Question Number	Acceptable Answers	Reject	Mark
1 (a)(i)	Correct answer with or without working scores **2 marks** $[H^+] = (1.00 \times 10^{-14} / 0.250) = 4 \times 10^{-14}$ **(1)** pH = (13.39794 =) 13.4 **(1)** **OR** pOH = -log 0.250 = 0.602 **(1)** pH = (13.39794 =)13.4 **(1)** *ALLOW* TE in second mark if error in $[H^+]$ calculation gives pH more than 7 3 or more sf *IGNORE* rounding errors e.g. accept 13.39		**2**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(ii)	(K_a =) $\frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$ **(1)** *ALLOW* H_30^+ instead of H^+ $\frac{[A^-][H^+]}{[HA]}$ if key to symbols given *IGNORE* state symbols	$\frac{[H^+]^2}{[CH_3COOH]}$	**1**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(iii)	Correct answer with or without working scores **2 marks** $1.7 \times 10^{-5} = \frac{[H^+]^2}{0.125}$ **(1)** $[H^+] = 1.46 \times 10^{-3}$ pH = 2.84/2.8 **(1)** no TE from an incorrect $[H^+]$		**2**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(iv)	pH = 4.8 / 4.77 **(1)** pH = pK_a / $[H^+] = K_a$ (when acid is half neutralized) **(1)**	 $H^+ = K_a$	**2**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(v)	Sigmoid curve starting between pH 2 and 4 (2.8), ending between pH 12 and 14 inclusive **(1)** with steep rise (may be vertical or gently sloping) of between 3 – 7 units between pH 6 and 12. Sloping section should not extend over more than 5cm^3. **(1)** When 12.5 cm^3, NaOH added. **(1)** *ALLOW* tolerance for grid Reverse curves lose first mark		**3**

Question Number	Acceptable Answers	Reject	Mark
1 (a)(vi)	**First mark** Thymolphthalein more suitable as it changes (from colourless to blue) in steep region of titration (pH 8.3 to 10.6)/ at the equivalence point / at the end point OR thymolphthalein has pH range in steep region of titration **(1)** **Second mark** Methyl yellow changes (from red to yellow at pH 2.9 to 4) before equivalence point / before the end point / doesn't change in steep section OR Methyl yellow has pH range before / outside steep region of titration **(1)** *ALLOW* 'Thymolphthalein more suitable as it changes at the equivalence point but methyl yellow does not.' This scores **2 marks** **OR** **First mark** pK_{in} ± 1 must lie within vertical region on titration curve **(1)** **Second mark** hence thymolphthalein is suitable and methyl yellow is not **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
1 (b)	Sodium ethanoate/ CH_3COONa Potassium ethanoate / CH_3COOK *ALLOW* other cations as alternatives to sodium	Use of sodium hydroxide (because it's in food)	**1**

Question Number	Acceptable Answers	Reject	Mark
2(a)(i)	K_w = $[H^+]$ x $[OH^-]$ OR K_w = $[H_3O^+]$ x $[OH^-]$ State symbols are not required IGNORE any incorrect state symbols	Inclusion of $[H_2O]$	**1**

Question Number	Acceptable Answers	Reject	Mark
2(a)(ii)	**FIRST, CHECK THE FINAL ANSWER** **IF** answer pH = 11.875 / 11.88 / 11.9 /12 award **2** marks **IGNORE** sf except 1 sf $[H^+] = \frac{K_w}{[OH^-]} = \frac{1.00 \times 10^{-14}}{0.00750}$ $= 1.3333 \times 10^{-12}$ $= 1.33 \times 10^{-12}$ **(1)** (mol dm^{-3}) **ALLOW** first mark for just $[H^+] = \frac{K_w}{[OH^-]}$ pH = $-\log_{10}[H^+]$ = 11.875 = 11.88 / 11.9 **(1)** OR pOH = $-\log_{10}[OH^-]$ = 2.12 **(1)** pH = pK_w – pOH pH = 11.88 / 11.9 **(1)** Second mark only awarded CQ if pH between 8 and 14		**2**

