Assessment Schedule – 2021

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

Evidence Statement

Q	Evidence	Achievement	Merit	Excellence
ONE (a)(i)	$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2OH^-$	• Correct equilibrium equation and K_s expression.		
(ii)	$K_s = [Mg^{2+}][OH^-]^2$			
(iii)	Let solubility be s: $[Mg^{2+}] = s$ $[OH^-] = 2s$ $4s^3 = 7.10 \times 10^{-12}$ $s = 1.21 \times 10^{-4}$ mol L^{-1} $[Mg^{2+}] = 1.21 \times 10^{-4}$ mol L^{-1} $[OH^-] = 2 \times 1.21 \times 10^{-4}$ mol L^{-1}	• Correct method for determining solubility.	• Correct solubility of $Mg(OH)_2$, including $[Mg^{2+}]$ and $[OH^-]$. Must have the correct unit.	
(b)(i)	$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2OH^-$ Addition of dilute NaOH causes an increase in $[OH^-]$ (OH^- is a common ion). As a result, the equilibrium favours the reverse reaction / speeds up the rate of the reverse reaction to consume some of the OH^-. This causes more solid $Mg(OH)_2$ to be produced, so $[Mg^{2+}]$ in solution decreases.	• Recognises $[OH^-]$ increases / OH^- is a common ion.	• Explains increase in $[OH^-]$ will favour the reverse reaction in (i).	• Fully explains why $[Mg^{2+}]$ decreases using equilibrium principles. AND Calculates $[Mg^{2+}]$. Must have correct unit and 2-4 significant figures.
(ii)	$K_s = [Mg^{2+}][OH^-]^2$ $7.10 \times 10^{-12} = [Mg^{2+}] \times (\frac{30}{50} \times 0.120)^2$ $[Mg^{2+}] = 1.37 \times 10^{-9}$ mol L^{-1}	• Correct process. OR Correct diluted $[OH^-]$.	• Calculates $[Mg^{2+}]$, but does not dilute OH^- in (ii).	

| (c) | $[Mg^{2+}] = \dfrac{65}{105} \times 0.240 = 0.149$ mol L^{-1}

 $[OH^-] = \dfrac{40}{105} \times (\dfrac{1 \times 10^{-14}}{10^{-12.8}}) = 0.0240$ mol L^{-1}

 $IP = [Mg^{2+}][OH^-]^2 = 0.149 \times (0.0240)^2$
 $= 8.58 \times 10^{-5}$
 Since IP $> K_s$, a precipitate of Mg(OH)$_2$ will form. | • Correctly calculates $[Mg^{2+}]$ or $[OH^-]$.
 • Correct comparison of IP with K_s. | • Correct process to determine IP and compare with K_s. | • Correct calculation and comparison with K_s to show Mg(OH)$_2$ will form a precipitate. Must have 2-4 significant figures. |

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e, allow minor error / omission in one part.	2e

Q	Evidence	Achievement	Merit	Excellence
TWO (a)(i)	A buffer solution resists a change in pH / maintains a fairly constant pH when a small volume of strong acid or base is added. When NaOH is added, the OH^- ions are neutralised by the acidic component of the buffer, HCOOH. As a result, the pH of the solution does not significantly change since the OH^- ions are removed from the solution / $HCOO^-$ produced is a much weaker base than NaOH.	• Correct description of a buffer solution. • Identifies the base / OH^- ions are removed / neutralised by the buffer.	• Explains that the HCOOH neutralises the OH^- and therefore the pH does not significantly change for (i). OR Explains the HCOOH: $HCOO^-$ ratio is unaltered, so pH is unchanged for (ii).	
(ii)	The addition of water dilutes the [HCOOH] and the $[HCOO^-]$ by the same factor. Thus, the ratio of HCOOH and $HCOO^-$ does not change. As a result, the pH of the buffer solution is unchanged.	• Recognises pH affected by weak acid : conjugate base composition.		• Explains the effect of adding EITHER a small volume of NaOH OR water on the buffer solution's pH. AND
(iii)	$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$ $n(HCOONa) = \dfrac{m}{M} = \dfrac{1.65}{68.0} = 0.0243$ mol $[HCOO^-] = \dfrac{0.0243\,\text{mol}}{0.250\,\text{L}} = 0.0971$ mol L^{-1} $K_a = \dfrac{[HCOO^-][H_3O^+]}{[HCOOH]}$ $1.82 \times 10^{-4} = \dfrac{0.0971 \times 10^{-2.93}}{[HCOOH]}$ $[HCOOH] = 0.627$ mol L^{-1}	• Calculates correct moles of HCOONa. OR Substitutes correctly into K_a expression.	• Correct process to determine [HCOOH], but has a minor error.	Correctly calculates [HCOOH]. Must have correct unit and 2-4 significant figures.

| (b) | Although both HCOOH and $CH_3NH_3^+$ are weak acids, HCOOH has a smaller pK_a than $CH_3NH_3^+$, so HCOOH dissociates to a greater extent than $CH_3NH_3^+$. Thus, HCOOH produces a higher $[H_3O^+]$ and therefore has a lower pH than $CH_3NH_3^+$.

