PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 4: CHIRALITY

SCORE	PERCENTAGE
/90	%

STEMUP

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Q1.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A sample of a bromoalkane, RBr, containing a single optical isomer reacts with hydroxide ions in an S_N1 mechanism.

$$RBr + OH^- \rightarrow ROH + Br^-$$

The alcohol formed is a racemic mixture.

From this information, it can be deduced that RBr is most likely to be

☒ **A** primary only

☒ **B** secondary only

☒ **C** tertiary only

☒ **D** primary, secondary or tertiary

(Total for question = 1 mark)

Q2.

This question is about carbonyl compounds.

(a) Three carbonyl compounds, **A**, **B** and **C**, are **straight-chain** structural isomers, with the formula $C_5H_{10}O$.

Only isomer **A** reacts with Tollens' reagent to give a silver mirror.
Only isomer **B** reacts with iodine in the presence of alkali to produce pale yellow crystals.

Draw the **displayed** structures of these three isomers.

(3)

A	
B	
C	

(b) Another carbonyl compound, propanal, reacts with HCN in the presence of KCN to form a racemic mixture of two optical isomers of $CH_3CH_2CH(OH)CN$.

(i) Give the IUPAC name for $CH_3CH_2CH(OH)CN$.

(1)

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(ii) Describe how you could distinguish between pure samples of the two optical isomers.

(1)

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(iii) Explain, with reference to the reaction mechanism, why this reaction produces a racemic mixture.

(2)

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(c) (i) Propanone, an isomer of propanal, also reacts with HCN in the presence of KCN.

Draw the **skeletal** formula of the product of this reaction.

(1)

(ii) State why the product formed in (c)(i) does **not** show optical isomerism.

(1)

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(d) ^{13}C NMR spectroscopy provides information about the structures of propanal and propanone.

(i) Identify the chemical shift range and carbon environment of **one** peak you would expect to see in **both** spectra.

(1)

Chemical shift range	Carbon environment

(ii) State the number of peaks you would expect to see in each ^{13}C NMR spectrum.

(1)

Propanal .....

Propanone .....

(Total for question = 11 marks)

Q3.

* Compare and contrast the reactions of propanal and propanone with **one** oxidising agent, **one** reducing agent and 2,4-dinitrophenylhydrazine.

In your answer include any relevant observations for the reactions you discuss and equations for

any reactions classified as oxidation, using [O] for the oxygen from the oxidising agent.

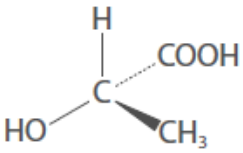
(Total for question = 6 marks)

Q4.

This question is about carboxylic acids and their derivatives.

(a) Lactic acid, $CH_3CH(OH)COOH$, is produced in muscles as a result of anaerobic respiration.

(i) The structure of lactic acid is



Give a reason why lactic acid shows optical isomerism.

(1)

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(ii) A laboratory sample of lactic acid does **not** rotate the plane of plane-polarised monochromatic light.

Give a reason for this observation.

(1)

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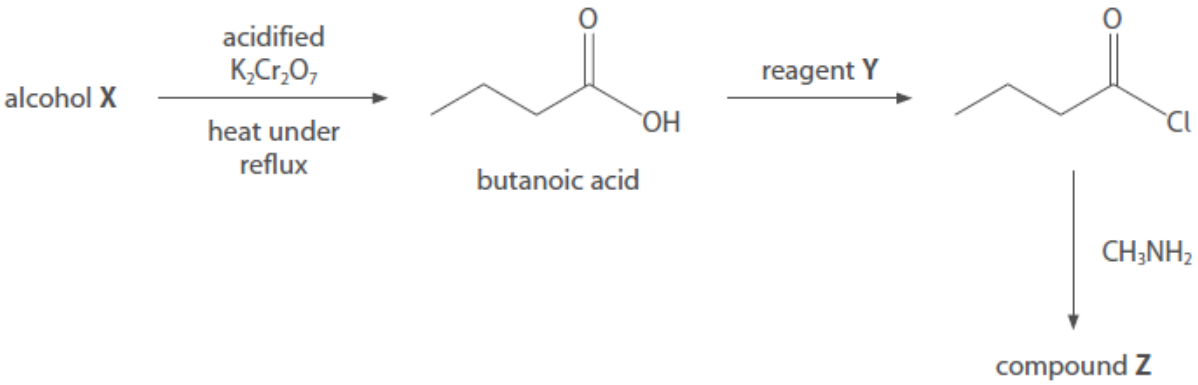
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(iii) Give the structure of the organic product formed when lactic acid reacts with concentrated phosphoric(V) acid, H_3PO_4 .

(1)

(b) A reaction scheme involving butanoic acid is shown.

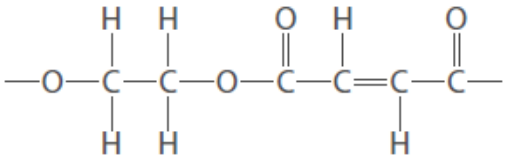


Identify **X**, **Y** and **Z** by name or formula.

(3)

Alcohol **X**
Reagent **Y**
Compound **Z**

(c) The repeat unit of a polyester is shown.



Give the structures of the two monomers that could form this polyester.

(2)

Monomer 1	Monomer 2

(d) An organic compound **E** contains carbon, hydrogen and oxygen only.

(i) The accurate relative atomic masses, A_r , of the three elements in **E** are shown in the table.

Element	A_r
hydrogen	1.0078
carbon	12.0000
oxygen	15.9949

E contains five carbon atoms and gives a molecular ion peak at $m / z = 102.0678$ in its mass spectrum.

Deduce the molecular formula of **E**.

(1)

(ii) Aqueous sodium hydrogencarbonate is added to a sample of **E**.
No effervescence occurs.

