



Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<ul style="list-style-type: none"> correct acid-base pairs identified and linked 	<p>Examples of acid-base pairs</p> $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ <p>base 2/B2 acid 1/A1 acid 2/ A2 base 1/B1 or</p> $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ <p style="text-align: center;"> </p> <p style="text-align: center;">base acid acid base</p> <p>or</p> $\text{CH}_3\text{COOH} + \text{HCOOH} \rightarrow \text{CH}_3\text{COOH}_2^+ + \text{HCOO}^-$ <p style="text-align: center;">base / B acid / A conjugate conjugate</p> <p>acid / CA base / CB Allow any clear identification of acid and base and connection between the correct pairs</p>	(1)

Q2.

Question Number	Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> (a Brønsted-Lowry base is a) proton acceptor 	<p>Allow accepts protons / H⁺ (ions) / hydrogen ions</p> <p>Do not award additional references to reacting with OH⁻ / alkali</p>	(1)



Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> axes the correct way round, labelled, including units and suitable scale with points covering at least half the paper in both directions (1) points plotted correctly ($\pm 1/2$ small square) and smooth curve (1) value of K_w at 45°C (1) 	<p><u>Example of graph</u></p> <p>Allow $K_w / 10^{-14} / \text{mol}^2 \text{dm}^{-6}$ as units on y axis Allow $K_w \times 10^{-14} / \text{mol}^2 \text{dm}^{-6}$ $4.0 \times 10^{-14} (\text{mol}^2 \text{dm}^{-6})$ Allow 3.8 to $4.2 \times 10^{-14} (\text{mol}^2 \text{dm}^{-6})$ with no working TE on their working from their graph If they have converted K_w to $\text{p}K_w$, drawn a graph with correctly labelled axes and line of best fit then they can access all three marks as long as their final answer is K_w</p>	(3)



Question Number	Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> deduction of expression relating K_w and $[H^+(aq)]$ (1) calculation of $[H^+(aq)]$ (1) calculation of pH (1) 	<p>Example of calculation $(K_w = [H^+(aq)][OH^-(aq)]$ but $[H^+(aq)] = [OH^-(aq)]$ so $K_w = [H^+(aq)]^2$</p> <p>$[H^+(aq)]^2 = 1.47 \times 10^{-14}$ $[H^+(aq)] = \sqrt{1.47 \times 10^{-14}}$ (so $[H^+(aq)] = 1.2124 \times 10^{-7}$ (mol dm⁻³))</p> <p>pH = $-\log 1.2124 \times 10^{-7}$ = 6.9163 / 6.916 / 6.92 / 6.9</p> <p>Do not award 1SF or final answer of 7 or answer incorrectly rounded to 6.91</p> <p>pH TE on $[H^+]$</p> <p>Correct answer with no working scores (3)</p> <p>Allow alternative methods</p>	(3)

Q4.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculation of $[H^+]$ (1) use of K_a expression to calculate K_a (1) calculation of pK_a (1) 	<p>Example of calculation</p> <p>$[H^+] = 10^{-2.20} = 6.3096 \times 10^{-3}$ (mol dm⁻³)</p> <p>$K_a = (6.3096 \times 10^{-3})^2 / 0.240$ = 1.6588×10^{-4}</p> <p>$pK_a = -\log [1.6588 \times 10^{-4}] = 3.7802$</p> <p>ignore SF except 1SF ignore units allow TE throughout</p> <p>correct answer with no working scores 3</p>	(3)



Q5.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculation of $[H^+(aq)]$ 	<p><u>Example of calculation</u> $[H^+(aq)] = 10^{-pH} = 10^{-9.43}$</p> <p>$= 3.7154 \times 10^{-10} / 3.715 \times 10^{-10} / 3.72 \times 10^{-10} / 3.7 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$</p> <p>Do not award 3.71×10^{-10}</p> <p>Ignore units even if incorrect</p> <p>Ignore SF except 1 SF</p> <p>Correct answer with no working scores (1)</p>	(1)

