Questions

Q1.

This question is about an experiment to determine the equilibrium constant, K_c , for an esterification reaction producing propyl ethanoate. The equation for the reaction is

$$\underset{\text{ethanoic acid}}{CH_3COOH(l)} + \underset{\text{propan-1-ol}}{CH_3CH_2CH_2OH(l)} \rightleftharpoons \underset{\text{propyl ethanoate}}{CH_3COOCH_2CH_2CH_3(l)} + H_2O(l)$$

In an experiment to determine the equilibrium constant, K_c , the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube.
In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

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(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $H^+(aq)$ ions.
Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid.

Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium

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Moles of propyl ethanoate at equilibrium

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Moles of water at equilibrium

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(d) (i) Write the expression for the equilibrium constant, K_c , for this reaction.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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(iii) Calculate the value of K_c.
Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.

Give a possible explanation for this observation.

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(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

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(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^{\ominus} = +21.4\,kJ\,mol^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

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(Total for question = 19 marks)

Q2.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

$CH_3CH_2CH_2COOH$ **A** or $HOCH_2CH{=}CHCH_2OH$ **B**

Deduce a **chemical** test which would give a positive result for **A** but **not** for **B**.
Include the reagent and observation.

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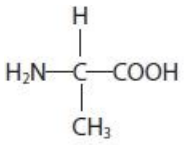
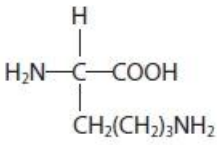
(Total for question = 2 marks)

Q3.

Alanine and lysine are amino acids.



alanine



lysine

Draw the **structure** of the organic product formed when **lysine** reacts with the following reagents:

(3)

aqueous sodium hydroxide, NaOH(aq)

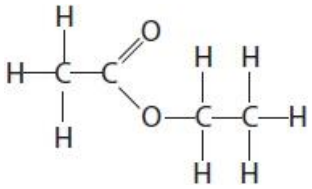
excess dilute hydrochloric acid, HCl(aq)

methanol, with warming, in the presence of a few drops of concentrated sulfuric acid.

(Total for question = 3 marks)

Q4.

Ethyl ethanoate is an ester.



Ethyl ethanoate can also be formed by reacting ethanol with ethanoyl chloride, CH_3COCl.

Identify **three** differences in the esterification reaction when ethanoyl chloride is used instead of ethanoic acid.

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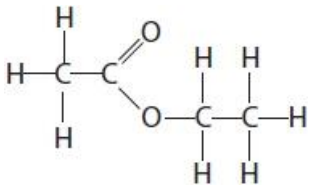
(Total for question = 3 marks)

Q5.

Ethyl ethanoate is an ester.



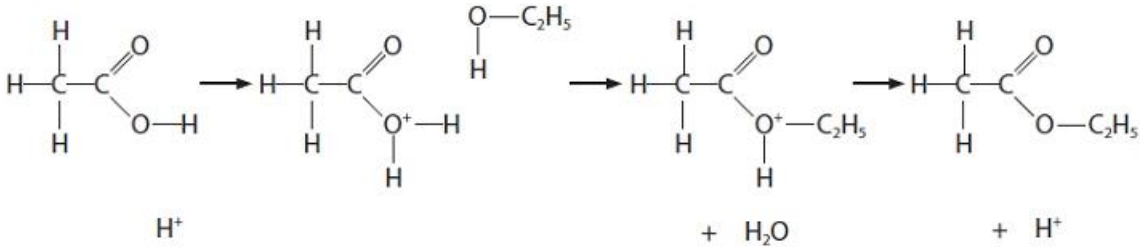
One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

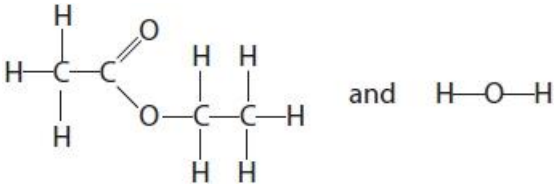
An incomplete simplified mechanism for this reaction is shown.