State what can be deduced by this observation.

(1)

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(iii) The infrared spectrum of **E** has an absorption in the range 1750 – 1735 cm^{-1}.

Name the functional group in **E**.

(1)

.....

(iv) Data from the high resolution proton NMR spectrum of **E** is shown.

Peak	Chemical shift, δ / ppm for TMS	Splitting pattern	Relative peak area
A	4.02	triplet	2
B	2.05	singlet	3
C	1.65	sextet	2
D	0.95	triplet	3

Deduce the structure of **E**.
Justify your answer by labelling the protons responsible for each peak.

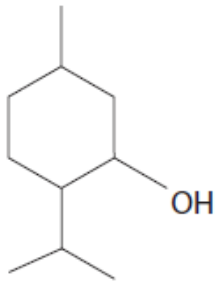
(3)

(Total for question = 14 marks)

Q5.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Menthol has a number of medicinal uses. It can be extracted from the peppermint plant.
The structure of menthol is



How many chiral centres are there in one molecule of menthol?

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(Total for question = 1 mark)

Q6.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When a single enantiomer of 2-iodobutane reacts with sodium hydroxide, the product is a mixture of enantiomers. This is because

☒ **A** the reaction is a nucleophilic substitution

☒ **B** the reaction proceeds via a negatively charged transition state

☒ **C** the reaction proceeds via a carbocation intermediate

☒ **D** the reaction rate depends on the concentration of 2-iodobutane

(Total for question = 1 mark)

Q7.

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

(a) Hexanoic acid, $C_5H_{11}COOH$, is a weak acid.

(i) Write the equation for the acid dissociation constant, K_a, of hexanoic acid.

(1)

(ii) Calculate the pH of a 0.100 mol dm^{-3} solution of hexanoic acid.

[pK_a of hexanoic acid = 4.88]

(4)

(iii) The solubility of hexanoic acid in water is 1.08 g per 100 g of water.

The isomer of hexanoic acid, butyl ethanoate, $CH_3CO_2C_4H_9$, has a solubility of 0.68 g per 100 g of water.

Explain the differences in these data in terms of the hydrogen bonding between hexanoic acid and water, and between butyl ethanoate and water.

(3)

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(b)(i) Compound **A** is thought to be another isomer of hexanoic acid.

10 g of compound **A** is found to contain 6.21 g of carbon and 1.03 g of hydrogen, with the remainder being oxygen.

Use the data to calculate the empirical formula of compound **A**.

You must show **all** your working.

(3)

(ii) State how you might use your answer to (b)(i) and a mass spectrum of compound **A** to prove that compound **A** is an isomer of hexanoic acid.

(1)

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*(iii) A series of tests was performed on compound **A**.

	Test	Observation
1	addition of phosphorus(V) chloride	misty fumes
2	addition of 2,4-dinitrophenylhydrazine	orange precipitate
3	addition of Benedict's or Fehling's reagent	solution remains blue with no precipitate
4	addition of acidified potassium dichromate(VI)	solution remains orange
5	test using polarimetry	plane of plane polarised light is rotated

Deduce the structure for compound **A**.
Justify your answer by using all the test results.

(6)

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(c) Compound **B**, another isomer with the molecular formula $C_6H_{12}O_2$, contains a ring of six carbon atoms.

The carbon-13 NMR spectrum has only two peaks, one of which is at 69 ppm.

Draw the structure of compound **B**.

(2)

(Total for question = 20 marks)

Q8.

Which of these molecules can rotate the plane of plane-polarised light?

☒ **A** H_2NCH_2COOH

☒ **B** $HOCH_2CH_2COOH$

☒ **C** $ClCH_2C(CH_3)(Cl)COOH$

☒ **D** $H_2NC(CH_3)_2COOH$

(Total for question = 1 mark)

Q9.

This question concerns six isomers each with the molecular formula $C_5H_{10}O_2$.

(a) Isomers **A**, **B**, **C** and **D** are structural isomers that all react with aqueous sodium carbonate

to produce carbon dioxide.

Isomer **A** is a straight-chain compound.

Isomer **B** has only two peaks in its high resolution proton NMR spectrum, both of which are singlets.

Isomer **C** contains a chiral centre but isomer **D** does not.

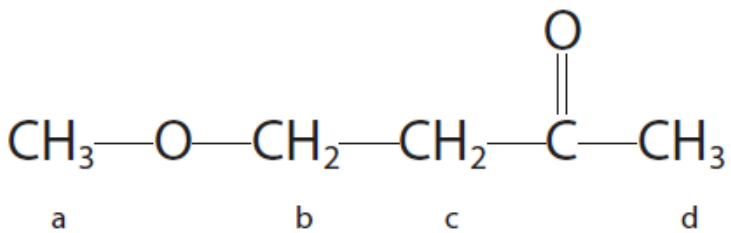
Give the structures of these **four** isomers.

(4)

A	B

C	D

(b) (i) Isomer **E** contains an ether functional group (R-O-R) and a ketone functional group. The **low** resolution proton NMR spectrum of isomer **E** has four peaks. The displayed formula of isomer **E** is



The four hydrogen environments responsible for the four peaks are labelled. Complete the table

of information regarding these peaks including the splitting pattern in the **high** resolution spectrum.

(3)

Peak	a	b	c	d
Relative peak area	3			
Chemical shift range, δ / ppm	2.9 – 4.2			
Splitting	singlet			

(ii) State the number of peaks in the carbon-13 (^{13}C) NMR spectrum of **E**.

(1)

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(c) Isomer **F** is a neutral compound that smells of pears.

It can be formed by the reaction between compounds **V** and **W** in the presence of concentrated sulfuric acid.