Q6.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculation amount of $H_2SO_4(aq)$ in mol (1) calculation amount of $H^+(aq)$ in mol / amount needed (1) calculation amount of $OH^-(aq)$ in mol (1) calculation amount of excess $OH^-(aq)$ in mol (1) calculation $[OH^-]$ in resultant mixture (1) calculation pH of resultant mixture (1) 	<p><u>Example of calculation</u> $= (40.4/1000) \times 0.370 = 0.014948$</p> <p>$0.014948 \times 2 = 0.029896 \text{ (mol)}$</p> <p>$= (51.2/1000) \times 0.927 = 0.047462 \text{ (mol)}$</p> <p>$= 0.047462 - 0.029896 = 0.017566 \text{ (mol)}$</p> <p>$= 0.017566 / (91.6/1000) = 0.19177 \text{ (mol dm}^{-3}\text{)}$</p> <p>$[H^+] = 1.00 \times 10^{-14} / 0.19177 = 5.2146 \times 10^{-14} \text{ (mol dm}^{-3}\text{)}$ $pH = -\log 5.2146 \times 10^{-14}$ $= 13.3$</p> <p>or $14 - (-\log(0.19177)) = 13.3$</p> <p>Final answer needs to be to at least 1dp Allow TE throughout but TE from M5 to M6 must give a pH > 7 Correct answer with no / some working scores 6 marks Ignore SF except 1 SF in M1 to M5</p>	(6)



Q7.

Question number	Answer	Mark
	<p>The only correct answer is A (solution J: HCl(aq) and NH₃(aq), solution K: CH₃COOH(aq) and NaOH(aq))</p> <p>B is incorrect because the salt formed from a strong acid (HCl) and a strong base (NaOH) will have pH 7 while that formed from a weak acid (CH₃COOH) and a weak base (NH₃) will have pH close to 7</p> <p>C is incorrect because the salt formed from a weak acid and a strong base will have a pH of about 9 while that formed from a strong acid and a strong base will have pH 7</p> <p>D is incorrect because the salt formed from a weak acid and a weak base will have a pH of about 7 while that formed from a strong acid and a weak base will have pH of about 5</p>	(1)



Q8.

Question Number	Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following points:</p> <p>Titration</p> <ul style="list-style-type: none"> titrate (ethanoic acid /weak acid) with strong base / sodium hydroxide (1) <p>Then follow the three points for Method 1 or Method 2</p> <p>Method 1</p> <ul style="list-style-type: none"> measure pH at regular intervals (1) plot pH against volume (of strong base) (1) use graph to find pH at half-equivalence point (1) <p>OR</p> <p>Method 2</p> <ul style="list-style-type: none"> use phenolphthalein indicator to find end-point (1) then add same volume of acid to mixture (at end-point) (1) 	<p>Stand alone</p> <p>Allow any indication of a titration</p> <p>Allow acid added to base or base added to acid</p> <p>In both methods, ignore reference to making a standard solution / calibration of the pH probe or meter / practical details of carrying out the titration</p> <p>Allow plot a titration / pH curve</p> <p>Allow use graph to find pH at volume when half neutralised</p> <p>Allow thymol blue / thymolphthalein indicators</p> <p>Ignore colour change even if incorrect</p> <p>Allow repeat titration (with same volumes but without indicator) then add original volume of acid to mixture (at end-point) or use same volume of acid and half the volume of base</p> <p>Do not award pH at end point is 7</p> <p>Stand alone</p> <p>Allow $[H^+] = 10^{-pH}$ and $K_a = [H^+]$</p>	(5)
	<ul style="list-style-type: none"> measure pH of resultant mixture (with pH meter) (1) <p>Determining K_a</p> <ul style="list-style-type: none"> (at half neutralisation $pH = pK_a$ so) $K_a = 10^{-pH}$ (1) 		



Q9.

Question Number	Answer	Additional Guidance	Mark
	<p>An answer that makes reference to one of the following points</p> <ul style="list-style-type: none"> the loss of a hydrogen from the O–H group is made possible by the delocalisation of charge of/stabilisation on the carboxylate ion or the loss of a hydrogen from a methyl group would produce a carbanion with no stabilisation or similar electronegativities of carbon and hydrogen means that there is a lack of C–H bond polarity or the enthalpy of hydration of the ions outweighs the energy needed to break the O–H bond 	<p>Allow the C–H bond is not polar but the O–H bond is/ O–H bond is more polar</p> <p>Do not award the O–H bond is weaker than the C–H bond</p>	(1)

