Question			Answer	Mark	Guidance
1	(a)	(i)	$HOCH_2COOH + NaOH \rightarrow HOCH_2COONa + H_2O$ ✓	1	**ALLOW:** $HOCH_2COOH + OH^- \rightarrow HOCH_2COO^- + H_2O$ **ALLOW:** $H^+ + OH^- \rightarrow H_2O$ **DO NOT ALLOW** molecular formulae (cannot see which OH has reacted)
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **0.142** (mol dm^{-3}), award **2 marks** --- amount of $HOCH_2COOH = 0.125 \times \frac{25.0}{1000}$ = 0.003125 (mol) ✓ concentration NaOH = $0.003125 \times \frac{1000}{22.00}$ = 0.142 (mol dm^{-3}) ✓ ---	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** 3.125×10^{-3} mol **ALLOW ECF**: answer above $\times \frac{1000}{22.00}$ **ALLOW** 2 SF: 0.14 to calculator value: 0.142045454 --- If candidate has written in **(a)(i)**: $HOCH_2COOH + \mathbf{2}NaOH$, mark by **ECF**: concentration NaOH = $\mathbf{2} \times 0.003125 \times \frac{1000}{22.00}$ = 0.284 (mol dm^{-3})
		(iii)	Vertical section matches the (pH) range (of the indicator) **OR** colour change (of the indicator) **OR** end point (of the indicator) ✓	1	**ALLOW** stated pH range for vertical section at about 7–10, 6–10, etc ie **ALLOW** 'pH range must be about 7–10' **ALLOW** 'pH changes rapidly' for vertical section **ALLOW** 'equivalence point' for vertical section, *ie* **ALLOW** equivalence point matches the (pH) range, *etc* **DO NOT ALLOW** just 'end point matches (pH) range' **DO NOT ALLOW** just 'indicator matches vertical section' Response **must** link either the pH range or colour change or end point with the vertical section / pH range ~ 7–10

Question			er	Mark	Guidance
	(b)	(i)	(K_a =) $\frac{[H^+][HOCH_2COO^-]}{[HOCH_2COOH]}$ ✓	1	**IGNORE** state symbols **IGNORE** $\frac{[H^+]^2}{[HOCH_2COOH]}$ in **(i)** but **ALLOW** in **(ii)**
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **1.46 x 10^{-4}**, award **2 marks** **THEN IF** units are **mol dm^{-3}**, award 1 **further mark** --- $[H^+] = 10^{-2.37} = 0.00427$ (mol dm^{-3}) ✓ $K_a = \frac{0.00427^2}{0.125} = 1.46 \times 10^{-4}$ ✓ units: mol dm^{-3} ✓	2 1	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **UNITS** can be credited with no numerical answer --- **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** 4.27 x 10^{-3} (mol) **ALLOW** 2 SF: 0.0043 up to 0.0042 5795188 (calc value) **IF** candidate has rounded to 0.00427 (mol dm^{-3}) in 1st response, credit **EITHER** 2 SF: 1.5 x 10^{-4} up to 1.458632 × 10^{-4} (from 0.00427) **OR** 2 SF: 1.5 x 10^{-4} up to 1.455760687 × 10^{-4} (from unrounded calculator value of 0.004265795188) **ALLOW** calculation based on equilibrium conc of glycolic acid as 0.125 – $[H^+]$: Using $[H^+] = 0.00427$, $K_a = \frac{0.00427^2}{0.125 - 0.00427} = 1.51 \times 10^{-4}$ For **UNITS** this is the **ONLY** correct answer
		(iii)	% dissociation = $\frac{0.00427}{0.125} \times 100$ = 3.4 (%) ✓ Assume working from **EITHER** from a rounded $[H^+]$ **OR** unrounded calculator value of **b(ii)** $[H^+]$	1	**ALLOW** ECF using calculated $[H^+]$ from **b(ii),** **ALLOW** 2 SF: 3.4 % up to calculator value ***Note:*** $[H^+]$ from **b(ii)** displayed *at top of answer window* ***DO NOT MARK THIS TWICE!***

