# Assessment Schedule – 2015

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

### Evidence Statement

| Q | Evidence | Achievement | Achievement with Merit | Achievement with Excellence |
|---|---|---|---|---|
| ONE (a)(i) | $CH_3NH_3Cl(s) \xrightarrow{H_2O} CH_3NH_3^+(aq) + Cl^-(aq)$ | • One correct equation. OR Four species identified. | | |
| (ii) | $CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$ | | | |
| (iii) | $Cl^- > CH_3NH_3^+ > H_3O^+ = CH_3NH_2 > OH^-$ OR $Cl^- > CH_3NH_3^+ > H_3O^+ > CH_3NH_2 > OH^-$ | | • Correct order, all species. | |
| (iv) | $K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]}$ <br> $2.29 \times 10^{-11} = \frac{[H_3O^+]^2}{0.0152}$ <br> $[H_3O^+] = 5.90 \times 10^{-7}$ mol $L^{-1}$ <br> pH = –log $5.90 \times 10^{-7}$ = 6.23 <br> $[H_3O^+] = \sqrt{K_a} \times HA$ <br> $= 5.90 \times 10^{-7}$ <br> pH = 6.23 | • Correct process. | • Correct pH. | |

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| (b) | **pH:**<br>The pH of a solution is calculated from its $[H_3O^+]$.<br><br>NaOH is an ionic solid that is a strong base and dissociates completely to produce a high $OH^-$ concentration (low $[H_3O^+]$). Since $[OH^-]$ is high / $[H_3O^+]$ is low, the pH is high.<br>$NaOH \rightarrow Na^+ + OH^-$<br><br>$CH_3NH_2$ is a weak base that partially reacts / dissociates / ionises with $H_2O$ producing a lower concentration of $OH^-$,<br>Therefore it has a lower pH than NaOH:<br>$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$<br><br>The $CH_3COONa$ is an ionic solid that dissociates completely in $H_2O$. The $CH_3COO^-$ ion is a weak base that partially reacts / dissociates / ionises with $H_2O$ producing a lower concentration of $OH^-$.<br>$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$<br><br>The pH is closer to 7, showing it is the weakest base.<br>Therefore it has a lowest pH<br><br>**Electrical conductivity:**<br>Electrical conductivity is determined by the concentration of ions. NaOH completely dissolves to produce a high concentration of $Na^+$ and $OH^-$ ions in solution.<br>$NaOH \rightarrow Na^+ + OH^-$ Therefore it is a good conductor.<br><br>Since $CH_3NH_2$ is a weak base, it only partially reacts with water to produce a low concentration of ions in solution so it is a poor electrical conductor.<br>$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$<br><br>$CH_3COONa$ is also an ionic solid. It dissolves completely to produce a high concentration of $Na^+$ and $CH_3COO^-$ ions:<br>$CH_3COONa \rightarrow Na^+ + CH_3COO^-$<br>Therefore it is a good conductor. | • Recognises that pH depends upon $[H_3O^+]$ / $[OH^-]$ ratio.<br>OR<br>States that NaOH is a strong base whereas $CH_3COONa$ and $CH_3NH_2$ form weakly basic solutions.<br><br>• Recognises that electrical conductivity depends upon concentration / amount of ions in solution.<br>OR<br>Relates conductivity to the degree of dissociation. | • Links the pH of each solution to its strength and degree of dissociation.<br><br>• Links the ion concentration / amount of each solution to the degree of dissociation and its electrical conductivity. | • Compares and contrasts the pH of each solution.<br><br>• Compares and contrasts the electrical conductivity of each solution. |

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

| Q | Evidence | Achievement | Achievement with Merit | Achievement with Excellence |
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| TWO (a)(i) | $CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$ | • (i) and (ii) correct. | | |
| (ii) | $K_s = [Ca^{2+}][CO_3^{2-}]$ | | | |
| (iii) | $K_s(CaCO_3) = (5.74 \times 10^{-5})^2 = 3.29 \times 10^{-9}$ | • Method correct. | • Correct answer for $K_s$. | |
| (b) | The $H_3O^+$ from the acidic solution reacts with the $CO_3^{2-}$. This reduces $[CO_3^{2-}]$, causing the equilibrium to shift towards the products / RHS to replace some of the lost $CO_3^{2-}$. Therefore more solid $CaCO_3$ will dissolve.<br>$2H_3O^+ + CO_3^{2-} \rightarrow 3H_2O + CO_2$ (or other correct alternative). | • Recognises $H_3O^+$ will remove / neutralise the $CO_3^{2-}$ from the equilibrium. | • Recognises $H_3O^+$ will remove / reacts with $CO_3^{2-}$ with a relevant balanced equation AND uses equilibrium principles to link to an increased solubility of $CaCO_3$. | |
| (c) | $Pb(OH)_2 \rightleftharpoons Pb^{2+} + 2OH^-$<br>$Q = [Pb^{2+}][OH^-]^2$<br>$[Pb^{2+}] = 0.5 \times 0.00421 = 2.105 \times 10^{-3}$<br>$[OH^-] = 0.5 \times 0.0398 = 1.99 \times 10^{-2}$<br>$Q = (2.105 \times 10^{-3}) \times (1.99 \times 10^{-2})^2$<br>$Q = 8.34 \times 10^{-7}$<br>Since $Q > K_s$, a precipitate of $Pb(OH)_2$ will form.<br>pH =12.6<br>pOH = 1.4<br>$[OH^-] = 0.0398$ | • Correct equation / expression.<br>• Compares incorrect $Q$ value to $K_s$, to prove $Pb(OH)_2$ forms a precipitate.<br>OR<br>Correct working. | • Method uses correct $Q$ expression but has one calculation error<br>AND<br>Compares $Q$ and $K_s$ to prove a $Pb(OH)_2$ precipitate forms. | • Correct calculation with comparison of $Q$ and $K_s$ to prove $Pb(OH)_2$ forms a precipitate. |