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	<ul style="list-style-type: none"> calculation of moles of H⁺ in 25.0 cm³ (1) calculation of moles of H⁺ in 250 cm³ flask (1) 	<p>Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only</p> <p><u>Example of calculation:</u> (moles NaOH = $0.200 \times \frac{23.60}{1000}$) = 0.00472 (mol) (= mol H⁺ in 25.0 cm³) (= 10×0.00472) = 0.0472 (mol) (in 250 cm³)</p> <p>Allow TE for M2 on moles of NaOH</p> <p>Correct answer with or without working scores 2 marks</p>	(2)



Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	<ul style="list-style-type: none"> subtracts moles of H⁺ in HCl from answer to (b)(i) 	Example of calculation: $0.0472 - 0.00400 = 0.0432$ (mol) Allow TE on answer to part (b)(i)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	<ul style="list-style-type: none"> calculation of moles of CH₃COOH that have reacted 	Example of calculation: $(0.105 - 0.0432) = 0.0618$ Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	<ul style="list-style-type: none"> calculation of equilibrium moles of CH₃CH₂CH₂OH (1) calculation of equilibrium moles of CH₃COOCH₂CH₂CH₃ (1) calculation of equilibrium moles of H₂O (1) 	Example of calculation: $0.0800 - 0.0618 = 0.0182$ 0.0618 $0.111 + 0.0618 = 0.1728$ Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	$(K_c =)$ $\frac{[\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: <ul style="list-style-type: none"> Same number of moles/molecules on both sides of the equation (1) (so) volume / V cancels in K_c expression (1) 	2 marks could be scored by a correct mathematical expression showing V or dm ³ cancel Allow same number of terms on top and bottom of K _c expression Allow units cancel out Allow "all divided by the same volume"	(2)



Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	<ul style="list-style-type: none"> calculates value of K_c (1) final value of K_c quoted to 2 or 3 SF (1) 	<p>Example of calculation</p> $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ <p>= 14 / 13.6 (no units)</p> <p>Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression</p>	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the equilibrium shifts to the left or the mixture absorbs carbon dioxide from the atmosphere (1) so the mixture is (becoming more) acidic / the acid reforms (1) 	<p>Mark independently</p> <p>Allow no longer alkaline Do not award just "pH decreases"</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> carry out / repeat experiment and leave for longer than a week (1) the titre value / K_c value will remain unchanged (if equilibrium has been established) (1) 	<p>Ignore pH probes / checking pH</p> <p>Allow repeat experiment and check titres within first week</p> <p>Allow moles / concentration are unchanged Ignore just "results unchanged"</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> K_c value will be greater than that calculated in (d)(iii) (1) because the (forward) reaction is endothermic or backward / reverse reaction is exothermic (1) 	<p>M2 depends on M1</p> <p>Ignore References to the equilibrium position shifting to the right (with increasing temperature)</p>	(2)



Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> calculation of K_a (1) calculation of $[H^+]$ (1) calculation of pH (1) 	<p>Example of calculation $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm⁻³)</p> <p>$[H^+] = \sqrt{K_a[H_3BO_3]} = \sqrt{5.7544 \times 10^{-10} \times 0.05}$ $= 5.364 \times 10^{-6}$ (mol dm⁻³) TE on K_a</p> <p>$pH = -\log_{10} [H^+] = -\log_{10} 5.364 \times 10^{-6}$ $= 5.2705 / 5.271 / 5.27 / 5.3$ TE on $[H^+]$ provided pH is >2 and <7</p> <p>Accept alternative methods, for example $[H^+] = \sqrt{K_a[H_3BO_3]}$ $pH = \frac{1}{2}pK_a - \frac{1}{2}\log[H_3BO_3]$ (1) $= \frac{1}{2}9.24 - \frac{1}{2}\log 0.05$ (1) $= 5.2705 / 5.271 / 5.27 / 5.3$ (1)</p> <p>Alternative method: $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10}$ (mol dm⁻³) (1) $[H^+]^2 = K_a ([H_3BO_3] - [H^+])$ $= 5.7544 \times 10^{-10} \times (0.05 - [H^+])$ $[H^+] = 5.135 \times 10^{-6}$ (1) $pH = 5.29$ (1)</p> <p>Ignore SF except 1SF</p> <p>Correct answer without working scores 3 marks</p>	(3)



Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • $[H^+] = [H_2BO_3^-]$ or no H^+ from the (ionisation of) water / ionisation of water is negligible or H^+ is only from the acid or no H^+ from ionisation of <p>$H_2BO_3^-(1)$</p> <ul style="list-style-type: none"> • ionisation / dissociation of the acid is negligible / very small / insignificant or $[H_3BO_3]_{initial} = [H_3BO_3]_{equilibrium}$ or $[H_3BO_3]_{equilibrium} = 0.05 \text{ (mol dm}^{-3}\text{)}$ or $[H^+]/[H_2BO_3] \ll [H_3BO_3]$ or $[H_3BO_3]$ / acid concentration remains constant or $[H_3BO_3]_{equilibrium} = [H_3BO_3]_{initial} - [H^+]$ used in calculation in (i) 	<p>Allow $[A^-]$ for $[H_2BO_3^-]$ / $[HA]$ for $[H_3BO_3]$ Allow any of the expressions described in words Allow approximately equal to for = (in symbols or words)</p> <p>Ignore reference to standard conditions</p> <p>Do not award two marks from the same marking point</p> <p>Allow the effect of the third ionisation is negligible</p> <p>Ignore partial dissociation / not completely dissociated</p> <p>Do not award H_3BO_3 / $[HA]$ is completely dissociated</p>	(2)

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<ul style="list-style-type: none"> • (a Brønsted-Lowry acid is a) proton donor 	<p>Allow donates / gives away protons / H^+ (ions) / hydrogen ions</p> <p>Allow releases / loses protons / H^+ / hydrogen ions</p> <p>Do not award 'donates H_3O^+ (ions)'</p>	(1)



Q13.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> (M1) calculation of concentration of diluted acid (1) (M2) calculation of pH (1) 	<u>Example of calculation</u> $c = (15 \times 15.9 / 100) = 2.385 \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = -\log(2.385) = -0.377 / -0.38 / -0.4$ TE on M1 provided answer <7 Final answer without working scores (2) Ignore SF	(2)

Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> expression for K_a (1) calculation of $[\text{H}^+]$ (1) calculation of pH to 2/3 SF (1) 	<u>Example of calculation</u> $K_a = \frac{[\text{H}^+] \times [\text{A}^-]}{[\text{HA}]}$ $[\text{H}^+] = \sqrt{K_a \times [\text{HA}]} = \sqrt{(1.35 \times 10^{-6})}$ $= 1.16... \times 10^{-3} \text{ (mol)}$ $\text{pH} = -\log(1.16... \times 10^{-3}) = 2.93 / 2.9$ TE on M2 provided answer <7 Final answer without working scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark
(ii)	An answer which makes reference to the following points <ul style="list-style-type: none"> (assumption 1) $[C_2H_5COOH]_{initial} = [C_2H_5COOH]_{eqm}$ (1) (assumption 2) $[H^+] = [C_2H_5COO^-]$ (1) 	ACCEPT assumptions in any order Allow HA for C_2H_5COOH Allow A^- for $C_2H_5COO^-$ Dissociation of propanoic acid is negligible Ignore propanoic acid is a weak acid ALLOW for M2 "Negligible $[H^+]$ from water" Ignore reference to standard conditions	(2)

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculates moles of X^- / NaOH present in the mixture (1) calculates moles of HX which remain unreacted (1) calculates / shows ratio of [HX] to $[X^-]$ OR ratio of moles of HX : X^- (as total V cancels) (1) re-arranges K_a or pK_a expression correctly and substitutes appropriate values (1) final pH to 2 or 3SF (1) 	<u>Example of calculation:</u> $(\text{moles of } X^- = \text{mol NaOH} = \frac{0.8(00)}{10.5}) \times \frac{1000}{1000}$ $= 0.0084(0) / 8.4(0) \times 10^{-3} \text{ (mol)}$ $(\text{moles of HX} - \text{mol NaOH} = \frac{0.92(0)}{25.0 - 0.0084(0)}) \times \frac{1000}{1000}$ $= 0.023(0) - 0.0084(0)$ $= 0.0146 / 1.46 \times 10^{-2} \text{ (mol)}$ $[HX] = \frac{0.0146}{0.0355} \text{ and } [X^-] = \frac{0.0084(0)}{0.0355}$ $= 0.411 \text{ and } 0.237 \text{ (mol dm}^{-3}\text{)}$ Allow use of the ratio of the moles as above (as total V cancels) $[H^+] = K_a \times \frac{[HX]}{[X^-]} = 5.25 \times 10^{-5} \times \frac{0.411}{0.237}$ $[H^+] = 9.10443038 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = 4.04$ Allow use of pH expression to get answer: $\text{pH} = pK_a - \log \frac{[HX]}{[X^-]} \text{ or } pK_a + \log \frac{[X^-]}{[HX]}$	(5)



		ALLOW TE M5 for calculation of pH from any $[H^+]$ Correct answer with no working scores (5)	
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Q16.