(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O. The products of the esterification are



Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, Δ*G*,
and the data in the table.

Include sign and units in your answer.
Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, *R*	8.31 J mol^{-1} K^{-1}
Temperature, *T*	298 K
Equilibrium constant of esterification reaction, *K*	4.0
Enthalpy change of esterification reaction, Δ*H*	–6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, $S^{\ominus}$	159.8 J K^{-1} mol^{-1}
Standard molar entropy of ethanol, $S^{\ominus}$	160.7 J K^{-1} mol^{-1}
Standard molar entropy of water, $S^{\ominus}$	69.9 J $K^{-1}mol^{-1}$

(6)

(Total for question = 12 marks)

Q6.

This question is about the identification of some organic compounds.

Compound **T**, $C_4H_{10}O$, is oxidised by acidified potassium dichromate(VI) to form compound **U**, C_4H_8O.

U gives an orange precipitate with 2,4-dinitrophenylhydrazine (Brady's reagent) but does **not** give a red precipitate when heated with Fehling's solution.

T reacts with ethanoyl chloride to form compound **V**, $C_6H_{12}O_2$.

Deduce the structures of compounds **T**, **U** and **V**. Justify your answers.

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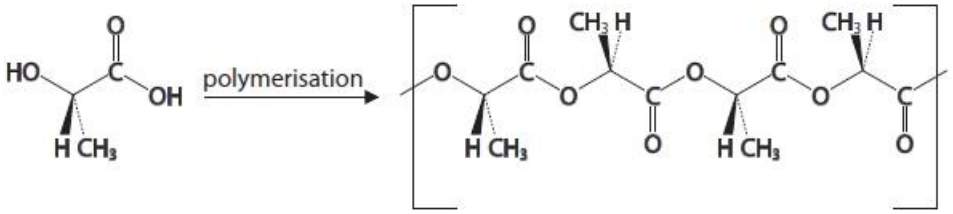
(Total for question = 6 marks)

Q7.

This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

Polymerisation of lactic acid forms poly(lactic acid) as shown in the diagram.



(i) State the type of polymerisation occurring in this reaction.

(1)

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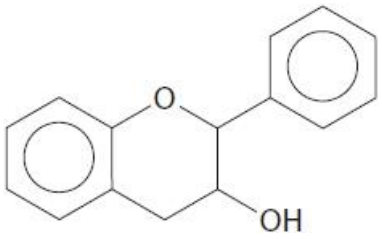
(ii) **On the diagram**, draw a circle around the repeat unit of the polymer.

(1)

(Total for question = 2 marks)

Q8.

The compound flavan-3-ol is found in tea, fruit and wine.



*A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

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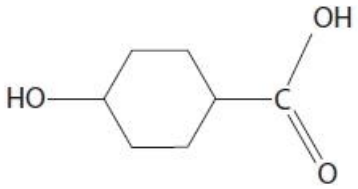
(Total for question = 6 marks)

Q9.

* This question is about polymers.

Compare and contrast how each of these monomers forms a polymer.

cyclohexene



4-hydroxycyclohexanecarboxylic acid

Include equations, showing the formation of a single repeat unit for each polymer.

(6)

(Total for question = 6 marks)

Q10.

The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3, with $CH_3CH_2CH_2Cl$ and with CH_3CH_2COCl.

Predict the mechanism for the reaction of CH_3CH_2COCl with ammonia. Include curly arrows and relevant lone pairs.

(3)

(Total for question = 3 marks)

Q11.

The table contains data on propanone and ethanoic acid.

Substance	Molar mass / g mol^{-1}	Boiling temperature / °C	Solubility in water
Propanone	58	56	completely miscible
Ethanoic acid	60	118	completely miscible

(i) Explain, by reference to the data and any intermolecular forces involved, the difference in the boiling temperatures.

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(ii) Explain, with the aid of a diagram, why propanone is completely miscible with water.

