

Question			Answer/Indicative content	Marks	Guidance						
1	a	i	<p>HCOOH + CH₃COOH ⇌ HCOO⁻ + CH₃COOH₂⁺ ✓</p> <p>A1 B2 B1 A2 OR A2 B1 B2 A1 ✓</p> <p>CARE: Both + and – charges required for products in equilibrium</p> <p>DO NOT AWARD the 2nd mark from an equilibrium expression that omits either charge</p>	2 (AO 1.2×2)	<p>IGNORE state symbols (even if wrong)</p> <p>IF proton transfer is wrong way around ALLOW 2nd mark for idea of acid–base pairs, i.e. HCOOH + CH₃COOH ⇌ HCOOH₂⁺ + CH₃COO⁻ B2 A1 A2 B1</p> <p>NOTE For the 2nd marking point (acid–base pairs), this is the ONLY acceptable ECF i.e. NO ECF from impossible chemistry</p>						
	b	i	<p>[H⁺] = 10^{-2.72} OR 1.905 × 10⁻³ (mol dm⁻³) ✓</p> <p>[CH₃COOH] = $\frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}}$ ✓ (= 0.204 mol dm⁻³)</p>	2 (AO 2.4×2)	<p>ALLOW 2SF up to calculator value of 1.905460718 x 10⁻³</p> <p>ALLOW use of [HA]</p> <p>Mark is for working.</p>						
		ii	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.4 × 10⁻² (mol dm⁻³) award 4 marks</p> <hr style="width: 50%; margin-left: 0;"/> <div style="text-align: center;"> Calculation of H⁺ in buffer [H⁺] buffer = 10^{-4.00} OR 1 × 10⁻⁴ (mol dm⁻³) ✓ </div> <div style="text-align: center;"> Calculation of CH₃COOH in buffer $n(\text{CH}_3\text{COOH}) \text{ OR } [\text{CH}_3\text{COOH}]_{\text{buffer}} = \frac{0.204}{1000} \times 400 \text{ OR } 8.16 \times 10^{-2}$ ✓ </div> <div style="text-align: center;"> Calculation of [CH₃COO⁻] in buffer (in 1 dm³) $[\text{CH}_3\text{COO}^-]_{\text{buffer}} = 1.78 \times 10^{-5} \times \frac{8.16 \times 10^{-2}}{1 \times 10^{-4}} \text{ OR } 1.5 \times 10^{-2} (\text{mol dm}^{-3})$ ✓ </div> <div style="text-align: center;"> Calculation of original [CH₃COO⁻] (in 600 cm³) $[\text{CH}_3\text{COO}^-]_{\text{initial}} = \left(\frac{1.45248 \times 10^{-2} \times 1000}{600} \right) = 2.4 \times 10^{-2} (\text{mol dm}^{-3})$ ✓ </div> <hr style="width: 50%; margin-left: 0;"/> <p>ALLOW alternative approach based on Henderson–</p>	4 (AO 3.3×3) (AO 3.4×1)	<p>ALLOW ECF</p> <p>ALLOW [HA] and [A⁻] in working</p> <p>ALLOW 1.5 × 10⁻² up to calculator value 1.45248 × 10⁻² (mol dm⁻³)</p> <p>ALLOW 2.4 × 10⁻² up to calculator value 2.4208 × 10⁻² (mol dm⁻³)</p> <p>COMMON ERRORS BUT CHECK WORKING</p> <table style="width: 100%;"> <tr> <td>[CH₃COO⁻]_{initial} = 8.7 × 10⁻³ 600 and 1000 inverted</td><td style="text-align: right;">3 marks</td></tr> <tr> <td>[CH₃COO⁻]_{initial} = 3.6 × 10⁻⁶ [CH₃COOH] : [H⁺] inverted</td><td style="text-align: right;">3 marks</td></tr> <tr> <td>[CH₃COO⁻]_{initial} = 1.3 × 10⁻⁶ [CH₃COOH] : [H⁺] inverted AND 600 and 1000 inverted</td><td style="text-align: right;">2 marks</td></tr> </table>	[CH ₃ COO ⁻] _{initial} = 8.7 × 10 ⁻³ 600 and 1000 inverted	3 marks	[CH ₃ COO ⁻] _{initial} = 3.6 × 10 ⁻⁶ [CH ₃ COOH] : [H ⁺] inverted	3 marks	[CH ₃ COO ⁻] _{initial} = 1.3 × 10 ⁻⁶ [CH ₃ COOH] : [H ⁺] inverted AND 600 and 1000 inverted	2 marks
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		<p>Hasselbalch equation (ALLOW $-\log K_a$ for pK_a) e.g.</p> $pH = pK_a + \log \frac{[CH_3COOH]}{[CH_3COO^-]} \text{ OR } pK_a - \log \frac{[CH_3COO^-]}{[CH_3COOH]} \text{ OR}$ $4 = 4.75 + \log \frac{8.16 \times 10^{-2}}{[CH_3COO^-]} \text{ OR } 4.75 - \log \frac{[CH_3COO^-]}{8.16 \times 10^{-2}} \checkmark$ $\log [CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84 \checkmark$ $[CH_3COO^-]_{\text{buffer}} = 1.5 \times 10^{-2} \checkmark$ $[CH_3COO^-]_{\text{initial}} = 2.4 \times 10^{-2} \checkmark$		<p>No volumes used = 3.6×10^{-2} 2 marks</p> <p>ALLOW $-\log K_a$ for pK_a</p> <hr/> <p>Examiner's Comments</p> <p>This question required the candidate to calculate the original concentration of ethanoate ions in the buffer. Higher-attaining students gained full credit. Most students calculated the concentration in the buffer solution but did not factor for the original solution. Lower-attaining candidates often scored the first two marking points but did not use the buffer equation.</p>
		Total	8	
2		<p> $CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+ \quad \checkmark$ A1 B2 B1 A2 ✓ </p> <p>For an equilibrium shown using CH_3COOH instead of H_2O, mark acid–base pairs by ECF, i.e.</p> <p> $CH_3SO_2OH + CH_3COOH \rightleftharpoons CH_3SO_2O^- + CH_3COOH_2^+ \quad \boxtimes$ A1 B2 B1 A2 ECF ✓ </p> <p>CH_3SO_2OH dissociates more (than CH_3COOH) OR CH_3SO_2OH is a stronger acid ✓</p> <p>ORA in terms of CH_3COOH being a weaker acid</p> <p>Student is correct AND (sulfonic acid has) lower pK_a/higher K_a OR greater $[H^+]$ ORA ✓</p>	<p>4 (AO 2.1×2)</p> <p>(AO 3.1)</p> <p>(AO 3.2)</p>	<p>ALLOW \rightarrow for \rightleftharpoons</p> <p>ALLOW acid–base pairs labelled other way round. i.e. $CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$ A2 B1 B2 A1</p> <p>ALLOW small slip</p> <p>If ONE charge is missing from equilibrium. ALLOW ECF for acid–base pairs mark</p> <p>IGNORE 'more acidic' <i>Response needs strength/dissociation</i></p> <p>ALLOW maths explanation for final 2 marks, e.g.</p> <p> $K_a(CH_3COOH) = 10^{-(4.76)} = 1.74 \times 10^{-5}$ $[H^+] = \sqrt{(1.74 \times 10^{-5}) \times 1} = 4.17 \times 10^{-3}$ $pH = -\log 4.17 \times 10^{-3} = 2.38 \checkmark$ </p> <p> $K_a(CH_3SO_2OH) = 10^{-(1.90)} = 79.4$ $[H^+] = \sqrt{(79.4) \times 1} = 8.91$ $pH = -\log 8.91 = -0.95 \checkmark$ </p> <p>BOTH pH calcs subsumes 'Student is correct'</p> <p>Examiner's Comments</p>

				<p>Most candidates completed a correct equilibrium equation and assigned the correct acid-base pairs. A significant number of candidates used ethanoic acid instead of water in the equation. The examiners allowed error carried forward in this case for the acid-base pairs.</p> <p>Candidates found it much more difficult to explain whether the sulfonic acid had a lower pH value. The higher-attaining candidates answered concisely. They usually identifying that the sulfonic acid would have a lower pH as the pK_a value was lower (or the K_a value greater), leading to more dissociation than ethanoic acid. Lower-attaining candidates often produced unfocussed and lengthy responses, sometimes relating increased dissociation in an acid to a higher, rather than a lower, pH.</p> <p>Some candidates approached their explanation mathematically, calculating pH values for ethanoic acid and sulfonic acid from their concentrations and pK_a values. If correct, this approach was fully credited.</p>
			Total	4
3	a	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.98 award 2 marks</p> <p>-----</p> <p>$[H^+] = \sqrt{(K_a \times [C_2H_5COOH])} = 1.039 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$pH = -\log 1.039 \times 10^{-3} = 2.98 \text{ (Must be to 2 DP)} \checkmark$</p>	<p>2 (AO 2.2 ×2)</p>	<p>ALLOW ECF throughout</p> <p>ONLY ALLOW pH mark by ECF if K_a AND 0.080 used and AND pH <7</p> <p>Common errors (Must be to 2 DP) One mark for pH = 5.97 (<i>No square root</i>):</p> <p>One mark for pH = 0.92 OR pH = 5.15 (<i>Using incorrect K_a values</i>)</p> <p><u>Examiner's Comments</u></p> <p>Most candidates could calculate the pH of a weak acid although a significant number gave the answer as 3.0, presumably confusing the demand for two decimal points with two significant figures.</p>
	b i	<p>$n(C_2H_5COOH) = (0.0800 \times \frac{25.0}{1000}) = 0.002 \text{ (mol)}$</p> <p>AND</p> <p>$V(NaOH) = \frac{0.002}{0.100} \times 1000 = (= 20(.0))$</p>	<p>1 (AO 2.5)</p>	<p>ALLOW 0.02 dm³ if unit given</p> <p>Mark is for WORKING which could all be shown as 1 step</p> <p>ALLOW method showing 20cm³ NaOH contains the same moles as acid $n(C_2H_5COOH) = 0.08(00) \times 0.025(0) = 0.002$</p>

		cm ³) ✓		(mol) and $n(\text{NaOH}) = 0.02(00) \times 0.1 = 0.002(00) \text{ (mol)}$ Examiner's Comments Showing by calculation something already known is a skill that some candidates find challenging. Many responses included rows of figures with '20 cm ³ ' appearing at the end. Clarity of working is essential and in questions such as this, candidates are advised to include word descriptions of what they are calculating, even if it is abbreviations such as 'n' for number of moles.
	ii	<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 12.55 award 4 marks</p> <p>-----</p> <p>Excess mol of NaOH:</p> $n(\text{OH}^-)_{\text{excess}} = n(\text{OH}^-) - n(\text{C}_2\text{H}_5\text{COOH})$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ $= 0.0045 - 0.002 = 0.0025 \text{ (mol) } \checkmark$ <p>Concentration of OH⁻:</p> $[\text{OH}^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357 \text{ (mol dm}^{-3}\text{) } \checkmark$ <p>Concentration of H⁺:</p> $[\text{H}^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13} \text{ (mol dm}^{-3}\text{) } \checkmark$ <p>Conversion to pH: $\text{pH} = (-\log 2.8 \times 10^{-13}) = 12.55 \checkmark$</p>	4 (AO 1.2 ×1) (AO 2.6 ×3)	<p>ALLOW ECF throughout For first mark ALLOW (Excess volume of NaOH = 25(.0) cm³)</p> $n(\text{OH}^-)_{\text{excess}} = 0.100 \times \frac{25.0}{1000} = 0.0025 \text{ (mol)}$ <p>Common errors If initial V(NaOH) = 45 cm³ [OH⁻] = 0.0643 (mol) [H⁺] = 1.56 × 10⁻¹³ (mol dm⁻³) pH = 12.81 award three marks (no 1st mark)</p> <p>If $n(\text{OH}^-)_{\text{excess}}$ is used in [H⁺] calculation $n(\text{OH}^-)_{\text{excess}} = 0.0025 \text{ (mol)}$</p> $[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12} \text{ (mol dm}^{-3}\text{)}$ <p>pH = 11.40 award three marks (no 2nd mark)</p> <p>ALLOW pOH method for last two marks $\text{pOH} = -\log[\text{OH}^-] = 1.447$</p> $\text{pH} = 14 - 1.447 = 12.55$ <p>ALLOW ECF for conversion from [H⁺] to pH provided value calculated is above 7 and from derived [H⁺]</p> <p>Examiner's Comments</p> <p>This calculation proved difficult with once again, many figures and sums appearing with little indication as to their relevance.</p>

