

**Assessment Schedule – 2022 FINAL****Chemistry: Demonstrate understanding of equilibrium principles in aqueous systems (91392)****Evidence Statement**

Q	Evidence	Achievement	Merit	Excellence
ONE (a)(i)	$\text{Ag}_2\text{CrO}_4 \rightleftharpoons 2\text{Ag}^+ + \text{CrO}_4^{2-}$	<ul style="list-style-type: none"> <li>Correct equilibrium equation and <math>K_s</math> expression.</li> </ul>		
(ii)	$K_s = [\text{Ag}^+]^2[\text{CrO}_4^{2-}]$			
(iii)	$K_s = (2 \times 6.50 \times 10^{-5})^2 \times (6.50 \times 10^{-5})$ $= 1.10 \times 10^{-12}$	<ul style="list-style-type: none"> <li>Method correct for determining <math>K_s</math>.</li> </ul>	<ul style="list-style-type: none"> <li>Correct <math>K_s</math> (accept 2 – 4 significant figures).</li> </ul>	
(b)(i)	When $\text{AgNO}_3$ is added, $[\text{Ag}^+]$ increases. Since $\text{Ag}^+$ is a common ion, this causes the reverse reaction of the equilibrium to speed up to use up some of the extra $\text{Ag}^+$ . As a result, more solid $\text{Ag}_2\text{CrO}_4$ is formed, i.e. the solubility of $\text{Ag}_2\text{CrO}_4$ decreases.	<ul style="list-style-type: none"> <li>Recognises <math>[\text{Ag}^+]</math> increases / <math>\text{Ag}^+</math> is a common ion.</li> </ul>	<ul style="list-style-type: none"> <li>Explains that increase in <math>[\text{Ag}^+]</math> favours the reverse reaction.</li> </ul>	
(ii)	When $\text{NaCN}$ is added, the $\text{CN}^-$ ions form a complex ion with the $\text{Ag}^+$ ions: $\text{Ag}^+ + 2\text{CN}^- \rightarrow [\text{Ag}(\text{CN})_2]^-$ Since the $\text{Ag}^+$ ions are removed from the equilibrium, the forward reaction speeds up to replace some of the $\text{Ag}^+$ . This causes more solid $\text{Ag}_2\text{CrO}_4$ to dissolve, i.e. the solubility of $\text{Ag}_2\text{CrO}_4$ increases.	<ul style="list-style-type: none"> <li>Recognises <math>\text{Ag}^+</math> ions form a complex ion with <math>\text{CN}^-</math> ion</li> </ul> OR <ul style="list-style-type: none"> <li><math>\text{Ag}^+</math> reacts with <math>\text{CN}^-</math> so <math>[\text{Ag}^+]</math> decreases.</li> </ul>	<ul style="list-style-type: none"> <li>Explains that the formation of a complex ion removes <math>\text{Ag}^+</math> from equilibrium / causes decrease in <math>[\text{Ag}^+]</math>.</li> </ul>	<ul style="list-style-type: none"> <li>Fully explains, using equilibrium principles, how the solubility of <math>\text{Ag}_2\text{CrO}_4</math> is affected by addition of a common ion and formation of a complex ion. Complex ion equation required.</li> </ul>
(c)	$\text{IP} = \left(\frac{50}{80} \times 0.00154\right) \times \left(2 \times \frac{30}{80} \times 0.0686\right)$ $= 4.95 \times 10^{-5}$ Since $\text{IP} > K_s$ , a precipitate of $\text{AgCl}$ will form.	<ul style="list-style-type: none"> <li>EITHER correct <math>[\text{Ag}^+]</math> OR <math>[\text{Cl}^-]</math></li> <li>Correct comparison of IP with <math>K_s</math>.</li> </ul>	<ul style="list-style-type: none"> <li>Correct process to calculate IP and compare with <math>K_s</math>, but does not multiply <math>[\text{Cl}^-]</math> by 2.</li> </ul>	<ul style="list-style-type: none"> <li>Correct calculation (accept 2 – 4 significant figures) and comparison with <math>K_s</math> to show that <math>\text{AgCl}</math> will form a precipitate.</li> </ul>