Question			Answer	Mark	Guidance
	(c)		**ONE mark for equilibrium expression** equilibrium: $HOCH_2COOH \rightleftharpoons H^+ + HOCH_2COO^-$ ✓ --- **Four marks for action of buffer** $HOCH_2COOH$ reacts with added alkali **OR** $HOCH_2COOH + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓ $\rightarrow HOCH_2COO^-$ **OR** Equilibrium $\rightarrow$ right ✓ $HOCH_2COO^-$ reacts with added acid ✓ $\rightarrow HOCH_2COOH$ **OR** Equilibrium $\rightarrow$ left ✓ --- **Two marks for preparation of buffer** Ammonia reacted with an **excess** of glycolic acid **OR** some glycolic acid remains ✓ $HOCH_2COOH + NH_3 \rightarrow HOCH_2COONH_4$ ✓	1 4 2	**ANNOTATE WITH TICKS AND CROSSES, etc** **DO NOT ALLOW** H^+, A^- and HA **ALLOW** < – > as alternative for equilibrium sign --- **ALLOW** response in terms of H^+, A^- and HA Equilibrium responses **must** refer back to a written equilibrium: **IF** more than one equilibrium shown, assume correct one **ALLOW** weak acid reacts with added alkali **DO NOT ALLOW** acid reacts with added alkali **ALLOW** conjugate base reacts with added acid **DO NOT ALLOW** salt/base reacts with added acid --- **ALLOW** as products $HOCH_2COO^- + NH_4^+$ **ALLOW** $\rightleftharpoons$ sign instead of $\rightarrow$
	(d)		Base 1 + Acid 2 $\rightleftharpoons$ Acid 1 + Base 2 1st mark for identifying acids and bases. ✓ 2nd mark for correct pairing (ie numbers) ✓	2	**ALLOW**: Base 2 + Acid 1 $\rightleftharpoons$ Acid 2 + Base 1

Question	Answer	Mark	Guidance
(e)	$2HSCH_2COO^- + R–S–S–R \longrightarrow {}^-OOCCH_2S–SCH_2COO^- + 2$ SH ✓		**ALLOW** $(SCH_2COO^-)_2$ **ALLOW** equation with ammonium salt, ie:
	$2R–SH + H_2O_2 \longrightarrow R–S–S–R + 2H_2O$ ✓	2	$2HSCH_2COONH_4$ + ……. $\longrightarrow H_4NOOCCH_2S–SCH_2COONH_4$ + …….
	Total	**20**	

Question			Answer	Mark	Guidance
2	(a)	(i)	(K_w =) $[H^+(aq)]$ $[OH^-(aq)]$ ✓	1	**IGNORE** state symbols **ALLOW** $[H_3O^+(aq)]$ $[OH^-(aq)]$
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **2.3×10^{-10}** (mol dm^{-3}), award **2 marks** **IF** answer = **2.34×10^{-10}** (mol dm^{-3}) , award **1 mark** --- $[H^+] = 10^{-pH} = 4.27 \times 10^{-5}$ (mol dm^{-3}) ✓ $[OH^-] = \frac{1.0 \times 10^{-14}}{4.27 \times 10^{-5}}$ $= 2.34 \times 10^{-10}$ $= 2.3 \times 10^{-10}$ (mol dm^{-3}) ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ANNOTATE WITH TICKS AND CROSSES, etc** --- **ALLOW** 4.3×10^{-5} up to calculator: $4.265795188 \times 10^{-5}$ **ALLOW** 0.0000427 Answer **MUST** be to 2 SF (in question) **ALLOW** = 2.3×10^{-x} (mol dm^{-3}) for 1 mark (must be a negative power) **ALLOW** alternative approach based on pOH: pOH = 14 – 4.27 = 9.63 ✓ (**DO NOT ALLOW** 9.6) $[OH^-] = 10^{-pOH} = 10^{-9.63} = 2.3 \times 10^{-10}$ (mol dm^{-3}) ✓
	(b)	(i)	Endothermic **because** K_w increases with temperature ✓	1	Endothermic **AND** reason required for the mark **ALLOW** Endothermic **because** increasing temperature shifts equilibrium/reaction to the right
		(ii)	K_w value from graph from 2.2 to 2.6 × 10^{-14} (mol^2 dm^{-6})✓ Using 2.4×10^{-14}, $[H^+] = \sqrt{2.4 \times 10^{-14}}$ **OR** 1.55×10^{-7} ✓ pH = –log (1.55×10^{-7}) = 6.81 (using $K_w = 2.4 \times 10^{-14}$) ✓	3	**ANNOTATE WITH TICKS AND CROSSES, etc** Actual $K_w = 2.38 \times 10^{-14}$ mol^2 dm^{-6} For this mark, candidate **must** use a value between 2.0 and 3.0×10^{-14} (mol^2 dm^{-6}), *ie* from the approximately correct region of the graph, **ALLOW** 6.8 up to calculator value **Note**: You will need to calculate the pH value from the candidate's estimate of K_w at 37 ºC before awarding the 3rd marking point **ONLY** award an **ECF** pH mark if candidate has generated a value of $[H^+]$ by attempting to take a square root of a value between 2.0 and 3.0×10^{-14}

