



Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> phenolphthalein (1) pH at equivalence point / 9 is very close / ± 1 to pK_{in} / 9.3 or pH range is (completely) within the (first) vertical jump in the titration curve / between the range of (pH) 8.5 - pH9.5 (1) 	<p>Allow recognisable spellings</p> <p>Allow indicator will change colour in the vertical section of the curve / at the end / equivalence point</p> <p>Accept correct reference to the pH range for phenolphthalein from the data book (8.2-10.0) if there is a connection to the graph Do not allow colourless to pink/red if the colour change of phenolphthalein is mentioned</p>	(2)
Question Number	Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> equation 	<p><u>Example of equation</u> $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$ or $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2$ Allow $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{CO}_3$ Allow multiples Ignore state symbols even if incorrect</p>	(1)



Question Number	Answer	Additional Guidance	Mark
(iii)	<ul style="list-style-type: none"> (solution at X) contains a large amount of / reservoir of carbonate ions / CO_3^{2-} and hydrogencarbonate ions / HCO_3^- (1) carbonate ions / CO_3^{2-} react with added hydrogen ions / H^+ / acid or $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-$ (1) hydrogencarbonate ions / HCO_3^- react with added hydroxide ions / OH^- / alkali or $\text{HCO}_3^- + \text{OH}^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$ (1) 	<p>Allow there is a large amount of Na_2CO_3 and NaHCO_3 Allow solution at X contains a reservoir of an acid and its conjugate base</p> <p>Allow Na_2CO_3 reacts with added hydrogen ions / H^+ / acid to form NaHCO_3 or $\text{CO}_3^{2-} + \text{HCl} \rightarrow \text{HCO}_3^- + \text{Cl}^-$ or $\text{A}^- + \text{H}^+ \rightarrow \text{HA}$</p> <p>Allow NaHCO_3 reacts with added hydroxide ions (to form $\text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$) Allow hydroxide ions react with hydrogen ions to form water and hydrogencarbonate ions dissociate to replace / form hydrogen ions or $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$ and $\text{HCO}_3^- \rightarrow \text{CO}_3^{2-} + \text{H}^+$ or $\text{HA} + \text{OH}^- \rightarrow \text{A}^- + \text{H}_2\text{O}$ Allow \rightleftharpoons in equations Ignore state symbols</p>	(3)

Q2.

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) 	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only <u>Example of calculation:</u> (moles NaOH = $0.200 \times \frac{23.60}{1000}$) = 0.00472 (mol) (= mol H ⁺ in 25.0 cm ³) (= 10×0.00472) = 0.0472 (mol) (in 250 cm ³) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	(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) 	<u>Example of calculation:</u> 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 	<u>Example of calculation:</u> (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) 	<u>Example of calculation:</u> 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)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> Same number of moles/molecules on both sides of the equation <p>(1)</p> <ul style="list-style-type: none"> (so) volume / V cancels in K_c expression (1) 	<p>2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel</p> <p>Allow same number of terms on top and bottom of K_c expression</p> <p>Allow units cancel out</p> <p>Allow "all divided by the same volume"</p>	(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</p> <p>Ignore units</p> <p>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</p> <p>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</p> <p>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)

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> named indicator (1) matching colour change (1) <p>or</p> <ul style="list-style-type: none"> pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve) <p>or</p> <ul style="list-style-type: none"> indicator will change colour in the vertical / straight / steep region of the graph <p>or</p> <ul style="list-style-type: none"> pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap (1) 	<p>Examples of indicators and colour changes</p> <p>phenol red – red to orange / yellow</p> <p>phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear)</p> <p>bromothymol blue – blue to yellow</p> <p>M2 is conditional on a correct indicator in M1</p> <p>Do not allow unsuitable indicators e.g. litmus</p> <p>Stand alone mark</p> <p>Allow</p> <p>$pK_{in} (\pm 1)$ is in the vertical jump</p> <p>or</p> <p>pK_{in} is nearest to the pH at the end / equivalence point</p> <p>or</p> <p>indicator will change colour at the end / equivalence point</p> <p>or</p> <p>(because it is a) titration of a weak acid with a strong base</p>	(3)

