Question			Answer	Marks	Guidance
1	(a)		Proton/H^+ donor **AND** Partially dissociates/ionises ✓	**1**	
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 13.7(0), award **2 marks** **----------** $[H^+] = \frac{1.00 \times 10^{-14}}{0.5(00)}$ **OR** $2(.00) \times 10^{-14}$ (mol dm^{-3}) ✓ pH = –log $2(.00) \times 10^{-14}$ = **13.7(0)** ✓	**2**	For pOH method:, **ALLOW** pOH = –log$[OH^-]$ = 0.3(0) ✓ (calculator 0.301029995) **ALLOW** pH = 14 – 0.3 = 13.7 ✓ **ALLOW** 13.7 up to calculator value of 13.69897 correctly rounded. **ALLOW ECF** from incorrect $[H^+(aq)]$ provided that pH >7
	(c)	(i)	$(K_a =) \frac{[H^+]\,[C_2H_5COO^-]}{[C_2H_5COOH]}$ ✓	**1**	**IGNORE** $\frac{[H^+]^2}{[C_2H_5COOH]}$ **OR** $\frac{[H^+]\,[A^-]}{[HA]}$ **ALLOW** $[H_3O^+]$ for $[H^+]$ **IGNORE** state symbols

Question			Answer	Marks	Guidance
	(c)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **2.9(0)**, award **3 marks** **----------** [C_2H_5COOH] = 0.12(0) mol dm^{-3} ✓ $[H^+] = \sqrt{K_a \times [C_2H_5COOH]} = \sqrt{1.35 \times 10^{-5} \times 0.12(0)}$ **OR** 1.27×10^{-3} (mol dm^{-3}) ✓ pH = –log 1.27×10^{-3} = **2.9(0)** ✓ **NOTE**: The final two marks are **ONLY** available from attempted use of K_a **AND** [C_2H_5COOH]	**3**	**ALLOW** HA for C_2H_5COOH and A^- for $C_2H_5COO^-$ **ALLOW ECF** from incorrectly calculated [C_2H_5COOH] **ALLOW** 1.27×10^{-3} to calculator value of $1.272792206 \times 10^{-3}$ correctly rounded **ALLOW** $2.9(0) \times 10^{-3}$ to calculator value of 2.895242493 correctly rounded **ALLOW** use of quadratic equation which gives same answer of 2.90 from 0.120 mol dm^{-3} **----------** **COMMON ERRORS (MUST be to AT LEAST 2 DP unless 2nd decimal place is 0)** **pH = 2.59 2 marks** –log√ (1.35 x 10^{-5} × 0.480) *Original conc* **pH = 5.79 2 marks** –log(1.35 x 10^{-5} × 0.120) *No √* **pH = 5.19 1 mark** –log (1.35 x 10^{-5} × 0.480) *Original conc, no √* **pH = 4.87 0 marks** –log(1.35 x 10^{-5}) = 4.87 *–log K_a*

Question			Answer	Marks	Guidance
	(d)	(i)	$2C_2H_5COOH + Na_2CO_3 \rightarrow 2C_2H_5COONa + CO_2 + H_2O$ ✓	1	**IGNORE** state symbols and use of equilibrium sign **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3 **ALLOW** $C_2H_5COO^-Na^+$ **OR** $C_2H_5COO^- + Na^+$ **BUT BOTH** + and – charges **must** be shown **ALLOW** NaC_2H_5COO
	(d)	(ii)	$H^+ + OH^- \rightarrow H_2O$ ✓	1	**ALLOW** $C_2H_5COOH + OH^- \rightarrow C_2H_5COO^- + H_2O$ **IGNORE** state symbols
	(e)	(i)	pH = –log 1.35×10^{-5} = **4.87** ✓	1	**ONLY** correct answer **DO NOT ALLOW** 4.9 (*Question asks for 2 DP)*
	(e)	(ii)	**Added ammonia** C_2H_5COOH removes added NH_3/alkali/base **OR** $C_2H_5COOH + NH_3 / OH^- \rightarrow$ **OR** NH_3/alkali reacts with/accepts H^+ **OR** $H^+ + NH_3 \rightarrow$ **OR** $H^+ + OH^- \rightarrow$ ✓ Equlibrium → $C_2H_5COO^-$ **OR** Equilibrium → right ✓	2	**ALLOW** use of HA/weak acid/acid for C_2H_5COOH; **ALLOW** use of NH_4OH for NH_3 **ALLOW** A^- for $C_2H_5COO^-$ **ASSUME** that equilibrium applies to that supplied in the question, i.e. **IGNORE** any other equilibria