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(Total for question = 6 marks)

Q12.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

Deduce the structural formula of the carboxylic acid that could be used to form both isoamyl acetate and amyl acetate.

(1)

(Total for question = 1 mark)

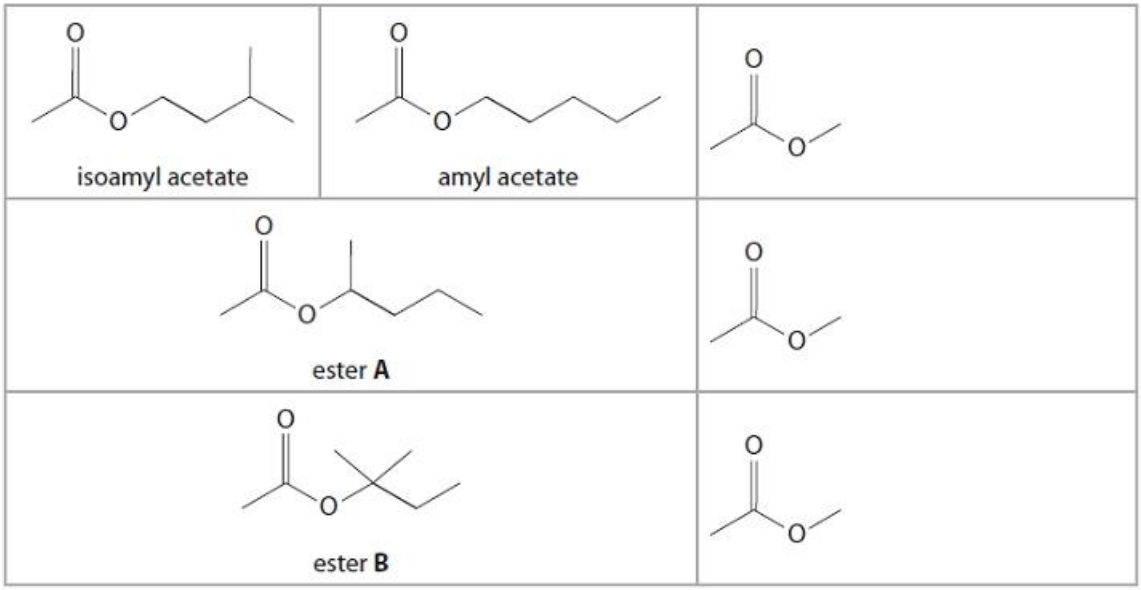
Q13.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

The carboxylic acid used to make isoamyl acetate and amyl acetate can also be used to make six further ester isomers. The structures of two of these esters, **A** and **B**, are shown.

(i) Complete the **skeletal** formulae of **three** of the remaining esters. Names are **not** required.

(3)



(ii) Write an equation to show the formation of ester **A** from an acyl chloride and an alcohol.

(2)

(Total for question = 5 marks)

Q14.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

Give the systematic name for amyl acetate.

(1)

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(Total for question = 1 mark)

Q15.

This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

Lactic acid can be made in a two-step synthesis starting from ethanal, CH_3CHO.

Devise a reaction scheme for a two-step synthesis.

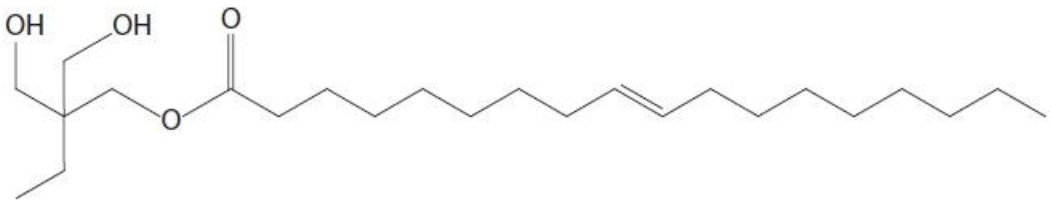
Include in your answer all reagents and conditions, the type of reaction occurring at each step, and a balanced equation for each reaction.
State symbols are **not** required.