Compound **V** has an absorption in its infrared spectrum at 1720 cm^{-1} and a broad absorption around 3050 cm^{-1}.

Compound **W** can be formed directly from propanal.

(i) Identify, by name or formula, compounds **V**, **W** and **F**.

Justify your answer by using **all** the available information.

(4)

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(ii) State the conditions required and the reagent needed to form compound **W** from propanal.

(1)

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(iii) State the role of sulfuric acid in the formation of **F**.

(1)

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(d) State which one of the isomers **A**, **E** and **F** has the highest boiling temperature.

Justify your answer.

(3)

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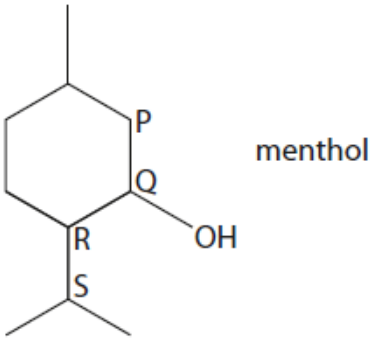
(Total for question = 17 marks)

Q10.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The compound menthol has the structure shown.

Some of the carbon atoms are labelled P, Q, R and S.



menthol

(a) What is the number of chiral centres in a molecule of menthol?

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) Which of the carbon atoms is responsible for a peak at 72 ppm in the ^{13}C NMR spectrum of menthol?

(1)

☒ **A** P

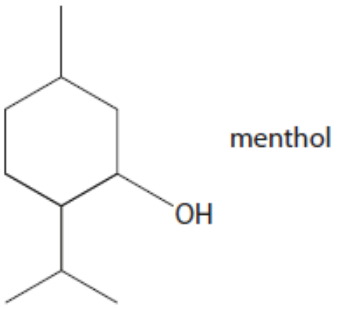
☒ **B** Q

☒ **C** R

☒ **D** S

(c) Four groups of students warmed samples of menthol with sodium dichromate(VI) in acid. They purified the reaction mixture and carried out a series of qualitative tests on the organic product.

The findings of each group in the class are shown in the table.



menthol

Group	Qualitative test		
	Add 2,4-dinitrophenylhydrazine	Warm with Fehling's solution	Add PCl_5
One	✓	×	✓
Two	✓	×	×
Three	✓	✓	×
Four	×	×	✓

A tick (✓) shows a positive result, a cross (×) shows a negative result.
Which group recorded the results you would expect?

(1)

☒ **A** One

☒ **B** Two

☒ **C** Three

☒ **D** Four

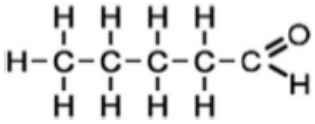
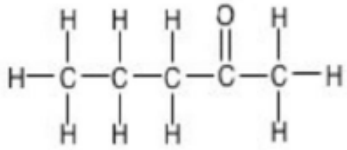
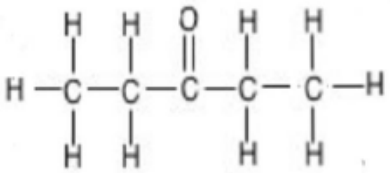
(Total for question = 3 marks)

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is C (tertiary only) ***A** is not correct because primary bromoalkanes react by an SN2 mechanism and the product would be optically active* ***B** is not correct because secondary bromoalkanes react by an SN1 or an SN2 mechanism and the product could be optically active* ***D** is not correct because primary and secondary bromoalkanes react by SN1 and SN2 mechanisms and the products could be optically active*	**(1)**

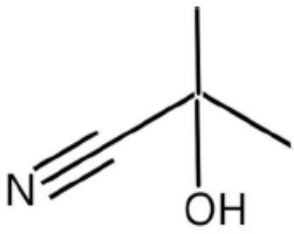
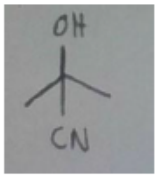
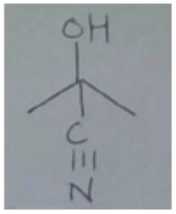
Q2.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • **A**  **(1)** • **B**  **(1)** • **C**  **(1)**	Allow structural or skeletal formulae for max 2 marks Ignore any names even if incorrect Ignore bond angles/lengths Penalise missing Hs only once	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• 2-hydroxybutanenitrile	Allow 2-hydroxy(l)buta(n)nitrile Allow 2-hydroxy(l)butane-1-nitrile Do not award 2-hydroxobutanenitrile Do not award 2-oxobutanenitrile Do not award cyanides or other non IUPAC names Ignore any extra hyphens, commas and spaces	**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• one isomer rotates (the plane of monochromatic) plane-polarised light in one direction and the other in the opposite direction/ the isomers rotate (the plane of) plane-polarised light in opposite directions/clockwise and anticlockwise	Do not award bends Allow different directions Allow PPL for plane polarised light Allow the direction of rotation of plane polarised light Allow see which way the sample rotates PPL	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following points: • propanal is planar around the CHO/reaction site/C=O/carbonyl (1) • CN^-/nucleophile can attack on either side/both sides/above and below (giving a racemic/equimolar/ 50/50 mixture) (1)	Do not award just propanal is planar Do not award planar intermediate/carbocation Do not award any reference to nucleophilic substitution (S_N1/S_N2)	(2)

Question Number	Answer	Additional Guidance	Mark
(c)(i)		Ignore displayed or structural formulae Ignore bond lengths and bond angles Allow   Ignore connectivity if vertical bond	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• no carbon atom has 4 different groups or (central) carbon atom is bonded to two CH_3/same groups or no asymmetric/chiral carbon atom or the compound is superimposable on its mirror image or it does not have a chiral centre	Ignore symmetrical Do not award 2 of the same molecules/compounds attached to the carbon atom Do not award racemic mixture	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(i)	• correct chemical shift **and** carbon environment	<table><tr><th>Chemical shift range</th><th>Carbon environment</th></tr><tr><td>190-225 (ppm)</td><td>C=O</td></tr><tr><td colspan="2">**OR**</td></tr><tr><td>0-60 (ppm)</td><td>C—C</td></tr></table> Both range **and** carbon environment required. Allow the full range or a number/ smaller range within the range. Allow for carbon environment C-**C**=O **and** C-**C**=O | | C H Ignore any splitting patterns	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	• Propanal: 3/three **and** • Propanone: 2/two		(1)

Q3.