Question Number	Answer	Mark
(ii)	<p>The only correct answer is C</p> <p><i>A is not correct because used the volumes the wrong way round</i></p> <p><i>B is not correct because not used the volume of glycolic acid from the graph</i></p> <p><i>D is not correct because used a 1:2 mole ratio</i></p>	(1)



Question Number	Answer	Mark
(iii)	<p>The only correct answer is C</p> <p><i>A is not correct because this is the pH of glycolic acid</i></p> <p><i>B is not correct because this is the pH at the end of the vertical jump in the curve</i></p> <p><i>D is not correct because this is the pH at the start of the vertical jump</i></p>	(1)

Q4.

Question Number	Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> carbon dioxide dissolved in the blood forms carbonic acid (and so this concentration increases) (1) the equilibrium will shift to the right and produces more H⁺/acid ions (1) the (high) concentration of hydrogencarbonate ions suppress the ionisation of carbonic acid (to help to control pH) or the (large) reservoir/excess of hydrogencarbonate ions combine with the H⁺ ions (to help to control blood pH) (1) 	<p>Can be shown in an equation Do not award 'CO₂ reacts with H⁺ to form carbonic acid'</p> <p>Allow Carbonic acid (partially) dissociates to produce H⁺ Do not award 'CO₂ reacts with H⁺ so equilibrium shifts to the right to produce more H⁺'</p> <p>Ignore general comments about the effects of adding acid and/or alkali to a buffer which do not relate to carbon dioxide</p>	(3)

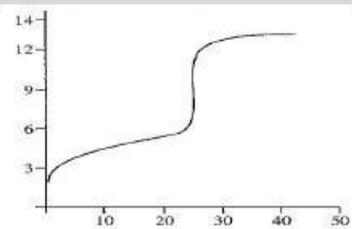


Q5.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> calculation of the amount of NaOH / salt (1) calculation of initial amount of acid (1) calculation of the amount of acid left (1) calculation of $[H^+]$ (1) 	<p><u>Example of calculation</u> amount of NaOH = amount of salt formed $= 0.100 \times 20.0/1000 = 0.00200$</p> <p>initial amount of acid = $0.150 \times 25.0/1000 = 0.00375$</p> <p>amount of acid left = $0.00375 - 0.00200 = 0.00175$</p> <p>total volume = $20.0 + 25.0 = 45.0 \text{ (cm}^3\text{)}$ $[salt] = 0.00200 \times 1000/45.0 = 0.0444 \text{ (mol dm}^{-3}\text{)}$ $[acid] = 0.00175 \times 1000/45.0 = 0.0389 \text{ (mol dm}^{-3}\text{)}$</p> <p>$K_a = \frac{[H^+][salt]}{[acid]}$ so $[H^+] = K_a \frac{[acid]}{[salt]}$</p> <p>$[H^+] = 1.74 \times 10^{-5} \times 0.0389/0.0444 = 1.52446 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$</p> <p>Allow use of moles instead of concentrations</p>	(5)
	<ul style="list-style-type: none"> calculation of pH (1) 	<p>$pH = -\log[H^+] = -\log(1.52446 \times 10^{-5}) = 4.817 / 4.82 / 4.8$</p> <p>Allow TE for each step</p> <p>Ignore SF except 1 SF</p> <p>Correct answer without working score (5)</p> <p>Allow alternative methods, for example $pH = pK_a - \log \frac{[acid]}{[salt]}$ $pH = -\log 1.74 \times 10^{-5} - \log \frac{0.0389}{0.0444}$ $pH = 4.817 / 4.82 / 4.8$ scores M4 and M5</p> <p>or $pH = pK_a + \log \frac{[salt]}{[acid]}$ $pH = -\log 1.74 \times 10^{-5} + \log \frac{0.0444}{0.0389}$ $pH = 4.817 / 4.82 / 4.8$ scores M4 and M5</p>	



Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	<p>A sketch graph which shows the following:</p> <ul style="list-style-type: none"> a starting pH between 2 and 4 (inclusive) (1) correct general shape and ends at pH = 12-13 (1) (any) vertical at 25 cm³ (1) vertical between pH = 6 - 7 and pH = 10 - 12 (1) 	 <p>Vertical must be no more than 5 pH units within these ranges</p>	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (Read off) pH at half-neutralisation (point) / pH at 12.5 (cm³) OR pH at half-equivalence (point) (1) As $\text{pH} = \text{p}K_a / [\text{H}^+] = K_a / K_a = 10^{-\text{pH}}$ (1) 	<p>May be shown on the sketch graph ALLOW read equivalence vol, add same volume of (propanoic) acid and measure pH</p> <p>M2 dependent on mentioning half equivalent / 12.5 cm³</p>	(2)

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An assessment that includes</p> <ul style="list-style-type: none"> (M1) the vertical part of the graph is at ~7 - 10/ the mid-point is at 8.5-8.8 (1) (M2) the mid-point of the colour change of methyl red is 5.1 (1) (M3) pH range of methyl red does not lie (completely) within the vertical range of the pH curve (so it is not suitable) (1) (M4) the colour change will be complete before the equivalence point is reached (1) 	<p>Allow 'equivalence point/end-point' for 'the vertical part of the graph/ the mid-point'</p> <p>Allow methyl red changes colour in the range/ has a pH range 4.2 - 6.3/ $\text{p}K_{\text{in}}$ 5.1</p> <p>Allow, after stating M1 and M2, 'this means that methyl red is unsuitable'</p> <p>Allow end-point/neutralisation point for equivalence point Do not award colour change to red</p> <p>Ignore references to choice of other indicators</p>	(4)



Question Number	Answer	Additional Guidance	Mark															
(ii)	An answer that includes <ul style="list-style-type: none"> two ticks and two crosses as shown 	<table border="1"> <thead> <tr> <th>Indicator</th> <th>pH range</th> <th>Tick or Cross</th> </tr> </thead> <tbody> <tr> <td>Bromocresol purple</td> <td>5.2 - 6.8</td> <td>x</td> </tr> <tr> <td>Thymol blue</td> <td>8.0 - 9.6</td> <td>✓</td> </tr> <tr> <td>Thymolphthalein</td> <td>8.3 - 10.6</td> <td>✓</td> </tr> <tr> <td>Alizarin yellow R</td> <td>10.1 - 13.0</td> <td>x</td> </tr> </tbody> </table> <p>Do not award blank boxes for (x)</p>	Indicator	pH range	Tick or Cross	Bromocresol purple	5.2 - 6.8	x	Thymol blue	8.0 - 9.6	✓	Thymolphthalein	8.3 - 10.6	✓	Alizarin yellow R	10.1 - 13.0	x	(1)
Indicator	pH range	Tick or Cross																
Bromocresol purple	5.2 - 6.8	x																
Thymol blue	8.0 - 9.6	✓																
Thymolphthalein	8.3 - 10.6	✓																
Alizarin yellow R	10.1 - 13.0	x																

Q8.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> general shape of weak acid-strong base curve (1) curve starts at pH of 3.0 and ends at pH of 12-13 (1) vertical part of the curve at 40 cm³ (1) labelling of area indicating buffer action (1) 	<p><u>Exemplar graph</u></p> <p>Ignore missing initial rise in pH Vertical part must cover 3-5 pH units between 6 – 11</p> <p>The curve should reach pH~12-13 by 10cm³ after vertical section</p> <p>The curve must start at zero and continue to 100 cm³</p> <p>Allow buffering area to be labelled anywhere between ~5 and 35 cm³ inclusive</p>	(4)



Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to</p> <ul style="list-style-type: none"> determine the pH at the point when half of the acid is neutralised (1) $K_a = 10^{-pH}$ / $K_a = 10^{-pK_a}$ (1) 	<p>Standalone marks</p> <p>Allow 'pH at half-equivalence point'</p> <p>Allow 'pH at half neutralisation point'</p> <p>Accept description in words such as inverse log of minus pH or value is pK_a and so inverse log of minus value gives K_a. Allow $pK_a = -\log K_a$</p> <p>Ignore any calculation</p>	(2)

