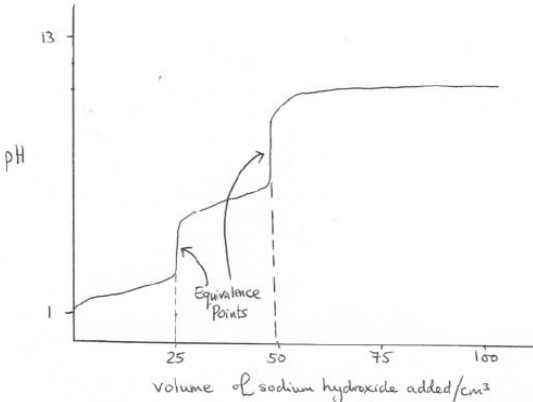


Question Number	Acceptable Answers	Reject	Mark
<b>1(a)</b>	$(K_{a1} =) \frac{[H_3O^+(aq)][HS^-(aq)]}{[H_2S(aq)]}$ <p style="text-align: right;"><b>(1)</b></p> $(K_{a2} =) \frac{[H_3O^+(aq)][S^{2-}(aq)]}{[HS^-(aq)]}$ <p>Allow H<sup>+</sup>(aq) for H<sub>3</sub>O<sup>+</sup>(aq) Ignore missing / incorrect state symbols</p> <p style="text-align: right;"><b>(1)</b></p>	<p>[H<sub>3</sub>O<sup>+</sup>]<sup>2</sup> numerator</p> <p>[H<sub>3</sub>O<sup>+</sup>]<sup>2</sup> numerator</p>	<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(b)(i)</b>	$(H_2S + H_2O \rightleftharpoons H_3O^+ + HS^-)$ <p>Initially 0.100                      0            0</p> <p>At eqm 0.100                        x            x</p> $K_{a1} = \frac{x^2}{0.100}$ <p><b>M1:</b> <math>x^2 = 8.91 \times 10^{-9} \text{ (mol}^2 \text{ dm}^{-6}\text{)}</math></p> <p style="text-align: right;"><b>(1)</b></p> <p><b>M2:</b> (<math>x = 9.4393 \times 10^{-5}</math>) [HS<sup>-</sup>] = <math>9.44 \times 10^{-5} / 0.0000944 \text{ (mol dm}^{-3}\text{)}</math></p> <p>For M2, answer must be to 3 sf</p> <p style="text-align: right;"><b>(1)</b></p> <p>Correct answer without working scores (2)</p>		<b>(2)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(b)(ii)</b>	$([H^+] = (\sqrt{8.91 \times 10^{-9}})$ $=) 9.439 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ <p>pH = <math>(-\log 9.439 \times 10^{-5}) = 4.0251/4.025 /4.03/4.0</math></p> <p>TE on answer to (b)(i) provided pH &lt; 7</p>	4/4.02	<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
*1(b)(iii)	<p><b>Any THREE from:</b></p> <p><b>Assumption 1</b>  <math>[H_2S]_{\text{equilibrium}} = [H_2S]_{\text{initial}}</math>  OR  The dissociation of <math>H_2S</math> is negligible  OR  0.0000944 is <b>very</b> small compared to the initial concentration of <math>H_2S</math>/ 0.100 (hence a valid assumption)</p> <p><b>Assumption 2</b>  <math>[H_3O^+] = [HS^-] / [H^+] = [HS^-]</math>  OR  Ignore any <math>H^+</math> from (the dissociation of) water / <math>H^+</math> only from <math>H_2S</math></p> <p><b>Assumption 3</b>  Ignored ionization of <math>HS^-</math> /  <math>HS^-</math> doesn't (significantly) dissociate further  OR  <math>K_{a2}</math> very much smaller than <math>K_{a1}</math></p> <p><b>Assumption 4</b>  Measurements at 298 K / standard <b>temperature</b>  IGNORE  References to the concentration of water  References <b>just</b> to "standard conditions"</p>		<b>(3)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(c)(i)</b>	<p><b>M1:</b> General shape of an acid-base curve with the pH increasing and either one or two steep / vertical sections shown <b>NOTE</b> Penalise a pH range for a single vertical with a range of eight or more pH units (as this is the typical range for a strong monobasic acid with a strong base titration curve)</p> <p style="text-align: right;"><b>(1)</b></p> <p><b>M2:</b> Vertical / steep section at 25 cm<sup>3</sup></p> <p style="text-align: right;"><b>(1)</b></p> <p><b>M3:</b> Vertical / steep section at 50 cm<sup>3</sup></p> <p style="text-align: right;"><b>(1)</b></p> <p><b>M4:</b> Either equivalence point labelled anywhere on vertical section