Question			Answer	Marks	Guidance
	(e)	(iii)	***CHECK WORKING CAREFULLY AS CORRECT NUMERICAL ANSWER IS POSSIBLE FROM WRONG VALUES*** ========== **ALLOW** HA and A^- throughout **Amount of Mg (1 mark)** $n(Mg) = \frac{6.075}{24.3} = 0.25(0)$ mol ✓ --- **Moles/concentrations(2 marks)** $n(C_2H_5COOH) = 1.00 - (2 \times 0.25) = 0.50$ (mol) ✓ $(C_2H_5COO^-) = 1.00 + (2 \times 0.25) = 1.50$ (mol) ✓ ~~n~~--- **$[H^+]$ and pH (1 mark)** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ **OR** 4.5×10^{-6} (mol dm^{-3}) pH = –log 4.5×10^{-6} = **5.35 2 dp required** ✓ **NOTE: IF there is no prior working,** **ALLOW 4 MARKS for** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ **AND** pH = **5.35** **IF the ONLY response is pH = 5.35, award 1 mark ONLY**	**4**	***FULL ANNOTATIONS MUST BE USED*** --- **For *n*(Mg), 1 mark** **ALLOW ECF f**or **ALL** marks below from incorrect *n*(Mg) **ECF ONLY** available from concentrations that have • subtracted 0.50 **OR** 0.25 from 1 for $[C_2H_5COOH]$ • added 0.50 **OR** 0.25 to 1 for $[C_2H_5COO^-]$ ***i.*** **For moles/concentration 1 mark (1 mark lost)** **1.** *n* $(C_2H_5COOH) = 0.75$ **AND** $n(C_2H_5COO^-) = 1.25$ ***2.*** $n(C_2H_5COOH) = 0.50$ **AND** $n(C_2H_5COO^-) = 1.25$ ***3.*** $n(C_2H_5COOH) = 0.75$ **AND** $n(C_2H_5COO^-) = 1.50$ --- **ALLOW ECF ONLY** for the following giving 1 additional mark and a total of **3 marks** **1.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.25}$ pH = –log 8.1×10^{-6} = **5.09** **2.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.25}$ pH = –log 5.4×10^{-6} = **5.27** **3.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.50}$ pH = –log 6.75×10^{-6} = **5.17**
			Award a maximum of 1 mark (for *n*(Mg) = 0.25 mol) for: pH value from K_a square root approach (weak acid pH) pH value from $K_w / 10^{-14}$ approach (strong base pH) --- **ALLOW** alternative approach based on Henderson–Hasselbalch equation for final 1 mark $pH = pK_a + \log \frac{1.5}{0.5}$ **OR** $pK_a - \log \frac{0.5}{1.5}$ pH = 4.87 + 0.48 = 5.35 ✓ **ALLOW** $-\log K_a$ for pK_a		
			Total	**16**	

Question			Answer	Marks	Guidance
2	(a)		CH_3COOH + H_2O ⇌ H_3O^+ + CH_3COO^- ✓ Acid 1 Base 2 Acid 2 Base 1 ✓	2	**IGNORE** state symbols (even if incorrect) **ALLOW** 1 **AND** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels if linked by lines so that it is clear what the acid–base pairs are **ALLOW** A and B for 'acid' and 'base' **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, *i.e.* CH_3COOH + H_2O ⇌ $CH_3COOH_2^+$ + OH^- × Base 2 Acid 1 Acid 2 Base 1 ✓ **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** *i.e., **NO ECF** from impossible chemistry*
	(b)	(i)	Water dissociates/ionises **OR** $H_2O \rightleftharpoons H^+ + OH^-$ **OR** $2H_2O \rightleftharpoons H_3O^+ + OH^-$ ✓	1	**ALLOW** $K_w = [H^+]\,[OH^-]$ **OR** $[H^+]\,[OH^-] = 10^{-14}$ ($mol^2\ dm^{-6}$) **IGNORE** breaking for dissociation **IGNORE** water contains H^+ and OH^- **IGNORE** $H_2O \rightarrow H^+ + OH^-$ *i.e. no equilibrium sign* **IGNORE** $2H_2O \rightarrow H_3O^+ + OH^-$ *i.e. no equilibrium sign*

