

Question	Answer	Marks	Guidance
1	C	1	ALLOW 4.1 in the box

Question		Answer	Marks	Guidance
2	(a)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 0.753, award 3 marks ----- $[H^+] = 10^{-pH} = 10^{-2.440} = 3.63 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ $[CH_3COOH] = \frac{[H^+]^2}{K_a} \text{ OR } \frac{(3.63 \times 10^{-3})^2}{1.75 \times 10^{-5}} \checkmark$ $= 0.753 \text{ (mol dm}^{-3}\text{)} \checkmark$	3	ALLOW use of HA and A⁻ ALLOW 3 SF up to calculator value of $3.630780548 \times 10^{-3}$ correctly rounded NOTE: Answer is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value ALLOW 0.749 if $[H^+]$ has been subtracted from $[CH_3COOH]$ for greater accuracy at end
	(b)	$CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COOH_2^+ + FCH_2COO^- \checkmark$ B2 A1 A2 B1 OR B1 A2 A1 B2 $\checkmark$ <i>i.e. labels other way round</i>	2	Watch for opposite order on RHS, i.e.: $FCH_2COO^- + CH_3COOH_2^+$ Take great care matching labels ALLOW ECF for incorrect proton transfer as below. This is the ONLY ECF $CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COO^- + FCH_2COOH_2^+ \times$ A1 B2 B1 A2 OR A2 B1 B2 A1 $\checkmark$ ECF <i>i.e. labels other way round</i>

Question			Answer	Marks	Guidance
	(c)	(i)	[CH₃COO⁻] $n(\text{CH}_3\text{COONa}) = \frac{9.08}{82.0} \text{ OR } 0.111 \checkmark \text{ (Calc: } 0.1107317073)$ $[\text{CH}_3\text{COO}^-] = \frac{9.08}{82.0} \times \frac{1000}{250} = 0.443 \text{ (mol dm}^{-3}\text{)}$ OR $n(\text{CH}_3\text{COOH}) = 0.800 \times \frac{250}{1000} = 0.200 \text{ (mol)} \checkmark$ [H⁺] $[\text{H}^+] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]} \text{ OR } K_a \times \frac{n(\text{CH}_3\text{COOH})}{n(\text{CH}_3\text{COO}^-)}$ $= 1.75 \times 10^{-5} \times \frac{0.800}{0.443} \text{ OR } 1.75 \times 10^{-5} \times \frac{0.200}{0.111} \checkmark$ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ pH (must come from <i>calculated</i> [H⁺]) $\text{pH} = -\log(3.16 \times 10^{-5}) = 4.50 \checkmark$ ----- LAST 3 marks are NOT available using • K_a square root approach (weak acid pH) • $K_w/10^{-14}$ approach (strong base pH) ----- Henderson–Hasselbalch (HH) alternative $\text{p}K_a = -\log 1.75 \times 10^{-5} = 4.757 \text{ (or } 4.756961951\text{..)}$ $\text{pH} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} \text{ OR } \text{pH} = \text{p}K_a - \log \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$ $\text{OR } \text{pH} = \text{p}K_a + \log \frac{0.443}{0.800} \text{ OR } \text{pH} = \text{p}K_a - \log \frac{0.800}{0.443} \checkmark$ $= \text{p}K_a - 0.257 \checkmark$ $= 4.757 - 0.257 = 4.50 \checkmark$	5	ALLOW 2 sig fig ALLOW use of HA and A⁻ Mark by ECF ----- Alternative method (If both methods are attempted, mark the method which produces the higher mark) [H⁺] $[\text{H}^+] = 10^{-\text{pH}} = 10^{-4.50}$ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ [CH₃COO⁻] $[\text{CH}_3\text{COO}^-] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{H}^+]}$ $\text{OR } 1.75 \times 10^{-5} \times \frac{0.800}{3.16 \times 10^{-5}} \checkmark$ $= 0.443 \text{ (mol dm}^{-3}\text{)} \checkmark$ mass of CH₃COONa $\text{mass CH}_3\text{COONa} = 0.443 \times \frac{250}{1000}$ OR 0.111 ✓ $0.111 \times 82.0 = \mathbf{9.08} \text{ (g)} \checkmark$ ----- Common errors 4.64 Use of $M(\text{CH}_3\text{COONa}) = 60$ 4 marks 2.40 Use of K_a of FCH_2COOH 4 marks

Question			Answer	Marks	Guidance
		(ii)	pH is the same/constant ✓ ratio/proportion $[HA]/[A^-]$ is the same ✓	2	M2 is dependent upon M1 ALLOW Change in $[HA]$ and $[A^-]$ is proportional
			Total	12	