or x-axis</p> <p style="text-align: right;"><b>(1)</b></p> <p><b>M5:</b> Initial pH = 1.5 <b>and</b> a <b>recognisable</b> 'plateau' in the pH range of 12 to 13</p> <p style="text-align: right;"><b>(1)</b></p> 		<b>(5)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>1(c)(ii)</b>	<p>The <b>pH</b> when 12.5 cm<sup>3</sup> of NaOH has been added OR the <b>pH</b> at "half-equivalence" (for the first equivalence point)</p> <p><b>ALLOW</b> "pH at half neutralisation"</p> <p>Allow TE from an incorrect graph</p>		<b>(1)</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(a)(i)</b>	$\text{HC}_2\text{O}_4^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_2\text{O}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ (or $\rightarrow$ )  ALLOW $\text{H}_2\text{O}(\text{aq})$  Equation <b>(1)</b> states <b>(1)</b>  ALLOW for 1 mark $\text{HC}_2\text{O}_4^-(\text{aq}) \rightleftharpoons \text{C}_2\text{O}_4^{2-}(\text{aq}) + \text{H}^+(\text{aq})$  States mark is not stand alone but can be awarded if the equation has a minor error e.g. an incorrect charge		<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(a)(ii)</b>	$K_a = [\text{C}_2\text{O}_4^{2-}] [\text{H}_3\text{O}^+] / [\text{HC}_2\text{O}_4^-]$ OR  $K_a = [\text{C}_2\text{O}_4^{2-}] [\text{H}^+] / [\text{HC}_2\text{O}_4^-]$ No TE on incorrect equation in (a)(i) Penalise incorrect charges in (i) and (ii) once only	$K_a =$  $[\text{H}^+]^2 /$ $[\text{HC}_2\text{O}_4^-]$  $[\text{H}^+][\text{A}^-]/$ $[\text{HA}]$	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(a)(i)</b>	No TE on (a)(ii)  $K_a = 10^{-4.28} \quad \text{OR} \quad 5.24807 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \quad \text{(1)}$  $K_a = [\text{H}^+]^2 / [\text{HC}_2\text{O}_4^-]$ $K_a = [\text{H}^+]^2 / 0.050$ $[\text{H}^+] = \sqrt{(0.05 \times 10^{-4.28})} = 1.61988 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \quad \text{(1)}$  TE on incorrect $K_a$ value  $\text{pH} = -\log 1.61988 \times 10^{-3} = 2.7905 = 2.8 \quad \text{(1)}$  For final mark TE on algebraic / arithmetical errors providing $\text{pH} \geq 1.3$  Correct answer with no working scores 3  Ignore SF except 1 SF		<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(b)(i)</b>	<p>IGNORE explanations</p> <p><b>First mark:</b>  <math>\text{HC}_2\text{O}_4^-</math>/hydrogenethanedioate ion ionization negligible  ALLOW  Acid for <math>\text{HC}_2\text{O}_4^-</math>  Slight / partial / incomplete / does not dissociate for negligible</p> <p>OR</p> <p><math>[\text{HC}_2\text{O}_4^-]_{\text{equilibrium}} = [\text{HC}_2\text{O}_4^-]_{\text{initial}} / 0.050 \text{ (mol dm}^{-3}\text{)}</math> <b>(1)</b></p> <p><b>Second mark:</b>  <math>[\text{H}^+]</math> due to ionization of water negligible  OR  auto ionization of water negligible</p> <p>OR</p> <p><math>[\text{H}^+]</math> only due to ionization of <math>\text{HC}_2\text{O}_4^-</math>/acid  OR  <math>[\text{C}_2\text{O}_4^{2-}] = [\text{H}^+]</math> <b>(1)</b></p> <p>IGNORE references to temperature and to HA and <math>\text{A}^-</math>  Penalize omission of [ ] in discussion once only</p>	<p>Use of <math>\text{NaHC}_2\text{O}_4</math> for <math>\text{HC}_2\text{O}_4^-</math>  