<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>
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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 an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

In general it would be expected that 5 or 6 indicative points would score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning.
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<td>6</td>
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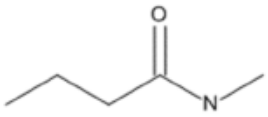
	Indicative Points Similarities: **IP1 Both** react with 2,4-dinitrophenylhydrazine to form a yellow / orange / red precipitate **IP2 Both** can be reduced by $LiAlH_4$ / Lithium tetrahydrido aluminate / lithium aluminium hydride (in dry ether) Differences: **IP3** but propanal forms a primary alcohol, propanone forms a secondary alcohol **IP4** Propanal will react with acidified potassium dichromate ((VI)) but propanone will not react **IP5** Equation for oxidation reaction **IP6** Observation for named oxidising agent Eg. orange to green (with acidified dichromate(VI)) Comment – Ignore equations involving 2,4 DNP	Ignore Iodoform reaction Accept **Both** can be reduced by $NaBH_4$ If name given it must be correct Accept propanal forms propan- 1- ol / $CH_3CH_2CH_2OH$ and propanone forms propan-2-ol / $CH_3CHOHCH_3$ Accept any named suitable oxidising agent eg. Fehling's / Benedict's solution/ Tollens' reagent / acidified potassium manganate((VII)) $CH_3CH_2CHO + [O] \rightarrow CH_3CH_2COOH$ If reduction of metal shown in oxidation equation it must be correct. Fehling's / Benedict's : blue solution to red / orange ppt Tollen's : silver mirror / ppt Allow grey ppt. Additional incorrect equations for organic reduction loses one reasoning mark	

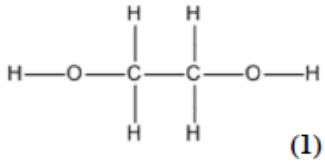
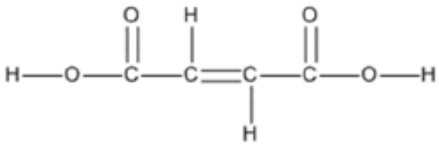
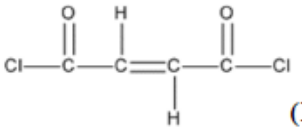
Q4.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following point: • it / lactic acid is non-superimposable on its mirror image	Allow there are four different atoms / groups attached to a carbon (atom) Allow it is chiral / has a chiral centre / has a chiral carbon (atom) / has an asymmetric carbon (atom) Ignore rotates the plane of plane-polarised light Do not award four different molecules attached to a carbon (atom)	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following point: • it is a racemic mixture or contains equal amounts of the two enantiomers / (optical) isomers	Allow rotations caused by both enantiomers / isomers cancel Ignore just contains two enantiomers / isomers Do not award plane-polarised light cannot pass through the solution	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• CH_2=CHCOOH	Allow any combination of structural or displayed formulae or skeletal formulae / $COOHCH=CH_2$	(1)

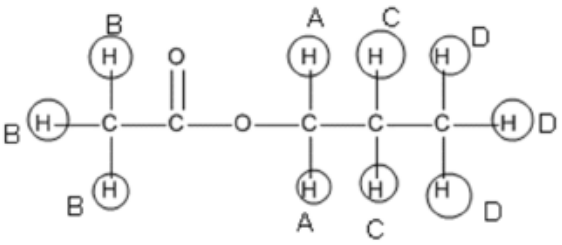
Question Number	Answer	Additional Guidance	Mark
(b)	• **X**: butan-1-ol or  or $CH_3CH_2CH_2CH_2OH$ / $CH_3(CH_2)_2CH_2OH$ (1) • **Y**: phosphorus(V) chloride / phosphorus pentachloride / PCl_5 (1) • **Z**: *N*-methylbutanamide or  or $CH_3CH_2CH_2CONHCH_3$ / $CH_3(CH_2)_2CONHCH_3$ (1)	Mark independently If names and formulae are given, both must be correct but penalise missing H from carbon chain displayed formulae once only Allow any combination of skeletal, structural or displayed formulae Ignore molecular formulae for **X**, **Y** and **Z** Ignore butanol / C_4H_9OH Do not award $CH_3CH_2CH_2CH_2O$ Do not award butanal Allow phosphorus(III) chloride / PCl_3 / thionyl chloride / $SOCl_2$ Do not award hydrochloric acid / HCl Ignore methylbutanamide / butanamide in addition to a correct structure Allow NH in skeletal formula Do not award $CH_3CH_2CH_2COHNCH_3$ / $CH_3CH_2CH_2COCH_3NH$	(3)

Question Number	Answer	Additional Guidance	Mark
(c)	• Monomer 1  (1) • Monomer 2  or  (1)	Allow monomers in either order Allow any combination of structural or displayed formulae / skeletal formulae Allow OH Ignore bond lengths and bond angles Penalise OH-C on left of molecules once only Penalise missing H from carbon chain displayed formulae once only Accept cis isomers	(2)

Question Number	Answer	Additional Guidance	Mark
(d)(i)	• $C_5H_{10}O_2$	Allow symbols in any order Ignore any working Ignore + charge	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	• **E** is not a carboxylic acid or does not contain COOH (group)	If name and formula are given, both must be correct Allow **E** is not an acid Do not award additional functional groups	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(iii)	• **E** is an ester	Ignore saturated / -COO- / C=O Do not award additional functional groups	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(iv)	• structure of **E** (1) • 2 or 3 proton environments correct (1) • 4th proton environment correct (1)	Example of structure:  Protons can be circled and labelled or just labelled Allow labels using data from the table Only 1 proton from each group needs to be labelled Allow whole groups to be labelled, including the carbon atom	(3)

Q5.