Q9.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> the colour of the pineapple juice masks the colour change or methyl orange only works with a strong acid or methyl orange does not change colour in the vertical section of the titration curve 	<p>Allow methyl orange is a similar colour to pineapple juice</p> <p>Accept methyl orange cannot be used with a weak acid (and strong alkali)</p> <p>Allow the pH range / 3.2-4.4 / pK_{in} of methyl orange is below the equivalence point / too low Allow the colour change would occur before the equivalence point / is not over the equivalence point</p> <p>Allow the pH at the equivalence point is not in the pH range of methyl orange</p> <p>Allow end point for equivalence point</p> <p>Ignore just 'no colour change observed'</p> <p>Ignore just 'end point is not accurate'</p>	(1)



Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the titre value would be greater (than expected) (1) as the titre value includes the volume of the air bubble (as well as sodium hydroxide solution) (1) 	<p>M2 conditional on M1 scored Allow some alkali / solution is used to fill the air bubble / jet Allow there is less sodium hydroxide in the burette than expected</p>	(2)

Q10.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (at the end point) all ascorbic acid is used up so the iodine is no longer reduced (to iodide ions) or ascorbic acid reacts with the iodine until all the (ascorbic) acid is used up (1) the (slight excess) iodine reacts / forms complex with the starch (1) (changing from yellow) to a blue/black colour (1) 	<p>Stand alone Allow starch in the presence of iodine Do not award starch and iodide ions</p> <p>Stand alone Allow just black or just (dark) blue Ignore initial colour of solution Do not award blue/black to colourless</p>	(3)



Question Number	Answer	Additional Guidance	Mark
(ii)	calculation of amount of IO_3^- (aq) (1) <ul style="list-style-type: none"> calculation of amount of iodine / ascorbic acid in 5.00 cm^3 sample (1) calculation of amount of ascorbic acid in 150.0 cm^3 sample (1) calculation of amount of citric acid in 150.0 cm^3 sample (1) calculation of mass of citric acid in 150.0 cm^3 sample (1) 	Example of calculation $= (9.50/1000) \times 0.00100 = 9.50 \times 10^{-6} \text{ (mol)}$ $= 9.50 \times 10^{-6} \times 3 = 2.85 \times 10^{-5} \text{ (mol)}$ TE on M1 $= 2.85 \times 10^{-5} \times 30 = 8.55 \times 10^{-4} \text{ (mol)}$ TE on M2 $= 8.00 \times 10^{-3} - 8.55 \times 10^{-4} = 7.145 \times 10^{-3} \text{ (mol)}$ TE on M3 $= 7.145 \times 10^{-3} \times 192 = 1.37184 \text{ g} = 1.37 \text{ (g)}$ TE on M4 Ignore SF except 1 SF Correct answer with some or no working scores (5)	(5)

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: <ul style="list-style-type: none"> compound E and as it has (two) COOH / (carboxylic) acid group(s) (1) these / this will (also) react with the NaOH / in the titration (in Experiment 1) (1) (the titre will be greater in Experiment 1 so suggests a greater total amount of acid) so the final mass of citric acid calculated will be greater (than the true amount) or the total amount of acid (calculated from the titration) includes citric acid and E so the actual mass of citric acid is less (than calculated in (b)(ii)) (1) 	Allow Compound E is a (di)carboxylic acid Ignore reference to OH group Do not award carbonyl group(s) Do not award if OH group reacts with NaOH Conditional on compound E selected	(3)



Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> ticks under titration numbers 2, 3, 4 (1) 17.65 (cm³) (1) 	ignore X under Titration 1 <u>example of calculation</u> $\frac{17.60 + 17.70 + 17.65}{3}$ $= 17.65$ scroll down as mean titre value may be written below (i) rather than in the table units not required must be 2 dp TE from M1 if Titration 1 has been ticked (17.74)	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> Phenolphthalein/ methyl orange (1) colourless to pink / red to orange (1) 	M2 depends on M1 allow any indicator other than litmus or universal indicator allow minor errors in spelling of phenolphthalein but not phenyl... do not award red/pink-red for phenolphthalein nor yellow for methyl orange allow correct colour change for other indicators	(2)



Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	<ul style="list-style-type: none"> converts [acid] from g dm⁻³ to mol dm⁻³ (1) calculates moles of acid in 25 cm³ (1) calculates moles of sodium hydroxide in titre cm³ (1) converts moles of sodium hydroxide in titre to mol dm⁻³ and gives the answer 3 SF (1) 	<p><u>Example of calculation</u></p> <p>3.80/90.0 = *4.22 x 10⁻² (mol dm⁻³)</p> <p>ans to M1 x 25 x 10⁻³ 25 x 10⁻³ x *4.22 x 10⁻² = **1.0556 x 10⁻³ (mol) allow M1 and M2 in any order one mark only if not divided by 90.0</p> <p>ans to M2** x 2 = 1.0556 x 10⁻³ x 2 = ***2.111 x 10⁻³ (mol)</p> <p>= ans to M3*** x 1000/17.65 = 0.1196 = 0.120 (mol dm⁻³)</p> <p>correct answer with no working scores 4 marks</p>	(4)



Q12.

Question Number	Answer	Additional Guidance	Mark
	EITHER <ul style="list-style-type: none"> calculation of $[H^+(aq)]$ (1) calculation of ratio of $[acid]/[salt]$ or $[salt]/[acid]$ or correct values substituted into expression for ratio (1) calculation of volume of acid required and salt required (1) OR <ul style="list-style-type: none"> calculation of $\log [acid]/[salt]$ using Henderson-Hasselbalch (1) calculation of ratio of $[acid]/[salt]$ (1) calculation volume of acid required and salt required (1) 	<u>Example of calculation</u> $[H^+(aq)] = 10^{-4.70} = 1.9953 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $[acid]/[salt] = 1.9953 \times 10^{-5} / 1.74 \times 10^{-5} = 1.1467 : 1 / 1 : 0.872$ or $[salt]/[acid] = 1.74 \times 10^{-5} / 1.9953 \times 10^{-5} = 0.872 : 1 / 1 : 1.1467$ $(1.1467 / 2.1467) \times 500 = 267 \text{ cm}^3 \text{ acid}$ $500 - 267 = 233 \text{ cm}^3 \text{ salt}$ $4.7595 - 4.70 = 0.05945$ $10^{0.05945} = 1.1467 : 1$ $(1.1467 / 2.1467) \times 500 = 267 \text{ cm}^3 \text{ acid}$ $500 - 267 = 233 \text{ cm}^3 \text{ salt}$ Allow $270 \text{ cm}^3 \text{ acid}$ and $230 \text{ cm}^3 \text{ salt}$ Ignore SF except 1 SF but allow 2 / 2.0 / 2.00 x 10^{-5} for M1 in 'EITHER' Allow TE from M1 throughout Correct answer with no working scores (3)	(3)



Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> calculation of acid concentration (1) calculation of salt concentration (1) calculation of hydrogen ion concentration (1) calculation of pH (1) 	<p><u>Example of calculation</u></p> $[\text{Acid}] = ((0.100 \times (20 \div 50)))$ $= 0.04 \text{ (mol dm}^{-3}\text{)}$ $[\text{A}^-] = ((0.305 \times (30 \div 50)))$ $= 0.183 \text{ (mol dm}^{-3}\text{)}$ $[\text{H}^+] = 1.52 \times 10^{-5} \text{ mol} \times (0.04 \div 0.183)$ $= 3.322 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ $\text{pH} = -\log(3.322 \times 10^{-6})$ $= 5.48/5.5$ <p>Correct answer without working scores (4) Ignore SF except 1SF</p> <p>Allow M3 and M4 if just moles and no volumes are used</p> <p>Accept use of the Henderson-Hasselbalch equation</p>	(4)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An answer which includes</p> <ul style="list-style-type: none"> suitable equation(s) (1) The pH stays approximately constant because there is a large reservoir of undissociated acid and so the ratio of acid:salt does not change (1) 	<p><u>Example equation</u></p> $\text{C}_3\text{H}_7\text{COOH} + \text{NaOH} \rightarrow \text{C}_3\text{H}_7\text{COONa} + \text{H}_2\text{O}$ <p>OR</p> $\text{C}_3\text{H}_7\text{COOH} + \text{OH}^- \rightarrow \text{C}_3\text{H}_7\text{COO}^- + \text{H}_2\text{O}$ <p>Allow</p> $\text{OH}^- + \text{H}^+ \rightarrow \text{H}_2\text{O}$ <p>followed by</p> $\text{C}_3\text{H}_7\text{COOH} \rightarrow \text{C}_3\text{H}_7\text{COO}^- + \text{H}^+$ <p>Allow use \rightleftharpoons of in all of above equations</p> <p>Allow (The pH stays approximately constant) as the hydroxide ions react to form water and butanoic acid dissociates to replace the hydrogen ions used up</p>	(2)