Question	Answer	Marks	AO element	Guidance
3	C	1	AO2.6	

Question			Answer	Marks	Guidance
4	(a)	(i)	$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ ✓	1	IGNORE state symbols Must be square brackets IGNORE expressions with HA or with $[H^+]^2$
		(ii)	FIRST, CHECK ANSWER ON ANSWER LINE IF answer = 4.76 award 3 marks ----- $[H^+] = 10^{-pH}$ $= 10^{-2.41} = 3.89 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ K_a $= \frac{[H^+]^2}{[CH_3COOH]} = \frac{(3.89 \times 10^{-3})^2}{0.870}$ $= 1.74 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ pK_a $= -\log K_a = -\log 1.74 \times 10^{-5} = 4.76 \checkmark$	3	ALLOW use of HA and A⁻ ALLOW 3 SF up to calculator value of: $3.89045145 \times 10^{-3}$ correctly rounded K_a $1.739725573 \times 10^{-5}$ NOTE: 1.74×10^{-5} is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value 2 DP required
		(iii)	% dissociation = $\frac{[H^+]}{[CH_3COOH]} \times 100$ $= \frac{3.89 \times 10^{-3}}{0.870} \times 100 = 0.447(\%) \checkmark$	1	3 SF required

Question		Answer	Marks	Guidance
	(b)	FIRST, CHECK ANSWER ON ANSWER LINE IF answer = 95.9(%) award 4 marks $[H^+] = 10^{-pH}$ $= 10^{-13.48} = 3.31 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$ [OH⁻] from K_w $= \frac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302 \text{ (mol dm}^{-3}\text{)} \checkmark$ Mass of (NaOH) $= 0.302 \times \frac{100}{1000} \times 40.0 = 1.21 \text{ (g)} \checkmark$ % of NaOH to 3 SF $= \frac{1.21}{1.26} \times 100 = 95.9 \text{ (%) } \checkmark$	4	ALLOW ECF throughout IGNORE rounding errors beyond 3rd SF throughout ALLOW $3.3 \times 10^{-14} \text{ (mol dm}^{-3}\text{)}$ ALLOW 0.30 ALLOW 0.303 if 3.3×10^{-14} used in the first marking point ALLOW pOH method: $pOH = 14 - 13.48 = 0.52$ $[OH^-] = 10^{-0.52} = 0.302 \text{ (mol dm}^{-3}\text{)}$ ALLOW $[OH^-] \times 0.1 \times 40$ Rounding $[OH^-]$ to 0.3(0) gives $1.2/1.26 = 95.2\%$ Award 4 marks Rounding $[OH^-]$ to 0.303 gives $1.212/1.26 = 96.2\%$ Award 4 marks

Question	Answer	Marks	AO	Guidance
5	D	1	AO1.2	

Question		Answer	Marks	AO element	Guidance
6	(a)	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 mark) Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Detailed explanation of equilibrium and the action of the buffer. OR Detailed explanation of equilibrium and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Detailed explanation of the action of the buffer and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Partial explanations of equilibrium, and the action of the buffer and attempt calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Detailed explanation of equilibrium. OR Correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Detailed explanation of the action of the buffer. OR Partial explanations of equilibrium and the action of the buffer.'	6	1.1 ×2 1.2 ×2 3.1 ×1 3.2 ×1	Indicative scientific points may include: (State symbols not required in equations) Equilibrium and equilibrium shifts $\text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$ - Addition of H^+ causes $\rightleftharpoons$ to shift to left - Addition of OH^- causes $\rightleftharpoons$ to shift to right Action of buffer - Increase in H^+ / addition of acid leads to: $\text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{H}_2\text{CO}_3(\text{aq})$ OR HCO_3^- reacts with added acid - Increase in OH^- / addition of alkali leads to: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$ OR $\text{H}_2\text{CO}_3(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{HCO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$ OR H_2CO_3 reacts with added alkali Calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio $K_a = 10^{-6.38}$ OR $4.17 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ $[\text{H}^+] = 10^{-7.40}$ OR $3.98 \times 10^{-8} \text{ (mol dm}^{-3}\text{)}$ $\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ OR $\frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}}$ - ratio = 10.47(:1) OR 10.48(:1) ALLOW 10.5 OR 10(:1) (after working shown) ALLOW $\frac{4.2 \times 10^{-7}}{4.0 \times 10^{-8}}$ And ratio = 10.5 OR 11 (after working shown)

Question			Answer	Marks	AO element	Guidance
			OR Partial explanation of equilibrium and attempt at calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio.' OR Partial explanation of the action of the buffer and attempt at calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>			ALLOW $\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$ OR $\frac{3.98 \times 10^{-7}}{4.17 \times 10^{-7}}$ And ratio = 1 : 0.095 ..