Question Number	Correct Answer	Mark
	The only correct answer is C (3) ***A*** *is incorrect because there are three chiral centres* ***B*** *is incorrect because there are three chiral centres* ***D*** *is incorrect because there are three chiral centres*	(1)

Q6.

Question Number	Correct Answer	Mark
	The only correct answer is C (the reaction proceeds via a carbocation intermediate) ***A*** *is incorrect because while it is true, it does not explain the observation* ***B*** *is incorrect because this would lead to only one enantiomer* ***D*** *is incorrect because while this is true, it does not explain the observation*	(1)

Q7.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • $K_a = \frac{[C_5H_{11}COO^-][H^+]}{[C_5H_{11}COOH]}$	Accept $[CH_3CH_2CH_2CH_2CH_2CO_2^-]$ and $[CH_3CH_2CH_2CH_2CH_2CO_2H]$ Accept $[H_3O^+]$ instead of $[H^+]$ Accept other representations of the chain of hexanoic acid / hexanoate ion, such as $[CH_3(CH_2)_4COO^-]$ Ignore equation for dissociation Do not award $[H^+]^2/[C_5H_{11}COOH]$ Do not award brackets that are not square brackets Do not award molecular formulae	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• uses expression for pK_a **(1)** • use of K_a expression **(1)** • rearrange and solve for H^+ **(1)** • find pH	Example calculation $K_a = 10^{-pK_a}$ / $K_a = 10^{-4.88}$ / $pK_a = -\log_{10}K_a$ / $4.88 = -\log_{10}K_a$ / $K_a = 0.000013183$ / 1.3183×10^{-5} $10^{-4.88}$ / 1.3183×10^{-5} / $0.000013183 = \frac{[H^+]^2}{0.1}$ $[H^+] = \sqrt{0.000013183 \times 0.1}$ = 0.0011482 / 0.00115 / 1.1482×10^{-3} / 1.15×10^{-3} (mol dm^{-3}) $pH = -\log_{10}[H^+] = 2.94$ / 2.9400 Do not award M4 with units Final correct answer with no working scores (4) Final correct answer scores (4) Allow TE at each stage Omitting the square root gives 5.88 scores (3) Use of 4.88 for K_a gives 0.1558 scores (3) Ignore SF except 1 SF	**(4)**

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	An answer that makes reference to the following points: • hexanoic acid forms more hydrogen bonds (per molecule) with water than butyl ethanoate does **(1)** **(1)** • hexanoic acid has an -OH group which forms hydrogen bonds (with water) **(1)** • butyl ethanoate / hexanoic acid has a C=O group which forms hydrogen bonds (with water)	All marks may be scored with a diagram or diagrams Allow hexanoic forms two hydrogen bonds per molecule but butyl ethanoate forms only one Ignore references to the strength of the hydrogen bonds Ignore all references to other intermolecular forces	**(3)**

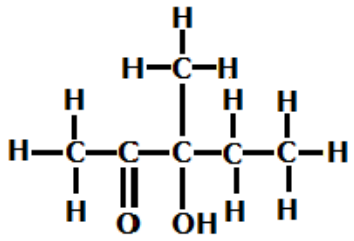
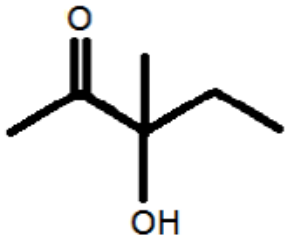
Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculate mass of oxygen **(1)** **(1)** • divides masses by atomic mass • divides by smallest to find the simplest ratio **(1)** **and** correct empirical formula	Example calculation Mass of O = 10 - 6.21 - 1.03 = 2.76(g) Element / Mass / Mass / Atomic Mass / Ratio C: 6.21 / 6.21 / 12 = 0.5175 / 3 H: 1.03 / 1.03 / 1 = 1.03 / 6 O: 2.76 / 2.76 / 16 = 0.1725 / 1 C_3H_6O Correct answer with mass/atomic mass ratios calculated scores (3) Do not award $C_6H_{12}O_2$ stated as empirical formula Ignore SF Ignore reference to $C_6H_{12}O_2$ after finding empirical formula Allow 1 mark for CH_2 deduced without finding the mass of oxygen Allow max 1 mark for incorrect masses of oxygen divided correctly by atomic mass Correct answer with no working scores (1)	**(3)**

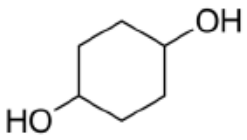
Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • molecular ion peak / peak at highest mass will be at twice the mass of the empirical formula / will be at 116	Ignore references to n.m.r or i.r.	**(1)**

Question Number	Answer	Additional guidance	Mark
(b)(iii)	This question assesses a 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. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning.	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, an answer with five 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 are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general, an answer with 5 or 6 IPs would score 2 reasoning marks, 3 or 4 IPs would score 1 reasoning mark, 0, 1 or 2 IPs would score 0 reasoning marks.	**(6)**

	<table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and 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>	If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s). Candidates may treat each test separately or may build on each test. Accept statements in any order.