Question Number	Acceptable Answers	Reject	Mark
2(b))	**First mark** Moles NaOH = $\frac{0.00750 \times 20.0}{1000}$ $= 1.50 \times 10^{-4}$ (mol) **(1)** (Since HCOOH : NaOH ratio is 1:1) **Second mark** [HCOOH(aq)] = $\frac{1.50 \times 10^{-4}}{0.0250}$ **OR** $= 1.50 \times 10^{-4} \times \frac{1000}{25.0}$ **(1)** ($= 6.00 \times 10^{-3}$ mol dm^{-3}) **ALTERNATIVE APPROACH:** Use of an expression such as 0.00750 x 20.0 = 25 x **y** **(1)** **y** = $\frac{0.00750 \times 20.0}{25}$ **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)(i)	**(Weak)** dissociates / ionizes to a small extent **OR** dissociate / ionizes partially **OR** dissociates / ionizes incompletely **OR** does not fully dissociate / ionize **OR** forms an equilibrium when reacted with water **(1)** **(Acid)** proton donor ALLOW 'proton donator' **OR** produces / releases H^+ ions **OR** produces / releases H_3O^+ ions **(1)** Ignore reference to typical acid reactions	'not easily dissociated'	**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)(ii)	(K_a =) $\frac{[HCOO^-]\,[H^+]}{[HCOOH]}$ State symbols are NOT required IGNORE any incorrect state symbols	(K_a =) $\frac{[H^+]^2}{[HCOOH]}$ Inclusion of $[H_2O]$	**1**

Question Number	Acceptable Answers	Reject	Mark
2(c)(iii)	**IGNORE** sf except 1 sf THROUGHOUT **FIRST, CHECK THE FINAL ANSWER** **IF** answer $K_a = 1.59 \times 10^{-4}$ (mol dm^{-3}) award the first two **2** marks $[H^+]$ $(= 10^{-pH} = 10^{-3.01})$ $= 9.77 \times 10^{-4}$ (mol dm^{-3}) **(1)** $K_a = \frac{[H^+]^2}{[HCOOH]}$ $K_a = \frac{(9.77 \times 10^{-4})^2}{6.00 \times 10^{-3}}$ $= 1.59 \times 10^{-4}$ (mol dm^{-3}) **(1)** **Assumption 1** $[H^+] = [HCOO^-]$ **OR** no H^+ from the (ionization of) water **OR** H^+ only from the acid **(1)** **Assumption 2** Ionization of the (weak) acid is negligible / very small / insignificant **OR** $[HCOOH]_{in\,tial} - x = [HCOOH]_{eqm}$ **OR** $[HCOOH]_{eqm} = [HCOOH]_{initial}$ **OR** $[HCOOH]_{eqm} = 6.00 \times 10^{-3}$ (mol dm^{-3}) **OR** $[H^+] << [HA]$ **(1)** **Assumptions can be in either order**	If incorrect units max 1 **Just** 'partial' / 'incomplete' **Or** **'** no dissociation'	**4**

2(c)(iii) cont'd	**OR** $[H^+]$ $(= 10^{-pH} = 10^{-3.01})$ $= 9.77 \times 10^{-4}$ (mol dm^{-3}) **(1)** $K_a = \frac{[H^+]^2}{[HCOOH]}$ $K_a = \frac{(9.77 \times 10^{-4})^2}{(6.00 \times 10^{-3} - 9.77 \times 10^{-4})}$ **(1)** $= 1.90 \times 10^{-4}$ (mol dm^{-3}) **(1)** **Assumption** $[H^+] = [HCOO^-]$ **OR** no $[H^+]$ from the (ionization of) water **OR** H^+ only from the acid **(1)** Ignore references to constant temperature		

Question Number	Acceptable Answers	Reject	Mark
3 (a)(i)	(Ka =) $[H^+][C_6H_5COO^-]/[C_6H_5COOH]$ Penalise missing charges ALLOW $[H_3O^+]$ in place of $[H^+]$ IGNORE state symbols and units even if incorrect	Ka = $[H^+]^2/[C_6H_5COOH]$	**1**

Question Number	Acceptable Answers	Reject	Mark
3(a)(ii)	$[H^+] = \sqrt{(6.3 \times 10^{-5} \times 0.0025)}$ (1) pH = − log $\sqrt{(6.3 \times 10^{-5} \times 0.0025)}$ = 3.4 **(1)** Answer without working scores (2) marks 6.8 scores (1) IGNORE sf except 1	answer if units given	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)	(pH) range (of indicator) 3.8 to 5.4 OR pK_{in} = 4.7 **(1)** Bubble bath is (initially yellow since) pH less than 3.8 / is 3.4 **(1)** Adding of water/dilution (of acid) causes pH to rise/ means $[H^+]$ decreases **(1)** Hence pH rises to ≥ 5.4 so blue/changes colour **(1)** If a(ii) pH>3.8 and <5.4 then loses second marking point but can score other marking points. If a(ii) pH>5.4 then can score first and third marking points only	Water neutralizes acid	**4**

Question Number	Acceptable Answers	Reject	Mark
18 (a)	pH = (-log 0.25) = 0.602 / 0.60 / 0.6 Ignore significant figures		**1**