				Responses to 20bi/ii often featured rows of figures and random sums without a single word about what the figures were or sums were set to calculate. Candidates should remember to provide written indications of what it is they're working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation.
ii i		<p>Shape Slight rise/flat, AND (near) vertical, AND then slight rise/flat ✓</p> <p>pH Vertical section within the extremes of pH 5 to 12 and a minimum range of three pH units AND middle of vertical section (equivalence point) needs to be above pH 7 ✓</p> <p>End point Vertical section at ~ 20 cm³ NaOH ✓</p>	<p>3 (AO 2.3 ×1) (AO 2.4 ×2)</p>	<p>If pH curves wrong way round (i.e. adding acid to alkali), ONLY award mark for End point (~ 20 cm³)</p> <p><u>Examiner's Comments</u></p> <p>This weak acid / strong alkali titration curve required candidates to apply their knowledge. Some candidates found it difficult to draw an adequate titration curve.</p> <p>The key points to titration curves are:</p> <ul style="list-style-type: none"> • A 'vertical' section at the end point • The vertical section with pH range correct to relative to the strength of acid/alkali • A correct equivalence point relative to pH 7 with respect to the strength of acid/alkali • A 'shallow curve' leading from 0 cm³ to vertical section • A 'shallow curve' leading from the vertical section to the total volume added <p>For this reaction:</p> <ul style="list-style-type: none"> • The vertical section was at 20 cm³ (given in 20bi) • As it was a weak acid and strong alkali reacting, the vertical section should start above pH 5 and finish around pH 11 • The equivalence point (half-way up the vertical section) for a weak acid / strong alkali titration should be above pH 7 • The starting pH should be that of the weak acid, C₂H₅COOH (answer to 20(a)) • The final pH should be that of the final solution (answer to 20(b)(ii))

		i v	<p>cresol purple</p> <p>AND pH range matches vertical section/rapid pH change OR end point/colour change matches vertical section/rapid pH change ✓</p>	1 (AO 3.3)	<p>ALLOW pH range (of the indicator) matches equivalence point ALLOW end point/colour change matches equivalence point IGNORE colour change matches end point <i>Colour change is the same as end point</i></p> <p><u>Examiner's Comments</u></p> <p>Some candidates realised that the most suitable indicator for a weak acid / strong alkali titration would be cresol purple. For incorrect responses, other indicators appeared to be selected at random, suggesting that candidates were unclear on the criteria for selected a suitable indicator.</p>
		v	<p>similarity: end point / volume (20 cm^3) of NaOH needed to neutralise OR final pH / shape of curve after end point ✓</p> <p>difference: HCN higher starting pH OR HCN shorter vertical section ✓</p>	2 (AO 3.2 ×2)	<p>End point must not refer to same pH</p> <p>ALLOW different equivalence point IGNORE different starting pH</p> <p><u>Examiner's Comments</u></p> <p>When identifying a similarity, many candidates confused the term 'equivalence point' with the term 'end point'.</p> <p>For differences, many candidates realised that HCN had a different K_a to $\text{C}_2\text{H}_5\text{COOH}$ but often did not appreciate that this would lead to a starting point with a higher pH.</p>
		c	<p>HIO_3 dissociation is not negligible / dissociates to a significant extent OR Large K_a and HIO_3 is 'stronger' (weak) acid OR $[\text{HIO}_3]_{\text{eqm}}$ is significantly lower than $[\text{HIO}_3]_{\text{initial/undissociated}}$ ✓</p>	1 (AO 3.3)	<p>ALLOW use of HA Ignore $[\text{HIO}_3]_{\text{equilibrium}} < [\text{HIO}_3]_{\text{initial/undissociated}}$</p> <p>ALLOW $[\text{HIO}_3]_{\text{equilibrium}} \sim [\text{HIO}_3]_{\text{undissociated}}$ is no longer a valid assumption</p> <p>ALLOW $[\text{HIO}_3]$ has a larger K_a so the assumption that $[\text{HIO}_3]$ at equilibrium = $[\text{HIO}_3]$ initially so assumption is not valid</p> <p><u>Examiner's Comments</u></p> <p>Very few candidates scored the mark for this question.</p> <p>The most common error was to write 'HIO_3 dissociates'. While correct, this is true of all weak acids.</p> <p>The subtlety in this question was to realise</p>

					that because K_a was relatively high, the resultant acid strength would mean that the degree of dissociating was significant enough so initial $[HIO_3]$ was significantly less than $[HIO_3]$ at equilibrium. In other words, the assumption $[HIO_3]_{\text{initial}} = [HIO_3]_{\text{equilibrium}}$ is not valid in this case.
			Total	14	
4			<p>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 mark) Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[HCO_3^-] : [H_2CO_3]$ ratio.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Detailed explanation of equilibrium and the action of the buffer. OR Detailed explanation of equilibrium and correct calculation of $[HCO_3^-] : [H_2CO_3]$ ratio. OR Detailed explanation of the action of the buffer and correct calculation of $[HCO_3^-] : [H_2CO_3]$ ratio.</p> <p>OR Partial explanations of equilibrium, and the action of the buffer and attempt calculation of $[HCO_3^-] : [H_2CO_3]$ ratio.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Detailed explanation of equilibrium. OR Correct calculation of $[HCO_3^-] : [H_2CO_3]$ ratio. OR Detailed explanation of the action of the buffer. OR Partial explanations of equilibrium and the action of the buffer. OR Partial explanation of equilibrium and attempt at calculation of $[HCO_3^-] : [H_2CO_3]$ ratio. OR Partial explanation of the action of the buffer and attempt at calculation of $[HCO_3^-] : [H_2CO_3]$ ratio.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p>	<p>6 (AO1. 1 × 2) (AO1. 2 × 2) (AO3. 1 × 1) (AO3. 2 × 1)</p>	<p>Indicative scientific points may include: (State symbols not required in equations)</p> <p>Equilibrium and equilibrium shifts</p> <ul style="list-style-type: none"> $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ Addition of H^+ causes \rightleftharpoons to shift to left Addition of OH^- causes \rightleftharpoons to shift to right <p>Action of buffer</p> <ul style="list-style-type: none"> Increase in H^+ / addition of acid leads to: $H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$ OR HCO_3^- reacts with added acid Increase in OH^- / addition of alkali leads to: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ OR $H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$ OR H_2CO_3 reacts with added alkali <p>Calculation of $[HCO_3^-] : [H_2CO_3]$ ratio</p> <ul style="list-style-type: none"> $K_a = 10^{-6.38}$ OR 4.17×10^{-7} (mol dm^{-3}) $[H^+] = 10^{-7.40}$ OR 3.98×10^{-8} (mol dm^{-3}) <math>\frac{[HCO_3^-]}{[H_2CO_3]} \text{ OR } \frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}}</math> ratio = 10.47(:1) OR 10.48(:1) ALLOW 10.5 OR 10(:1) (after working shown) <p>ALLOW $\frac{4.2 \times 10^{-7}}{4.0 \times 10^{-8}}$</p> <p>And ratio = 10.5 OR 11 (after working shown)</p>

0 marks*No response or no response worthy of credit.*

$$\text{ALLOW } \frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]} \quad \text{OR } \frac{3.98 \times 10^{-7}}{4.17 \times 10^{-7}}$$

And ratio = 1 : 0.095 ..

Examiner's Comments

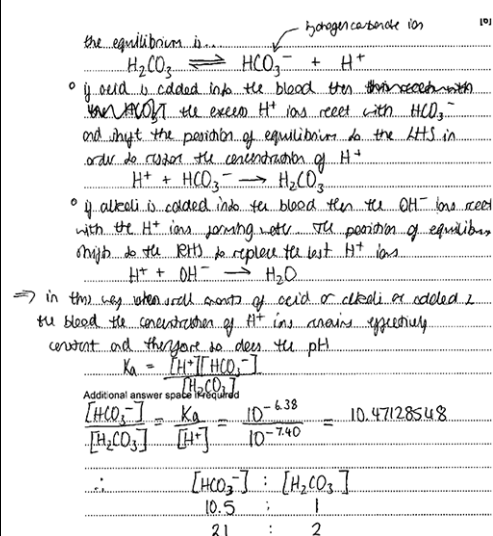
This Level of Response question was generally well answered with many candidates achieving maximum marks by simply considering what was required in the question.

The calculation of the $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio was well described although sometimes the final expression of the ratio left ambiguity as it was hard to tell whether the ratio given referred to the $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio or the $[\text{H}_2\text{CO}_3] : [\text{HCO}_3^-]$ ratio

The buffer reactions on separate addition of acid (H^+ ions) and alkali (OH^- ions) were explained and, better still, shown in equation form.

The direction of shift on the $\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$ equilibrium was invariably correct, but many candidates did not achieve credit for responses such as 'Addition of H^+ ions shifts the equilibrium to the left' because they did not give the equilibrium which was undergoing shift.

An example of a complete answer gaining L3 (6 marks) is given.

Exemplar 5

The candidate clearly writes the equilibrium at the top.

The first bullet point gives a chemical

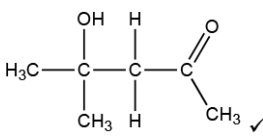
					<p>equation for the reaction occurring when H^+ ions are added as well as the shift in equilibrium.</p> <p>The second bullet point gives a chemical equation for the reaction occurring when OH^- ions are added as well as the shift in equilibrium.</p> <p>The steps in the calculation are clearly shown and the ratio is clear.</p>
			Total	6	
5			<p>Initial rate = $10^{-2} \times 2.4 \times 10^{-3} \text{ s}^{-1}$</p> <p>$= 2.4 \times 10^{-5} (\text{mol dm}^{-3} \text{ s}^{-1}) \checkmark$</p>	<p>1 AO 2.2</p>	<p><u>Examiner's Comments</u></p> <p>This part tested an understanding of pH as a logarithmic scale and the relationship between rates and order. This part discriminated extremely well. A pH of 3 meant that the H^+ concentration would be 100 times less than at a pH of 1. Being a first order reaction with respect to H^+, the initial rate is simply 100 times less than at a pH of 1: $2.4 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$.</p> <p>The higher-ability candidates identified the relationships and often wrote the correct answer on the answer line with no visible working (presumably doing the calculation in their head). Others used their well-learned equations to calculate the same correct answer.</p> <p>Many candidates found the calculation difficult and 7.2×10^{-3} ($3 \times (2.4 \times 10^{-3})$) was a very common incorrect answer. If candidates had fully scrutinised this answer, they may have realised that a more dilute solution cannot produce a faster rate.</p>
			Total	1	
6	a		<p>$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{OH}^- + \text{HCO}_3^-$</p> <p>OR</p> <p>$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{CO}_2 \checkmark$</p>	<p>1 AO 1.2</p>	<p>ALLOW $\text{CO}_3^{2-} + 2\text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{H}_2\text{CO}_3$</p> <p>IGNORE state symbols</p> <p>ALLOW inclusion of Na^+ as spectator ion, e.g. $2\text{Na}^+ + \text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^- + 2\text{Na}^+ + \text{CO}_2$</p> <p>IGNORE $\text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{CO}_2$ <i>ionic equation required</i></p> <p>IGNORE equation with H^+ or H_3O^+</p>

				<p>e.g. $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{OH}^- + \text{CO}_2$ <i>Question asks for reaction with H_2O</i></p> <p><u>Examiner's Comments</u></p> <p>This equation presented problems for many candidates, despite the question asking for an equation between carbonate ions and water. An acceptable equation had to be ionic and needed to produce OH^- (for the alkaline solution) and either HCO_3^- or CO_2.</p> <p>Many candidates wrote an equation with H^+ instead of H_2O, with lower ability candidates showing the carbonate ion with the wrong charge as CO_3^-.</p> <p>Many candidates wrote full equations despite the question asking for an ionic equation. Candidates do need to read the instructions in the question.</p>
	b	<p>Acid/H^+/HCl reacts with OR protonates</p> <ul style="list-style-type: none"> benzoate / $\text{C}_6\text{H}_5\text{COO}^-$ carboxylate / salt <p>(to form benzoic acid) ✓</p>	<p>1 AO 2.3</p>	<p>ALLOW suitable equation, e.g. $\text{C}_6\text{H}_5\text{COO}^- + \text{H}^+ \rightarrow \text{C}_6\text{H}_5\text{COOH}$</p> <p>IGNORE responses purely in terms of neutralisation of alkali, e.g. Acid/H^+/HCl neutralises / reacts with/removes alkali / OH^- / CO_3^{2-} / Na_2CO_3</p> <p><u>Examiner's Comments</u></p> <p>Candidates found this part extremely difficult. The question was aimed to stretch and challenge.</p> <p>Many candidates followed on directly from part (a), stating in simple terms that the alkaline solution needed to be neutralised to remove hydroxide ions. However, candidates were expected to recognise that the alkaline conditions would lead to benzoate ions rather than benzoic acid being present in the mixture. The mixture is acidified to protonate the benzoate. The hint in the question was about making the benzoic acid appearing when acid is added.</p>
	c	$\text{C}_6\text{H}_5\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{C}_6\text{H}_5\text{COOH} + \text{H}_2\text{O}$ ✓	<p>1 AO 2.6</p>	<p>ALLOW molecular, structural, displayed formulae, etc e.g. molecular: $\text{C}_7\text{H}_8\text{O} + 2[\text{O}] \rightarrow \text{C}_7\text{H}_6\text{O}_2 + \text{H}_2\text{O}$</p> <p><u>Examiner's Comments</u></p> <p>This part discriminated well with many</p>