	Indicative content • **IP1** Misty fumes suggest OH group present • **IP2** Orange precipitate suggests a carbonyl group is present (so no carboxylic acid, must be alcohol) • **IP3** (Negative) Benedict's / Fehling's reagent suggests no aldehyde group present / a ketone is present	Accept alcohol or carboxylic acid group present (must state both) Accept ketone or aldehyde present (must state both Ignore C=O is present Accept just 'no oxidisable groups present / cannot be oxidised' in either IP3 or IP4 but not both Allow tertiary alcohol is present	

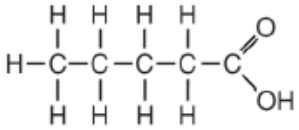
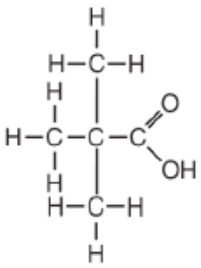
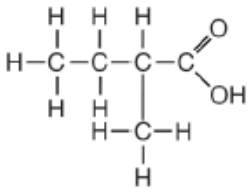
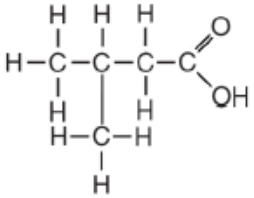
	• **IP4** Acidified potassium dichromate(VI) suggests not a primary, a secondary alcohol or an aldehyde present	Accept just no primary or secondary alcohol present Ignore references to ketone and carboxylic acid giving no result	
	• **IP5** Polarimetry indicates a chiral centre is present / it is a chiral molecule	Ignore S_N2 Allow 4 different groups on a carbon Allow optically active Allow contains a single enantiomer	
	• **IP6** Structure of 3-hydroxy-3-methylpentan-2-one  	Allow the correct name Allow displayed or structural formula or combinations Allow contractions such as CH_3- C_2H_5-	

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • a structure containing **two** –OH groups **(1)** • correct structure **(1)**	Do not award an –OH group and a -COOH group Award this mark even if the structure does not contain a ring of six atoms.  Structure may be skeletal or displayed or a mixture, as long as it is clear. Allow, for example, a displayed formula with condensed CH_2. Ignore connectivity of -OH	**(2)**

Q8.

Question Number	Answer	Mark
	The only correct answer is **C** ($ClCH_2C(CH_3)(Cl)COOH$) *A is incorrect as compound 1 does not have a chiral carbon atom B is incorrect as compound 2 does not have a chiral carbon atom* *D is incorrect as compound 4 does not have a chiral carbon atom*	1

Q9.

Question Number	Answer	Additional guidance	Mark
(a)	• Structure A **(1)** • Structure B **(1)** • Structure C **(1)** • Structure D **(1)**	A  B  C  D  Allow condensed or skeletal formulae If Structure B has not been scored allow this structure as a correct answer for Structure D Penalise OH−C connectivity once only to horizontal bonds Ignore connectivity on vertical bonds to OH and all bonds to CH_3 groups. Penalise incorrect names also given once only	(4)

Question Number	Answer	Additional guidance	Mark
(b)(i)	• 3, 4 or 5 correct boxes (1) • 6, 7 or 8 correct boxes (2) • Nine correct boxes (3)	<table><tr><th>b</th><th>c</th><th>d</th></tr><tr><td>2</td><td>2</td><td>3</td></tr><tr><td>2.7 – 4.2</td><td>1.5 – 2.9</td><td>1.5 – 2.9</td></tr><tr><td>triplet</td><td>triplet</td><td>singlet</td></tr></table> Allow a value or range within the range Allow triple / single 3lines / 1 line	(3)

Question Number	Answer	Additional guidance	Mark
(b)(ii)	• Five / 5 (peaks)		(1)

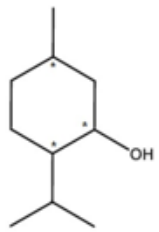
Question Number	Answer	Additional guidance	Mark
(c)(i)	• Identifies isomer **F** (1) • Identifies compound **V** and compound **W** (1) • Two points of justification for identification of isomer **F**, compound **V** and compound **W** (2)	Penalise use of C_3H_7 for formulae once only **F** is propyl ethanoate / $CH_3COOCH_2CH_2CH_3$ Allow TE on incorrect alcohol or carboxylic acid for V and W If name and formula is given both must be correct Compound **V** is ethanoic acid / CH_3COOH and Compound **W** is propan-1-ol / $CH_3CH_2CH_2OH$ Ignore just 'propanol' Any two from: Compound **V** is a carboxylic acid justified by infra-red Award for correct identification of the bond responsible for either peak? Compound **W** is propan-1-ol / an alcohol / propanol justified by reduction of propanal Allow propanol here but not in M2 Compound **V** or **W** justified by reaction with the other to form an ester Compound **F** is an ester justified by smell / neutral compound	(4)

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• (Lithium tetrahydridoalumate(III) / lithium aluminium hydride) / $LiAlH_4$ **AND** in dry ether / diethyl ether / ethoxyethane (solvent)	ALLOW Lithal ALLOW Sodium tetrahydridoborate / sodium borohydride AND Water / ethanol solvent	(1)

Question Number	Answer	Additional guidance	Mark
(c)(iii)	• Catalyst	Ignore mention of acid / homogeneous / proton donor Ignore additional words Do not award just 'proton donor' or donates hydrogen ions	(1)

Question Number	Answer	Additional guidance	Mark
(d)	An explanation that makes reference to the following points: • Isomer A (has the highest boiling temperature) **(1)** • (Isomer A has the) **only** molecules held together by hydrogen bonding / Isomer A forms hydrogen bonds but E and F do not **(1)** • Hydrogen bonds are the strongest intermolecular forces **(1)**	In general ignore reference to other intermolecular forces (but see below) Allow it forms hydrogen bonds Ignore it forms hydrogen bonds with other compounds/substances Ignore comments about straight chain so stronger London forces Allow hydrogen bonding is stronger than London forces and/or permanent dipoles Allow just 'forms strong hydrogen bonds'	(3)

Q10.