Question			Answer	Marks	AO element	Guidance
7	(a)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.98 award 2 marks $[H^+] = \sqrt{(K_a \times [C_2H_5COOH])} = 1.039 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ $pH = -\log 1.039 \times 10^{-3} = 2.98 \text{ (Must be to 2 DP)} \checkmark$	2	2.2 x2	ALLOW ECF throughout ONLY ALLOW pH mark by ECF if K_a AND 0.080 used and AND pH <7 Common errors (Must be to 2 DP) One mark for pH = 5.97 (<i>No square root</i>): One mark for pH = 0.92 OR pH = 5.15 (<i>Using incorrect K_a values</i>)
	(b)	(i)	$n(C_2H_5COOH) = (0.0800 \times \frac{25.0}{1000}) = 0.002 \text{ (mol)}$ AND $V(NaOH) = \frac{0.002}{0.100} \times 1000 = (= 20(.0) \text{ cm}^3) \checkmark$	1	2.5	ALLOW 0.02 dm ³ if unit given Mark is for WORKING which could all be shown as 1 step ALLOW method showing 20cm ³ NaOH contains the same moles as acid $n(C_2H_5COOH) = 0.08(00) \times 0.025(0) = 0.002 \text{ (mol)}$ and $n(NaOH) = 0.02(00) \times 0.1 = 0.002(00) \text{ (mol)}$
7	b	(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE	4		ALLOW ECF throughout

Question			Answer	Marks	AO element	Guidance
7			If answer = 12.55 award 4 marks ----- Excess mol of NaOH: $n(\text{OH}^-)_{\text{excess}} = n(\text{OH}^-) - n(\text{C}_2\text{H}_5\text{COOH})$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ $= 0.0045 - 0.002 = 0.0025 \text{ (mol)} \checkmark$ Concentration of OH⁻: $[\text{OH}^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357 \text{ (mol dm}^{-3}\text{)} \checkmark$ Concentration of H⁺: $[\text{H}^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13} \text{ (mol dm}^{-3}\text{)} \checkmark$ Conversion to pH: $\text{pH} = (-\log 2.8 \times 10^{-13}) = 12.55 \checkmark$			For first mark ALLOW (Excess volume of NaOH = 25(.0) cm³) $n(\text{OH}^-)_{\text{excess}} = 0.100 \times \frac{25.0}{1000} = 0.0025 \text{ (mol)}$ Common errors If initial V(NaOH) = 45 cm³ $[\text{OH}^-] = 0.0643 \text{ (mol)}$ $[\text{H}^+] = 1.56 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$ pH = 12.81 award three marks (no 1st mark) If $n(\text{OH}^-)_{\text{excess}}$ is used in $[\text{H}^+]$ calculation $n(\text{OH}^-)_{\text{excess}} = 0.0025 \text{ (mol)}$ $[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.00 \times 10^{-12} \text{ (mol dm}^{-3}\text{)}$ pH = 11.40 award three marks (no 2nd mark) ALLOW pOH method for last two marks pOH = $-\log[\text{OH}^-] = 1.447$ pH = $14 - 1.447 = 12.55$ ALLOW ECF for conversion from $[\text{H}^+]$ to pH provided value calculated is above 7 and from derived $[\text{H}^+]$
	b	(iii)	Shape	3	2.3 x1	If pH curves wrong way round (i.e. adding acid to

Question			Answer	Marks	AO element	Guidance
			Slight rise/flat, AND (near) vertical, AND then slight rise/flat ✓ 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 ✓ End point Vertical section at ~ 20 cm³ NaOH ✓		2.4 × 2	alkali), ONLY award mark for End point (~ 20 cm ³)
		(iv)	cresol purple AND pH range matches vertical section/rapid pH change OR end point/colour change matches vertical section/rapid pH change ✓	1	3.3	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>
		(v)	similarity: end point / volume (20 cm³) of NaOH needed to neutralise OR final pH / shape of curve after end point ✓ difference: HCN higher starting pH OR HCN shorter vertical section ✓	2	3.2 × 2	End point must not refer to same pH ALLOW different equivalence point IGNORE different starting pH