				<p>candidates being able to write a correct equation using their knowledge of the oxidation of alcohols. Mistakes usually resulted in the balancing with either [O] instead of 2[O] or 2H₂O instead of H₂O.</p> <p>Written equations always need to be checked for the atoms balancing.</p>
d		<p>FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 33.8 OR 33.9 (%) award 3 marks</p> <hr/> <p>Theoretical moles $n(\text{C}_6\text{H}_5\text{COOH})$ OR $n(\text{C}_6\text{H}_5\text{CH}_2\text{OH})$</p> $= \frac{4.00 \times 1.04}{108.0} \text{ OR } 0.0385\dots (\text{mol}) \checkmark$ <p>Actual moles</p> $n(\text{C}_6\text{H}_5\text{COOH}) = \frac{1.59}{122.0} \text{ OR } 0.013(0)\dots$ <p>(mol) ✓</p> $\% \text{ yield} = \frac{0.0130\dots}{0.0385\dots} \times 100 = 33.8\% \text{ OR } 33.9$ <p>(3 sig fig) ✓</p> <p><i>Answer depends on some intermediate roundings to 3SF</i></p>	<p>3</p> <p>AO2. 8×1</p> <p>AO2. 8×1</p> <p>AO1. 2</p>	<p>ALLOW ECF for each step</p> <p>Calculator = 0.03851851852</p> <p>Calculator = 0.01303278689</p> <hr/> <p>Alternative method using mass</p> <p>1. Theoretical moles = 0.0385 mol</p> <p>2. Mass = 0.0385 × 122.0 = 4.70 g</p> <p>3. % yield = $\frac{1.59}{4.70} \times 100 = 33.8\%$</p> <hr/> <p>Common errors</p> <p>35.2% → 2 marks</p> <p>• From $\frac{4.00}{108} = 0.0370$</p> <p>(no use of density)</p> <p>36.5 OR 36.6% → 2 marks</p> <p>• $\frac{4.00/1.04}{108} = \frac{3.846}{108} = 0.0356$</p> <p>(÷ density instead of × density)</p> <p><u>Examiner's Comments</u></p> <p>Candidates are well practised with percentage yield calculations with about half obtaining the correct percentage yield of 33.8 or 33.9% to secure all 3 marks. Many were able to secure partial credit for incorrect answers, provided that the working was laid out clearly.</p>

				Some responses showed a simple percentage of the two masses with no consideration of moles or molar masses. Such a response received no credit.
e			<p>Dissolve in the minimum quantity of hot water/solvent ✓</p> <p>Cool AND Filter AND (leave to) dry ✓ <i>All three needed</i></p>	<p>ALLOW any solvent</p> <p>DO NOT ALLOW use of drying agent (e.g. MgSO_4)</p> <p>IGNORE</p> <ul style="list-style-type: none"> Initial filtering hot filtration to remove insoluble impurities <p><u>Examiner's Comments</u></p> <p>Many candidates produced thorough responses, showing that they had encountered recrystallisation as a technique in their practical work.</p> <p>Most candidates were aware that the impure product is dissolved in a minimum volume of hot solvent, although 'minimum' was sometimes omitted.</p> <p>The subsequent stages were sometimes incomplete or in the wrong order. Many were aware that the hot solution can be passed through fluted filter paper to remove solid impurities. (This is beyond the specification requirements for A Level but good practice).</p> <p>Most candidates were aware of the need to filter (usually under reduced pressure) but the necessary cooling stage to form the crystals was sometimes omitted.</p> <p>Finally, many responses omitted the need to dry the crystals. Candidates did sometimes dry the crystals by adding an anhydrous salt (e.g. CaCl_2 or MgSO_4), a clear confusion with drying an organic liquid. Others</p>

					described the purification of an organic liquid for their response, including use of a separating funnel, drying and distillation.
			Total	8	
7	i	3-hydroxybutanal ✓		1	<p>ALLOW 3-hydroxybutan-1-al</p> <p>IGNORE lack of hyphens or addition of commas</p> <p>ALLOW 4-oxobutan-2-ol OR 1-oxobutan-3-ol</p> <p>DO NOT ALLOW</p> <ul style="list-style-type: none"> • 3-hydroxybutal • 3-hydroxylbutanal <p><u>Examiner's Comments</u></p> <p>Most candidates made good attempts at the name, the difficulty being that hydroxyl group needed to be shown as a hydroxy-prefix, rather than the suffix -ol.</p> <p>Common errors included 2-hydroxybutanal (counting the carbon chain from the wrong end) and 2- or 3-hydroxybutanoic acid (reading the aldehyde group as a carboxylic acid).</p>
	ii	Addition ✓		1	<p>IGNORE nucleophilic OR electrophilic OR radical</p> <p>DO NOT ALLOW addition–elimination, condensation, polymerisation</p> <p><u>Examiner's Comments</u></p> <p>This part was answered well with most choosing nucleophilic addition. Credit was given just for 'addition'.</p>
	ii i	<p>ALLOW any formula provided that number and type of atoms and charge are correct, e.g. For CH₃CHO, ALLOW CH₃COH, C₂H₄O, etc.</p> <hr/> <p>Step 1:</p> <ul style="list-style-type: none"> • Correct equation ✓ • One correct acid–base pair ✓ • i.e. A1 and B1 OR A2 and B2 		3	<p>Throughout, IGNORE 'connectivity in any formula or structures shown. Examples in Answer column and in 6a(iv) guidance below</p> <hr/> <p>Step 1: ALLOW H⁺ transfer from OH[−], i.e.</p> $\text{CH}_3\text{CHO} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{CH}_2\text{O}^+ + \text{O}^{2-}$ <p>✓</p>

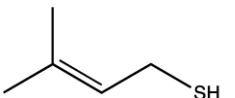
		<p>OR</p> $\text{CH}_3\text{CHO} + \text{OH}^- \rightleftharpoons \text{CH}_2\text{CHO}^- + \text{H}_2\text{O}$ $\text{CH}_3\text{CHO} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{CO}^- + \text{H}_2\text{O} \checkmark$ <p>A1 B2 B1 A2</p> <p>OR A2 B1 B2 A1</p> <p>Step 2:</p> $\text{CH}_3\text{CHO} + \text{CH}_2\text{CHO}^- + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CHOHCH}_2\text{CHO} + \text{OH}^- \checkmark$ <p>For CH_2CHO^-: ALLOW CH_2CHO^-; CH_3CO^-; $\text{C}_2\text{H}_3\text{O}^-$</p> <p>For $\text{CH}_3\text{CHOHCH}_2\text{CHO}$, ALLOW $\text{C}_4\text{H}_8\text{O}_2$</p>	<p>B2 A1 A2 B1</p> <p>OR B1 A2 A1 B2</p> <p>Step 2:</p> $\text{CH}_3\text{CHO} + \text{CH}_3\text{CH}_2\text{O}^+ + \text{O}^{2-} \rightarrow \text{CH}_3\text{CHOHCH}_2\text{CHO} + \text{OH}^- \checkmark$ <p>For $\text{CH}_3\text{CH}_2\text{O}^+$: ALLOW CH_3CHOH^+, $\text{C}_2\text{H}_5\text{O}^+$</p> <p>Examiner's Comments</p> <p>This novel question linked together acid–base equilibria with a multi-step process. Many candidates completed an equation to generate acid–base pairs, which were then usually assigned correctly. The final equation was challenging but the highest ability candidates were able to combine together all the information with their earlier responses to arrive at the correct equation. See Exemplar 15.</p> <p>Exemplar 15</p> $\text{CH}_3\text{CHO} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{CO}^- + \text{H}_2\text{O} \checkmark$ <p>acid 1 base 2 base 1 acid 2</p> <p>• Suggest the equation for step 2.</p> $\text{CH}_3\text{CHO} + \text{CH}_3\text{CO}^- + \text{H}_2\text{O} \rightarrow \text{H}-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\overset{\text{OH}}{\underset{\text{H}}{\text{C}}}-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\overset{\text{O}}{\underset{\text{H}}{\text{C}}} + \text{OH}^- \checkmark$ <p>[3]</p>
i v			<p>ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous</p> <p>For connectivity,</p> <p>ALLOW $\text{OH} \quad \text{CH}_3 \quad \text{CH}_3- \quad \text{C}_3\text{H}- \quad \text{OH}$</p> <p>1</p> <p>(Connectivity not being assessed)</p> <p>Examiner's Comments</p> <p>This part was one of the most challenging on the paper.</p> <p>Candidates needed to link the earlier information for combining two ethanal molecules to derive the product for combining two propanone molecules. Despite the challenge, the highest ability</p>

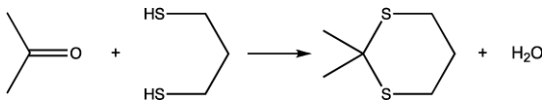
					candidates were able to come up with the correct structure.
			Total	6	
8	a	i	$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} \checkmark$	1	<p>IGNORE state symbols</p> <p>Must be square brackets</p> <p>IGNORE expressions with HA or with $[H^+]^2$</p> <p>Examiner's Comments</p> <p>Almost universally known.</p> <p>Common errors were the use of [HA], $[A^-]$ or $[H^+]^2$.</p>
		ii	<p>FIRST, CHECK ANSWER ON ANSWER LINE IF answer = 4.76 award 3 marks</p> <p>-----</p> <p>$[H^+] = 10^{-pH}$</p> <p>$= 10^{-2.41} = 3.89 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$K_a$</p> $= \frac{[H^+]^2}{[CH_3COOH]} = \frac{(3.89 \times 10^{-3})^2}{0.870}$ <p>$= 1.74 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$pK_a$</p> <p>$= -\log K_a = -\log 1.74 \times 10^{-5} = 4.76 \checkmark$</p>	3	<p>ALLOW use of HA and A^-</p> <p>ALLOW 3 SF up to calculator value of: $3.89045145 \times 10^{-3}$ correctly rounded</p> <p>K_a $1.739725573 \times 10^{-5}$</p> <p>NOTE: 1.74×10^{-5} is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value</p> <p>2 DP required</p> <p>Examiner's Comments</p> <p>This three-step calculation was successfully completed by almost all candidates.</p> <p>The common errors were to omit giving the final answer to 2 decimal places or to use $[H^+]$ rather than $[H^+]^2$ in the calculation, leading to a pK_a of 2.35.</p>
		ii i	<p>% dissociation $= \frac{[H^+]}{[CH_3COOH]} \times 100$</p> $= \frac{3.89 \times 10^{-3}}{0.870} \times 100 = 0.447(\%) \checkmark$	1	<p>3 SF required</p> <p>Examiner's Comments</p> <p>This proved a more difficult calculation than expected, but higher ability candidates realised that $[H^+]$ (determined from the pH) divided by the given concentration of CH_3COOH was required. Answers had to be expressed to three significant figures in order to receive credit.</p>
	b		<p>FIRST, CHECK ANSWER ON ANSWER LINE IF answer = 95.9(%) award 4 marks</p>	2	