Since $CH_3NH_3^+$ is an acidic salt, it dissociates completely to produce a relatively high $[CH_3NH_3^+]$ and $[Cl^-]$, i.e. high [ions]. This means CH_3NH_3Cl is a good electrical conductor.

$CH_3NH_3Cl \rightarrow CH_3NH_3^+ + Cl^-$

HCOOH is a weak acid, and therefore only partially dissociates to produce a lower [ions]. This means HCOOH is a poor electrical conductor.

$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$ | • Identifies HCOOH is a stronger acid / has a lower pH than $CH_3NH_3^+$.
• Recognises that ions are required for the electrical conductivity of the solutions. | • Explains that HCOOH has a lower pH with reference to degree of dissociation and $[H_3O^+]$.
• Explains that CH_3NH_3Cl is a better electrical conductor with reference to degree of dissociation and [ions]. | • Fully compares both the pH and electrical conductivity of HCOOH and CH_3NH_3Cl. Must refer to $[H_3O^+]$ for pH and include at least one relevant equation. |

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e, allow minor error / omission in one part.	2e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)(i)	$CH_3CH_2COOH > CH_3CH_2COO^- = H_3O^+ > OH^-$	• THREE boxes correctly completed.		
(ii)	$CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$ $$K_a = \frac{[CH_3CH_2COO^-][H_3O^+]}{[CH_3CH_2COOH]}$$ $$1.35 \times 10^{-5} = \frac{\left(10^{-2.78}\right)^2}{[CH_3CH_2COOH]}$$ $[CH_3CH_2COOH] = 0.204 \text{ mol L}^{-1}$	• Correct process to calculate $[CH_3CH_2COOH]$, but minor error.	• Correct calculation.	

(b)(i)	Cross halfway up vertical section of curve.	• Cross halfway up vertical section.		
(ii)	Tick for Nile blue. Nile blue changes colour over a pH range 8.70 – 10.70. This pH range falls within the vertical section of the curve / the pH at the equivalence point falls within this range, so Nile blue will change colour at the equivalence point. The other two indicators will both change colour before the vertical section of the curve, and will therefore be unsuitable because they will change colour before the equivalence point.	• Tick for Nile blue with brief explanation that it is the only indicator that changes colour at the equivalence point.	• Explains why Nile blue is the most suitable indicator for the titration, with reference to the pH range of the indicator and the vertical section of the curve / pH at the equivalence point.	• Fully explains choice of indicator and correctly calculates the pH at the equivalence point.
(iii)	$CH_3CH_2COO^- + H_2O \rightleftharpoons CH_3CH_2COOH + OH^-$ For this solution: $[CH_3CH_2COOH] = [OH^-] = \dfrac{K_w}{[H_3O^+]}$ Using K_a to calculate pH: $K_a = \dfrac{[H_3O^+][CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$ $1.35 \times 10^{-5} = \left(0.204 \times \dfrac{20}{45}\right) \times \dfrac{[H_3O^+]^2}{10^{-14}}$ $[H_3O^+] = 1.22 \times 10^{-9}$ mol L^{-1} pH $= 8.91$	• Correct process to calculate the pH of a basic solution.	• Calculates pH of $CH_3CH_2COO^-$ solution, but does not appropriately dilute the solution.	

(c)(i)	$n(\text{NaOH}) = cv = 0.163 \times 0.004 = 6.52 \times 10^{-4}$ mol $c(\text{NaOH}) = \dfrac{6.52 \times 10^{-4}}{0.049}$ $= 0.0133$ mol L^{-1} $[\text{H}_3\text{O}^+] = \dfrac{1 \times 10^{-14}}{0.0133} = 7.52 \times 10^{-13}$ pH $= -\log 7.52 \times 10^{-13} = 12.1$	• Calculates correct moles of NaOH.	• Correct process for calculating pH, but minor error. OR	• Correct pH of diluted NaOH and explanation as to why the pH is less than the original NaOH solution.
(ii)	The moles of NaOH present in the extra 4 mL of 0.163 mol L^{-1} NaOH added after the equivalence point have been diluted; i.e. total volume in conical flask is now 0.49 mL. Since [OH$^-$] has decreased, the pH also decreases.		Links decrease in pH of NaOH to decrease in [OH$^-$] due to dilution.	

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e, allow minor error / omission in one part.	2e

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 7	8 – 12	13 – 18	19 – 24