Question Number	Acceptable Answers	Reject	Mark
1(a)(i)	(K_C =) $\frac{[CH_3COOCH_2CH_3]\ [H_2O]}{[CH_3COOH]\ [CH_3CH_2OH]}$ ALLOW C_2H_5 for CH_3CH_2 State symbols are not required IGNORE any incorrect state symbols		**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)			**2**

Component	$CH_3COOH(l)$	$C_3CH_2OH(l)$	$C_3COOCH_2CH_3(l)$	$_2O(l)$
Equilibrium amount / mol	(0.20)	**0.10**	**0.20**	**0.35**

BOTH 0.10 AND 0.20 (1) **0.35 (1)**

0.10 **and** 0.20 scores first mark
Allow 0.1 and 0.2
0.35 scores second mark

Question Number	Acceptable Answers	Reject	Mark
1(a)(iii)	Units cancel **OR** same number of **moles**/same number of **molecules** on each side **OR** volume / V cancels Ignore statements such as 'concentrations cancel' 'products and reactants cancel' 'same number of products as reactants'	Concentrations are the same	**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iv)	K_C = $\frac{(0.20)\ /\ V\ \times\ (0.35)\ /\ V}{(0.20)\ /\ V\ \times\ (0.10)\ /\ V}$ = 3.5 / 3.50 Correct answer with or without working scores 1 Ignore omission of V	K_C = 4	**1**
	TE from values in (ii) table		

Question Number	Acceptable Answers	Reject	Mark
1(b)	• No effect on (position of) equilibrium **(1)** • Rate (of attainment of equilibrium) is faster / equilibrium reached sooner **(1)**		**2**

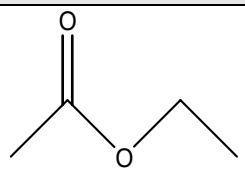
Question Number	Acceptable Answers	Reject	Mark
1(c)(i)	**Bonds Broken** C—O **and** O—H **(1)** Ignore where these bonds are broken in the acid and alcohol molecules. **ALLOW** C—OH for C—O CO−H for O—H **Bonds Made** C—O **and** O—H **(1)** Ignore where these bonds are made in the ester and water molecules. **ALLOW** C—OC for C—O H—OH for O−H Marks can be awarded by annotating displayed or structural formulae. Comment: Max **1** if any other bonds mentioned	**Two** O—H bonds formed in H_2O molecule **ONLY** C—O bond broken and made scores **(0)** overall	**2**

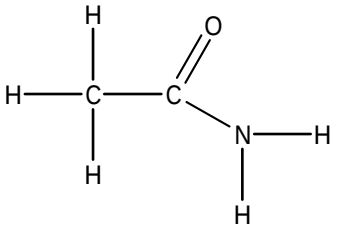
Question Number	Acceptable Answers	Reject	Mark
1(c)(ii)	(C−O and O−H) bond enthalpies differ in: different environments /different molecules /different compounds OR Bond enthalpies/bond energies are average values **ALLOW** Bonds being broken and made are attached to different atoms	'Heat loss'	**1**

Question Number	Acceptable Answers	Reject	Mark
1(d)(i)	$\Delta S_{total} = R \ln K$ Allow ΔS_{total} is proportional to **ln**K ALLOW K_c or K_p instead of K	log instead of ln ΔS_{total} is proportional to K / ΔS_{total} increases as K increases	**1**

Question Number	Acceptable Answers	Reject	Mark
***1(d)(ii**	**mark:** (ΔH = 0 so) $\Delta S_{surroundings}$ = 0 OR $-\frac{\Delta H}{T}$ = 0 **(1)** IGNORE "$\Delta S_{surroundings}$ stays the same". **Second mark:** (so) ΔS_{total} does not change OR (so) ΔS_{total} = ΔS_{system} **(1)** **Third mark:** (As ΔS_{total} = $R \ln K$) ***K*** does not alter **(1)** **ALLOW** "it does not alter" to assume K does not alter. ALLOW use of K_c or K_p instead of K **Each point is stand alone** **IGNORE** justifications in terms of Le Chatelier's Principle **NOTE:** **Can award max (1) (i.e. the third scoring point) if the effect on *K* stated follows on CQ from a change to ΔS_{total}**	If only mentions 'no effect on position of equilibrium' rather than the equilibrium constant	**3**