OR  sodium hydrogenethanedioate for hydrogenethanedioate ion throughout this item</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(b)(ii)</b>	<p>Ethanedioic acid is a (much) stronger acid (than hydrogenethanedioate ion / sodium hydrogenethanedioate)</p> <p>OR</p> <p>Ethanedioic acid has a (much) smaller <math>pK_a</math> (than hydrogenethanedioate)</p> <p>OR</p> <p>Ionization / dissociation of ethanedioic acid is (much) greater (than hydrogenethanedioate)</p> <p>OR</p> <p>Reverse arguments <b>(1)</b></p> <p>IGNORE</p> <p><math>\text{NaHC}_2\text{O}_4</math> ionization negligible</p> <p>Approximation of negligible ionization invalid / incorrect</p> <p>OR</p> <p><math>[\text{H}_2\text{C}_2\text{O}_4]_{\text{equilibrium}}</math> not equal to <math>[\text{H}_2\text{C}_2\text{O}_4]_{\text{initial}}</math> <b>(1)</b></p> <p>No TE on 18(a)(iii)</p> <p>IGNORE</p> <p>Second ionization occurs</p>	<p>Ethanedioic acid is a strong acid / fully dissociated</p> <p>Just 'approximation invalid'</p>	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>2(c)(i)</b>	<p>Start pH at 2.8</p> <p>ALLOW</p> <p>2—4 <b>(1)</b></p> <p>Vertical section at <math>25 \text{ cm}^3</math> within pH range 6-11 and 2.5-4 units long <b>(1)</b></p> <p>end pH (approaching) value in range 12-13 (asymptotically) <b>(1)</b></p>	<p>deviation from vertical</p> <p>maximum before final pH</p>	<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
2(c)(ii)	<p><b>F mark:</b>  Methyl yellow range = 2.9—4  and the phenolphthalein range = 8.2—10  ALLOW  <math>pK_{in}</math> (methyl yellow) = 3.5  and <math>pK_{in}</math> (phenolphthalein) = 9.3 (1)</p> <p><b>Second mark:</b>  (The volumes are different) because ethanedioic acid is dibasic / diprotic / has two <b>replaceable/acidic</b> hydrogen atoms  ALLOW dicarboxylic (acid)  (therefore there are two stages to the neutralization)</p> <p>OR</p> <p>Methyl yellow range coincides with neutralization of first proton and phenolphthalein range coincides with neutralization of second proton (1)</p>		2

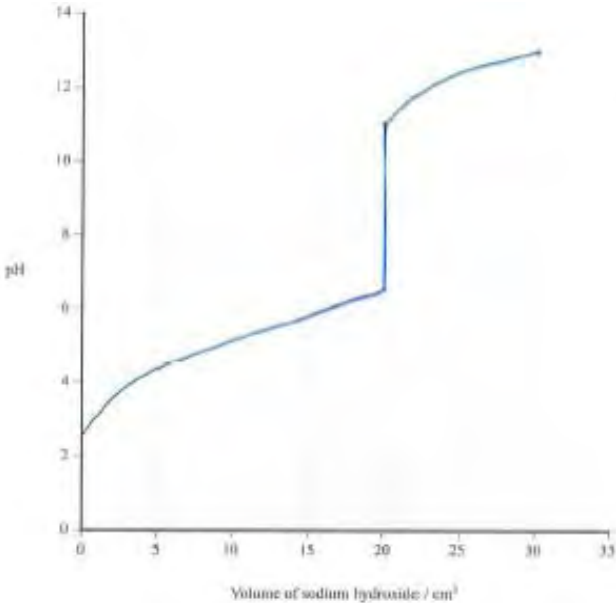
Question Number	Acceptable Answers	Reject	Mark
<b>3</b> <b>(a)(i)</b>	$K_a = [\text{CH}_3\text{CO}_2^-] [\text{H}^+] / [\text{CH}_3\text{CO}_2\text{H}]$ OR $K_a = [\text{CH}_3\text{CO}_2^-] [\text{H}_3\text{O}^+] / [\text{CH}_3\text{CO}_2\text{H}]$ OR Use of $[\text{CH}_3\text{COO}^-]$ instead of $[\text{CH}_3\text{CO}_2^-]$ and $[\text{CH}_3\text{COOH}]$ instead of $[\text{CH}_3\text{CO}_2\text{H}]$  IGNORE state symbols even if wrong	Numerator as $[\text{H}^+]^2$ Expressions in terms of HA alone Round/curved brackets '()'' Any other carboxylic acid	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(a)(ii)</b>	$1.7 \times 10^{-5} = [\text{H}^+]^2 / 0.5$ $[\text{H}^+] = \sqrt{1.7 \times 10^{-5} \times 0.5} / 2.915(476) \times 10^{-3}$ <b>(1)</b>  $\text{pH} = (-\log[\text{H}^+]) = 2.53529$ OR = 2.54 OR = 2.5 <b>(1)</b>  ALLOW TE for second mark from any hydrogen ion concentration as long as pH less than 7  Correct answer alone scores <b>(2)</b>  ALLOW $\text{pH} = 2.53$ if $[\text{H}^+]$ is rounded to $2.92 \times 10^{-3}$  IGNORE sf except 1	4.77 or 4.8 from using $\text{pH} = -\log K_a$ loses both marks	<b>2</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(a)(iii)</b>	20 (cm <sup>3</sup> ) IGNORE units OR 0.02 dm <sup>3</sup>		<b>1</b>