| NØ | N1 | N2 | A3 | A4 | M5 | M6 | E7 | E8 |
|---|---|---|---|---|---|---|---|---|
| No response or no relevant evidence | 1a | 2a | 3a | 4a | 2m | 3m | 1e + 1m | 1e + 2m |

| Q | Evidence | Achievement | Achievement with Merit | Achievement with Excellence |
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| THREE (a)(i) | $Na^+$, $F^-$, $H_2O$, HF, $OH^-$, $H_3O^+$. | • Three species listed. | | |
| (ii) | A weak base, $F^-$, is present at the equivalence point:<br>$F^- + H_2O \rightleftharpoons HF + OH^-$<br>This increase in $[OH^-]$ causes the pH to be greater than 7. | • Recognises $F^-$ is the weak base responsible for pH > 7.<br>OR<br>Correct equation. | • Links pH at equivalence to increased $[OH^-]$, including an equation for the dissociation of $F^-$. | |
| (iii) | $K_a = \frac{[F^-][H_3O^+]}{[HF]}$<br>$10^{-3.17} = \frac{1 \times [H_3O^+]}{2}$<br>$[H_3O^+] = 2 \times 10^{-3.17} = 1.35 \times 10^{-3}$ mol $L^{-1}$<br>pH = –log $(1.35 \times 10^{-3})$ = 2.87.<br><br>Since there are significant concentrations of the weak acid and its conjugate base the solution can resist added acid or base. However, since the pH of the buffer solution is less than the $pK_a$, / [HF] > $[F^-]$, it is more effective against added base than acid.<br><br>pH = $pK_a$ + log $[F^-]$ / [HF]<br>= 3.17 + log 0.5<br>= 2.87 | • Correct process for determining the pH.<br><br>• Recognises solution is more effective against added base.<br>OR<br>Describes function of a buffer by resisting added acid and base. | • Correct pH<br>OR<br>Evaluates the function of the buffer. | • Correct pH and full evaluation. |
| (iv) | $n(NaOH) = cv = 0.258 \times \frac{24-20}{1000} = 1.032 \times 10^{-3}$ mol<br>$c(NaOH) = \frac{n}{v} = \frac{1.032 \times 10^{-3}}{44/1000} = 0.0235$ mol $L^{-1}$<br>$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1 \times 10^{-14}}{0.0235} = 4.26 \times 10^{-13}$ mol $L^{-1}$<br>$pH = -\log 4.26 \times 10^{-13} = 12.4$<br><br>$[OH^-]$ = 0.258 × 4 / 44<br>= 0.02345 mol $L^{-1}$<br>pOH = –log (0.02345)<br>= 1.63<br>pH = 14 – pOH<br>= 12.4 | • Correct $n$(NaOH).<br>OR<br>One correct step. | • Correct process but one error in calculation. | • Correct answer. |

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| (b) | Since $CH_3COOH$ has a higher p$K_a$, it is a weaker acid than HF. Therefore its conjugate base, $CH_3COO^-$, will be a stronger base than $F^-$. This means $[OH^-]$ will be higher at the equivalence point for the $CH_3COOH$ vs NaOH titration, so the equivalence point pH will be higher. | • States $CH_3COOH$ is a weaker acid than HF.<br>OR<br>States equivalence point is higher with some evidence. | • Links higher equivalence point for $CH_3COOH$ to the strength of the weak acid, its p$K_a$, and the relative strength of its conjugate base. | • Contrasts the equivalence point for both titrations. |

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

## Cut Scores

| Not Achieved | Achievement | Achievement with Merit | Achievement with Excellence |
|---|---|---|---|
| 0 – 7 | 8 – 13 | 14 – 18 | 19 – 24 |