Question Number	Answer	Additional Guidance	Mark												
*	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p>	
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														



The following table shows how the marks should be awarded for structure and lines of reasoning.		In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks. 3 and 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning.	(6)
	Number of marks awarded for structure of answer and sustained line of reasoning		
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2		
Answer is partially structured with some linkages and lines of reasoning.	1		
Answer has no linkages between points and is unstructured.	0		

<p>Comment: Look for the indicative marking points first, then consider the mark for the structure of answer and sustained line of reasoning.</p> <p>Indicative content</p> <p>Hydrochloric acid and nitric acid</p> <ul style="list-style-type: none"> (same value for) hydrochloric acid and nitric acid as they are strong / completely dissociated into ions (in solution) reaction taking place is $H^+ + OH^- \rightarrow H_2O$ / $H_3O^+ + OH^- \rightarrow 2H_2O$ 	<p>Allow correct formulae for names throughout the answer</p> <p>Ignore sulfuric acid as strong(est) acid</p> <p>Allow $HCl + NaOH \rightarrow NaCl + H_2O$ and $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$</p> <p>Allow hydrochloric acid and nitric acid are both monoprotic / monobasic / provide 1 mol H^+ / produce 1 mol H_2O</p>
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	<p>Sulfuric acid</p> <ul style="list-style-type: none"> sulfuric acid is diprotic / dibasic or (1 mol of) sulfuric acid provides 2 mol H⁺ / produces 2 mol H₂O so value is (almost) twice that of hydrochloric acid / nitric acid or reverse argument <p>Ethanoic acid</p> <ul style="list-style-type: none"> ethanoic acid is weak /partially dissociated into ions (in solution) / CH₃COOH ⇌ CH₃COO⁻ + H⁺ / CH₃COOH + H₂O ⇌ CH₃COO⁻ + H₃O⁺ some energy is needed to break (O-H) bond(s) to release H⁺ ions (so enthalpy change of neutralisation is less than for a strong acid) or enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic 	<p>Allow H₂SO₄ + 2NaOH → Na₂SO₄ + 2H₂O</p> <p>Allow ethanoic acid is the weakest acid</p> <p>Allow some energy is needed to ionise ethanoic acid</p>	
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Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculation of [H⁺(aq)] 	<p><u>Example of calculation</u> [H⁺(aq)] = 10^{-pH} = 10^{-2.76}</p> <p>= 1.7378 x 10⁻³ / 1.738 x 10⁻³ / 1.74 x 10⁻³ / 1.7 x 10⁻³ / 0.0017378 / 0.001738 / 0.00174 / 0.0017 (mol dm⁻³)</p> <p>Ignore units even if incorrect</p> <p>Correct answer to 2 or more SF with no working scores (1)</p>	(1)



Q18.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH₂OH) withdraws / attracts electrons (1) stabilises the anion / CH₂OHCOO⁻ ion or weakens O-H bond in acid so hydrogen ion / H⁺ lost more easily (1) 	<p>Allow reference to intramolecular hydrogen bonding</p> <p>Allow hydrogen ion / H⁺ more easily dissociates</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>(CH₂OHCOOH + CH₃COOH →)</p> <ul style="list-style-type: none"> CH₂OHCOO⁻ + CH₃COOH₂⁺ 	<p>Both correct for the mark</p> <p>Allow formulae in either order</p> <p>Allow formulae in brackets with charge outside</p> <p>Allow displayed formulae</p> <p>Do not allow CH₃C(OH)₂⁺</p>	(1)

Q19.