		<p>-----</p> <p>[H⁺] = 10^{-pH}</p> <p>$= 10^{-13.48} = 3.31 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>[OH⁻] from K_w</p> <p>$= \frac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302 \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Mass of (NaOH)</p> <p>$= 0.302 \times \frac{100}{1000} \times 40.0 = 1.21 \text{ (g)} \checkmark$</p> <p>% of NaOH to 3 SF</p> <p>$= \frac{1.21}{1.26} \times 100 = 95.9 \text{ (%) } \checkmark$</p>		<p>ALLOW ECF throughout</p> <p>IGNORE rounding errors beyond 3rd SF throughout</p> <p>ALLOW $3.3 \times 10^{-14} \text{ (mol dm}^{-3}\text{)}$</p> <p>ALLOW 0.30</p> <p>ALLOW 0.303 if 3.3×10^{-14} used in the first marking point</p> <p>ALLOW pOH method;</p> <p>$\text{pOH} = 14 - 13.48 = 0.52$</p> <p>$[\text{OH}^-] = 10^{-0.52} = 0.302 \text{ (mol dm}^{-3}\text{)}$</p> <p>ALLOW $[\text{OH}^-] \times 0.1 \times 40$</p> <p>Rounding $[\text{OH}^-]$ to 0.3(0) gives $1.2/1.26 = 95.2\%$ Award 4 marks</p> <p>Rounding $[\text{OH}^-]$ to 0.303 gives $1.212/1.26 = 96.2\%$ Award 4 marks</p> <p><u>Examiner's Comments</u></p> <p>To help candidates, on this occasion early rounding was ignored and consequently most candidates scored full marks in this multi-step calculation. However, candidates should be advised not to round in the early stages of calculations such as this, as this introduces rounding errors into the final answer.</p> <p>Candidates should be encouraged to indicate what they are attempting to calculate in unstructured calculations such as this.</p> <p>The first step was frequently seen as $10^{-13.48} = 3.31... \times 10^{-14}$ which most examiners could take to be $[\text{H}^+]$. However, it is clearer to write $[\text{H}^+] = 10^{-13.48} = 3.31... \times 10^{-14} \text{ mol dm}^{-3}$. Even inclusion of units would help some candidates achieve partial credit as this might allow examiners to determine what a candidate is attempting to do.</p>
		Total	9	
9	a	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 0.753, award 3 marks</p>	3	

		<p>.....</p> <p>$[H^+] \text{ m} = 10^{-\text{pH}} = 10^{-2.440} = 3.63 \times 10^{-3}$ (mol dm⁻³) ✓</p> <p>$[CH_3COOH] = \frac{[H^+]^2}{K_a} \text{ OR } \frac{(3.63 \times 10^{-3})^2}{1.75 \times 10^{-5}} \checkmark$</p> <p>$= 0.753 \text{ (mol dm}^{-3}\text{)} \checkmark$</p>		<p>ALLOW use of HA and A⁻</p> <p>ALLOW 3 SF up to calculator value of $3.630780548 \times 10^{-3}$ correctly rounded</p> <p>NOTE: Answer is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value</p> <p>ALLOW 0.749 if $[H^+]$ has been subtracted from $[CH_3COOH]$ for greater accuracy at end</p> <p>Examiner's Comments Most candidates coped with this commonly seen type of calculation and were able to correctly calculate the concentration of the weak acid</p>
b		<p>$CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COOH_2^+ + FCH_2COO^- \checkmark$</p> <p>B2 A1 A2 B1 OR</p> <p>B1 A2 A1 B2 ✓</p> <p><i>i.e. labels other way round</i></p>	2	<p>Watch for opposite order on RHS, i.e.:</p> <p>$FCH_2COO^- + CH_3COOH_2^+$</p> <p>Take great care matching labels</p> <p>ALLOW ECF for incorrect proton transfer as below. This is the ONLY ECF</p> <p>$CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COO^- + FCH_2COOH_2^+ \times$</p> <p>A1 B2 B1 A2 OR</p> <p>A2 B1 B2 A1 ✓ECF</p> <p><i>i.e. labels other way round</i></p> <p>Examiner's Comments For the able candidate, this question was quite straightforward but for the weaker candidate, there were many pitfalls. Candidates struggled with the idea that the equilibrium needed a positive ion and a negative ion on the product side. Others were unable to use K_a values in order to decide which of the two starting acids should become protonated. Finally, the assigning of the conjugate acid-base pairs was also challenging.</p>

	c i	<p>[CH₃COO⁻] $n(\text{CH}_3\text{COONa}) = \frac{9.08}{82.0}$ OR 0.111 ✓ (Calc: 0.1107317073) $[\text{CH}_3\text{COO}^-] = \frac{9.08}{82.0} \times \frac{1000}{250} = 0.443 \text{ (mol dm}^{-3}\text{)}$ OR $n(\text{CH}_3\text{COOH}) = 0.800 \times \frac{250}{1000} = 0.200 \text{ (mol) ✓}$</p> <p>[H⁺] $[\text{H}^+] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$ OR $K_a \times \frac{n(\text{CH}_3\text{COOH})}{n(\text{CH}_3\text{COO}^-)}$ $= 1.75 \times 10^{-5} \times \frac{0.800}{0.443}$ OR $1.75 \times 10^{-5} \times \frac{0.200}{0.111}$ ✓ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{) ✓}$</p> <p>pH (must come from <i>calculated</i> [H⁺]) $\text{pH} = -\log(3.16 \times 10^{-5}) = 4.50 \text{ ✓}$</p> <p>.....</p> <p>LAST 3 marks are NOT available using</p> <ul style="list-style-type: none"> • K_a square root approach (weak acid pH) • $K_w/10^{-14}$ approach (strong base pH) <p>.....</p> <p>Henderson-Hasselbalch (HH) alternative $\text{p}K_a = -\log 1.75 \times 10^{-5} = 4.757 \text{ (or } 4.756961951\dots)$ $\text{pH} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$ OR $\text{pH} = \text{p}K_a - \log \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$ OR $\text{pH} = \text{p}K_a + \log \frac{0.443}{0.800}$ OR $\text{pH} = \text{p}K_a - \log \frac{0.800}{0.443}$ ✓ $= \text{p}K_a - 0.257 \text{ ✓}$ $= 4.757 - 0.257 = 4.50 \text{ ✓}$</p>	<p>ALLOW 2 sig fig ALLOW use of HA and A⁻</p> <p>Mark by ECF</p> <p>.....</p> <p>Alternative method (If both methods are attempted, mark the method which produces the higher mark)</p> <p>[H⁺] $[\text{H}^+] = 10^{-\text{pH}} = 10^{-4.50}$ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{) ✓}$</p> <p>[CH₃COO⁻] $[\text{CH}_3\text{COO}^-] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{H}^+]}$ OR $1.75 \times 10^{-5} \times \frac{0.800}{3.16 \times 10^{-5}}$ ✓ $= 0.443 \text{ (mol dm}^{-3}\text{) ✓}$</p> <p>mass of CH₃COONa</p> <p>mass CH₃COONa = $0.443 \times \frac{250}{1000}$ OR 0.111 ✓ $0.111 \times 82.0 = \mathbf{9.08 \text{ (g) ✓}}$</p> <p>.....</p> <p>Common errors</p> <p>4.64 Use of $M(\text{CH}_3\text{COONa}) = 60$ 4 marks 2.40 Use of K_a of FCH₂COOH 4 marks</p> <p>Examiner's Comments This question caused difficulty for all but the more able. For many weaker candidates getting beyond a concentration of CH₃COONa was a problem. Once again, candidates should be advised to show every step in their calculation. This would allow method marks to be applied in the absence of a correct final answer.</p>
	ii	<p>pH is the same/constant ✓</p> <p>ratio/proportion [HA]/[A⁻] is the same ✓</p>	<p>M2 is dependent upon M1</p> <p>ALLOW Change in [HA] and [A⁻] is proportional</p> <p>Examiner's Comments</p>

					Only the very able were able to explain that the ratio of concentrations of acid and salt would remain constant and as K_a is constant, $[H^+]$ and therefore pH would remain constant.
			Total	12	
1 0	i	$K_a = \frac{[H^+][C_4H_9S^-]}{[C_4H_9SH]} \quad \checkmark$ <p>Square brackets required</p>	1	<p>ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous</p> <p>Examiner's Comment: This part was very well answered. Candidates responded with either near molecular formulae, such as C_4H_9SH, structural formulae or with skeletal formulae. Some candidates made careless errors such as omitting the negative charge or showing $[H^+]^2$ as numerator rather than $[C_4H_9S^-][H^+]$.</p>	
	ii	<p>$CH_3CH_2CH_2CH_2SH + H_3C-C(=O)OH$</p> <p>$\longrightarrow H_3C-C(=O)S-CH_2CH_2CH_2CH_3 + H_2O$</p> <p>Structure of thioester ✓</p> <p>Complete equation ✓</p>	2	<p>ALLOW correct skeletal OR displayed formula OR mixture of the above as long as non-ambiguous</p> <p>ALLOW C_4H_9SH</p> <p>ALLOW CH_3COOH</p> <p>Thioester functional group must be fully displayed, OR as a skeletal formula but allow SC_4H_9 in thioester</p> <p>Examiner's Comment: In this part, candidates were expected to apply their knowledge and understanding of esterification to thiols and thioesters. Over half the candidates obtained a correct structure of the thioester. Most of these candidates constructed a balanced equation although some omitted the water product. Common errors included formation of a conventional ester and H_2S, and retaining the O atom from the OH in the carboxyl group to form $-COOS-$. As with 4(b)(i), structural and skeletal formulae were used. Candidates are less likely to omit H atoms if the skeletal formula is used.</p>	
	ii i		1	<p>IF correct skeletal formula is shown, IGNORE displayed formula in a second structure</p>	

					<p>Examiner's Comment:</p> <p>Just over half the candidates drew the correct structure, displaying a good understanding of interpreting organic nomenclature when drawing a structure.</p> <p>Common errors included omission of the CH₂ adjacent to the terminal –SH group and placing the branch or double bond in wrong positions. Some candidates spoilt an otherwise good response by showing a structural formula or a mixture of skeletal and structural formulae.</p>
		i v	 <p>Reactants ✓</p> <p>Products AND balanced equation ✓</p>	2	<p>ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non- ambiguous</p> <p>Examiner's Comment:</p> <p>In this part, candidates were expected to apply their knowledge and understanding of condensation to an entirely new context. One mark was allocated for the reactants and this was usually scored. The second mark for the novel cyclic compound and water was much more difficult, aimed at stretch and challenge. A significant number of candidates interpreted the information to obtain a correct cyclic structure but this mark was the domain of the most able candidates.</p>
			Total	6	
1 1		i	<p>Complete dissociation would give $[H^+] = 0.2 \text{ (mol dm}^{-3})$ ✓</p> <p>pH from complete dissociation = $-\log 0.2 = 0.7$ OR actual $[H^+] = 10^{-0.96} = 0.11 \text{ (mol dm}^{-3})$ ✓</p> <p>Stage 1 is complete dissociation AND Stage 2 is partial dissociation ✓</p>	3	<p>IGNORE Stage 1 is a strong acid AND Stage 2 is a weak acid.</p>
		ii	<p>Observation: fizzing ✓</p> <p>H⁺ reacts with carbonate AND (Stage 2) equilibrium shifts to the right ✓</p>	2	ALLOW effervescence/‘bubbling’

			Total	5	
1 2	a	i	$(K_a =) \frac{[H^+][C_6H_7O_6^-]}{[C_6H_8O_6]} \checkmark$ ALL species MUST have square brackets State symbols not required TAKE CARE that 'H' is different on top and bottom of expression	1	ALLOW $[H_3O^+]$ for $[H^+]$ IGNORE state symbols, even if wrong IGNORE $\frac{[H^+]^2}{[C_6H_8O_6]}$ OR $\frac{[H^+]^2[A^-]}{[HA]}$
		ii	$pK_a = -\log K_a = -\log (6.76 \times 10^{-5}) = 4.17 \checkmark$	1	Answer required to two DP
		ii i	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.82 award 4 marks $n(\text{vitamin C}) = \frac{3 \times 0.500}{176}$ $= 8.52(2) \times 10^{-3} \text{ (mol)} \checkmark$ $[\text{vitamin C}] = 8.52 \times 10^{-3} \times \frac{1000}{250}$ $= 0.0341 \text{ (mol dm}^{-3}\text{)} \checkmark$ $[H^+] = \sqrt{(K_a \times [C_6H_8O_6])}$ OR $\sqrt{(6.76 \times 10^{-5} \times 0.0341)}$ OR $1.52 \times 10^{-3} \text{ mol dm}^{-3} \checkmark$ $pH = -\log(1.52 \times 10^{-3}) = 2.82 \checkmark$ Answer required to two DP	4	ALLOW ECF from incorrect $n(\text{vitamin C})$ ALLOW ECF from incorrect $[\text{vitamin C}]$ must be derived from $\sqrt{(K_a \times [C_6H_8O_6])}$ ALLOW ECF from incorrect $[H^+]$ but ONLY if derived from $\sqrt{(K_a \times [C_6H_8O_6])}$
	b	i	FIRST, CHECK THE ANSWER ON ANSWER LINE IF ratio = 0.708 award 3 marks $[H^+] = 10^{-pH} = 10^{-4.02} = 9.55 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ $\frac{[C_6H_7O_6^-]}{[C_6H_8O_6]} = \frac{K_a}{[H^+]} = \frac{6.76 \times 10^{-5}}{9.55 \times 10^{-5}} \checkmark$ $\frac{0.708}{1} \checkmark$	3	IF there is an alternative answer, check to see if there is any ECF credit possible using working below ANNOTATIONS MUST BE USED ALLOW ALTERNATIVE using Henderson-Hasselbalch equation ALLOW 9.55×10^{-5} up to calculator value of $9.54992586 \times 10^{-5}$ correctly rounded ALLOW ECF from incorrect $[H^+]$ ALLOW 0.71 (2 SF) up to calculator value correctly rounded

