $\left[\text{H}_{3}\text{O}^{+}\right] = \frac{1 \times 10^{-14}}{8.75 \times 10^{-3}} = 1.14 \times 10^{-12} \text{ mol L}^{-1}$ $\text{pH} = -\log 1.14 \times 10^{-12} = 11.9$	Correct <i>n</i> (NaOH). OR One correct step.	Correct process but one error in calculation.	Correct pH.

#### NCEA Level 3 Chemistry (91392) 2019 — page 4 of 6

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	2m	3m	1e	2e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)(i) (ii)	CH <sub>3</sub> COOH has the smaller $pK_a$ / larger $K_a$ , so it will be a stronger acid than NH <sub>4</sub> <sup>+</sup> . This means CH <sub>3</sub> COOH will dissociate to a greater extent to produce a higher [H <sub>3</sub> O <sup>+</sup> ] than NH <sub>4</sub> <sup>+</sup> , so CH <sub>3</sub> COOH will have a lower pH. The electrical conductivity of a solution depends upon [ions]. NH <sub>4</sub> Cl is an acidic salt, so it completely dissociates / dissolves to produce a relatively high [NH <sub>4</sub> <sup>+</sup> ] and [Cl <sup>-</sup> ]. This makes NH <sub>4</sub> Cl a good electrical conductor. NH <sub>4</sub> Cl $\rightarrow$ NH <sub>4</sub> <sup>+</sup> + Cl <sup>-</sup> However, CH <sub>3</sub> COOH is a weak acid and only partially dissociates to produce a relatively low [CH <sub>3</sub> COO <sup>-</sup> ] and [H <sub>3</sub> O <sup>+</sup> ]. This makes CH <sub>3</sub> COOH a poorer electrical conductor than NH <sub>4</sub> Cl. CH <sub>3</sub> COOH + H <sub>2</sub> O $\Rightarrow$ CH <sub>3</sub> COO <sup>-</sup> + H <sub>3</sub> O <sup>+</sup>	Recognises $pK_a$ is a measure of the extent of dissociation of a weak acid. Recognises electrical conductivity in a solution requires ions.	Links magnitude of pK <sub>a</sub> (or K <sub>a</sub> ) to degree of dissociation, [H <sub>3</sub> O <sup>+</sup> ] and pH. OR Links the [ions] to the electrical conductivity of BOTH solutions.	Full explanation of the pH and electrical conductivity of BOTH solutions, i.e. links degree of dissociation to BOTH [H <sub>3</sub> O <sup>+</sup> ] and pH AND [ions] and electrical conductivity, including supporting equations.
(iii)	CH <sub>3</sub> COOH + H <sub>2</sub> O $\Rightarrow$ CH <sub>3</sub> COO <sup>-</sup> + H <sub>3</sub> O <sup>+</sup> $K_{a} = \frac{\left[H_{3}O^{+}\right]\left[CH_{3}COO^{-}\right]}{\left[CH_{3}COOH\right]}$ $10^{-4.76} = \frac{\left(1.78 \times 10^{-3}\right)^{2}}{\left[CH_{3}COOH\right]}$ $\left[CH_{3}COOH\right] = 0.182 \text{ mol } L^{-1}$	Correct process for determining [CH <sub>3</sub> COOH]. ( <i>correct substitution</i> <i>into formula</i> ) OR One correct step	Correct [CH <sub>3</sub> COOH].	

(b)(i)	$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$	Correct process for determining pH.	Correct pH.	
	$K_{a} = \frac{\left[ \text{CH}_{3}\text{COO}^{-} \right] \left[ \text{H}_{3}\text{O}^{+} \right]}{\left[ \text{CH}_{3}\text{COOH} \right]}$	One correct step.		
	$10^{-4.76} = 2 \times \frac{\left[H_{3}O^{+}\right]}{5}$			
	$\left[\mathrm{H}_{3}\mathrm{O}^{+}\right] = 4.34 \times 10^{-5} \mathrm{mol} \mathrm{L}^{-1}$			
	$pH = -\log 4.34 \times 10^{-5} = 4.36$			
(ii)	[CH <sub>3</sub> COOH] > [CH <sub>3</sub> COO <sup>−</sup> ] / pH < pK <sub>a</sub> Therefore the buffer solution is more effective at neutralising strong base: CH <sub>3</sub> COOH + OH <sup>−</sup> → CH <sub>3</sub> COO <sup>−</sup> + H <sub>2</sub> O	Equation. OR [CH <sub>3</sub> COOH] > [CH <sub>3</sub> COO <sup>-</sup> ]	Links ratio of [CH <sub>3</sub> COOH]:[CH <sub>3</sub> COO <sup>-</sup> ] to buffer effectiveness, including equation.	Full explanation of buffer behaviour for (ii) and (iii).
(iii)	When water is added, the ratio of CH <sub>3</sub> COOH to CH <sub>3</sub> COO <sup>-</sup> is unchanged, so the pH of the buffer solution is unaffected.	Recognises pH remains unchanged.	Explains effect of dilution on pH in terms of ratio between CH <sub>3</sub> COOH and CH <sub>3</sub> COO <sup>-</sup> .	

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	2m	3m	1e	2e

## Cut Scores

Not Achieved	Not Achieved Achievement		Achievement with Excellence	
0 - 6	7 – 13	14 – 19	20 – 24	