	(b)	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 1.15 × 10^{-11}, award 2 marks** --- $[H^+] = 10^{-3.06} = 8.71 \times 10^{-4}$ (mol dm^{-3}) ✓ $[OH^-] = \frac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓ **ALLOW** answer to two or more significant figures 2SF: 1.1×10^{-11}; 4SF: 1.148×10^{-11}; calculator $1.148153621 \times 10^{-11}$	**2**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. --- **ALLOW 2 SF:** 8.7×10^{-4} up to calculator value of 8.7096359×10^{-4} correctly rounded **ALLOW** alternative approach using pOH: pOH = 14 – 3.06 = 10.94 ✓ $[OH^-] = 10^{-10.94} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓
	(c)	**(i)**	$2CH_3COOH + CaCO_3 \rightarrow (CH_3COO)_2Ca + CO_2 + H_2O$ ✓	**1**	**IGNORE** state symbols **ALLOW** ⇌ provided that reactants on LHS For $CO_2 + H_2O$, **ALLOW** H_2CO_3 **ALLOW** $Ca(CH_3COO)_2$ **ALLOW** $(CH_3COO^-)_2Ca^{2+}$ **BUT DO NOT ALLOW** if either charge is missing or incorrect

	(c)	**(ii)**	solution contains CH_3COOH **AND** CH_3COO^- ✓	**1**	**ALLOW** names: ethanoic acid for CH_3COOH ethanoate for CH_3COO^- **ALLOW** calcium ethanoate **OR** $(CH_3COO)_2Ca$ for CH_3COO^- **IGNORE** 'acid, salt, conjugate base; responses must identify the acid and conjugate base as ethanoic acid and ethanoate **IGNORE** ethanoic acid is in excess (*in question*) **BUT DO ALLOW** some ethanoic acid is left over/present/some ethanoic acid has reacted **IGNORE** equilibrium: $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ *Dissociation of ethanoic acid only*

	(c)	**(iii)**	**Quality of written communication, QWC** 2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^- (see below) --- $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ ✓ --- CH_3COOH reacts with added alkali **OR** $CH_3COOH + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓ Equilibrium → right **OR** Equilibrium → CH_3COO^- ✓ (**QWC**) CH_3COO^- reacts with added acid ✓ Equilibrium → left **OR** Equilibrium → CH_3COOH ✓ (**QWC**)	**5**	***FULL ANNOTATIONS MUST BE USED*** --- **Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2** **DO NOT ALLOW** $HA \rightleftharpoons H^+ + A^-$ **DO NOT ALLOW** more than one equilibrium equation. --- **ALLOW** response in terms of H^+, A^- and HA **IF** more than one equilibrium shown, it **must** be clear which one is being referred to by labeling the equilibria. **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

	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 11.48 OR 11.5 (g), award 5 marks** --- $[H^+] = 10^{-5}$ (mol dm^{-3}) ✓ --- **$[CH_3COO^-]$** = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.200 = 0.350 mol dm^{-3} ✓ *n*(**CH_3COONa/CH_3COO^-**) in 400 cm^3 = 0.350 × $\frac{400}{1000}$ = 0.14(0) (mol) ✓ --- mass **CH_3COONa** = 0.140 × 82.0 = 11.48 **OR** 11.5 (g) ✓ For **ECF**, ***n*(CH_3COONa/CH_3COO^-) must** have been calculated in step before	**5**	***FULL ANNOTATIONS MUST BE USED*** --- **IF** there is an alternative answer, check to see if there is any **ECF** credit possible. **Incorrect use of $[H^+] = \sqrt{([CH_3COOH] \times K_a)}$ scores zero** **BUT IGNORE** if an alternative successful method is present **Incorrect use of K_w, 1 max for $[H^+] = 10^{-5}$ (mol dm^{-3})** **BUT IGNORE** if an alternative successful method is present --- **ALLOW** *n*(**CH_3COONa/CH_3COO^-**) = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.08 = 0.14(0) (mol) ✓✓ **Note: There is no mark just for** *n*(**CH_3COOH**) in 400 cm^3 = 0.200 × $\frac{400}{1000}$ = 0.08 (mol) --- As alternative for the 4th and 5th marks, **ALLOW**: mass of CH_3COONa in 1 dm^3 = 0.350 × 82.0 = 28.7 g ✓ mass of CH_3COONa in 400 cm^3 = 28.7 × $\frac{400}{1000}$ = 11.48 g ✓ --- **COMMON ECF** 4.592 **OR** 4.6 g **AWARD** 4 marks *use of 400/1000 twice*