Question Number	Acceptable Answers	Reject	Mark
18 (b) (i)	(K_a =) $\frac{[H^+][CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$ ALLOW $[H_3O^+]$ for $[H^+]$ ALLOW C_2H_5 for CH_3CH_2 ALLOW $\frac{[H^+][A^-]}{[HA]}$ if HA and A^- identified	Wrong / missing charge on $CH_3CH_2COO^-$ $K_a = \frac{[H^+]^2}{[CH_3CH_2COOH]}$ unless full expression also given	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (b) (ii)	$1.3 \times 10^{-5} = \frac{[H^+]^2}{0.25}$ / rearrangement of this expression **(1)** ($[H^+] = 1.8 \times 10^{-3}$) pH = **2.74** **(1)** Correct answer with no working scores (2) No TE for incorrect $[H^+]$ Ignore significant figures except 1 Minimum of 1 decimal place needed		**2**

Question Number	Acceptable Answers	Reject	Mark
18 (c) (i)	$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COO^{(-)}Na^{(+)} + H_2O$ OR $CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$ Accept $CH_3CH_2CO_2H$, C_2H_5COOH, $C_2H_5CO_2H$	Equations for ethanoic acid	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (c) (ii)	$1.3 \times 10^{-5} = \frac{[H^+][5 \times 10^{-2}]}{[7.5 \times 10^{-2}]}$ (concentration ratio) OR $1.3 \times 10^{-5} = \frac{[H^+](1 \times 10^{-3})}{(1.5 \times 10^{-3})}$ (ratio by moles) (ratio by moles allowed as volumes acid and salt equal) **(1)** ($[H^+]$ = **1.95×10^{-5}**) pH = **4.7** / 4.7099654 **(1)** Second mark dependent on first Correct answer with or without working **(2)** OR $pH = pK_a - \log \frac{(1.5 \times 10^{-3})}{1 \times 10^{-3}}$ OR $pH = pK_a - \log \frac{(7.5 \times 10^{-2})}{5 \times 10^{-2}}$ **(1)** pH = 4.7 **(1)** Correct answer with or without working **(2)** Accept any value which rounds to 4.7		**2**

Question Number	Acceptable Answers	Reject	Mark
***18 (c) (iii)**	Mixture is a buffer **(1)** EITHER OH^- combines with H^+ in solution **(1)** Propanoic acid dissociates to replace H^+ **(1)** *Correct equations could gain these marks* OR OH^- reacts with propanoic acid **(1)** *Correct equation could gain this mark* Significant quantities of weak acid and salt are both present /ratio of acid and salt does not change **(1)** ALLOW a reservoir of weak acid and salt are present: Allow conjugate base for salt	NaOH combines	**3**

Question Number	Acceptable Answers	Reject	Mark
18 (c) (iv)	S-shaped curve, vertical at 25 cm^3 (with kink at start) **(1)** Starting at pH 2-3 (TE from (b)(ii), finishing at pH 12 -13 **(1)** Vertical section between 3 and 6 units high centred round a pH of between 8 and 9 **(1)** Vertical section should not extend over more than $\pm 2.5 cm^3$ This section should start between 5.5 and 7.5 and finish between 9.5 and 11.5 but do not penalise for very small differences. Reverse curve maximum 2		**3**

Question Number	Acceptable Answers	Reject	Mark
18 (c) (v)	Either Need indicator changing in vertical region of curve / need indicator changing where pH changes sharply / bromocresol green changes before the vertical region **(1)** **Not** bromocresol green which changes at **3.8 – 5.4** **(1)** OR pK_{in} ±1 must be in vertical section / sharply changing section **(1)** **Not** bromocresol green because pK_{in} is **4.7** **(1)** TE from curve with vertical section including pH 3.7 – 5.7	Just "the equivalence point is outside the bromocresol green range"	**2**

Question Number	Acceptable Answers	Reject	Mark
18 (d) (i)	Dilute acid / dilute strong named acid or formula / NaOH(aq) followed by dilute acid /water plus dilute acid / water plus H^+	NaOH alone water any weak acid concentrated sulfuric acid HCN acid hydrolysis alone	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (d) (ii)	$CH_3CH_2COCl + H_2O \rightarrow CH_3CH_2COOH + HCl$ / $C_2H_5COCl + H_2O \rightarrow C_2H_5COOH + HCl$ Accept displayed formula	Equations with NaOH or OH^-	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (d) (iii)	Colour change orange to green / blue		**1**

Question Number	Acceptable Answers	Reject	Mark
18 (e)	Reducing agent /Reduction (of the acid) occurs **(1)** Li Al H_4 / lithium tetrahydridoaluminate / lithium aluminium hydride **(1)** Allow minor error in name if correct formula is given Ignore solvent ALLOW nucleophile AND H^- for 1 mark	Lithal without correct name or formula	**2**

Question Number	Acceptable Answers	Reject	Mark
5 (a)(i)	(pH =) -log $[H^+]$ OR (pH =) -log $[H_3O^+]$ OR **Accept** Definition in words (For example: "It is minus / negative log(arithm) of the hydrogen **ion** concentration") Base 10 does not have to be there, but reject "**ln**"	**Just** "concentration of hydrogen ions" { } curly brackets -log H^+	**1**