(7)

(Total for question = 7 marks)

Q16.

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

The effectiveness of this synthetic oil is much reduced if it is contaminated with water.

Give, in terms of a chemical reaction, a possible reason for this.

(1)

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(Total for question = 1 mark)

Q17.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of
but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

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(Total for question = 3 marks)

Q18.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

Deduce the **name** of the alcohol that forms isoamyl acetate.

(1)

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(Total for question = 1 mark)

Q19.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

Esters can be hydrolysed by heating under reflux with aqueous acid or alkali.

Compare and contrast these two methods of hydrolysis for amyl acetate.

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(Total for question = 4 marks)

Mark Scheme

Q1.

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)	• calculation of moles of H^+ in 25.0 cm^3 **(1)** • calculation of moles of H^+ in 250 cm^3 flask **(1)**	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only Example of calculation: (moles NaOH = 0.200 x $\frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3) (= 10 x 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)	• subtracts moles of H^+ in HCl from answer to (b)(i)	Example of calculation: 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)	• calculation of moles of CH_3COOH that have reacted	Example of calculation: (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)	• calculation of equilibrium moles of $CH_3CH_2CH_2OH$ **(1)** • calculation of equilibrium moles of $CH_3COOCH_2CH_2CH_3$ **(1)** • calculation of equilibrium moles of H_2O **(1)**	Example of calculation: 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 =) $\frac{[CH_3COOCH_2CH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2CH_2OH]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to the following points: • Same number of moles/molecules on both sides of the equation **(1)** • (so) volume / V cancels in K_c expression **(1)**	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "**all** divided by the same volume"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	• calculates value of K_c **(1)** • final value of K_c quoted to 2 or 3 SF **(1)**	Example of calculation $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ = 14 / 13.6 (no units) Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • 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)**	Mark independently Allow no longer alkaline Do not award just "pH decreases"	(2)

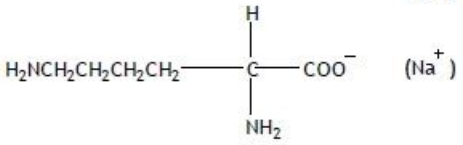
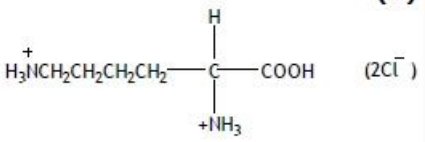
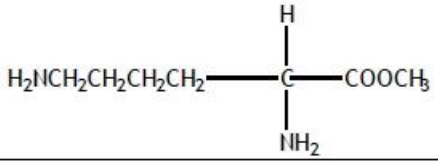
Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An explanation that makes reference to the following points: • carry out / repeat experiment **and** leave for longer than a week **(1)** • the titre value / K_c value will remain unchanged (if equilibrium has been established) **(1)**	Ignore pH probes / checking pH Allow repeat experiment **and** check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following points: • 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)**	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	**(2)**

Q2.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to the following points: • reagent **(1)** • observation **(1)**	Examples of reagents and observations Reagent / Observation: any carbonate / $NaHCO_3$ / $KHCO_3$ (added to aqueous acid) / effervescence / fizzing / bubbles / gas evolved that turns limewater milky magnesium (added to aqueous acid) / effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint alcohol **and** (concentrated) H_2SO_4 / HCl / H^+ / characteristic smell (of an ester) Allow names or formulae for reagents but if both are given, both must be correct Ignore conditions e.g. heat Do not award PCl_5 / Na If more than one test is given, penalise any incorrect tests	**(2)**

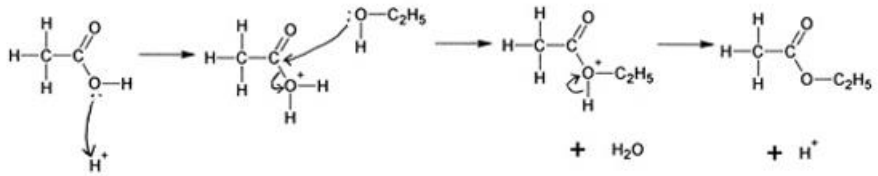
Q3.