					ALLOW variants of Henderson–Hasselbalch equation. $pK_a = -\log(1.75 \times 10^{-5}) = 4.757$ ✓ *Calc: 4.75696…..* $\log \frac{[CH_3COO^-]}{[CH_3COOH]} = pH - pK_a = 5 - 4.757 = 0.243$ $\frac{[CH_3COO^-]}{[CH_3COOH]} = 10^{0.243} = 1.75$ ✓ $[CH_3COO^-] = 1.75 \times 0.200 = 0.350$ mol dm^{-3} ✓ n(**CH_3COONa/CH_3COO^-**) in 400 cm^3 $= 0.350 \times \frac{400}{1000} = 0.14(0)$ (mol) ✓ --- mass **CH_3COONa** = 0.140 × 82.0 = 11.48 **OR** 11.5 (g) ✓
			Total	**17**	

Question			er	Marks	Guidance
3	(a)		HC*l* is a strong acid **AND** HC*l*O is a weak acid ✓ **HC*l***: pH = –log 0.14 = 0.85 (**2 DP** required) ✓ **HC*l*O**: **CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 4.14, award all three calculation marks --- $K_a = 10^{-7.43}$ **OR** 3.7×10^{-8} (mol dm^{-3}) ✓ $[H^+] = \sqrt{K_a \times [HClO]}$ **OR** $\sqrt{K_a \times [HA]}$ **OR** $\sqrt{K_a \times 0.14}$ **OR** $\sqrt{3.7 \times 10^{-8} \times 0.14}$ ✓ pH = 4.14 (**2 DP** required) ✓	5	**ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** HC*l* completely dissociates **AND** HC*l*O partially dissociates **ALLOW** $HCl \rightarrow H^+ + Cl$ **AND** $HClO \rightleftharpoons H^+ + ClO^-$ **IGNORE** HC*l* is a stronger acid than HC*l*O **IGNORE** HC*l* produces more H^+ **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ALLOW** 2 SF to calculator value: $3.715352291 \times 10^{-8}$, correctly rounded **IGNORE** 'HC*l*' if it is clear that it is a 'slip' Always **ALLOW** calculator value irrespective of working as number may have been kept in calculator. ***Note**: pH = 4.14 is obtained from all three values above* *From no square root, pH = 8.28. Worth K_a mark only*

Question			er	Marks	Guidance
	(b)		$2Al + 6CH_3COOH \longrightarrow 2(CH_3COO)_3Al + 3H_2$ ✓ $2Al + 6H^+ \longrightarrow 2Al^{3+} + 3H_2$ ✓	2	**IGNORE** state symbols **ALLOW** correct multiples, e.g.: $Al + 3CH_3COOH \longrightarrow (CH_3COO)_3Al + 1.5H_2$ **ALLOW** any unambiguous formula for $(CH_3COO)_3Al$, *i.e.* $(CH_3CO_2)_3Al$, $Al(CH_3CO_2)_3$, $(CH_3COO^-)_3Al^{3+}$, etc. **Note**: **IF** charges are shown, they **must** be correct with **both** – and 3+ shown **ALLOW** multiples, e.g.: $Al + 3H^+ \longrightarrow Al^{3+} + 1.5H_2$
	(c)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 13.6(0), award **2 marks** --- $[H^+] = \frac{K_w}{[OH^-]}$ **OR** $\frac{1.0 \times 10^{-14}}{[OH^-]}$ **OR** $\frac{1.0 \times 10^{-14}}{0.4(0)}$ **OR** 2.5×10^{-14} (mol dm^{-3}) ✓ Correctly calculates pH = –log 2.5×10^{-14} = 13.6(0) ✓	2	 **ALLOW** alternative approach using pOH: pOH = 0.4(0) ✓ pH = 14 – 0.40 = 13.6(0) ✓ **ALLOW ECF** from $[H^+]$ derived using K_w and $[OH^-]$ BUT **DO NOT ALLOW** an acid pH. **ALLOW** one or more decimal places