Question Number	Acceptable Answers	Reject	Mark
<b>3(a)(iv)</b>	<p>Moles of excess NaOH = <math>10/1000 \times 0.50</math>  <math>= 5 \times 10^{-3}</math> <b>(1)</b></p> <p>So <math>[\text{NaOH}/\text{OH}^-] = 5 \times 10^{-3} \times 1000/50 =</math>  <math>0.10 \text{ mol dm}^{-3}</math> <b>(1)</b></p> <p>EITHER</p> <p style="padding-left: 40px;">Kw route:</p> <p><math>[\text{H}^+] \times 0.1 = 1 \times 10^{-14}</math> <b>(1)</b></p> <p>So <math>\text{pH} = -\log 1 \times 10^{-14} / 0.1 = 13</math> <b>(1)</b></p> <p>OR</p> <p style="padding-left: 40px;">pOH route:</p> <p>pOH = 1 <b>(1)</b>  So pH = <math>(14 - 1) = 13</math> <b>(1)</b></p> <p>ALLOW TE throughout</p> <p>Correct final answer scores <b>(4)</b></p>		<b>4</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(a)(v)</b>	<p>Starting at pH 2-3 AND finishing at pH between 12 and 13.7 inclusive <b>(1)</b></p> <p>Vertical section at 20 cm<sup>3</sup> <b>(1)</b></p> <p>S-shaped curve, with gradual rise and vertical section within the pH range 5.5 and 11.5 and of 3 to 5 units in length <b>(1)</b></p> <p>These are stand alone marks</p> 		<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(b)(i)</b>	<p>EITHER</p> <p><math>[\text{base}] = K_a [\text{acid}]/[\text{H}^+]</math>  Or  <math>[\text{H}^+] = (10^{-\text{pH}4.70}) = 1.995 \times 10^{-5}</math> (1)</p> <p><math>[\text{base}] = 1.7 \times 10^{-5} \times 1/(1.995 \times 10^{-5}) = 0.852</math> (1)</p> <p>moles base = <math>0.852 \times 0.5 = 0.426</math> (mol) (1)</p> <p>mass base = <math>0.426 \times 82 = 34.9</math> g (1)</p> <p>IGNORE sf except 1</p> <p>Correct answer, with or without working (4)</p> <p>OR</p> <p><math>\text{pH} = \text{p}K_a - \log[\text{acid}]/[\text{base}]</math>  <math>4.70 = 4.8 - \log [1/[\text{base}]]</math></p> <p><math>\text{Log}[1/[\text{base}]] = 0.1</math> (1)</p> <p><math>[\text{base}] = 0.794(328)</math> (mol dm<sup>-3</sup>) (1)</p> <p>So in 500 cm<sup>3</sup>  Moles = <math>0.794 \times 0.5 = 0.397</math> mol (1)</p> <p>Mass = <math>0.397 \times 82 = 32.554/32.6</math> g (1)</p> <p>(ALLOW using pKa = 4.77)</p>		<b>4</b>

Question Number	Acceptable Answers	Reject	Mark
<b>3(b)(ii)</b>	<p><b>First mark</b> Buffer has large amount/ excess/ reservoir of CH<sub>3</sub>COOH (and CH<sub>3</sub>COO<sup>-</sup>) <b>(1)</b></p> <p><b>Second mark</b> OH<sup>-</sup> ions added react with CH<sub>3</sub>COOH</p> <p>OR CH<sub>3</sub>COOH + OH<sup>-</sup> → CH<sub>3</sub>COO<sup>-</sup> + H<sub>2</sub>O</p> <p>OR OH<sup>-</sup> + H<sup>+</sup> → H<sub>2</sub>O <b>and</b> CH<sub>3</sub>COOH → CH<sub>3</sub>COO<sup>-</sup> + H<sup>+</sup></p> <p>OR Equations described in words <b>(1)</b></p> <p><b>Third mark</b> Ratio / values of [CH<sub>3</sub>COOH] to [CH<sub>3</sub>COO<sup>-</sup>] remains (almost) unchanged <b>(1)</b></p> <p>IGNORE concentration of hydrogen ions remains constant</p> <p>ALLOW answers in terms of HA and A<sup>-</sup></p>		<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4 (a)</b>	$K_a = (10^{-10.64}) = 2.3 \times 10^{-11} / 2.2909 \times 