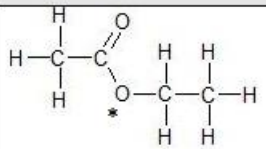
Question Number	Acceptable Answers	Additional Guidance	Mark
	• Deprotonated structure **(1)** 	Allow displayed /structural /condensed formulae Allow NH_2- Allow $-CO_2^-$ Allow –COONa but penalise if O–Na covalent bond is shown	**(3)**
	• Protonated structure **(1)** 	**Both** NH_2 groups must be protonated Allow NH_3^+- / $^+H_3N-$ Allow $-CO_2H$	
	• Ester structure **(1)** 	Allow CO_2CH_3 Allow NH_3^+- or NH_2- for each amine group Penalise wrong side chain only once If alanine used throughout then only MP3 can be awarded	

Q4.

Question Number	Answer	Additional Guidance	Mark
	A comparison that makes reference to: (with ethanoyl chloride) • the reaction is irreversible compared to reversible **(1)** • hydrogen chloride is the by-product rather than water **(1)** • the reaction is very fast/occurs at room temperature so an acid catalyst is not needed **(1)**	Accept reverse arguments Allow steamy fumes for 'HCl'	**(3)**

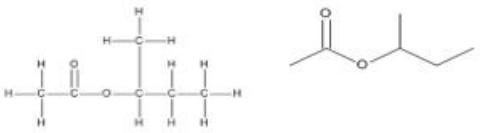
Q5.

	Answer	Additional Guidance	Mark
(i)	• oxygen lone pair and curly arrow to the H^+ **(1)** • curly arrow from oxygen lone pair on the ethanol to the carbon of the C = O **(1)** • curly arrow from C-O bond to oxygen of water molecule **(1)** • curly arrow from O–H bond back to the O^+ oxygen **(1)** Example of reaction mechanism  Penalise additional curly arrows for each marking point Penalise missing lone pair on oxygen once only in M1 and M2		**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct oxygen identified **(1)** • the single bond C–O in the carboxylic acid breaks rather than the one in ethanol **or** the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) **(1)**	 Allow 'loss of OH from the carboxylic acid'	**(2)**

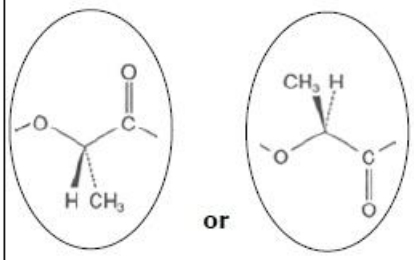
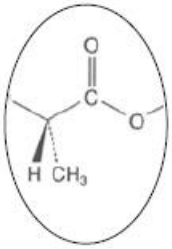
Question Number	Answer	Additional Guidance	Mark
(iii)	• **(M1)** calculation of ΔG **(1)** • **(M2)** correct equation **(1)** • **(M3)** rearrangement of equation **(1)** • **(M4)** calculation of ΔS_{system} **(1)** • **(M5)** rearrangement of equation so $S_{(ethyl\ ethanoate)}$ = **(1)** • **(M6)** calculation of $S_{(ethyl\ ethanoate)}$ with sign and units **(1)**	Example of calculation $\Delta G = -RT \ln K$ = −8.31 x 298 x ln 4.0 = −3433 (J mol^{-1}) $\Delta G = \Delta H - T\Delta S_{system}$ $\Delta S_{system} = (\Delta H - \Delta G) \div T$ ΔS_{system} = (−6.0 x 10^3 − (−3433)) ÷ 298 = −8.614.... (J mol^{-1} K^{-1}) ($\Delta S_{system} = \Sigma S_{(products)} - \Sigma S_{(reactants)}$) $S_{(ethyl\ ethanoate)} = \Delta S + \Sigma S_{(reactants)} - S(water)$ $S_{(ethyl\ ethanoate)}$ = (−8.614 + (159.8+160.7) - 69.9) = +242/240 J mol^{-1} K^{-1} Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	(6)

Q6.