Question			er	Marks	Guidance
	(d)	(i)	A buffer solution minimises pH changes ✓ on addition of **small** amounts of acid/H^+ or alkali/OH^-/base ✓ --- $HCOOH \rightleftharpoons H^+ + HCOO^-$ ✓ *Equilibrium sign essential*	7	**ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** resists pH changes **ALLOW** buffer solutions maintains a **nearly/virtually** constant pH **DO NOT ALLOW** a response that implies that the pH is actually constant, e.g. does not change pH; maintains pH --- **DO NOT ALLOW** $COOH^-$ **OR** CHOOH **OR** COOH **DO NOT ALLOW** $HA \rightleftharpoons H^+ + A^-$
			For effect of acid and alkali, **ALLOW** wrong carboxylic acid (e.g. CH_3COOH) **OR** HA; **ALLOW** CHOOH for acid (effectively **ECF**) **ALLOW** $COOH^-$ for base **ALLOW** responses based on $COOH \rightleftharpoons H^+ + COO^-$ **DO NOT ALLOW** other incorrect formula, e.g. CH_3OOH		**Quality of written communication, QWC** *2 marks are for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^-*
			Added alkali HCOOH reacts with added alkali/base/OH^- **OR** added alkali/OH^- reacts with H^+ ✓ **QWC**: Equilibrium shifts forming $HCOO^-$ **OR** H^+ **OR** (HCOOH) Equilibrium → right ✓ **Added acid** $HCOO^-$ reacts with added acid/H^+ ✓ **QWC**: Equilibrium shifts forming HCOOH **OR** (HCOOH) Equilibrium → left ✓		**ALLOW** HA **OR** weak acid reacts with added alkali **DO NOT ALLOW** this mark if there is no equilibrium system shown, e.g. $HCOOH \rightleftharpoons H^+ + HCOO^-$ is absent **ALLOW** A^- **OR** conjugate base reacts with added acid **IGNORE** salt reacts with added acid **DO NOT ALLOW** this mark if there is no equilibrium system shown, e.g. $HCOOH \rightleftharpoons H^+ + HCOO^-$ is absent

Question			er	Marks	Guidance
	(d)	(ii)	**HCOOH** reacts with **NaOH** forming **$HCOO^-$/HCOONa** **OR** $HCOOH + NaOH \rightarrow HCOONa + H_2O$ ✓ *Equilibrium sign allowed*	6	**ANNOTATE WITH TICKS AND CROSSES, etc** **DO NOT ALLOW** just 'methanoate/$HCOO^-$ forms' *formulae or names of reactants also required* **ALLOW** $HCOOH + OH^- \rightarrow HCOO^- + H_2O$ ✓ **IGNORE** conjugate base/**salt forms**
			(Some) HCOOH/(weak) acid remains **OR** HCOOH/(weak) acid is in excess ✓		**IGNORE** HCOOH has been partially neutralised
			Calculation **CHECK THE ANSWER** **IF** answer = 3.99, award all **four** calculation marks		
			n(HCOOH) **OR** [HCOOH] = 0.24(0) (mol / mol dm^{-3}) ✓ *n*($HCOO^-$) **OR** [$HCOO^-$] **OR** [HCOONa] = 0.4(00) (mol / mol dm^{-3}) ✓ $[H^+] = K_a \times \frac{[HCOOH]}{[HCOO^-]}$ ✓ $pH = -\log [H^+] = -\log(1.70 \times 10^{-4} \times \frac{0.24}{0.4}) = 3.99$ ✓ --- **OR** use of Henderson–Hasselbalch equation: $pH = pK_a + \log \frac{[HCOO^-]}{[HCOOH]}$ **OR** $pH = -\log K_a + \log \frac{[HCOO^-]}{[HCOOH]}$ ✓ $= 3.77 + 0.22 = 3.99$ ✓		**Note:** There must be a clear statement that 0.24 and 0.4 apply to moles or concentrations of HCOOH and $HCOO^-$. **DO NOT ALLOW** these values if unlabelled **ALLOW** HA/acid and A^-/salt for HCOOH and $HCOO^-$ **DO NOT ALLOW ECF for this mark:** **3.99 is the ONLY correct answer** --- **ALLOW** HA/acid and A^-/salt for HCOOH and $HCOO^-$ **ALLOW** $pH = pK_a - \log \frac{[HCOOH]}{[HCOO^-]}$ **OR** $pH = -\log K_a - \log \frac{[HCOOH]}{[HCOO^-]}$ **ALLOW** = 3.77 – (–0.22) = 3.99 **DO NOT ALLOW ECF for this mark:** **3.99 is the ONLY correct answer**
			Total	**22**	