		ii	<p>mass of $\text{C}_6\text{H}_7\text{O}_6\text{Na} = 0.708 \times \frac{300}{176} \times 198.0$</p> <p>= 239 OR 240 (mg) ✓</p>	1	ALLOW ECF from answer to (i)
		c	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 0.0524 (mol dm⁻³) award 2 marks </p> <p>$[\text{H}^+(\text{aq})] = 10^{-\text{pH}} = 10^{-12.72}$ $= 1.91/1.9 \times 10^{-13} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$[\text{NaOH}] / [\text{OH}^-(\text{aq})] = \frac{K_w}{[\text{H}^+(\text{aq})]} = \frac{1.0 \times 10^{-14}}{1.91 \times 10^{-13}}$ $= 0.0524 \text{ (mol dm}^{-3}\text{)} \checkmark$</p>	2	<p>ALLOW alternative approach via pOH $\text{pOH} = 14 - 12.72 = 1.28 \checkmark$ $[\text{NaOH}] / [\text{OH}^-(\text{aq})] = 10^{-\text{pOH}}$ $= 0.0524 \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>ALLOW any value between 0.052 and 0.053 <i>answer depends on degree of rounding for H⁺ but 2 SF minimum</i> calculator: 0.052480746</p>
			Total	12	
1 3		a	<p>$(K_a =) \frac{[\text{H}^+][\text{NO}_2^-]}{[\text{HNO}_2]} \checkmark$</p> <p>IGNORE state symbols</p>	1	<p>IGNORE $\frac{[\text{H}^+]^2}{[\text{HNO}_2]}$ OR $\frac{[\text{H}^+][\text{A}^-]}{[\text{A}]}$</p> <p>ALLOW H_3O^+ for H^+</p> <p>Square brackets required</p> <p>Examiner's Comments</p> <p>Almost all candidates successfully wrote the expression for K_a. Responses using $[\text{H}^+(\text{aq})]^2$ were not credited. Rarely, the expression was shown inverted or square brackets were omitted from one or more of the terms. For most candidates, this was an easy mark.</p>
		b	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.12 award 2 marks </p> <p>$[\text{H}^+] = \sqrt{K_a \times [\text{HNO}_2]} = 7.502 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$\text{pH} = -\log 7.502 \times 10^{-3} = 2.12 \checkmark$</p> <p style="text-align: right;">pH to 2 DP</p>	2	<p>.....</p> <p>ALLOW intermediate value from 3 SF (7.50 up to calculator value of $7.501999733 \times 10^{-3}$)</p> <p>ALLOW 1 mark for 2.1 OR answer > 2 DP (i.e. not 2 DP)</p> <p>ONLY ALLOW pH mark by ECF if K_a AND 0.120 used and AND pH < 7</p> <p>.....</p> <p>COMMON ERRORS (MUST be to 2 DP)</p> <p>pH = 4.25 No square root: 1 mark $[\text{H}^+] = (4.69 \times 10^{-4} \times 0.120) = 5.628 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$</p>

				<p>pH = $-\log 5.628 \times 10^{-5} = 4.25 \checkmark$ pH = 0.92 no K_a used: zero marks</p> <p>pH = $-\log 0.120 = 0.92$</p> <p>pH = 13.08 K_w / pOH used: zero marks</p> <p>pH = $-\log \frac{1.00 \times 10^{-4}}{0.120}$ OR $14 - \log 0.120 = 13.08$</p> <p>Examiner's Comments</p> <p>Most candidates calculated $[H^+]$ as the square root of $K_a \times [HNO_2]$, and then the correct pH value. The commonest errors were incorrect rounding of the pH value (e.g. 2.13) and missing out the square root (giving 4.25). Answer: pH = 2.12</p>
	c	i		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.43, AWARD 4 marks</p> <p>.....</p> <p><i>Expression: $K_a \times \text{acid} / \text{base ratio}$</i> Use of $K_a \times \frac{[HNO_2]}{[NO_2^-]}$ OR $4.69 \times 10^{-4} \times \frac{[HNO_2]}{[NO_2^-]}$ \checkmark</p> <p><i>Using correct concs / mol in expression</i> $[H^+] = 4.69 \times 10^{-4} \times \frac{0.0400}{0.0500}$ \checkmark <i>Subsumes previous mark</i></p> <p><i>Calculation of $[H^+]$</i> $[H^+] = 3.752 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p><i>pH to 2 DP (From 3.42573717)</i> $pH = -\log 3.752 \times 10^{-4} = 3.43 \checkmark$</p> <p>NO marks are available using K_a square root approach (weak acid pH) $K_w/10^{-14}$ approach (strong base pH)</p> <p>.....</p> <p>ALLOW alternative approach based on Henderson–Hasselbalch equation (ALLOW $-\log K_a$ for pK_a) $pH = pK_a + \log \frac{[NO_2^-]}{[HNO_2]}$ OR $pK_a - \log \frac{[HNO_2]}{[NO_2^-]}$ \checkmark $pH = pK_a + \log \frac{0.0500}{0.0400}$ OR $pK_a - \log \frac{0.0400}{0.0500}$ \checkmark $pH = pK_a + 0.097 \checkmark$</p> <p>$pH = 3.329 + 0.097 = 3.43 \checkmark$</p>
			4	<p>FULL ANNOTATIONS MUST BE USED </p> <p>ALLOW just $K_a \times \frac{\text{acid}}{\text{salt}}$ <i>expression</i></p> <p>Mark by ECF from $4.69 \times 10^{-4} \times \frac{[NO_2^-]}{[HNO_2]}$ <i>inverted expression</i></p> <p>Mark by ECF from incorrect $[HNO_2]$ and $[NO_2^-]$ ONLY award marks for a pH calculation via K_a AND using concentrations / mol derived from the question</p> <p>DO NOT ALLOW final pH mark by ECF if pH > 7</p> <p>.....</p> <p>COMMON ERRORS BUT CHECK WORKING pH = 2.82 3 marks initial concs: 0.200 and 0.0625 pH = 3.23 3 marks 0.0400 and 0.0500 acid / base ratio inverted pH = 3.83 2 marks initial concs: 0.200 and 0.0625 and ratio inverted pH = 2.73 3 marks Incorrect $[NO_2^-] = 0.01$ and correct $[HNO_2] =$</p>

				<p>0.04</p> <p>pH = 4.03 3 marks</p> <p>correct $[\text{NO}_2^-] = 0.05$ and incorrect $[\text{HNO}_2] = 0.01$</p> <p>Examiner's Comments</p> <p>This buffer calculation was easier than some on recent papers as the equilibrium moles had been provided. Some candidates tried to mimic the approach for a more complex calculation, introducing errors where there were none.</p> <p>The simpler problem allowed more candidates to obtain the correct value for the pH of the buffer solution than in recent examinations.</p> <p>Answer: pH = 3.43</p>
	ii	<p>Equilibrium: 1 mark</p> <p>$\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^- \checkmark$</p> <p>(ignore state symbols)</p> <p>Control of pH: 2 marks (QWC)</p> <p>Added HCl</p> <p>NO_2^- reacts with added acid / HCl / H^+</p> <p>OR $\text{NO}_2^- + \text{H}^+ \rightarrow$</p> <p>OR more HNO_2 forms \checkmark</p> <p>Added NaOH</p> <p>HNO_2 reacts with added alkali / NaOH / OH^-</p> <p>OR $\text{HNO}_2 + \text{OH}^- \rightarrow$</p> <p>OR more NO_2^- forms</p> <p>OR H^+ reacts with added alkali / NaOH</p> <p>OR $\text{H}^+ + \text{OH}^- \rightarrow \checkmark$</p> <p>Equilibrium shift:</p> <p>1 mark for shifts in $\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^-$ (See 1st mark)</p> <p>Equilibrium for added acid \rightarrow left</p> <p>AND Equilibrium for added alkali \rightarrow right \checkmark (QWC)</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>.....</p> <p>IGNORE $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$</p> <p>Equilibrium sign essential</p> <p>BUT ALLOW small slips in its appearance if it is obviously an attempt to show an equilibrium sign rather than an arrow</p> <p>QWC: Quality of written communication</p> <p>DO NOT ALLOW HA and A^- for HNO_2 and NO_2^-</p> <p>IGNORE just acid reacts with added alkali</p> <p>IGNORE just conjugate base / salt / base reacts with added acid</p> <p>DO NOT ALLOW salt / base reacts with added acid</p> <p>AWARD 'shift mark' ONLY if correct equilibrium equation has been given</p> <p>IGNORE any other equilibria in response</p> <p>Examiner's Comments</p> <p>The role of buffers in controlling pH is a common question and most candidates had prepared their rehearsed answers. Consequently these candidates could obtain the four marks easily. As always, candidates who had not learnt the work produced</p>

					muddled responses that made little sense and could not be credited.
		d i	<p>Endothermic AND K_w increases with temperature OR Endothermic AND dissociation increases with temperature OR Endothermic AND (dissociation) involves breaking bonds ✓</p>	1	<p>Endothermic and reason required for the mark</p> <p>ALLOW Endothermic AND increasing temperature shifts equilibrium / reaction to the right / favours forward reaction</p> <p>DO NOT ALLOW breaking hydrogen bonds OR intermolecular bonds / forces</p> <p>Examiner's Comments</p> <p>Candidates were expected to predict the type of energy change using the provided information. Credit was given for responses linking an endothermic change with the increase of K_w with temperature or breaking bonds during dissociation.</p>
		ii	<p>OH^- concentration</p> <p>$[OH^-] = \frac{9.311 \times 10^{-14}}{1.00 \times 10^{-7}} = 9.311 \times 10^{-7} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Explanation (dependent on 1st mark) $9.311 \times 10^{-7} > 1.00 \times 10^{-7}$ OR $[OH^-] > [H^+]$ OR OH^- in excess AND Alkaline ✓</p>	2	<p>H^+ OR OH^- concentration (neutral pH) $[H^+] = [OH^-] = \sqrt{9.311 \times 10^{-14}} = 3.05 \times 10^{-7} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Explanation (dependent on 1st mark) $pH = -\log(3.05 \times 10^{-7}) = 6.5 \rightarrow 6.515501837 \text{ (calc)}$ AND Alkaline ✓</p> <p>Examiner's Comments</p> <p>Most candidates calculated a value for $[H^+]$ using the K_w value at 60°C. Many recognised that $[OH^-] > [H^+]$ giving an alkaline solution. An alternative and equally valid method seen was to calculate the pH of a neutral solution at 60°C as 6.52 and then to relate water at a pH of 7 as being alkaline. Many using this approach thought that water would be acidic rather than alkaline, presumably because $6.52 < 7.00$.</p>
		ii i	<p>$pK_w = 13.03 \checkmark$</p>	1	<p>ONLY correct answer</p> <p>Examiner's Comments</p> <p>Despite the novel context, almost all candidates obtained the correct pK_w value of 13.03.</p>
		i v	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 10.76, award 3 marks </p>	3	<p>FULL ANNOTATIONS MUST BE USED </p>

