PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 4: CARBONYL COMPOUNDS

SCORE	PERCENTAGE
/120	%

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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 ☒.

Which alcohol could **not** be formed by the reduction of an aldehyde or a ketone?

☒ **A** 2-methylpentan-1-ol

☒ **B** 3-methylpentan-2-ol

☒ **C** 3-methylpentan-3-ol

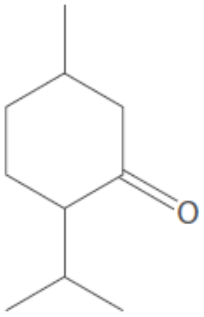
☒ **D** 2-methylpentan-3-ol

(Total for question = 1 mark)

Q2.

This question is about carbonyl compounds.

(a) The skeletal formula of menthone is shown.



Give the molecular formula of menthone.

(1)

.....

(b) Ethanal, CH_3CHO , reacts with hydrogen cyanide in the presence of cyanide ions to form 2-hydroxypropanenitrile.

Draw the mechanism for this reaction.
Include curly arrows, and any relevant lone pairs and dipoles.

(4)

(c) A carbonyl compound, **F**, has the molecular formula $C_6H_{12}O$.

(i) **F** reacts with iodine in an alkaline solution to give a pale yellow precipitate.

Give the name or formula of the group in **F** identified by this test.

(1)

.....

(ii) Draw the **skeletal** formulae of the four possible structures of carbonyl compound **F**.

(2)

(iii) The carbon-13 (^{13}C) NMR spectrum of **F** has four peaks.

Identify **F** by drawing its **displayed** formula.
Justify your answer by labelling the carbon atoms or groups of carbon atoms responsible for the four peaks in the spectrum.

(2)

*(d) Explain, in terms of all the intermolecular forces involved, why butanal has a higher boiling temperature than pentane but a lower boiling temperature than propanoic acid.

Substance	Boiling temperature / °C
butanal	76
pentane	36
propanoic acid	141

(6)

(Total for question = 16 marks)

Q3.

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)

Q4.

* 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)

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 ☒.

The following methods can be used to distinguish between pairs of organic compounds with **no** further tests.

A warm each compound with Fehling's or Benedict's solution

B warm each compound with acidified potassium dichromate(VI) solution

C add 2,4-dinitrophenylhydrazine (Brady's reagent) to each compound

D add a few drops of each compound, drop by drop, to water

(a) Which test would distinguish between 2-methylpropan-2-ol, $(CH_3)_3COH$, and butanone, $CH_3CH_2COCH_3$?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which test would distinguish between 2-methylpropan-2-ol, $(CH_3)_3COH$, and butan-1-ol, $CH_3CH_2CH_2CH_2OH$?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which test could **not** be used to distinguish between 2-methylpropan-2-ol, $(CH_3)_3COH$, and butanal, $CH_3CH_2CH_2CHO$?

(1)

☒ **A**

☒ **B**

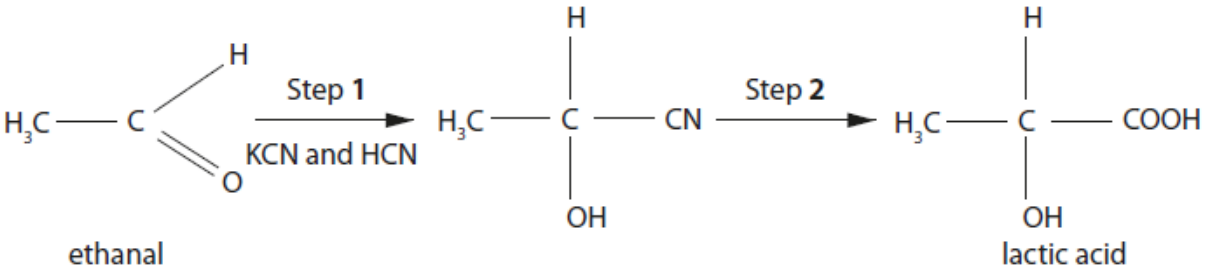
☒ **C**

☒ **D**

(Total for question = 3 marks)

Q6.