Question		Answer	Mark	Guidance
(b)	(iii)	(Work is) inaccurate **OR** invalid **because** K_w varies with temperature ✓	1	Response requires **reason** for inaccuracy/invalidity in terms of K_w **ALLOW** incorrect with reason **IGNORE** unreliable **ALLOW** inaccurate because wrong K_w was used For K_w varies with temperature, **ALLOW** equilibrium shifts with temperature
(c)		Acid and alkali mixed ✓ Amounts of acid **AND** alkali stated ✓ Temperature taken at start **AND** finish ✓ energy, $Q = mc\Delta T$ **OR** in words **AND** meaning of m, c **AND** ΔT given ✓ Energy scaled up to form 1 mol of water ✓ ΔH_{neut} = –energy change ✓	6	**ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** 'base' for 'alkali throughout **ALLOW** if mentioned anywhere which could be within a definition for enthalpy change of neutralisation Amounts could be expressed as amounts, moles, volumes **OR** concentrations **ALLOW** temperature change m = mass/volume of solution/reactants/mixture, etc (but **NOT** surroundings) c = (specific) heat capacity (of solution/water) **OR** 4.18/4.2 ΔT = temperature change **ALLOW** divide energy by moles **ALLOW** '–' sign shown in earlier part, ie $\Delta H_{neut} = -\frac{Q}{n}$ **ALLOW** a statement linking ΔH with temperature change, *ie*: **IF** temperature increases, ΔH_{neut} is –**ve** **OR IF** temperature decreases, ΔH_{neut} is +ve

Question	Answer	Mark	Guidance
(d)	**Ionic radius** Potassium ion **OR** K^+ **OR** K ion is smaller **OR** K^+ has greater charge density ✓ **Lattice enthalpy** Lattice enthalpy of KF is more negative than RbF ✓ **OR** K^+ has greater attraction for F^- **Hydration enthalpy** ΔH(hydration) of K^+ is more negative than Rb^+ ✓ **OR** K^+ has greater attraction for H_2O **Enthalpy change of solution** Idea that ΔH(solution) is affected more by lattice enthalpy than by hydration enthalpy ✓	4	**ANNOTATE WITH TICKS AND CROSSES, etc** **Throughout question, ORA** in terms of Rb^+ **Throughout question, ALLOW** energy for enthalpy **DO NOT ALLOW** potassium **OR** K **OR** reference to atoms (*ie* reference to ions is required throughout a response) **ALLOW** lattice enthalpy of KF > lattice enthalpy of RbF **ALLOW** more energy needed to separate K^+ **AND** F^- **IGNORE** KF has stronger bonds **ALLOW** ΔH(hydration) of K^+ > ΔH(hydration) of Rb^+ **ALLOW** more energy needed to separate K^+ **AND** H_2O **IGNORE** K^+ has a stronger bond to H_2O **ALLOW** a correct attempt to link the contribution of lattice enthalpy and hydration enthalpy to ΔH(solution), *ie* lattice enthalpy is a more important factor than hydration enthalpy
(e)	(During dissolving,) entropy/disorder increases **OR** disorder increases ✓ $T\Delta S > \Delta H$ **OR** $T\Delta S$ is more positive than ΔH **OR** $\Delta H - T\Delta S$ is negative ✓	2	**ALLOW** entropy change is positive **OR** ΔS is positive **OR** $T\Delta S$ is positive **ALLOW** ΔS(system) > $\Delta H/T$ **ALLOW** ΔS(system) is more positive than $\Delta H/T$ ✓ **ALLOW** ΔS(system) + ΔS(surroundings) is positive **ALLOW** Energy contribution from increase in entropy is greater than decrease in energy from enthalpy change **OR** entropy change outweighs enthalpy change **IGNORE** ΔG is negative
	Total	**20**	