		<p>Dilution 1 mark</p> $[\text{OH}^-(\text{aq})] = [\text{NaOH}(\text{aq})] = \frac{0.0270}{5} = 0.00540 \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>[H⁺] 1 mark</p> $[\text{H}^+(\text{aq})] = \frac{9.311 \times 10^{-14}}{0.00540} = 1.72 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>Calculator: $1.724259259 \times 10^{-11}$</p> <p>pH 1 mark</p> $\text{pH} = -\log 1.72 \times 10^{-11} = \mathbf{10.76} \checkmark$ <p>.....</p> <p>ALLOW pOH method for 2nd and 3rd mark:</p> $\text{pOH} = -\log 0.00540 = 2.27 \checkmark \text{ (calculator 2.26760624)}$ $\text{pH} = 13.03 - 2.27 = 10.76 \checkmark$		<p>ALLOW dilution AFTER calculation of [H⁺(aq)]</p> $\text{i.e. original } [\text{H}^+] = \frac{9.311 \times 10^{-14}}{0.0270} = 3.45 \times 10^{-12} \text{ (m$ <p>After dilution, $[\text{H}^+] = 3.45 \times 10^{-12} \times 5 = 1.72 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> $\text{pH} = -\log 1.72 \times 10^{-11} = \mathbf{10.76} \checkmark$ <p>ALLOW ECF from incorrect [H⁺(aq)] provided that pH > 7</p> <p>.....</p> <p>COMMON ERRORS (MUST be to 2 DP)</p> <p>pH = 11.73 At 25°C (1.00×10^{-14}): 2 marks</p> $\text{pH} = -\log 1.85 \times 10^{-12} = \mathbf{11.73}$ <p>pH = 11.46 No dilution at 60°C (9.311×10^{-14}) 2 marks</p> $\text{pH} = -\log(3.45 \times 10^{-12}) = \mathbf{11.46}$ <p>pH = 12.43 No dilution AND 25°C (1.00×10^{-14}) 1 mark</p> $\text{pH} = -\log(3.70 \times 10^{-13}) = \mathbf{12.43}$ <p>pH = 12.16 $\times 5$ instead of $\div 5$ at 60°C (9.311×10^{-14}) 2 marks</p> $\text{pH} = -\log(6.879 \times 10^{-13}) = \mathbf{12.16}$ <p>pH = 13.13 $\times 5$ instead of $\div 5$ at 25°C (1.00×10^{-14}) 1 mark</p> $\text{pH} = -\log(7.407 \times 10^{-14}) = \mathbf{13.13}$ <p>NOTE: Attempts at dilution $\rightarrow 0.0270$ with error in powers of 10 $\rightarrow 12.46$ from 0.00270, etc may give 2 marks by ECF</p> <p>Examiner's Comments</p> <p>The majority of candidates correctly calculated the pH via K_w but many had problems in initially deriving the concentration of the diluted solution of NaOH. Some candidates did not consider the dilution at all; others produced long calculations of this simple dilution, obtaining an array of concentrations. Provided that this concentration was then converted to a pH by a correct method, credit could still be given for the second part of the problem. Answer: pH = 10.76</p>
		Total	18	
1 4	i	$\text{AND } \text{Base}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{Acid 1} + \text{HCN} + \text{OH}^-$ <p>Acid 2+ Base 1 ✓</p> <p>CN</p>	1	<p>State symbols NOT required</p> <p>ALLOW CNH and HO⁻ (i.e. any order)</p> <p>ALLOW 1 and 2 labels the other way</p>

				<p>around.</p> <p>ALLOW 'just acid' and 'base' labels throughout if linked by lines so that it is clear what the acid-base pairs are.</p> <p>Examiner's Comments</p> <p>The majority of candidates were able to complete the equation for acid–base equilibrium and to identify the acid–base pairs. Candidates are advised to use numbers to label the acid–base pairs, such as 'acid 1' and 'base 1'. Attempts at using 'acid' and 'conjugate base' are ambiguous when more than one acid–base pair is involved. Although credited, it was strange to see hydrogen cyanide often written as CNH.</p>
		<p>H⁺ reacts with CN[−] OR HCN forms</p> <p>ii OR equation: $\text{H}^+ + \text{CN}^- \rightarrow \text{HCN}$ (ALLOW \rightleftharpoons)</p> <p>OR CN[−] accepts a proton / H⁺</p> <p>OR equilibrium shifts right AND CN[−] is removed ✓</p>	1	<p>ALLOW Acid reacts with / removes OH[−] ions (to form HCN)</p> <p>ALLOW CNH (i.e. any order)</p> <p>IGNORE other equilibrium comments</p> <p>Examiner's Comments</p> <p>The majority of candidates recognised that acid conditions would lead to protonation of CN[−] forming toxic HCN.</p>
		Total	2	
1 5	a	<p>Proton / H⁺ donor</p> <p>AND</p> <p>Partially dissociates / ionises ✓</p>	1	<p>Examiner's Comments</p> <p>For most candidates, this was an easy mark, although some only responded for a weak acid (partial dissociation) or for a Brønsted–Lowry acid (proton donor).</p>
	b	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 13.7(0), award 2 marks</p> <p>.....</p> <p>$[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.5(00)}$ OR $2(.00) \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>pH = $-\log 2(.00) \times 10^{-14} = \mathbf{13.7(0)} \checkmark$</p>	2	<p>For pOH method:, ALLOW pOH = $-\log[\text{OH}^-] = 0.3(0) \checkmark$ (calculator 0.301029995)</p> <p>ALLOW pH = $14 - 0.3 = 13.7 \checkmark$</p> <p>ALLOW 13.7 up to calculator value of 13.69897 correctly rounded.</p>

					<p>ALLOW ECF from incorrect $[H^+(aq)]$ provided that $pH > 7$</p> <p>Examiner's Comments</p> <p>The majority of candidates correctly calculated the pH via K_w. Another less popular but successful approach was via pOH. Either approach could result in both marks. Weaker candidates sometimes calculated the pH as 0.30 (from $-\log 0.500$). This gained no credit.</p> <p>Answer: $pH = 13.70$</p>
c	i	$(K_a =) \frac{[H^+][C_2H_5COO^-]}{[C_2H_5COOH]} \checkmark$	1	<p>IGNORE $\frac{[H^+]^2}{[C_2H_5COOH]}$ OR $\frac{[H^+][A^-]}{[HA]}$</p> <p>ALLOW $[H_3O^+]$ for $[H^+]$</p> <p>IGNORE state symbols</p> <p>Examiner's Comments</p> <p>Almost all candidates successfully wrote the expression for K_a. Responses using $[H^+(aq)]^2$ were not credited. Rarely, the expression was shown inverted or square brackets were omitted from one or more of the terms. Candidates are recommended to carefully check the formulae as this easy mark was sometimes not awarded for a missing C atom within a formula (even in the scripts of able candidates).</p>	
		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.9(0), award 3 marks</p> <p>ii $[C_2H_5COOH] = 0.12(0) \text{ mol dm}^{-3} \checkmark$ $[H^+] = \sqrt{K_a \times [C_2H_5COOH]} = \sqrt{1.35 \times 10^{-5} \times 0.12(0)}$</p> <p>OR $1.27 \times 10^{-3} \text{ (mol dm}^{-3}) \checkmark$</p> <p>pH = $-\log 1.27 \times 10^{-3} = \mathbf{2.9(0)} \checkmark$</p> <p>ii NOTE: The final two marks are ONLY available from attempted use of K_a AND $[C_2H_5COOH]$</p>		<p>ALLOW HA for C_2H_5COOH and A^- for $C_2H_5COO^-$</p> <p>ALLOW ECF from incorrectly calculated $[C_2H_5COOH]$</p> <p>ALLOW 1.27×10^{-3} to calculator value of $1.272792206 \times 10^{-3}$ correctly rounded</p> <p>ALLOW $2.9(0) \times 10^{-3}$ to calculator value of 2.895242493 correctly rounded</p> <p>ALLOW use of quadratic equation which gives same answer of 2.90 from 0.120 mol dm^{-3}</p>	3

				<p>.....</p> <p>.....</p> <p>COMMON ERRORS (MUST be to AT LEAST 2 DP unless 2nd decimal place is 0)</p> <p>pH = 2.59 2 marks $-\log\sqrt{(1.35 \times 10^{-5} \times 0.480)}$ <i>Original conc</i></p> <p>pH = 5.79 2 marks $-\log(1.35 \times 10^{-5} \times 0.120)$ <i>No \sqrt</i></p> <p>pH = 5.19 1 mark $-\log(1.35 \times 10^{-5} \times 0.480)$ <i>Original conc, no \sqrt</i></p> <p>pH = 4.87 0 marks $-\log(1.35 \times 10^{-5}) = 4.87$ $-\log K_a$</p> <p>Examiner's Comments</p> <p>This part discriminated extremely well. The added stage of an initial dilution to a stock weak acid pH calculation created problems for many candidates. Although most were able to use the correct square root expression to obtain a value for $[H^+(aq)]$, the concentration used was often incorrect. Although just a four times dilution from $0.480 \text{ mol dm}^{-3}$ to $0.120 \text{ mol dm}^{-3}$, many candidates obtained 0.120 using learnt equations rather than the simple ratio. Others used the original concentration of $0.480 \text{ mol dm}^{-3}$ or incorrectly calculated concentrations, commonly seen as 0.0480, 0.0120 or even 0.192 (from $\times 4$). Some candidates calculated $[H^+(aq)]$ using $0.480 \text{ mol dm}^{-3}$ but then divided by 4 before calculating the pH. Able candidates invariably obtained the correct pH but many obtained pH values from the values above such as a pH of 2.59 (from $0.480 \text{ mol dm}^{-3}$), for which partial credit could be awarded.</p> <p>Answer: pH = 2.90</p>
	d	i	<p>pH = $-\log 1.35 \times 10^{-5} = 4.87 \checkmark$</p>	<p>1</p> <p>ONLY correct answer DO NOT ALLOW 4.9 (<i>Question asks for 2 DP</i>)</p> <p>Examiner's Comments</p> <p>Some candidates correctly calculated the pH here as $-\log K_a$ but most used the standard buffer pH method, using a 1:1 acid–base ratio. Weak candidates often first</p>

				<p>took the square root of the K_a value, obtaining a pH of 2.43. Unfortunately, some candidates rounded a correct pH to 4.9, despite a two decimal place requirement being emphasised in the question.</p> <p>Answer: pH = 4.87</p>
		ii	<p>Added ammonia C_2H_5COOH removes added NH_3 / alkali / base OR $C_2H_5COOH + NH_3 + OH^- \rightarrow$ OR NH_3 / alkali reacts with / accepts H^+ OR $H^+ + NH_3 \rightarrow$ OR $H^+ + OH^- \rightarrow \checkmark$</p>	<p>ALLOW use of HA / weak acid / acid for C_2H_5COOH;</p> <p>ALLOW use of NH_4OH for NH_3</p> <p>ALLOW A^- for $C_2H_5COO^-$</p> <p>ASSUME that equilibrium applies to that supplied in the question, i.e. IGNORE any other equilibria</p> <p>Examiner's Comments</p> <p>The role of buffers in controlling pH is a common recall question and most candidates had prepared their rehearsed answers. Although this question asked for the addition of ammonia as a specific base, all but the weakest candidates identified that this was a question about addition of a base. The commonest and best answers stated that NH_3 accepts a proton to form NH_4^+ (with many ionic equations seen). The correct equilibrium shift was usually included.</p>
		ii	<p>Equilibrium $\rightarrow C_2H_5COO^-$ OR Equilibrium \rightarrow right \checkmark</p>	2
		i	<p>CHECK WORKING CAREFULLY AS CORRECT NUMERICAL ANSWER IS POSSIBLE FROM WRONG VALUES</p> <p>.....</p> <p>ALLOW HA and A^- throughout</p> <p>Amount of Mg (1 mark)</p> <p>$n(Mg) = \frac{6.075}{24.3} = 0.25(0) \text{ mol } \checkmark$</p> <p>.....</p> <p>Moles / concentrations (2 marks)</p> <p>$n(C_2H_5COOH) = 1.00 - (2 \times 0.25) = 0.50 \text{ (mol) } \checkmark$ $n(C_2H_5COO^-) = 1.00 + (2 \times 0.25) = 1.50 \text{ (mol) } \checkmark$</p> <p>.....</p> <p>$[H^+]$ and pH (1 mark)</p> <p>$[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ OR $4.5 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ <p>pH = $-\log 4.5 \times 10^{-6} = 5.35$ 2 dp required \checkmark</p> </p>	4
				<p>FULL ANNOTATIONS MUST BE USED</p> <p>.....</p> <p>For $n(Mg)$, 1 mark ALLOW ECF for ALL marks below from incorrect $n(Mg)$</p> <p>ECF ONLY available from concentrations that have</p> <ul style="list-style-type: none"> subtracted 0.50 OR 0.25 from 1 for $[C_2H_5COOH]$ added 0.50 OR 0.25 to 1 for $[C_2H_5COO^-]$ <p>i.e. For moles / concentration 1 mark (1 mark lost)</p>