The compound lactic acid can be synthesised from ethanal in two steps.



(a) (i) Give the mechanism for Step **1**. Include curly arrows, and any relevant lone pairs and dipoles.

(4)

(ii) A student predicted that the product of Step **1** would rotate the plane of plane-polarised light.

Comment on this prediction.

(3)

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(iii) Complete the table that summarises information about Step **2**.
State symbols are not required for the equation.

(4)

Conversion of $CH_3CH(OH)CN$ to lactic acid	
Reaction type	
Reagent	
Conditions	
Equation	

(b) Sodium hydrogencarbonate, $NaHCO_3$, has been used by some athletes to help prevent lactic acid causing muscle pain during exercise.

Write an equation for the reaction between sodium hydrogencarbonate and lactic acid.

(1)

(c) Sodium hydrogencarbonate is part of a buffer in the body that controls the pH of blood. Two of the equilibria involved in this process are shown.

Equilibrium 1 $HCO_3^- + H_3O^+ \rightleftharpoons H_2CO_3 + H_2O$

Equilibrium 2 $H_2CO_3 \rightleftharpoons CO_2 + H_2O$

(i) Use the equilibria to explain how the buffer keeps the pH of blood nearly constant when a small increase in the concentration of hydrogen ions occurs.

(3)

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(ii) The pH of a blood sample was found to be 7.41.
Calculate the ratio of the concentration of HCO_3^- to H_2CO_3 in the blood sample.

$$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$$

$$K_a = 4.50 \times 10^{-7} \text{ mol dm}^{-3}$$

(3)

(Total for question = 18 marks)

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 compound has the highest boiling temperature?

(1)

☒ **A** butanal

☒ **B** butan-1-ol

☒ **C** butanone

☒ **D** butanoic acid

(Total for question = 1 mark)

Q9.

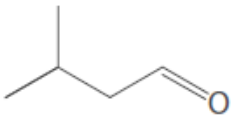
Answer the question with a cross in the box you think is correct ☒ . If you change

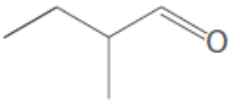
your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

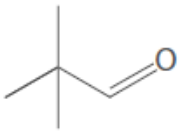
A compound **X**, with molecular formula $C_5H_{10}O$, gave an orange precipitate with 2,4-dinitrophenylhydrazine.

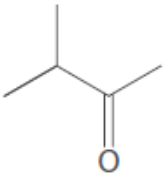
X gave a silver mirror with Tollens' reagent.

Which of these could **not** be **X**?

☒ **A** 

☒ **B** 

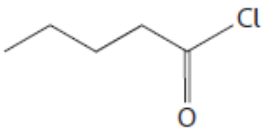
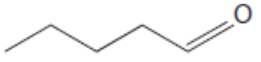
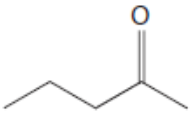
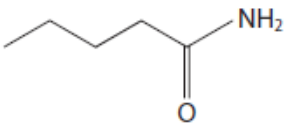
☒ **C** 

☒ **D** 

(Total for question = 1 mark)

Q10.

This question is about four organic compounds each with five carbon atoms but different functional groups.

Compound	Skeletal formula
1	
2	
3	
4	

(a) Which of these, when mixed with water, produces the solution with the **lowest** pH?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(b) Which of these reacts with ethylamine, $CH_3CH_2NH_2$, to form an N-substituted amide?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(c) Which of these reacts with iodine and sodium hydroxide in solution to produce a pale yellow precipitate?

(1)

☒ **A** compound **1**

☒ **B** compound **2**

☒ **C** compound **3**

☒ **D** compound **4**

(Total for question = 3 marks)

Mark Scheme

Q1.