Question Number	Acceptable Answers	Reject	Mark
1(e)(i)	$CH_3COCl + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + HCl$ Allow C_2H_5 for CH_3CH_2 Allow $CH_3CO_2CH_2CH_3$ for $CH_3COOCH_2CH_3$ IGNORE missing or incorrect state symbols	CH_3CClO/ CH_2CH_3OH	**1**

Question Number	Acceptable Answers	Reject	Mark
1(e)(ii)	 **IGNORE** Bond angles and length of the lines.		**1**

Question Number	Acceptable Answers	Reject	Mark
1(e)(iii)	 **IGNORE** Other products of the reaction if the above structure has been correctly drawn.	NH_2 or CH_3	**1**

Question Number	Acceptable Answers	Reject	Mark
1(f)(i)	$(CH_3COOCH_2CH_3 + NaOH \rightarrow)$ $CH_3COONa + CH_3CH_2OH$ /C_2H_5OH Allow ionic representations of the sodium salt $CH_3COO^-Na^+$ IGNORE missing or incorrect state symbols	CH_2CH_3OH for ethanol	**1**

Question Number	Acceptable Answers	Reject	Mark
1(f)(ii)	(Reaction with sodium hydroxide is) **not** an equilibrium / **not** reversible / goes to completion OR Reverse argument for acid hydrolysis		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (a)	$K_p = \frac{p(H_2)^3\ p(CO)}{p(CH_4)p(H_2O)}$ **(1)** Brackets not required	**[ ]** $K_p = \frac{p(H_2)^3 + p(CO)}{p(CH_4) + p(H_2O)}$	**1**

Question Number	Acceptable Answers	Reject	Mark
2 (b)(i)	No effect (as K_p dependent only on temperature) **(1)**		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (b)(ii)	**(**Since $K_p = \frac{x(H_2)^3\ x(CO)}{x(CH_4)x(H_2O)} \times \frac{P_T^4}{P_T^2}$ to maintain K_p constant, mole fractions of numerator must decrease OR mole fractions of denominator must increase as $\times P_T^2$ overall**)** **First mark:** *EITHER* mole fractions/partial pressures of numerator decrease *OR* mole fractions/partial pressures of denominator increase **(1)** **Second mark:** any mention of $\times P_T^2$ OR $\times \frac{P_T^4}{P_T^2}$ **(1)** *ALLOW* ***P*** for P_T **NOTE:** **If Le Chatelier quoted, statements such as:** "Equilibrium shifts to side of fewer moles (of gas molecules)/fewer (gas) molecules" **max (1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
2 (b)(iii)	Reaction takes place on **surface** of the catalyst **(1)** Active sites/(catalyst) surface is saturated with reactant molecules/reactants (at the pressure of the reaction) **(1)** *NOTE:* an answer such as "... depends on the availability of active sites on catalyst surface" scores **(2)**		**2**

Question Number	Acceptable Answers	Reject	Mark
2 (c)	$CO + H_2O \rightleftharpoons CO_2 + H_2$ **initial: 1, 1, 0, 0** **eq'm: 0.25, 0.25, 0.75, 0.75** **mol frac: 0.125, 0.125, 0.375, 0.375** **pp: 3.75, 3.75, 11.25, 11.25** • eq'm moles all correct **(1)** • mole fractions all correct **(1)** • partial pressures and answer = 9 **with no units** **(1)** *NOTE:* **3rd** mark not awarded if any units shown *NOTE:* $\frac{11.25^2}{3.75^2}$ = 9 **scores (3)** *NOTE:* Mark each step CQ. **CHECK ALL WORKING**		**3**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(i)	production (of hydrogen) forms CO_2 OR production (of hydrogen) forms a Greenhouse gas OR production (of hydrogen) forms CO OR CO_2 is a Greenhouse gas OR CO is a Greenhouse gas ALLOW production (of hydrogen) uses/requires energy *ALLOW* CO is toxic/poisonous	methane **produced (0)**	**1**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(ii)	$2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$ *ALLOW* multiples		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (e)	products removed OR not a closed system OR balance between rate and yield OR balance between time and yield OR recycling of reactants OR more product in unit time (so process more economically viable) *IGNORE* any comments relating to cost	references to atom economy dangers of maintaining high pressures	**1**