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

Q	Evidence	Achievement	Merit	Excellence
<p>TWO (a)(i)</p> <p>(ii)</p> <p>(iii)</p>	<p><math>\text{Na}^+ &gt; \text{OCl}^- &gt; \text{HOCl} = \text{OH}^- &gt; \text{H}_3\text{O}^+</math></p> <p><math>\text{HOCl} + \text{H}_2\text{O} \rightleftharpoons \text{OCl}^- + \text{H}_3\text{O}^+</math></p> $K_a = \frac{[\text{OCl}^-][\text{H}_3\text{O}^+]}{[\text{HOCl}]}$ $2.95 \times 10^{-8} = \frac{(10^{-4.80})^2}{[\text{HOCl}]}$ $[\text{HOCl}] = 0.00851 \text{ mol L}^{-1}$ <p>NaOCl is a basic salt and completely dissociates to produce a high [ions], i.e. <math>\text{Na}^+</math> and <math>\text{OCl}^-</math> ions, in solution.  <math>\text{NaOCl} \rightarrow \text{Na}^+ + \text{OCl}^-</math>          Since the [ions] is high, NaOCl solution will be a good electrical conductor.</p> <p>HOCl is a weak acid and only partially dissociates to produce a relatively low [ions], i.e. <math>\text{OCl}^-</math> and <math>\text{H}_3\text{O}^+</math> ions, in solution.  <math>\text{HOCl} + \text{H}_2\text{O} \rightleftharpoons \text{OCl}^- + \text{H}_3\text{O}^+</math>          Since the [ions] is low, HOCl solution will be a poor electrical conductor.</p>	<ul style="list-style-type: none"> <li>THREE correct species identified in the correct order.</li> <li>Correct process for calculating [HOCl].</li> <li>Recognises a solution requires mobile ions for electrical conductivity.</li> </ul>	<ul style="list-style-type: none"> <li>Correctly calculates [HOCl], including correct unit (accept 2 – 4 significant figures).</li> <li>Explains why NaOCl is a good electrical conductor. OR Explains why HOCl is a poor electrical conductor.</li> </ul>	<ul style="list-style-type: none"> <li>Fully compares the electrical conductivity of BOTH solutions, including relevant equations (equation for HOCl must include water).</li> </ul>
(b)	<p>When HCl is added, the <math>\text{H}_3\text{O}^+</math> ions are neutralised by the basic component of the buffer, <math>\text{OCl}^-</math>. As a result, the pH of the solution does not significantly change, since the <math>\text{H}_3\text{O}^+</math> ions are removed from the solution / HOCl produced is a much weaker acid than HCl.</p>	<ul style="list-style-type: none"> <li>Identifies the acid / <math>\text{H}_3\text{O}^+</math> ions are removed / neutralised by the buffer.</li> </ul>	<p>Explains that the <math>\text{OCl}^-</math> neutralises/removes the <math>\text{H}_3\text{O}^+</math> and therefore the pH does not significantly change.</p>	