Question			Answer	Marks	AO element	Guidance
7	(c)		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 $[\text{HIO}_3]_{\text{initial/undissociated}}$ ✓	1	3.3	ALLOW use of HA Ignore $[\text{HIO}_3]_{\text{equilibrium}} < [\text{HIO}_3]_{\text{initial/undissociated}}$ ALLOW $[\text{HIO}_3]_{\text{equilibrium}} \sim [\text{HIO}_3]_{\text{undissociated}}$ is no longer a valid assumption

Question	Answer	Marks	AO	Guidance
8	D	1	2.2	

9(a)		$\text{HCOOH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{HCOO}^- + \text{CH}_3\text{COOH}_2^+ \checkmark$ A1 B2 B1 A2 OR A2 B1 B2 A1 $\checkmark$ CARE: Both + and – charges required for products in equilibrium DO NOT AWARD the 2nd mark from an equilibrium expression that omits either charge	2	1.2×2	IGNORE state symbols (even if wrong) IF proton transfer is wrong way around ALLOW 2nd mark for idea of acid–base pairs, <i>i.e.</i> $\text{HCOOH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{HCOOH}_2^+ + \text{CH}_3\text{COO}^-$ B2 A1 A2 B1 NOTE For the 2nd marking point (acid–base pairs), this is the ONLY acceptable ECF <i>i.e. NO ECF from impossible chemistry</i>
	(b)	(i) $[\text{H}^+] = 10^{-2.72}$ OR $1.905 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $\checkmark$ $[\text{CH}_3\text{COOH}] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}} \checkmark$ (= 0.204 mol dm^{−3})	2	2.4×2	ALLOW 2SF up to calculator value of $1.905460718 \times 10^{-3}$ ALLOW use of [HA] Mark is for working.

[illegible]

Question			Answer	Marks	AO element	Guidance
			ALLOW alternative approach based on Henderson–Hasselbalch equation (ALLOW $-\log K_a$ for pK_a) e.g. $pH = pK_a + \log \frac{[CH_3COOH]}{[CH_3COO^-]} \text{ OR } pK_a - \log \frac{[CH_3COO^-]}{[CH_3COOH]} \text{ OR}$ $4 = 4.75 + \log \frac{8.16 \times 10^{-2}}{[CH_3COO^-]} \text{ OR } 4.75 - \log \frac{[CH_3COO^-]}{8.16 \times 10^{-2}} \checkmark$ $\log [CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84 \checkmark$ $[CH_3COO^-]_{\text{buffer}} = 1.5 \times 10^{-2} \checkmark$ $[CH_3COO^-]_{\text{initial}} = 2.4 \times 10^{-2} \checkmark$			ALLOW $-\log K_a$ for pK_a -----

Question	Answer	Marks	AO element	Guidance
10	A	1	AO2.6	

Question			Answer	Marks	AO element	Guidance
11	(a)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 13.15 award 2 marks ----- $[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.140} = 7.14 \dots \times 10^{-14} \text{ (mol)} \checkmark$ $\text{pH} = -\log (7.14 \dots \times 10^{-14}) = 13.15 \checkmark$ 2 DP required	2	AO2.2 ×2	ALLOW ECF providing $\text{pH} > 7$ Calculator: $7.142857143 \times 10^{-14}$ ALLOW pOH method $\text{pOH} = -\log(0.14) = 0.85 \dots \dots \checkmark$ $\text{pH} = 14.00 - (0.85 \dots \dots) = 13.15 \checkmark$

Question		Answer	Marks	AO element	Guidance
	(b)*	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Reaches a comprehensive conclusion with most detail and few errors for the formation of the buffer AND Calculation of the correct buffer pH AND Correct mass of N_2O_3. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a sound conclusion with some detail and some errors for Formation of buffer AND Calculation of the buffer pH OR Formation of buffer AND Mass of N_2O_3. OR Calculation of the buffer pH AND Mass of N_2O_3. OR Partial explanations of formation of the buffer AND buffer pH AND Mass of N_2O_3. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts, with some success, to: Describe formation of buffer OR Calculate buffer pH OR Obtain mass of N_2O_3. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	AO1.2 ×2 AO2.6 ×2 AO3.1 ×2	Indicative scientific points may include: 1. Formation of buffer - Acid / HNO_2 is in excess $\text{HNO}_2 + \text{NaOH} \rightarrow \text{NaNO}_2 + \text{H}_2\text{O}$ - Partial neutralisation of HNO_2 $\rightarrow$ formation of NO_2^- / NaNO_2 - Buffer contains HNO_2 AND NO_2^- / NaNO_2 2. Calculation of buffer pH $n(\text{HNO}_2)$ added = 0.0500 (mol) $n(\text{NaOH})$ added = 0.0150 (mol) $n(\text{NO}_2^-)$ formed = 0.0150 (mol) $n(\text{HNO}_2)$ remaining = $0.0500 - 0.0150 = 0.0350$ (mol) $K_a = 10^{-3.34} = 4.57 \dots \times 10^{-4}$ (mol dm^{-3}) - Concentrations = mol (volume 1 dm^3) $[\text{H}^+] = \frac{4.57 \dots \times 10^{-4} \times 0.0350}{0.0150}$ $= 1.0665 \dots \times 10^{-3}$ (mol dm^{-3}) - pH = 2.97 - pH to 2 dec places 3. Calculation of mass of N_2O_3 1 mol $\text{N}_2\text{O}_3 \rightarrow 2$ mol HNO_2 OR $\text{N}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_2$ $n(\text{HNO}_2) = 0.0500$ (mol) $n(\text{N}_2\text{O}_3) = 0.0500/2 = 0.0250$ (mol) $m(\text{N}_2\text{O}_3) = 0.0250 \times 76 = 1.9(0)$ g