Question			Answer	Marks	Guidance
4	(a)	(i)	$(K_a =) \dfrac{[H^+][CH_3(CH_2)_2COO^-]}{[CH_3(CH_2)_2COOH]}$ ✓	1	**ALLOW** $CH_3CH_2CH_2COOH$ **OR** C_3H_7COOH in expression **DO NOT ALLOW** use of HA and A^- in this part. **DO NOT ALLOW**: $\dfrac{[H^+][CH_3(CH_2)_2COO^-]}{[CH_3(CH_2)_2COOH]} = \dfrac{[H^+]^2}{[CH_3(CH_2)_2COOH]}$: **CON**
		(ii)	$pK_a = -\log K_a = 4.82$ ✓	1	**ALLOW** 4.82 up to calculator value of 4.821023053 **DO NOT ALLOW** 4.8
		(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 2.71 award **3 marks** --- $[H^+] = \sqrt{[K_a][CH_3(CH_2)_2COOH]}$ **OR** $\sqrt{1.51\times10^{-5}\times0.250}$ ✓ $[H^+] = 1.94 \times 10^{-3}$ (mol dm^{-3}) ✓ $pH = -\log[H^+] = 2.71$ ✓	3	**IF** alternative answer to more or fewer decimal places, check calculator value and working for 1st and 2nd marks --- **ALLOW** use of HA and A^- in this part **Calculator**: $1.942935923 \times 10^{-3}$ **ALLOW** use of calculated K_a value, either calculator value or rounded on script. pH **must** be to 2 decimal places **ALLOW ECF** from incorrectly calculated $[H^+]$ and pH **ONLY** when values for both K_a **AND** $[CH_3CH_2CH_2COOH]$ have been used, i.e. 1.5×10^{-5} **AND** 0.250. e.g.: pH = 5.42 2 marks $-\log(1.51 \times 10^{-5} \times 0.250)$ *No* √ pH = 2.11 2 marks $-\log(\sqrt{\dfrac{1.51\times10^{-5}}{0.250}})$ pH = 4.22 1 mark $-\log(\dfrac{1.51\times10^{-5}}{0.250})$ *No* √ **DO NOT ALLOW** just $-\log(1.51 \times 10^{-5}) = 4.82$ **NO MARKS**

Question			Answer	Marks	Guidance
	(b)	**(i)**	$Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$ ✓	1	**IGNORE** state symbols **ALLOW** $Mg + 2\ CH_3(CH_2)_2COOH \longrightarrow 2CH_3(CH_2)_2COO^- + Mg^{2+} + H_2$ **DO NOT ALLOW** on RHS: $(CH_3(CH_2)_2COO^-)_2Mg^{2+}$ ***Ions must be shown separately***
		(ii)	$CO_3^{2-} + 2H^+ \longrightarrow H_2O + CO_2$ ✓	1	**IGNORE** state symbols **ALLOW** $CO_3^{2-} + 2\ CH_3(CH_2)_2COOH \longrightarrow 2\ CH_3(CH_2)_2COO^- + H_2O + CO_2$ **ALLOW** as product H_2CO_3
	(c)	**(i)**	$CH_3(CH_2)_2COONa$ **OR** $CH_3(CH_2)_2COO^-$ forms **OR** $CH_3(CH_2)_2COOH + OH^- \rightarrow CH_3(CH_2)_2COO^- + H_2O$ ✓ $CH_3(CH_2)_2COOH$ is in excess **OR** acid is in excess **OR** some acid remains ✓	2	**ALLOW names throughout** **ALLOW** '**sodium** salt of **butanoic acid**' **ALLOW** $CH_3(CH_2)_2COOH + NaOH \rightarrow CH_3(CH_2)_2COONa + H_2O$ **DO NOT ALLOW** just 'forms a salt/conjugate base' i.e. identity of product is required