Question Number	Answer	Mark
(a)	<p>The only correct answer is C</p> <p><i>A is not correct because this is for a 100-fold increase in concentration</i></p> <p><i>B is not correct because this is for no change in concentration</i></p> <p><i>D is not correct because this is for a 10000-fold decrease in concentration</i></p>	(1)



Question Number	Answer	Additional Guidance	Mark
(b)	<ul style="list-style-type: none"> calculation of $[H^+]$ (1) expression relating K_a, $[H^+]$ and $[CH_2OHCOOH]$ (1) calculation of $[CH_2OHCOOH]$ (1) 	<p>Example of calculation $[H^+] = 10^{-pH} = 0.01 / 1 \times 10^{-2} / 10^{-2} \text{ (mol dm}^{-3}\text{)}$</p> <p>$K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ or $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$</p> <p>Allow [HA] in M2 and M3</p> <p>$[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ $= 0.667 / 0.67$ (mol dm⁻³)</p> <p>Ignore SF except 1 SF Ignore units Correct answer with no working scores (3)</p>	(3)

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<ul style="list-style-type: none"> (pH =) $-\log[H^+(aq)]$ or (pH =) $-\log[H_3O^+(aq)]$ 	<p>Allow \log_{10} / lg for log Ignore missing (aq) Do not award $-\log$ conc H^+ Do not award round brackets / no brackets for concentration but allow round brackets around the square brackets e.g. $-\log([H^+(aq)])$</p>	(1)



Q21.

Question Number	Acceptable Answers	Additional Guidance	Mark
	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • $[H^+]$ / $[H_3O^+]$ / concentration of hydrogen ions from water is $1(.0) \times 10^{-7}$ (mol dm⁻³) (1) • so total $[H^+]$ is greater than $1(.0) \times 10^{-7}$ (mol dm⁻³) / is 1.1×10^{-7} (mol dm⁻³) <p>or the pH cannot be more than 7 / alkaline (for an acid)</p> <p>or concentration of hydrogen ions from water is not negligible / cannot be ignored</p> <p>or 10^{-8} is only the concentration of ions from the acid, it doesn't include those from the water (1)</p>	<p>Penalise reference to nitric acid as a weak acid in M2 only</p> <p>Allow $[H^+]$ from water = $\sqrt{1(.00) \times 10^{-14} / K_w}$ Allow this shown as part of a calculation</p> <p>Allow $[H_3O^+]$ / concentration of hydrogen ions for $[H^+]$ Allow $[H^+]$ is greater than 1×10^{-8} (mol dm⁻³) Allow $[H^+]$ cannot be less than $[OH^-]$ / $[OH^-]$ cannot be more than $[H^+]$ Allow the addition of nitric acid to water decreases pH by increasing $[H^+]$</p> <p>Allow pH is 6.96 Allow pH 8 / >7 is alkaline Allow acid must have pH below 7 Do not award $10^{-14} / 10^{-8} = 10^{-6}$ so pH = 6 for M2 only</p> <p>Allow water also dissociates to form H^+ ions</p>	(2)



Q22.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> square root of K_w at 310K to get $[H^+]$ (1) calculation of pH to 2 decimal places (1) 	<p>Example of calculation:</p> $[H^+] = (\sqrt{2.40 \times 10^{-14}}) = 1.549 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = (-\log 1.549 \times 10^{-7}) = (6.809894379) = 6.81$ <p>Correct answer with no working scores (2)</p> <p>Allow TE from incorrect $[H^+]$ as long as answer is in the pH range 6.00 – 7.00 inclusive</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> (M1) neutral (1) (M2) because $[H^+(aq)] = [OH^-(aq)]$ /equal amounts of H^+ and OH^- ions (1) 	<p>Acidic or alkaline scores (0)</p> <p>Allow both $[H^+]$ and $[OH^-]$ have increased equally (from 298 K to 310 K)</p> <p>M2 dependent on M1</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	<p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> positive / + sign because K_w increases as the temperature increases 	<p>Allow 'positive because'</p> <p>bond breaking requires energy or equilibrium shifts to the right or there is greater/more ionisation/dissociation</p> <p>Ignore 'endothermic'</p>	(1)



Q23.

Question Number	Answer	Mark
(i)	<p>The only correct answer is B</p> <p><i>A is not correct because there is no extrapolation to the largest temperature increase carried out</i></p> <p><i>C is not correct because the extrapolation is at the wrong time</i></p> <p><i>D is not correct because the extrapolation extends beyond the time of addition of alkali</i></p>	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to</p> <ul style="list-style-type: none">ethanoic acid is a weak(er) acid / only partially ionised/dissociated (1)(some) energy is used to fully/completely ionise the ethanoic acid (1)	<p>Allow hydrochloric acid is a strong(er) acid/fully ionised</p> <p>Do not award 'more NaOH will react so more energy given off'</p>	(2)