Question	Answer	Marks	AO	Guidance
12	D	1	2.3	

Question	Answer	Marks	AO	Guidance
13	C	1	1.2	

Question			Answer	Marks	AO element	Guidance
14(a)		(i)	(Glycolic) acid is in excess/partially neutralised AND glycolate/potassium glycolate (ions) are present/produced ✓	1	AO1.1	ALLOW some acid remains ALLOW conjugate base for glycolate ions/salt of weak acid ALLOW HOCH ₂ COO ⁻
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 3.93 award 4 marks Initial amounts $n(\text{HOCH}_2\text{COOH}) = 0.750 \times \frac{60.0}{1000} \quad \text{OR} \quad 0.045(0) \text{ (mol)}$ $\text{AND } n(\text{KOH}) = 0.625 \times \frac{40.0}{1000} \quad \text{OR} \quad 0.025(0) \checkmark$ Amounts in the buffer solution $n(\text{HOCH}_2\text{COOH}) = 0.0450 - 0.0250 \quad \text{OR} \quad 0.02(00) \text{ (mol)}$ $\text{AND } n(\text{HOCH}_2\text{COO}^-) \quad \quad \quad 0.025(0) \text{ (mol)} \checkmark$ pH $K_a = 10^{-3.83} \quad \text{OR} \quad 1.479 \dots \times 10^{-4} \checkmark$ $[\text{H}^+] = \frac{1.479 \dots \times 10^{-4} \times 0.200}{0.250} \quad \text{OR} \quad 1.183 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = 3.93 \text{ (2 DP)} \checkmark$	4	AO1.2 ×1 AO2.8 ×3	ALLOW use of moles for concentration $[\text{H}^+] = \frac{1.479 \dots \times 10^{-4} \times 0.0200}{0.0250}$ Common errors 3 marks pH = 3.57 not using n(HA) remaining 2 marks pH = 3.75 using HA and KOH concentrations within question

Question			Answer	Marks	AO element	Guidance
		(iii)	$\text{NH}_3 / \text{OH}^-$ reacts with $\text{H}^+ / \text{HOCH}_2\text{COOH}$ / (Glycolic) acid ✓ $\text{HOCH}_2\text{COOH} \rightleftharpoons \text{H}^+ + \text{HOCH}_2\text{COO}^-$ AND Equilibrium shifts to the right ✓	2	AO1.2 ×2	ALLOW NH_3 will act as a base (and form NH_4^+) ALLOW NH_3 decreases $[\text{H}^+]$ ALLOW $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$ Equilibrium equation needs to be