		<p>NOTE: IF there is no prior working,</p> <p>ALLOW 4 MARKS for $[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ AND pH = 5.35</p> <p>IF the ONLY response is pH = 5.35, award 1 mark ONLY</p> <p>.....</p> <p>Award a maximum of 1 mark (for $n(\text{Mg}) = 0.25$ mol) for:</p> <p>pH value from K_a square root approach (weak acid pH)</p> <p>pH value from $K_w / 10^{-14}$ approach (strong base pH)</p> <p>.....</p> <p>ALLOW alternative approach based on Henderson–Hasselbalch equation for final 1 mark</p> <p>$\text{pH} = \text{p}K_a + \log \frac{1.5}{0.5}$ OR $\text{pH} = \text{p}K_a - \log \frac{0.5}{1.5}$ $\text{pH} = 4.87 + 0.48 = 5.35 \checkmark$</p> <p>ALLOW $-\log K_a$ for $\text{p}K_a$</p>		<p>1. $n(\text{C}_2\text{H}_5\text{COOH}) = 0.75$ AND $n(\text{C}_2\text{H}_5\text{COO}^-) = 1.25$</p> <p>2. $n(\text{C}_2\text{H}_5\text{COOH}) = 0.50$ AND $n(\text{C}_2\text{H}_5\text{COO}^-) = 1.25$</p> <p>3. $n(\text{C}_2\text{H}_5\text{COOH}) = 0.75$ AND $n(\text{C}_2\text{H}_5\text{COO}^-) = 1.50$</p> <p>.....</p> <p>.....</p> <p>ALLOW ECF ONLY for the following giving 1 additional mark and a total of 3 marks</p> <p>1. $[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.25}$ $\text{pH} = -\log 8.1$</p> <p>2. $[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.25}$ $\text{pH} = -\log 5.4$</p> <p>3. $[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.50}$ $\text{pH} = -\log 6.75$</p> <p>Examiner's Comments</p> <p>This buffer calculation was aimed as stretch and challenge and the majority of candidates struggled to derive the concentrations of $\text{CH}_3\text{CH}_2\text{COOH}$ and $\text{CH}_3\text{CH}_2\text{COO}^-$. An easy mark for the amount of magnesium added was available for almost all candidates. The problem was then to derive the amount and concentration of $\text{CH}_3\text{CH}_2\text{COOH}$ that would be obtained 0.500 mol^{-3}. Many did not identify that Mg and $\text{CH}_3\text{CH}_2\text{COOH}$ react in a 1:2 molar ratio, subtracting 0.25, instead of 0.50, from the original concentration. Rarely did candidates realise that the $\text{CH}_3\text{CH}_2\text{COO}^-$ concentration would increase from the initial concentration of 1 mol dm^{-3}. Others assumed that no $\text{CH}_3\text{CH}_2\text{COO}^-$ was present at the start. Consequently, candidates often used a variety of acid–base ratios in their buffer calculation. Instead of the correct ratio of 0.5/1.5, it was very common to see 0.75/1.25, 0.75/0.25, and especially 0.5/1, 0.75/1 and 0.25/1.0.</p> <p>The very best candidates tackled the problem with apparent ease but this was seen comparatively rarely in scripts of other candidates.</p> <p>Answer: $\text{pH} = 5.35$</p>
		Total	14	
1 6	a	$\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CH}_3\text{COO}^- \checkmark$ Acid 1 Base 2 Acid 2 Base 1 \checkmark	2	IGNORE state symbols (even if incorrect)

				<p>ALLOW 1 AND 2 labels the other way around.</p> <p>ALLOW 'just acid' and 'base' labels if linked by lines so that it is clear what the acid—base pairs are</p> <p>ALLOW A and B for 'acid' and 'base'</p> <p>IF proton transfer is wrong way around</p> <p>ALLOW 2nd mark for idea of acid—base pairs, <i>i.e.</i></p> <p> $\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH}_2^+ + \text{OH}^- \times$ </p> <p>Base 2 Acid 1 Acid 2 Base 1 ✓</p> <p>NOTE For the 2nd marking point (acid—base pairs), this is the ONLY acceptable ECF <i>i.e.</i>, NO ECF from impossible chemistry</p> <p>Examiner's Comments</p> <p>Most candidates showed an acid-base equilibrium involving proton transfer and then identified the acid-base pairs. The acid-base pairs were usually correctly identified but the proton transfer was sometimes shown the wrong way round. Common errors included omission of a positive charge on H_3O^+ and an equilibrium involving OH^- ions rather than water. Neither approach could be credited.</p>
	b	i	<p>Water dissociates / ionises</p> <p>OR</p> <p>$\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$</p> <p>OR</p> <p>$2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^- \checkmark$</p>	<p>1</p> <p>ALLOW $K_w = [\text{H}^+][\text{OH}^-]$</p> <p>OR $[\text{H}^+][\text{OH}^-] = 10^{-14} \text{ (mol}^2 \text{ dm}^{-6}\text{)}$</p> <p>IGNORE breaking for dissociation</p> <p>IGNORE water contains H^+ and OH^-</p> <p>IGNORE $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$ <i>i.e.</i> no equilibrium sign</p> <p>IGNORE $2\text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{OH}^-$ <i>i.e.</i> no equilibrium sign</p> <p>Examiner's Comments</p> <p>The key required feature was the dissociation of water but many instead discussed dissociation of the acid.</p>
		ii	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 1.15×10^{-11}, award 2 marks</p> <p>.....</p>	<p>2</p> <p>IF there is an alternative answer, check to see if there is any</p> <p>ECF credit possible using working below.</p> <p>.....</p>

		<p>$[H^+] = 10^{-3.06} = 8.71 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$[OH^-] = \frac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>ALLOW answer to two or more significant figures 2SF: 1.1×10^{-11}; 4SF: 1.148×10^{-11}; calculator $1.148153621 \times 10^{-11}$</p>		<p>ALLOW 2 SF: 8.7×10^{-4} up to calculator value of 8.7096359×10^{-4} correctly rounded</p> <p>ALLOW alternative approach using pOH:</p> <p>pOH = $14 - 3.06 = 10.94 \checkmark$ $[OH^-] = 10^{-10.94} = 1.15 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Examiner's Comments</p> <p>The majority of candidates correctly calculated the hydroxide ion concentration via K_w. Another less popular but successful approach was via pOH. Either approach could result in both marks. Weaker candidates were successful in calculating the hydrogen ion concentration but this was then often shown also as the hydroxide ion concentration in the final answer.</p> <p>Answer: $1.15 \times 10^{-11} \text{ mol dm}^{-3}$</p>
	c i	<p>$2CH_3COOH + CaCO_3 \rightarrow (CH_3COO)_2Ca + CO_2 + H_2O \checkmark$</p>	1	<p>IGNORE state symbols ALLOW \rightleftharpoons provided that reactants on LHS For $CO_2 + H_2O$, ALLOW H_2CO_3</p> <p>ALLOW $Ca(CH_3COO)_2$</p> <p>ALLOW $(CH_3COO^-)_2Ca^{2+}$ BUT DO NOT ALLOW if either charge is missing or incorrect</p> <p>Examiner's Comments</p> <p>The equations seen were certainly better than in previous sessions, perhaps as candidates will have practised similar questions from past papers. Ionic signs within the formula of calcium ethanoate were allowed but both were then needed. Common errors included an incorrect formula of calcium ethanoate with one ethanoate group only and an unbalanced ethanoic acid on the left-hand side of the equation.</p>
	ii	<p>solution contains CH_3COOH AND $CH_3COO^- \checkmark$</p>	1	<p>ALLOW names: ethanoic acid for CH_3COOH ethanoate for CH_3COO^-</p> <p>ALLOW calcium ethanoate OR $(CH_3COO)_2Ca$ for CH_3COO^-</p> <p>IGNORE 'acid, salt, conjugate base; responses must identify the acid and</p>

				<p>conjugate base as ethanoic acid and ethanoate</p> <p>IGNORE ethanoic acid is in excess (<i>in question</i>)</p> <p>BUT DO ALLOW some ethanoic acid is left over / present / some ethanoic acid has reacted</p> <p>IGNORE equilibrium: $\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$</p> <p><i>Dissociation of ethanoic acid only</i></p> <p>Examiner's Comments</p> <p>The mark scheme was specific in wanting the names or formulae of the components of the buffer solution and also the idea that some ethanoic acid remains. More general responses in terms of an acid and its conjugate base were not credited.</p>
		<p>Quality of written communication, QWC</p> <p>2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^- (see below)</p> <p>.....</p> <p>$\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^- \checkmark$</p> <p>.....</p> <p>ii i CH_3COOH reacts with added alkali</p> <p>OR $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow$</p> <p>OR added alkali reacts with H^+</p> <p>OR $\text{H}^+ + \text{OH}^- \rightarrow \checkmark$</p> <p>Equilibrium \rightarrow right OR Equilibrium $\rightarrow \text{CH}_3\text{COO}^- \checkmark$ (QWC)</p> <p>CH_3COO^- reacts with added acid \checkmark</p> <p>Equilibrium \rightarrow left OR Equilibrium $\rightarrow \text{CH}_3\text{COOH} \checkmark$ (QWC)</p>	5	<p>FULL ANNOTATIONS MUST BE USED</p> <p>.....</p> <p>Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2</p> <p>DO NOT ALLOW $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$</p> <p>DO NOT ALLOW more than one equilibrium equation.</p> <p>.....</p> <p>ALLOW response in terms of H^+, A^- and HA</p> <p>IF more than one equilibrium shown, it must be clear which one is being referred to by labeling the equilibria.</p> <p>ALLOW weak acid reacts with added alkali</p> <p>DO NOT ALLOW acid reacts with added alkali</p> <p>ALLOW conjugate base reacts with added acid</p> <p>DO NOT ALLOW salt / base reacts with added acid</p> <p>Examiner's Comments</p> <p>The role of buffers in controlling pH is a common recall question and most candidates had prepared their rehearsed</p>

				<p>answers. Well-prepared candidates were thus able to collect full or nearly full marks for this part. There was a significant minority of candidates who had obviously not learnt this part of the specification and, despite their best efforts to invent answers, there was rarely anything that the examiners could credit. This was a great pity because marks were effectively being thrown away. Candidates are recommended to construct their responses using the weak acid equilibrium equation only. Some candidates shown both the correct relevant equilibrium but also others, including for calcium ethanoate. Subsequent explanations in terms of equilibrium were then ambiguous as the examiner could not tell which equilibrium was being discussed. Some candidates thankfully did label and reference multiple equilibria so that some credit could be awarded.</p>
d		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 11.48 OR 11.5 (g), award 5 marks</p> <p>.....</p> <p>$[H^+] = 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>.....</p> <p>$[CH_3COO^-] = \frac{1.75 \times 10^{-5}}{10^{-5}} \checkmark \times 0.200 = 0.350 \text{ mol dm}^{-3} \checkmark$</p> <p>$n(CH_3COONa / CH_3COO^-) \text{ in } 400 \text{ cm}^3 = 0.350 \times \frac{400}{1000} = 0.14(0) \text{ (mol)} \checkmark$</p> <p>.....</p> <p>mass $CH_3COONa = 0.140 \times 82.0 = 11.48 \text{ OR } 11.5 \text{ (g)} \checkmark$</p> <p>For ECF, $n(CH_3COONa/CH_3COO^-)$ must have been calculated in step before</p>	5	<p>FULL ANNOTATIONS MUST BE USED</p> <p>.....</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible.</p> <p>Incorrect use of $[H^+] = \sqrt{[CH_3COOH] \times K_a}$) scores zero</p> <p>BUT IGNORE if an alternative successful method is present</p> <p>Incorrect use of K_w, 1 max for $[H^+] = 10^{-5} \text{ (mol dm}^{-3}\text{)}$</p> <p>BUT IGNORE if an alternative successful method is present</p> <p>.....</p> <p>ALLOW $n(CH_3COONa / CH_3COO^-)$</p> <p>$= \frac{1.75 \times 10^{-5}}{10^{-5}} \checkmark \times 0.08 = 0.14(0) \text{ (mol)} \checkmark \checkmark$</p> <p>Note: There is no mark just for</p> <p>$n(CH_3COOH) \text{ in } 400 \text{ cm}^3 = 0.200 \times \frac{400}{1000} = 0.08 \text{ (mol)}$</p> <p>.....</p> <p>As alternative for the 4th and 5th marks, ALLOW:</p> <p>mass of CH_3COONa in $1 \text{ dm}^3 = 0.350 \times 82.0 = 28.7 \text{ g} \checkmark$</p> <p>mass of CH_3COONa in $400 \text{ cm}^3 = 28.7 \times \frac{400}{1000} = 11.48 \text{ g} \checkmark$</p>

.....
COMMON ECF 4.592 OR 4.6 g AWARD 4
 marks
use of 400 / 1000 twice

ALLOW variants of Henderson—
 Hasselbalch equation.