Q14.

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) 	<p>Example of calculation:</p> <p>(moles of X^- = mol NaOH = $\frac{0.8(00)}{10.5} \times 1000$) $= 0.0084(0) / 8.4(0) \times 10^{-3}$ (mol)</p> <p>(moles of HX – mol NaOH = $\frac{0.92(0)}{25.0} \times 1000 - 0.0084(0)$) $= 0.023(0) - 0.0084(0)$ $= 0.0146 / 1.46 \times 10^{-2}$ (mol)</p> <p>$[HX] = \frac{0.0146}{0.0355}$ and $[X^-] = \frac{0.0084(0)}{0.0355}$ $= 0.411$ and 0.237 (mol dm^{-3})</p> <p>Allow use of the ratio of the moles as above (as total V cancels)</p> <p>$[H^+] = K_a \times \frac{[HX]}{[X^-]} = 5.25 \times 10^{-5} \times \frac{0.411}{0.237}$ $[H^+] = 9.10443038 \times 10^{-5}$ (mol dm^{-3})</p> <p>pH = 4.04 Allow use of pH expression to get answer: $pH = pK_a - \log \frac{[HX]}{[X^-]}$ or $pK_a + \log \frac{[X^-]}{[HX]}$</p>	(5)
		<p>ALLOW TE M5 for calculation of pH from any $[H^+]$ Correct answer with no working scores (5)</p>	



Q15.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> • (M1) calculation of $[H^+]$ (1) • (M2) rearrangement of K_a and calculation of ethanoate concentration (1) • (M3) calculation of the number of moles of ethanoate in the buffer volume (1) • (M4) calculation of the mass of sodium ethanoate in the buffer volume (1) • (M5) answer to 2/3 SF (1) 	<p>Example of calculation</p> $[H^+] = 10^{-3.9} = 1.2589 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$	(5)
		$[CH_3COO^-] = \frac{(1.74 \times 10^{-5} \times 0.800)}{1.2589 \times 10^{-4}} = 0.11057 \text{ (mol dm}^{-3}\text{)}$ $n = (0.11057 \times 0.05) = 5.5285 \times 10^{-3} \text{ (mol)}$ $m = (5.5285 \times 10^{-3} \times 82) = 0.453339 \text{ g}$ $m = 0.45 / 0.453 \text{ (g)}$	
		<p>Award this mark only if there has been some attempt at calculation using an M_r.</p> <p>TE at each stage</p> <p>If Henderson-Hasselbalch equation used</p> <p>(M1) for calculation of $pK_a = 4.759$ (M2) for rearrangement and calculation of ethanoate concentration Remaining marking points as above</p>	

Q16.

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)

Q17.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> $\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$ or $\text{HPO}_4^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}$ (1) $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$ (1) 	<p>Penalise non-ionic equations, e.g. using NaOH or HCl once only</p> <p>Equations must show reaction of ions with H^+ / H_3O^+ and OH^-</p> <p>Allow \rightleftharpoons</p> <p>Ignore state symbols</p> <p>Allow $\text{H}_2\text{PO}_4^- \rightarrow \text{HPO}_4^{2-} + \text{H}^+$ and $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$</p>	(2)