Question Number	Answer	Additional Guidance	Mark
	Structures:	Examples of structures Ignore names, even if incorrect	**(6)**
	• **T**: structure of butan-2-ol **(1)**	**T**: $CH_3CH_2CHOHCH_3$ Ignore connectivity of OH group in displayed formula	
	• **U**: structure of butanone **(1)**	**U**: $CH_3CH_2COCH_3$	
	• **V**: structure of 1-methylpropyl ethanoate **(1)**	**V**: 	
		Allow skeletal formulae or any combination of displayed and structural formulae Do not award C_4H_9 from alcohol Allow butyl ethanoate if **T** is butan-1-ol	
	Justification:		
	• **U** is a ketone because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** does not give a precipitate with Fehling's solution **(1)**	Allow **U** is a carbonyl compound because it gives an orange precipitate with 2,4-dinitrophenylhydrazine **and** is not an aldehyde as it does not give a precipitate with Fehling's solution	
	• **T** is a secondary alcohol because it was oxidised to / formed a ketone **(1)**		
	• **V** is an ester as alcohols react with acyl chlorides / ethanoyl chloride to form esters **(1)**		

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• Condensation (polymerisation)	Ignore esterification or addition-elimination Do not award addition	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• Repeat unit circled on diagram as follows:  or	Allow any repeat unit e.g  Do not award circle containing more than one repeat unit	(1)

Q8.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

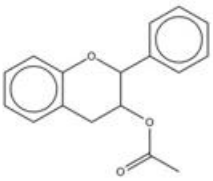
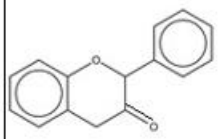
Typically

Number of IPs
Reasoning mark

6 or 5 scores 2

4 or 3 scores 1

2 or 1 or 0 scores 0
</td>
<td>(6)</td>
</tr>
</table>

	Indicative content • **IP1** any mention of **oxidation** of ethanol **or oxidation** of flavan-3-ol (by oxygen in the air) • **IP2** for formation of **either** ethanoic acid **or** ethanal (from ethanol) • **IP3** for formation of ethyl ethanoate (from the reaction between ethanol and ethanoic acid) • **IP4** for structure / name of flavan-3-one • **IP5** for (-OH group on) flavan-3-ol forms an ester with ethanoic acid • **IP6** correct structure of the ester formed between flavan-3-ol and ethanoic acid  **This is the structure of the ester formed between flavan-3-ol and ethanoic acid**	Allow names or formulae **but** if both are given **both** must be correct  **Comment** For correct structure of the ester formed between flavan-3-ol and ethanoic acid award both **IP5** and **IP6** Do not award IP4 if the product is described as an aldehyde	

Q9.

<table>
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<tr><td>*</td><td>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
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For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
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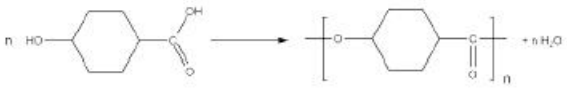
<tr><td></td><td>Indicative content
• IP1 in both cases many monomers join (by covalent bonds to form polymers)

• IP2 cyclohexene forms an addition polymer / the polymer is formed by an addition reaction