(c)	<p>Both HF and CH<sub>3</sub>COOH are weak acids. Since the solutions have the same concentration, but HF has a lower pH, this means HF dissociates to a greater extent than CH<sub>3</sub>COOH/HF must have a greater <math>K_a</math> than CH<sub>3</sub>COOH. This means HF has a higher [H<sub>3</sub>O<sup>+</sup>] and therefore a lower pH.</p> <p>CH<sub>3</sub>COONa is a basic salt. The CH<sub>3</sub>COO<sup>-</sup> is a weak base and therefore partially dissociates to produce a high [OH<sup>-</sup>]. This means CH<sub>3</sub>COONa has a lower [H<sub>3</sub>O<sup>+</sup>] than both HF and CH<sub>3</sub>COOH, so it has the highest pH.</p> <p>HF + H<sub>2</sub>O ⇌ F<sup>-</sup> + H<sub>3</sub>O<sup>+</sup></p> <p>CH<sub>3</sub>COOH + H<sub>2</sub>O ⇌ CH<sub>3</sub>COO<sup>-</sup> + H<sub>3</sub>O<sup>+</sup></p> <p>CH<sub>3</sub>COO<sup>-</sup> + H<sub>2</sub>O ⇌ CH<sub>3</sub>COOH + OH<sup>-</sup></p>	<ul style="list-style-type: none"> <li>Recognises HF has the highest [H<sub>3</sub>O<sup>+</sup>] / CH<sub>3</sub>COO<sup>-</sup> has the lowest [H<sub>3</sub>O<sup>+</sup>].</li> </ul>	<ul style="list-style-type: none"> <li>Explains the order for TWO of the solutions (ok to refer to only OH<sup>-</sup> for CH<sub>3</sub>COO<sup>-</sup>).</li> </ul>	<ul style="list-style-type: none"> <li>Fully justifies the order in terms of [H<sub>3</sub>O<sup>+</sup>], including at least two relevant equations.</li> </ul>
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No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e, with minor error / omission in one part.	2e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)	For this solution: $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ $[\text{NH}_3] = 0.124 \text{ mol L}^{-1}$ For this solution: $[\text{NH}_4^+] = [\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]}$ Using $K_a$ to calculate pH: $K_a = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]}$ $5.75 \times 10^{-10} = 0.124 \times \frac{[\text{H}_3\text{O}^+]^2}{10^{-14}}$ $[\text{H}_3\text{O}^+] = 6.81 \times 10^{-12} \text{ mol L}^{-1}$ pH = 11.2	<ul style="list-style-type: none"> <li>Correct process for calculating pH of ammonia solution.</li> </ul>	<ul style="list-style-type: none"> <li>Correctly calculates pH of ammonia solution (accept 2 – 4 significant figures).</li> </ul>	
(b)(i)	$K_a = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]}$ $5.75 \times 10^{-10} = 5 \times \frac{[\text{H}_3\text{O}^+]}{2}$ $[\text{H}_3\text{O}^+] = 2.30 \times 10^{-10}$ pH = 9.64 Since pH > pK <sub>a</sub> , [NH <sub>3</sub> ] > [NH <sub>4</sub> <sup>+</sup> ]. This means the buffer will be more effective at neutralising small volumes of strong acid. OR Evaluates effectiveness using 5 : 2 ratio.	<ul style="list-style-type: none"> <li>Correct process for calculating pH of buffer solution.</li> <li>Recognises the buffer is more effective at neutralising a strong acid.</li> </ul>	<ul style="list-style-type: none"> <li>Correctly calculates pH of buffer solution.</li> </ul> OR Since [NH <sub>3</sub> ] > [NH <sub>4</sub> <sup>+</sup> ] / [base] > [acid], the buffer is more effective at neutralising a strong acid / evaluates effectiveness using 5:2 ratio.	<ul style="list-style-type: none"> <li>Correct pH of buffer solution.</li> </ul> AND Explains why the buffer is more effective at neutralising strong acid. Must compare relative [NH <sub>3</sub> ] and [NH <sub>4</sub> <sup>+</sup> ] for E8. If only compares [base] and [acid], then minor error.
(ii)	The pH is 9.24 halfway to the equivalence point. Halfway to the equivalence point, [NH <sub>3</sub> ] = [NH <sub>4</sub> <sup>+</sup> ] since half of the NH <sub>3</sub> has reacted with HNO <sub>3</sub> to form NH <sub>4</sub> <sup>+</sup> . At this point, the pH of the solution will be equal to the pK <sub>a</sub> since 1NH <sub>3</sub> :1NH <sub>4</sub> <sup>+</sup> .	<ul style="list-style-type: none"> <li>Identifies the correct pH halfway to the equivalence point/pH equals pK<sub>a</sub></li> </ul> OR Recognises [NH <sub>3</sub> ] = [NH <sub>4</sub> <sup>+</sup> ].	<ul style="list-style-type: none"> <li>Explains that the pH equals the pK<sub>a</sub> since half of the NH<sub>3</sub> has reacted (with HNO<sub>3</sub>) to form NH<sub>4</sub><sup>+</sup>, so [NH<sub>3</sub>] = [NH<sub>4</sub><sup>+</sup>].</li> </ul>	

(c)(i)	CH <sub>3</sub> COOH is a stronger acid than NH <sub>4</sub> <sup>+</sup> since it has a larger $K_a$ . As a result, the conjugate base, CH <sub>3</sub> COO <sup>-</sup> , will be weaker base than NH <sub>3</sub> and will therefore have a lower [OH <sup>-</sup> ] / higher [H <sub>3</sub> O <sup>+</sup> ]. This means the initial pH will be lower.	<ul style="list-style-type: none"> <li>• Circles “lower” for both parts (i) and (ii)</li> </ul> OR <ul style="list-style-type: none"> <li>• Circles “lower” for one and correctly identifies differences in strength of either relevant bases for (i) or acids for (ii).</li> </ul>	<ul style="list-style-type: none"> <li>• Explains either (i) or (ii) by comparing relative size of <math>K_a</math> / <math>pK_a</math>.</li> </ul>	<ul style="list-style-type: none"> <li>• Explains both (i) and (ii) in terms of magnitude of <math>K_a</math> / <math>pK_a</math>, and either relative [H<sub>3</sub>O<sup>+</sup>] or [OH<sup>-</sup>].</li> </ul>
(ii)	At the equivalence point, the weak acids CH <sub>3</sub> COOH and NH <sub>4</sub> <sup>+</sup> will be present. Since CH <sub>3</sub> COOH is a stronger acid than NH <sub>4</sub> <sup>+</sup> , it will have a higher [H <sub>3</sub> O <sup>+</sup> ] and therefore a lower pH at the equivalence point.			

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No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e, with minor error / omission in one part.	2e

**Cut Scores**

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