Question	Answer	Marks	AO element	Guidance
15	D	1	AO2.6	

Question			Answer	Marks	AO element	Guidance
16	(a)	(i)	FIRST CHECK THE ANSWER ON ANSWER LINE if answer = 6.77 award 2 marks $K_w = [\text{H}^+][\text{OH}^-]$ OR $K_w = [\text{H}^+]^2$ OR $[\text{H}^+] = \sqrt{K_w}$ ✓ $([\text{H}^+] = \sqrt{(2.92 \times 10^{-14})})$ $\text{pH} = -\log(1.71 \times 10^{-7}) = 6.77$ ✓	2	AO1.1 ×1 AO2.2 ×1	DO NOT ALLOW use of A^- or X^-
		(ii)	(In pure water), $[\text{H}^+]$ (always) equals $[\text{OH}^-]$	1	AO3.2 ×1	ALLOW moles/number of H^+ is (always) equal to moles/number of OH^- DO NOT ALLOW ratio $[\text{H}^+] : [\text{OH}^-]$ doesn't change
	(b)		Equation $\text{Sr} + 2\text{H}_2\text{O} \rightarrow \text{Sr}(\text{OH})_2 + \text{H}_2$ ✓ CHECK THE ANSWER ON ANSWER LINE if answer = 11.51 award 4 calculation marks $n(\text{Sr}(\text{OH})_2)$ $= \frac{0.145}{121.6} = 1.1924 \dots \times 10^{-3}$ ✓ $[\text{OH}^-]$ $= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539 \dots \times 10^{-3}$ ✓ $[\text{H}^+] = K_w \div [\text{OH}^-]$ $= \frac{2.92 \times 10^{-14}}{9.539 \dots \times 10^{-3}} = 3.061 \dots \times 10^{-12}$ ✓	5	AO2.6 AO2.4 ×3 AO1.2 ×1	IGNORE state symbols (even if wrong) ALLOW multiples ALLOW $\text{Sr}^{2+} + 2\text{OH}^-$ for $\text{Sr}(\text{OH})_2$ ALLOW 3 SF up to the calculated value. Ignore RE after 3SF. ALLOW ECF throughout but final answer must be $\text{pH} > 7$

			$\text{pH} = -\log(3.061 \dots \times 10^{-12}) = 11.51 \checkmark$ 2 DP required		Final answer must be from calculated values. Common errors for 3 calculation marks 11.98 (<i>Use of $K_w = 1 \times 10^{-14}$</i>) 11.21 (<i>no $\times 2$</i>) 10.91 (<i>$\div$ by 2</i>) Common error for 2 calculation marks pH = 11.67 (<i>no $\times 2$ and wrong K_w</i>) ----- Alternative method for:- pH = pK_w – pOH $n(\text{Sr}(\text{OH})_2)$ $= \frac{0.145}{121.6} = 1.1924 \dots \times 10^{-3}$ [OH⁻] $= 2 \times (1.1924 \times 10^{-3} \div 0.25) =$ $9.539 \dots \times 10^{-3}$ pH = pK_w - pOH $= (-\log 2.92 \times 10^{-14}) - (-\log 9.539 \dots \times 10^{-3})$ pH = 13.53(46) - 2.02(05) = 11.51
--	--	--	--	--	--

	(c)	(i)	One mole of (butanoic) acid donates/dissociates to form one mole of protons/H ⁺ ✓	1	AO1.1	ALLOW One molecule of (butanoic) acid donates/dissociates to form one proton/H ⁺ ALLOW only one hydrogen ion in the acid can be replaced per molecule (in an acid-base reaction)
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE IF ANSWER = $1.5(3) \times 10^{-5}$ award 4 marks -----	4	AO1.2 ×1	FULL ANNOTATIONS MUST BE USED ----- ALLOW ECF throughout

			• $[H^+] = 10^{-pH}$ OR $10^{-5.07}$ OR 8.51×10^{-6} ✓ • $\left(\frac{3.39}{56.1}\right)$ OR 0.0604 (0.06042781) (nA^- in buffer) = ($n(KOH)$) OR 0.0604×4 OR 0.242 ✓ ($[A^-]$ in buffer) • nHA in buffer = $(0.376 \times 0.25) - 0.0604$ = $(0.094) - 0.0604$ OR 0.0336 (0.03357219...) OR $[HA]$ in buffer = $(0.376 - 0.242)$ OR 0.0336×4 OR 0.134 (0.13428877) ✓ • $K_a = [H^+][A^-] \div [HA]$ = $\frac{8.51 \times 10^{-6} \times 0.242}{0.134}$ = $1.5..... \times 10^{-5}$ (1.5319942×10^{-5}) ✓		AO2.6 ×3 ALLOW 2 SF for $[H^+]$ (use of pH) ALLOW 3 SF up to the calculated value. Ignore RE after 3SF for moles and concentration values Mark use of 2SF in working as incorrect once and then allow ECF ALLOW full marks for use of moles (volumes cancel) $K_a = \frac{8.51 \times 10^{-6} \times 0.0604}{0.0336}$ = 1.53×10^{-5} ALLOW final answer to 2SF Common errors for 3 marks $5.47(1731026) \times 10^{-6}$ (not subtracting moles of KOH from HA)
--	--	--	---	--	---

	(d)		ratio/proportion $[HA]/[A^-]$ is the same	1	AO3.1	ALLOW Change in $[HA]$ and $[A^-]$ is proportional ALLOW the concentrations of the weak acid and conjugate base change by same amount
--	-----	--	---	---	-------	---