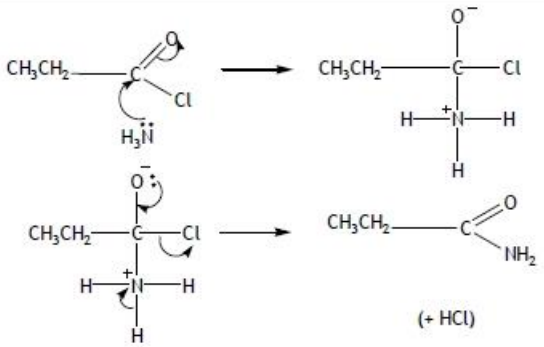
• IP3 4-hydroxycyclohexanecarboxylic acid forms a condensation polymer / the polymer is formed by a condensation reaction

• IP4 no additional products from when cyclohexene polymerises, but water is also</td><td>Allow both polymerisations require a catalyst
Allow both polymers are formed from a single type of monomer

Allow unsaturated monomer forms saturated polymer</td><td></td></tr>
</table>

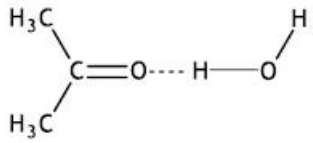
	formed when 4-hydroxycyclohexanecarboxylic acid polymerises • **IP5** • **IP6**  	Allow 'only 1 product in addition but two products in condensation' Allow only one functional group is needed for addition polymerisation but two different functional groups are needed for condensation polymerisation Allow cyclohexene polymerisation has 100% atom economy, 4-hydroxycyclohexanecarboxylic polymerisation has less than 100% atom economy Ignore omitted or misplaced n in **IP5** and **IP6** Allow 1 IP for IP5 and IP6 if both correct repeat units shown Allow 2 oxygen atoms on RHS and none on LHS for IP6 repeat unit	

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• first two curly arrows and lone pair shown on the nitrogen **(1)** • structure of intermediate including both charges **(1)** • three curly arrows and structure of final organic product **(1)**	 (+ HCl)	**(3)**

Q11.

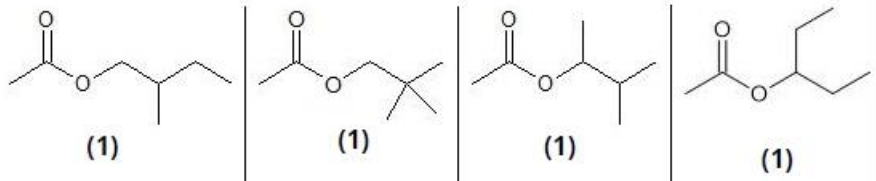
Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • similar molar masses so the number of electrons is similar/same resulting in similar London forces **(1)** • propanone (and ethanoic acid) form permanent dipole(-dipole) forces **(1)** • (only) ethanoic acid forms (intermolecular) hydrogen bonding **(1)** • which is stronger so requires more **energy** to break (giving a higher boiling temperature) **(1)**	Allow van der Waals' forces / dispersion forces / instantaneous dipole-induced dipole forces Ignore reference to ethanoic acid having greater London forces Ignore reference to hydrogen bonding to water by propanone Penalise abbreviation pd-d once only Ignore references to ethanoic acid dimerization Reference to energy must be linked to the breaking of hydrogen bonds	**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • forms hydrogen bonds with water **(1)** • diagram of hydrogen bond **(1)**	Allow H bonds for hydrogen bonds  Ignore bond angle and missing dipoles and missing lone pair Do not award incorrect dipoles Do not award incorrect propanone and/or water structure Do not award if second hydrogen bond drawn to the hydrogen of the CH_3	**(2)**

Q12.

Question Number	Answer	Additional Guidance	Mark
	• CH_3COOH	Allow displayed, skeletal or combination of Do not award molecular formula	**(1)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	Any three of the following four structures  (1) (1) (1) (1)	Accept formulae in any order Award (2) if 3 correct displayed/structural formulae given Award (1) if 2 correct displayed/structural formulae given	(3)

Question Number	Answer	Additional Guidance	Mark
(ii)	An equation that has • ethanoyl chloride **(1)** • alcohol **and** ester+ HCl product **(1)**	Example of equation  Allow structural, displayed formulae in any combination Ignore connectivity to OH except horizontal Ignore state symbols even if incorrect If molecular formulae used then allow (1) for correct equation Allow (1) for a correct equation to form ester A from ethanoic acid e.g. $CH_3COOH + CH_3CH(OH)CH_2CH_2CH_3 \rightleftharpoons CH_3COOCH(CH_3)CH_2CH_2CH_3 + H_2O$	(2)

Q14.