Q	Correct Answer	Mark
(a)	**The only correct answer is C** (3)  ***A*** *is incorrect as menthol has 3 chiral carbon atoms* ***B*** *is incorrect as menthol has 3 chiral carbon atoms* ***D*** *is incorrect as menthol has 3 chiral carbon atoms*	1

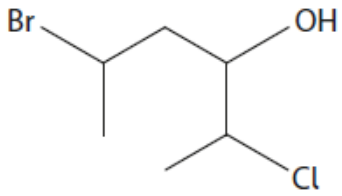
Q	Correct Answer	Mark
(b)	**The only correct answer is B** (Q) ***A*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm* ***C*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm* ***D*** *is incorrect as this carbon would produce a peak between 0 and 60 ppm*	1

Q	Correct Answer	Mark
(c)	**The only correct answer is B** (Two) ***A*** *is incorrect as the oxidation product is a ketone, so would not react with* PCl_5 ***C*** *is incorrect as the oxidation product is a ketone, so would not react with Fehling's solution* ***D*** *is incorrect as the oxidation product is a ketone, so would not react with* PCl_5 *but would react with 2,4- dinitrophenylhydrazine*	1

Q1.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

How many optical isomers does this molecule have?



☒ **A** 2

☒ **B** 3

☒ **C** 6

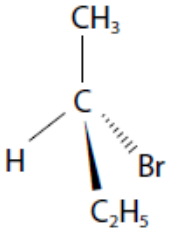
☒ **D** 8

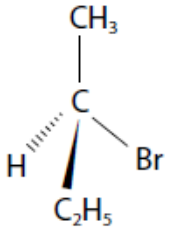
(Total for question = 1 mark)

Q2.

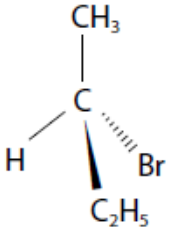
When mixed in equimolar quantities, which pair of molecules will **not** rotate the plane of plane-polarised light?

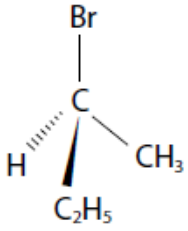
☒ **A**



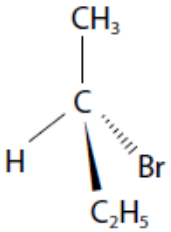


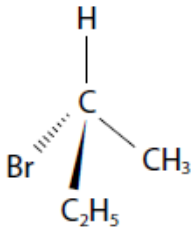
☒ **B**



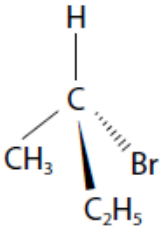


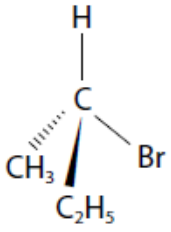
☒ **C**





☒ **D**





(Total for question = 1 mark)

Q3.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these reactions does **not** result in the formation of a racemic mixture?

☒ **A** but-2-ene with HCl

☒ **B** but-1-ene with HCl

☒ **C** propanal with HCN

☒ **D** propanone with HCN

(Total for question = 1 mark)

Q4.

Propanal reacts very slowly with HCN at 298 K. To increase the rate of reaction potassium cyanide, KCN, is added.

(a)(i) Complete the mechanism for this reaction by adding curly arrows, and relevant lone pairs and dipoles to Step **1** and Step **2**.

(4)

Step **1**



intermediate



Step **2**



intermediate

products

(ii) Explain why the reaction between propanal and HCN in the absence of KCN is very slow, referring to the value of K_a. No calculation is required.

[For HCN, $K_a = 4.9 \times 10^{-10}$ mol dm^{-3}]

(2)

.....

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(iii) KCN is a **homogeneous catalyst** in this reaction.

Justify this description by referring to the mechanism.

(2)

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(b) The organic products of this reaction are enantiomers.

Draw the three-dimensional structures of these enantiomers.

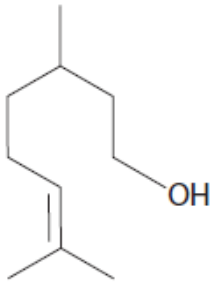
(2)

(Total for question = 10 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Citronellol is found in rose and geranium oils.



citronellol

The type(s) of stereoisomerism shown by citronellol is

☒ **A** optical and geometric isomerism

☒ **B** optical isomerism only

☒ **C** geometric isomerism only

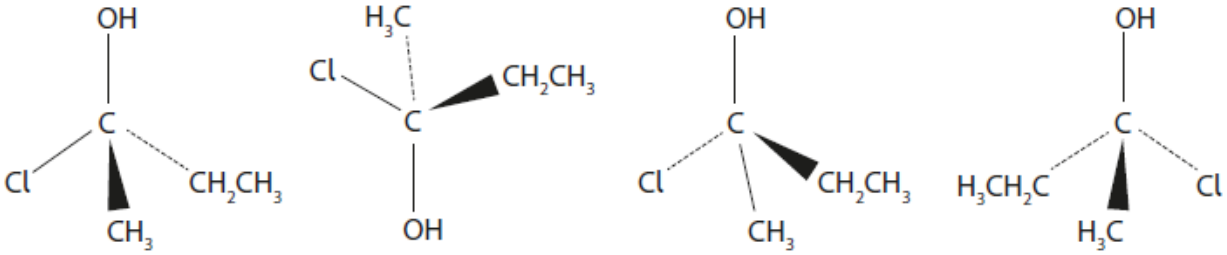
☒ **D** neither optical nor geometric isomerism

(Total for question = 1 mark)

Q6.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which of these structures is **not** identical to the others?