$pK_a = -\log(1.75 \times 10^{-5}) = 4.757 \checkmark$ *Calc:*
 4.75696.

$$\log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = \text{pH} - pK_a = 5 - 4.757$$

 $= 0.243$

$$\frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = 10^{0.243} = 1.75 \checkmark$$

$[\text{CH}_3\text{COO}^-] = 1.75 \times 0.200 = 0.350 \text{ mol dm}^{-3}$
 \checkmark

$n(\text{CH}_3\text{COONa}/\text{CH}_3\text{COO}^-) \text{ in } 400 \text{ cm}^3$
 $= 0.350 \times \frac{400}{1000} = 0.14(0) \text{ (mol)} \checkmark$

.....
 mass **CH₃COONa** = $0.140 \times 82.0 = 11.48$
OR 11.5 (g) \checkmark

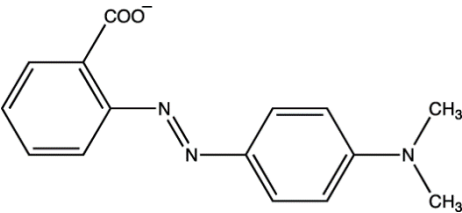
Examiner's Comments

Able candidates answered this question with comparative ease, collecting all five marks for a carefully constructed answer. This was in contrast to weaker candidate who struggled, often resorting to the 'square root' method for calculating the pH of a weak acid.

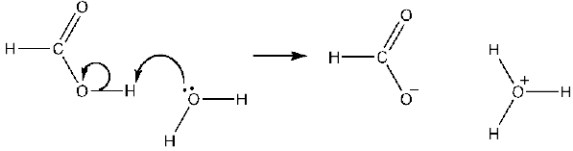
The calculation started off with an easy mark for calculating the hydrogen ion concentration from the pH. Unfortunately, this 'square root' method then resulted in another hydrogen ion concentration which contradicted the original. Other weak candidates resorted to use of K_w . The result was that weaker candidates would often score no marks at all for this part.

Many candidates were aware of the importance of the acid/base ratio in buffer calculations and were able to gain at least some marks for this part. The commonest error in partially successful responses was with the scaling factor of 400/1000, being either omitted to give an answer of 28.7 g, or used twice to give an answer of 4.952 g

Answer: 11.48 g

			Total	17	
1 7	a	i	Using a pH probe on a data logger OR pH meter	1	
		ii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 0.11(0) (mol dm⁻³), award 2 marks </p> $n(\text{NaOH}) = \frac{0.125 \times 22.0}{1000} = 2.75 \times 10^{-3} \text{ (mol)}$ $\text{concentration of CH}_3\text{COOH} = \frac{2.75 \times 10^{-3} \times 1000}{25.0}$ <p>= 0.11(0) (mol dm⁻³)</p>	2	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below. </p> <p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>ALLOW ECF: $n(\text{NaOH}) \times 1000/25.00$</p>
	b	i	<p>Brilliant yellow AND Vertical section / rapid pH change matches the pH range / end point / colour change (of the indicator)</p>	1	<p>ALLOW pH range (of the indicator) matches equivalence point ALLOW end point / colour change matches equivalence point IGNORE colour change matches end point <i>(colour change is the same as end point)</i></p>
		ii	 <p>Explanation: Acid / H⁺ reacts with A⁻ AND equilibrium (position) shifts towards HA (to give a red colour)</p> <p>Alkali / OH⁻ reacts with HA/H⁺ AND equilibrium (position) shifts towards A⁻ (to give a yellow colour)</p> <p>At end point, equal amounts of HA and A⁻ AND orange colour</p>	4	<p>ALLOW direction of equilibrium shift if equilibrium shown: $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$ i.e. 'towards HA' is equivalent to 'to left' i.e. 'towards A⁻' is equivalent to 'to right'</p> <p>ALLOW yellow-red colour</p>
	c	i	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 2.33 award 4 marks $K_a = 10^{-3.40} = 3.98 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$</p> $\text{Concentration of aspirin} = \frac{1.00 \times 10^{-2}}{180} \times 1000$ <p>= 0.0556 (mol dm⁻³)</p>	4	

		$[H^+] = \sqrt{K_a \times [HA]} = \sqrt{(3.98 \times 10^{-4} \times 0.0556)} = 4.70 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $pH = -\log 4.70 \times 10^{-3} = 2.33$		<p>ALLOW ECF</p> <p>ALLOW ECF only from $[H^+]$ calculation using $[H^+] = \sqrt{(K_a \times [HA])}$</p>
	ii	Salts are ionic AND attracted to polar H ₂ O	1	
	ii i	COO ⁻ reacts with H ⁺ forming COOH Aspirin precipitates out	2	ALLOW equilibrium shifts to left
		Total	15	
1 8	a	$[H^+] = 10^{-pH} = 10^{-2.19} = 6.46 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $[CH_3CH(OH)COOH] = \frac{[H^+]^2}{K_a} = \frac{(6.46 \times 10^{-3})^2}{1.38 \times 10^{-4}}$ $= 0.0302 \text{ (mol dm}^{-3}\text{)}$ $n(CH_3CH(OH)COOH) = \frac{0.0302 \times 250}{1000} = 0.0755 \text{ mol}$ Mass of CH ₃ CH(OH)COOH = 0.0755 × 90 = 6.80 g Dissolve 6.80 g of the solid in distilled water (less than 250 cm ³) in a beaker (then) transfer the solution to a 250 cm ³ volumetric flask AND ensure that all solution is washed out of beaker (washings transferred to volumetric flask) (then) make solution up to 250 cm ³ with distilled water AND ensure thorough mixing by inverting the flask several times	8	<p>ALLOW 5 marks for 6.80 g through any calculation.</p> <p>ALLOW ECF for incorrect calculation of mass. Mass used must be linked to calculation.</p>
	b	CH ₃ CH(OH)COO ⁻ + CH ₃ CH ₂ CH ₂ COOH ₂ ⁺ CH ₃ CH(OH)COOH AND CH ₃ CH(OH)COO ⁻ CH ₃ CH ₂ CH ₂ COOH AND CH ₃ CH ₂ CH ₂ COOH ₂ ⁺ Both pairs identified	2	<p>State symbols NOT required</p> <p>ALLOW labels 'acid 1', 'base 1' etc.</p> <p>ALLOW ECF for second mark</p>
	c i	$[H^+] = \frac{1 \times 10^{-14}}{0.185} = 5.405 \times 10^{-14}$ (Use of K_w) $pH = -\log(5.405 \times 10^{-14}) = 13.27$	2	<p>ALLOW 5.405405405 × 10⁻¹⁴ and correct rounding to 5.4 × 10⁻¹⁴</p> <p>ALLOW alternative approach using pOH: pOH = -log(0.185) = 0.73 pH = 14 - 0.73 = 13.27 Correct answer scores BOTH marks</p> <p>ALLOW 13.267</p>
	ii	$n(A^-) = 9.25 \times 10^{-3} \text{ (mol)}$ $n(HA) = 0.0165 - 9.25 \times 10^{-3} = 7.25 \times 10^{-3} \text{ (mol)}$ $[H^+] = K_a \times \frac{[HA]}{[A^-]}$	4	<p>ALLOW HA / acid and A⁻/salt throughout for butanoate and butanoic acid</p> <p>ALLOW pK_a = -log K_a OR -log 1.5 ×</p>

			$\text{pH} = -\log(1.5 \times 10^{-5} \times \frac{0.058}{0.074}) = 4.93$ $\text{OR } \text{pH} = -\log(1.5 \times 10^{-5} \times \frac{1000 \times \frac{7.25 \times 10^{-3}}{125}}{1000 \times \frac{9.25 \times 10^{-3}}{125}}) = 4.93$ Final mark also via Henderson-Hasselbalch equation: $\text{pH} = \text{p}K_a - \log \frac{[\text{HA}]}{[\text{A}^-]} = 4.82 - (-0.11) = 4.93$ $\text{OR } \text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]} = 4.82 + 0.11 = 4.93$		10^{-3} OR 4.82 ALLOW ECF from incorrect values of $n(\text{A}^-)$ or $n(\text{HA})$ ALLOW $\text{pH} = -\log(1.5 \times 10^{-5} \times \frac{7.25 \times 10^{-3}}{9.25 \times 10^{-3}}) = 4.93$
			Total	16	
1 9			 1 mark for correct reactants AND products AND correct positioning of + and - charges on products 1 mark for two correct curly arrows AND H ₂ O curly arrow starting from O lone pair	2	
			Total	2	
2 0	i		$K_a = \frac{[[\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+}(\text{aq})][\text{H}^+(\text{aq})]}{[[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq})]}$	1	state symbols not required
	ii		$[\text{H}^+] = \sqrt{6.00 \times 10^{-3} \times 0.100}$ OR 0.0245 (mol dm ⁻³) $\text{pH} = -\log 0.0245 = 1.61$	2	ALLOW ECF from calculated $[\text{H}^+]$ provided that BOTH 6.0×10^{-3} AND 0.100 only have been used ALLOW calculation via quadratic equation → pH 1.66
			Total	3	
2 1			K_w value from graph from 2.2 to 2.4×10^{-14} (mol ² dm ⁻⁶) Using 2.4×10^{-14} , $[\text{H}^+] = \sqrt{2.4 \times 10^{-14}} \quad \text{OR } 1.55 \times 10^{-7}$ $\text{pH} = -\log (1.55 \times 10^{-7}) = 6.81 \text{ (using } K_w = 2.4 \times 10^{-14})$	3	Actual $K_w = 2.38 \times 10^{-14}$ mol ² dm ⁻⁶ ALLOW ECF only if candidate uses a value between 2.0 and 2.6×10^{-14} (mol ² dm ⁻⁶), i.e. from the approximately correct region of the graph ALLOW 6.8 (1DP) up to calculator value ALLOW ECF only if candidate has generated a value of $[\text{H}^+]$ by attempting to take a square root of a value between 2.0 and 3.0×10^{-14}
			Total	3	

2 2	a	i	HNO_3 is a strong acid AND HNO_2 is a weak acid	1	<p>ALLOW HNO_3 completely dissociates AND HNO_2 partially dissociates ALLOW $\text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^-$ AND $\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^-$</p> <p>IGNORE HNO_3 is a stronger acid ORA IGNORE HNO_3 produces more H^+</p>
		ii	$\text{pH} = -\log 0.0450 = 1.35$ (2 DP required)	1	
		ii i	<p>FIRST CHECK THE ANSWER ON ANSWER LINE IF answer = 2.35, award all three calculation marks</p> <p>$K_a = 10^{-3.35}$ OR 4.47×10^{-4} (mol dm⁻³)</p> <p>$[\text{H}^+] = \sqrt{(K_a \times [\text{HNO}_2])}$ OR $\sqrt{(K_a \times [\text{HA}])}$ OR $\sqrt{(K_a \times 0.0450)}$ OR 4.48×10^{-3} (mol dm⁻³)</p> <p>$\text{pH} = 2.35$ (2 DP required)</p>	3	<p>ALLOW 2 SF to calculator value: $4.466835922 \times 10^{-4}$, correctly rounded IGNORE HNO_3 in working</p> <p>Always ALLOW calculator value irrespective of working as number may have been kept in calculator.</p> <p><i>Note: $\text{pH} = 2.35$ is obtained from all three values above From no square root, $\text{pH} = 4.70$. Worth K_a mark only.</i></p>
		b	<p>FIRST CHECK THE ANSWER ON ANSWER LINE IF answer = 0.810 (g) award 4 marks</p> <p>$[\text{H}^+] = 10^{-12.500} = 3.16 \times 10^{-13}$ (mol dm⁻³)</p> <p>$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{1.00 \times 10^{-14}}{3.16 \times 10^{-13}} = 0.0316$ (mol dm⁻³)</p> <p>$n(\text{RbOH}) = 0.0316 \times \frac{250}{1000} = 7.91 \times 10^{-3}$ (mol)</p> <p>mass $\text{RbOH} = 7.91 \times 10^{-3} \times 102.5 = 0.810$ (g)</p>	4	<p>Always ALLOW calculator value irrespective of working as number may have been kept in calculator.</p> <p>ALLOW alternative approach using pOH: $\text{pOH} = 14.000 - 12.500 = 1.500$</p> <p>$[\text{OH}^-] = 10^{-1.500} = 0.0316$</p> <p>ALLOW ECF from $[\text{H}^+]$ derived using K_w and $[\text{OH}^-]$ BUT DO NOT ALLOW an acid pH.</p> <p>ALLOW 0.81 g, up to calculator value but take care as rounding could be from any stage. <i>Last 3 SF figure is zero and is treated as a 'trailing zero' as specific number of SF has not been asked for.</i></p>
			Total	9	