Question			Answer	Marks	Guidance
	(c)	(ii)	**Moles (2 marks)** amount $CH_3(CH_2)_2COOH$ = 0.0100 (mol) ✓ amount $CH_3(CH_2)_2COO^-$ = 0.0025 (mol) ✓ **Concentration (1 mark)** $[CH_3(CH_2)_2COOH]$ = 0.100 mol dm^{-3} **AND** $[CH_3(CH_2)_2COO^-]$ = 0.025 mol dm^{-3} ✓ **$[H^+]$ and pH (2 marks)** $[H^+] = 1.51\times10^{-5} \times \frac{0.100}{0.025}$ = 6.04 x 10^{-5} (mol dm^{-3}) ✓ pH = –log 6.04 x 10^{-5} = 4.22 ✓ **pH to 2 DP**	2 1 2	***ANNOTATIONS MUST BE USED*** --- **ALLOW** HA and A^- throughout **Mark** by **ECF** throughout **ONLY** award final 2 marks via a correct pH calculation via $K_a \times \frac{[CH_3(CH_2)_2COOH]}{[CH_3(CH_2)_2COO^-]}$ using data derived from that in the question (i.e. not just made up values)
			ALLOW alternative approach based on Henderson–Hasselbalch equation for final 2 marks pH = $pK_a + \log\frac{0.025}{0.100}$ **OR** $pK_a - \log\frac{0.100}{0.025}$ ✓ pH = 4.82 – 0.60 = 4.22 ✓ **ALLOW** $-\log K_a$ for pK_a		
			TAKE CARE with awarding marks for pH = 4.22 There is a mark for the concentration stage. If this has been omitted, the ratio for the last 2 marks will be 0.0100 and 0.0025. **4 marks max.** **Common errors** **pH = 5.42** As above for 4.22 but with acid/base ratio inverted. Award 4 **OR** 3 marks **Award zero marks for:** 4.12 from no working or random values pH value from K_a square root approach (weak acid pH) pH value from K_w /10^{-14} approach (strong base pH)		**Common errors** **pH = 4.12** use of initial concentrations: 0.250 and 0.050 given in question. **Award last 3 marks for:** 0.250/2 **AND** 0.050/2 = 0.125 **AND** 0.025 ✓ $1.51\times10^{-5} \times \frac{0.125}{0.025}$ = 7.55 x 10^{-5} (mol dm^{-3}) ✓ pH = $-\log[H^+]$ = 4.12 ✓ **Award last 2 marks for:** $1.51\times10^{-5} \times \frac{0.250}{0.050}$ = 7.55 x 10^{-5} (mol dm^{-3}) ✓ pH = $-\log[H^+]$ = 4.12 ✓ **pH = 5.52** As above for 4.12 but with acid/base ratio inverted. Award 2 **OR** 1 marks as outlined for 4.12 above

Question			Answer	Marks	Guidance
	(d)		$HCOOH + CH_3(CH_2)_2COOH \rightleftharpoons HCOO^- + CH_3(CH_2)_2COOH_2^+$ ✓ acid 1 base 2 base 1 acid 2 ✓ **CARE:** Both + and – charges are required for the products in the equilibrium **DO NOT AWARD** the 2nd mark from an equilibrium expression that omits either charge	2	State symbols **NOT** required **ALLOW** 1 **and** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels throughout if linked by lines so that it is clear what the acid-base pairs are For 1st mark, **DO NOT ALLOW** $COOH^-$ (i.e. H at end rather than start) but within 2nd mark **ALLOW** $COOH^-$ by **ECF** **IF** proton transfer is wrong way around then **ALLOW** 2nd mark for idea of acid–base pairs, i.e. $HCOOH + CH_3(CH_2)_2COOH \rightleftharpoons HCOOH_2^+ + CH_3(CH_2)_2COO^-$ × base 2 acid 1 acid 2 base 1 ✓ For H_2COOH^+ shown with wrong proton transfer, **DO NOT ALLOW** an **ECF** mark for acid–base pairs
			Total	**16**	