Question	Answer	Marks	Guidance
17	A	1	

Question			Answer	Marks	Guidance
18	(a)	(i)	$(K_a) = \frac{[H^+][ClCH_2COO^-]}{[ClCH_2COOH]} \checkmark$	1	DO NOT ALLOW without square brackets DO NOT ALLOW $\frac{[H^+]^2}{[ClCH_2COOH]}$ DO NOT ALLOW $\frac{[H^+][A^-]}{[HA]}$
		(ii)	$[H^+] = [A^-]$ OR $[H^+]$ from water is negligible OR dissociation of water is negligible $\checkmark$	1	Answer must be in terms of concentration ALLOW $[H^+] \approx [A^-]$ IGNORE $HA \rightleftharpoons H^+ + A^-$ is a 1:1 mole ratio.
		(iii)	FIRST CHECK ANSWER ON ANSWER LINE If answer = 2.85 OR 2.86 OR 2.87 award 3 marks ----- $([H^+] =) 10^{-1.95}$ OR $= 1.1(22...) \times 10^{-2} \checkmark$ $(K_a) = \left(\frac{[H^+]^2}{[ClCH_2COOH]} \right)$ <math>= \frac{(1.122... \times 10^{-2})^2}{(0.090)} \text{ OR } \frac{(1.12 \times 10^{-2})^2}{(0.090)} \text{ OR } \frac{(1.1 \times 10^{-2})^2}{(0.090)}</math> <math>= 1.4(0) \times 10^{-3} \text{ OR } = 1.39 \times 10^{-3} \text{ OR } = 1.34 \times 10^{-3} \checkmark</math> <math>(pK_a = -\log_{10}(K_a) =) 2.85, 2.86 \text{ OR } 2.87 \text{ (2DP) } \checkmark</math>	3	ALLOW ECF throughout ALLOW $[H^+] = 1.1 \times 10^{-2}$ up to calculator value ALLOW 2 sig figs up to calculator value. ALLOW calculations based on finding the $[HA]_{\text{equ}}$ <math>\frac{(1.122... \times 10^{-2})^2}{(0.079)} \text{ OR } \frac{(1.12 \times 10^{-2})^2}{(0.079)} \text{ OR } \frac{(1.1 \times 10^{-2})^2}{(0.079)}</math> <math>= 1.59 \times 10^{-3} \text{ OR } = 1.59 \times 10^{-3} \text{ OR } = 1.53 \times 10^{-3} \checkmark</math> <math>(pK_a = -\log_{10}(K_a) =) 2.80 \text{ OR } 2.80 \text{ OR } 2.81 \text{ (2DP) } \checkmark</math> Must be 2DP

Question			Answer	Marks	Guidance
					Common error: 2 marks 0.90 (not using $[H^+]^2$)
	(b)	(i)	Smooth s-shaped curve using a best fit line that goes through the majority of points. ✓ Reading off x-axis at 12.5 cm³ ✓ $n(\text{Ba}(\text{OH})_2) = 0.0560 \times \frac{12.5}{1000}$ $= 7.00 \times 10^{-4}$ ✓ $n(\text{CH}_3\text{COOH}) = 2 \times (\text{moles Ba}(\text{OH})_2)$ $= 1.40 \times 10^{-3}$ ✓ (concentration) = $\frac{1.4 \times 10^{-3}}{(10/1000)}$ $= 0.14(0)$ (mol dm⁻³) ✓	5	DO NOT ALLOW point to point DO NOT ALLOW tram/feather lines. ALLOW Reading off x-axis from 12.4 – 12.6 cm ³ ALLOW ECF throughout ALLOW 3SF or more unless there is a trailing zero <u>Alternative answers:</u> 0.139 (mol dm ⁻³) (from reading off x-axis at 12.4 cm ³) 0.141 (mol dm ⁻³) (from reading off x-axis at 12.6 cm ³) Common errors: 3 Marks 0.134 (Use of 12 cm ³) 0.202 (use of 18 cm ³)