☒ **A** Structure A

☒ **B** Structure B

☒ **C** Structure C

☒ **D** Structure D

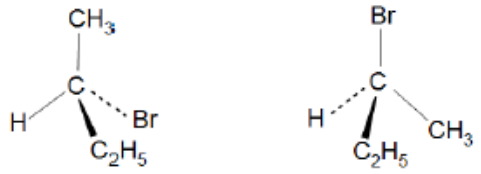
(Total for question = 1 mark)

Mark Scheme

Q1.

Q	Correct Answer	Mark
	The only correct answer is D (8) ***A*** *is incorrect as the number of optical isomers = 2^n, where n = number of chiral centres* ***B*** *is incorrect as the number of optical isomers = 2^n, where n = number of chiral centres* ***C*** *is incorrect as the number of optical isomers = 2^n, where n = number of chiral centres*	1

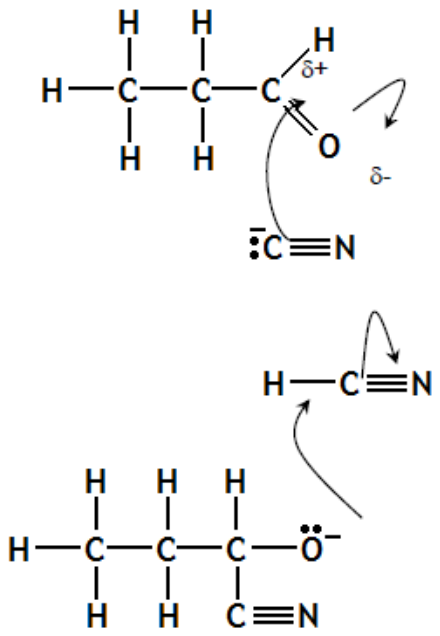
Q2.

Question number	Answer	Mark
	 B	1

Q3.

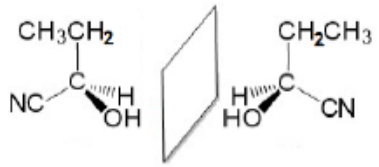
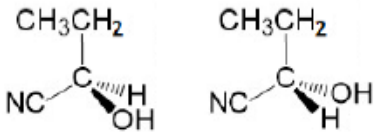
Question Number	Correct Answer	Mark
	The only correct answer is D (propanone with HCN) ***A*** *is incorrect because the product, 2-chlorobutane, is chiral and each enantiomer is formed in equal amounts* ***B*** *is incorrect because the product, 2-chlorobutane, is chiral and each enantiomer is formed in equal amounts* ***C*** *is incorrect because the product, 2-hydroxybutanenitrile is chiral and each enantiomer is formed in equal amounts*	(1)

Q4.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: Step 1 • lone pair of electrons on C of C≡N • curly arrow from anywhere on the C of C≡N to C in propanal including the charge • curly arrow from C=O bond to or just beyond O • dipole on C=O Step 2 • lone pair on O in intermediate Step 1 or Step 2 • curly arrow from the O (or minus charge) of intermediate to H of H-C≡N • curly arrow from H-C bond to C of H-C≡N	 All 7 points scores 4 marks 5 or 6 points scores 3 marks 3 or 4 points scores 2 marks 2 points scores 1 mark Ignore formula of products even if incorrect Ignore all dipoles on HCN Penalise dipoles on C-O in the intermediate	**(4)**

Question Number	Answer		Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points:			**(2)**
	• the value of K_a / dissociation is (very) small / the equilibrium lies (very) well to the left	**(1)**	Allow it is a (very) weak acid Allow it is partially dissociated	
	• so the concentration of CN^- ions is (very) low / there is a lack of CN^- ions	**(1)**	Allow a comment that all / most CN^- in the reaction come from KCN Ignore references to K_a of KCN Ignore references to rate of dissociation	

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	An answer that makes reference to the following points: • (it increases the rate of reaction by) providing **CN^- ions** in the same phase/state **(1)** • and it / KCN / CN^- ion is regenerated in Step 2 (so overall is not used up in the reaction) **(1)**	Ignore incorrect phases Allow it is regenerated at the end (of the reaction) Ignore references to adsorbing and desorbing If no other mark is scored for it is in the same phase/state **and** is not used up (1) OR A homogeneous catalyst / KCN is in the same phase/state **and** speeds up the reaction/provides an alternative pathway with lower activation energy (1)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)	• a three-dimensional diagram of 2-hydroxybutanenitrile showing at least one dotted bond **(1)** **and** at least one wedged bond which are next to each other **(1)** • the mirror image of the first structure	Allow just a three dimensional diagram of 2-hydroxybutanenitrile showing at least one dotted and one wedged bond Diagrams may show a mirror / plane of symmetry though this is not necessary  Allow diagrams that swap two of the four substituents e.g.  If not other marks are scored allow two tetrahedral structures which are mirror images that do not have wedged and dotted bonds scores (1) Ignore connectivity errors Allow TE in M2 for incorrect compounds	**(2)**

Q5.

Question number	Answer	Mark
	The only correct answer is B (optical isomerism only) ***A*** *is incorrect because one of the carbon atoms of the double bond has two methyl groups* ***C*** *is incorrect because one of the carbon atoms of the double bond has two methyl groups and there is a chiral carbon* ***D*** *is incorrect because there is a chiral carbon*	**(1)**

Q6.

Q	Correct Answer	Mark
	The only correct answer is D (Structure D) ***A*** *is incorrect as it is identical to B and C* ***B*** *is incorrect as it is identical to A and C* ***C*** *is incorrect as it is identical to A and B*	**1**