10^{-11}$ (mol dm <sup>-3</sup> )  Ignore sf except 1		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4 (b) (i)</b>	$K_a = \frac{[\text{HCOO}^-][\text{H}^+]}{[\text{HCOOH}]}$ OR written as HCO <sub>2</sub> <sup>-</sup> and HCO <sub>2</sub> H OR with H <sub>3</sub> O <sup>+</sup> instead of H <sup>+</sup>  Allow $K_a = \frac{[\text{A}^-][\text{H}^+]}{[\text{HA}]}$ if formula of HA and A <sup>-</sup> given as HCOOH and HCOO <sup>-</sup>	$K_a = \frac{[\text{H}^+]^2}{[\text{HCOOH}]}$ without also giving full expression	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4 (b) (ii)</b>	$1.6 \times 10^{-4} = \frac{[\text{H}^+]^2}{0.50} \quad (1)$  $[\text{H}^+] = \sqrt{1.6 \times 10^{-4} \times 0.5} \quad (1)$ $(= \sqrt{8 \times 10^{-5}} = 8.94 \times 10^{-3})$  $\text{pH} = (2.048455) = 2.05 / 2.0 \quad (1)$  Correct answer with no working <b>(3)</b>  TE for third mark if [H <sup>+</sup> ] calculated incorrectly  No TE from incorrect K <sub>a</sub> expression Ignore sf except 1	$\text{pH} = 2$ $\text{pH} = 2.1$	<b>3</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4 (b) (iii)</b>	All H <sup>+</sup> comes from acid / none from water / $[\text{H}^+] = [\text{HCOO}^-]$ OR $[\text{H}^+] = [\text{A}^-]$ OR Dissociation of acid is negligible / very small OR $[\text{HA}]_{\text{initial}} = [\text{HA}]_{\text{equilibrium}}$	$K_a$ is measured at 298K   Just "dissociation of acid is partial"	<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4</b> <b>(c) (i)</b>	HCOOH CH <sub>3</sub> COOH <sub>2</sub> <sup>+</sup> both correct <b>(1)</b>		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4</b> <b>(c) (ii)</b>	(HIO + CH <sub>3</sub> COOH $\rightleftharpoons$ ) H <sub>2</sub> IO <sup>+</sup> + CH <sub>3</sub> COO <sup>-</sup> / (HIO + CH <sub>3</sub> COOH $\rightleftharpoons$ ) HIOH <sup>+</sup> + CH <sub>3</sub> COO <sup>-</sup> Ignore position of positive charges		<b>1</b>

Question Number	Acceptable Answers	Reject	Mark
<b>4 (d)</b>	<p>(pH = 4.9) so <math>[H^+] = (1.2589254 \times 10^{-5})</math>  <math>= 1.259 \times 10^{-5}</math> (1)</p> <p>( <math>K_a = \frac{[HCOO^-]}{[H^+][HCOOH]}</math></p> <p><math>= \frac{1.6 \times 10^{-4}}{1.259 \times 10^{-5}}</math> )</p> <p><b>= 12.7 (:1) / 13(:1) (HCOO<sup>-</sup> per HCOOH or base:acid)</b></p> <p>(12.709252 from unrounded <math>[H^+]</math>  12.708499 from <math>[H^+]</math> rounded to <math>1.259 \times 10^{-5}</math>  12.3 from <math>[H^+]</math> rounded to <math>1.3 \times 10^{-5}</math>  TE from error in <math>[H^+]</math></p> <p><b>Allow 800:63 (1)</b></p> <p><b>Correct answer scores 2</b></p> <p>Accept (0.0786828) = <b>0.079 HCOOH per HCOO<sup>-</sup> for acid:base ratio</b></p> <p>(0.0786874) = 0.079 from rounded pH</p> <p><b>OR</b></p> <p><math>pK_a = -\log K_a = 3.79</math></p> <p><math>3.79 = 4.9 - \log \frac{[base]}{[acid]}</math> (1)</p> <p><math>\log \frac{[base]}{[acid]} = 1.11</math></p> <p><math>\frac{[base]}{[acid]} = (12.882496) = \mathbf{12.9 (:1) (1)}</math></p> <p><b>Correct answer scores 2</b></p> <p>Accept <b>0.0776/ 0.078 HCOOH per HCOO<sup>-</sup> for acid:base ratio</b>  (0.0776247)</p> <p>TE from error in <math>pK_a</math>  Ignore sf except 1</p>		<b>2</b>