Question			Answer	Marks	Guidance
			<u>Alternative method based on calculating pK_a from the half neutralisation point.</u> pH and $[H^+]$ reading will come from the candidates graph and the data points provided. e.g. pH at half neutralisation $6.25 \text{ cm}^3 = \text{pH } 4.7 = pK_a \checkmark$ $K_a = 10^{-4.7}$ $= 1.995 \times 10^{-5} \checkmark$ $[H^+]$ at pH 3.3 (obtained from data on the graph provided) $10^{-3.3} = 5.012 \times 10^{-4} \text{ (mol dm}^{-3}) \checkmark$ $[HA] = \frac{[H^+]^2}{[K_a]}$ $= \frac{(5.012 \times 10^{-4})^2}{(1.995 \times 10^{-5})}$ $= 0.0126 \text{ (mol dm}^{-3}) \checkmark$		ALLOW MP2 for $K_a = 1.7 \times 10^{-5}$ to 1.8×10^{-5} (knowledge of actual K_a value) ALLOW ECF from any quoted K_a
		(ii)	Phenol red OR Phenolphthalein✓	1	Both indicators can change colour on the sharp vertical section of the candidates curve.

Question	Answer	Marks	Guidance
19	C	1	

Question			Answer	Mark	Guidance
20	(a)		0.82 ✓	1	(pH = $-\log(0.15)$) = 0.82 2 DP required
	(b)		Higher (pH) AND (Nitric acid fully ionises and) nitrous acid partially dissociates/ionises ✓ Lower <u>concentration</u> of H ⁺ ions (in nitrous acid) ✓	2	DO NOT ALLOW nitric acid is a stronger acid (in the question) IGNORE easily dissociates IGNORE does not fully dissociate/dissociates less ASSUME "It" refers to HNO ₂

Question		Answer	Mark	Guidance
	(c)*	Level 3 (5–6 marks) Correct method for the calculation of $[H^+]$ AND correct method for the calculation of $[CH_3CH_2COO^-]$ AND correct mass of CH_3CH_2COONa AND explains how pH changes in a buffer when OH^- is added with reference to an equilibrium equation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Correct method for the calculation of $[H^+]$ AND correct method for the calculation of $[CH_3CH_2COO^-]$ AND attempt at a method for calculation of mass of CH_3CH_2COONa OR an attempt at an explanation of how pH changes in a buffer when OH^- is added OR Correct method for the calculation $[H^+]$ AND attempt of method for calculating $[CH_3CH_2COO^-]$ AND correct method for calculation of mass of CH_3CH_2COONa OR an attempt at an explanation of how pH changes in a buffer when OH^- is added <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i>	6	ALLOW use of 2 SF up to calculator value ALLOW use of HA and A^- Calculation of concentrations $[H^+] = 10^{-pH} = 10^{-4.85}$ $= 1.4(125375...) \times 10^{-5} \text{ mol dm}^{-3}$ $[CH_3CH_2COO^-] = \frac{K_a \times [CH_3CH_2COOH]}{[H^+]}$ $= \frac{1.32 \times 10^{-5} \times 0.180}{1.4(125) \times 10^{-5}}$ $= 0.168(208) \text{ mol dm}^{-3}$ OR $0.16971... \text{ mol dm}^{-3}$ if 1.4×10^{-5} used This method could be contained within the working for the mass calculation Calculation of mass $n(CH_3CH_2COO^-) = 0.168 \times 0.125$ $= 0.0210(26) \text{ (mol)}$ $n(CH_3CH_2COONa) = n(CH_3CH_2COO^-)$ $M_r = 96.0$ $m(CH_3CH_2COO^-) = 0.0210(26) \times 96.0$ $= 2.02 \text{ g OR } 2.018 \text{ g}$ ALLOW range 2.00 g to 2.04 g ALLOW alternative methods that lead to correct mass.

Question	Answer	Mark	Guidance
	Level 1 (1–2 marks) Method for the calculation of $[H^+]$ AND $[CH_3CH_2COO^-]$ OR correct method for calculation of mass of CH_3CH_2COONa OR Explanation of how pH changes in a buffer when OH^- is added OR Method for the calculation of $[H^+]$ and a simplistic explanation of how pH changes in a buffer when OH^- is added OR Attempts the calculation of concentration and mass with a simplistic explanation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>		Action of buffer OH^- from addition of alkali: $H^+ + OH^- \rightarrow H_2O$ OR $CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$ OR OH^- reacts with H^+ / CH_3CH_2COOH / (propanoic) acid $CH_3CH_2COOH \rightleftharpoons H^+ + CH_3CH_2COO^-$ ALLOW $HA \rightleftharpoons H^+ + A^-$ equilibrium shifts to the right / (acid) further dissociates restoring $[H^+]$ therefore only a small change in $[H^+]$ minimising change in $\frac{[CH_3CH_2COOH]}{[CH_3CH_2COO^-]}$ Examples of the communication statement for all levels being met could typically include: clear mathematical working and appropriate units for calculated values