Question Number	Answer	Additional Guidance	Mark
	• pentyl ethanoate	Allow pentanyl ethanoate	(1)

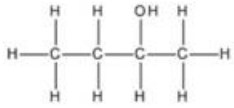
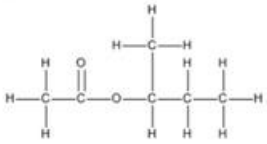
Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
	An answer that makes reference to the following points: (1st Step)	Ignore references to other conditions / solvent in step 1	(7)
	• HCN (and KCN) **(1)**	Allow HCN and CN^- / H^+ and CN^- / H^+ and KCN **or** KCN and H_2SO_4 / KCN and HCl **or** HCN at pH 8 – 9 M1 can be scored for the appearance of HCN in M3	
	• Nucleophilic addition **(1)**	Do not award additional incorrect reaction types e.g. nitrification Allow skeletal formulae in equations	
	• $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ **(1)**	M4, 5 & 6 dependent on the formation of any nitrile in step 1	
	(2nd Step)		
	• Any identified (dilute) strong acid / H^+ **(1)**	Allow sodium hydroxide followed by acid Do not award conc. acid / just "acidify" / just "acid"	
	• Heat (under reflux) / reflux **(1)**	Allow warm	
	• Hydrolysis **(1)**	Do not award additional incorrect reaction types	
	• $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ **or** $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ **(1)**	Allow two equations involving NaOH and H^+ Allow $CH_3CH(OH)CN + 2H_2O + HCl \rightarrow CH_3CH(OH)COOH + NH_4Cl$	

Q16.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following point • the ester (functional group) will react (with the water) in a hydrolysis reaction	Ignore reference to H-bonds between water and OH groups Allow 'hydrolysis reaction' if equation showing break up of ester group also shown	(1)

Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
	Identifications • structure of alcohol **B** **(1)** • structure of ester **A** **(1)** **Justification** • butan-2-ol / $CH_3CH_2CHOHCH_3$ is the **only** alcohol (with formula $C_4H_{10}O$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene **(1)**	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled **A** and **B** Penalise missing H once only Examples of identification **(B)**  Ignore connectivity of the OH group unless horizontal **(A)**  Ignore incorrect name for **A** TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene **and** 2- methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $C_4H_{10}O$) do not give but-2-ene	**(3)**

Q18.

Question Number	Answer	Additional Guidance	Mark
	• 3-methylbutan-1-ol	Allow 'methly' for methyl Allow name with missing hyphens Allow 3-methylbutane-1-ol Allow 3-methylbut-1-anol Allow 1-hydroxy-3-methylbutane Do not allow 3-methylbut-1-ol Ignore formulae even if incorrect	**(1)**

Q19.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: (similarity) • both make the (same) alcohol / pentan-1-ol **(1)** (differences) • acid hydrolysis is reversible, alkaline hydrolysis is irreversible **(1)** • acid hydrolysis produces the carboxylic acid/ ethanoic acid **and** alkaline hydrolysis produces the carboxylate / ethanoate (ion) **(1)** • the acid is a catalyst and the alkali is a reactant **(1)**	Points can be made in equations Accept acid hydrolysis is an equilibrium and alkaline hydrolysis goes to completion Allow just acid for carboxylic acid Allow salt for carboxylate Allow the acid will be regenerated /not used up but the alkali will be used up Ignore references to rate differences Ignore references to a need for the product of alkaline hydrolysis to be acidified which is different to acid hydrolysis	**(4)**