Question Number	Acceptable Answers	Reject	Mark
5 (a)(ii)	(pH = -log 0.0100) = 2(.00)	If any units given	**1**

Question Number	Acceptable Answers	Reject	Mark
5 (b)(i)	$[H_3O^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]}$ OR $[H_3O^+]^2 = K_a[CH_3COOH]$ **(1)** *ALLOW* [HA] for $[CH_3COOH]$ and $[A^-]$ for $[CH_3COO^-]$ in rearranged expression **Accept** $[H^+]$ for $[H_3O^+]$ $\therefore [H_3O^+] = \sqrt{1.75 \times 10^{-7}}$ OR $\therefore [H_3O^+] = 4.18(3) \times 10^{-4}$ (mol dm^{-3}) **(1)** pH = 3.38 / 3.4 **(1)** ignore sf except one sf Third mark TE from $[H^+]$ only if pH **less than 7** ***N.B. CORRECT ANSWER, WITH OR WITHOUT WORKING, SCORES (3)*** **Assumption** assumes that degree of ionisation of the acid is very small/negligible OR $[CH_3COOH]_{eqm} = [CH_3COOH]_{initial}$ OR $[H^+] = [CH_3COO^-]$ OR all of the hydrogen **ions** come from the acid / ignore hydrogen ions from the water **(1)** *IGNORE* any references to temperature	3.37 / 3 /3.39 / a correct pH value **with units** just "weak acid" / just "partially dissociates" / acid does not dissociate / $[CH_3COOH]$ **constant** $[H^+] = [OH^-]$ / $[H^+]$ = [salt]	**4**

Question Number	Acceptable Answers	Reject	Mark
5 (b)(ii)	**First mark:** (Dilution/addition of water) shifts the equilibrium $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ / $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ to the **right** OR the above stated in words such as: degree of dissociation increases/ proportion of dissociation increases/ more dissociation (as the ethanoic acid is diluted) **(1)** **Second mark:** so the $[H^+]$ is greater than expected/ so the decrease in $[H^+]$ is less than expected / so that the decrease in $[H^+]$ is less than that for hydrochloric acid **(1)** **Each mark is a stand alone mark.** *ALTERNATIVE ROUTE:* **First mark:** $[H^+] = \sqrt{K_a} \times [HA]$ OR $(K_a \times [HA])^{\frac{1}{2}}$ OR $pH = \frac{1}{2}pK_a - \frac{1}{2}\log[HA]$ **(1)** **Second mark:** use of mathematical expression given (e.g.$[H^+]$ affected by factor of $1/\sqrt{10}$ on dilution OR substitution of numerical values into the equation) **(1)** *IGNORE:* any comments or calculations relating to HCl(aq)	Reject just a reference to a 0.5 increase in pH for $CH_3COOH(aq)$ compared with a 1.0 increase in pH for HCl(aq)	**2**

Question Number	Acceptable Answers	Reject	Mark
5 (c)(i)	**These marks are stand alone.** Maintains an **almost** constant pH / resists change(s) in pH **(1)** for **small** addition of H^+ or OH^- ions (N.B. both ions needed) / for **small** additions of acid or alkali / for **small** additions of acid or base **(1)** *IGNORE* any references to named buffer mixtures	"resists small change(s) in pH" OR "pH does not change"	**2**

Question Number	Acceptable Answers	Reject	Mark
5 (c)(ii)	citric acid		**1**

Question Number	Acceptable Answers	Reject	Mark
5 (c)(iii)	**First mark:** (buffer contains) reservoir of HA **and** A^- OR (buffer contains) large concentrations of [HA] **and** $[A^-]$ OR **both** equations: $HA \rightleftharpoons A^- + H^+$ **and** $NaA \rightarrow Na^+ + A^-$ **(1)** **Second mark:** (Addition of alkali/base) $HA + OH^- \rightarrow A^- + H_2O$ OR description/equations to show that H^+ reacts with OH^- (to form H_2O) and more acid dissociates (to replace H^+) **(1)** **Third mark:** (Addition of acid) $A^- + H^+ \rightarrow HA$ OR A^- reacting with H^+ in any context described in words (e.g. by reference to weak acid equilibrium) **(1)** **Fourth mark:** the ratio of $[A^-] \div [HA]$ hardly changes / the ratio of $[HA] \div [A^-]$ hardly changes OR $[A^-]$ nor [HA] changes **significantly (1)**	<u>**JUST**</u> $NaA \rightleftharpoons Na^+ + A^-$ and $HA \rightarrow H^+ + A^-$ without correct description **Just** $[H^+]$ remains constant	**4**