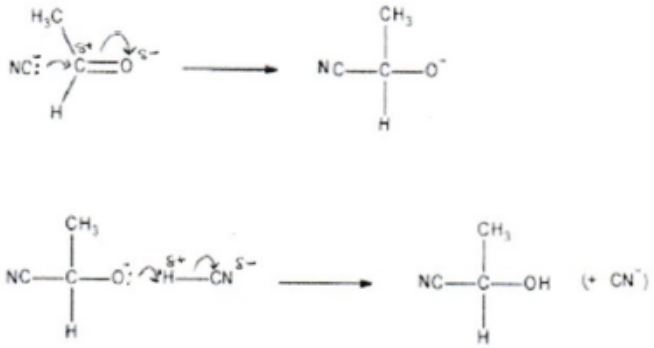
Question Number	Answer	Mark
	The only correct answer is C (3-methylpentan-3-ol) ***A*** *is not correct because this is a primary alcohol and so can be formed by the reduction of an aldehyde* ***B*** *is not correct because this is a secondary alcohol and so can be formed by the reduction of a ketone* ***D*** *is not correct because this is a secondary alcohol and so can be formed by the reduction of a ketone*	(1)

Q2.

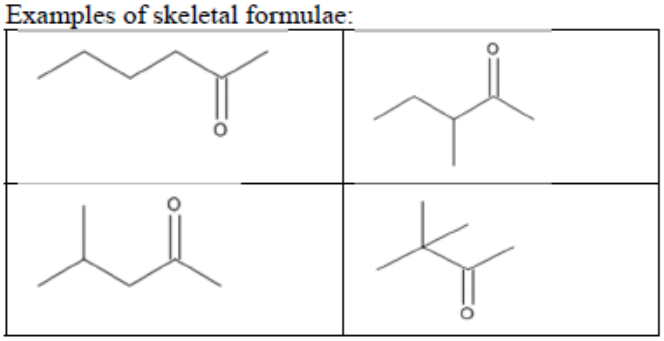
Question Number	Answer	Additional Guidance	Mark
(a)	• $C_{10}H_{18}O$	Allow symbols in any order i.e. $C_{10}OH_{18}$ / $H_{18}C_{10}O$ / $H_{18}OC_{10}$ / $OC_{10}H_{18}$ / $OH_{18}C_{10}$ Allow large numbers e.g. C10H18O Do not award superscripts e.g. $C^{10}H^{18}O$	(1)

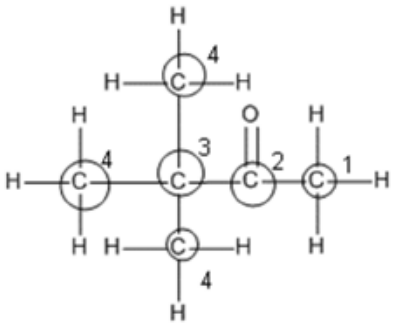
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • curly arrow from lone pair on C of CN^- towards C of aldehyde group (1) • curly arrow from C=O to, or just beyond, O **and** dipole on C=O (1) • intermediate (1) • curly arrow from lone pair on O^- to H **and** curly arrow from H-CN bond to anywhere on CN **and** final organic product (1)	Penalise an incorrect dipole in M1 and M4 once only Penalise curly arrow not starting from lone pair once only in M1 and M4 Penalise half arrow-heads once only Allow CN^- to attack C=O from any angle Allow CN bond displayed If M1 lost as curly arrow from N of CN^-, allow CN joined to carbon through N Ignore connectivity for vertical CN groups Allow curly arrow from lone pair on O^- to H^+ Ignore missing dipole in HCN	(4)

Example of mechanism:



Question Number	Answer	Additional Guidance	Mark
(c)(i)	• CH_3CO- / $-COCH_3$ / methyl ketone	Allow any combination of structural / displayed formula or skeletal formula Allow methyl next to ketone / methyl and ketone / methylcarbonyl Allow CH_3COR / $RCOCH_3$ Ignore missing continuation bond from structures Do not award ethanal / methyl secondary alcohol / a specific compound	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• any 2 skeletal formulae (1) • remaining 2 skeletal formulae (1)	Examples of skeletal formulae:  Ignore bond lengths and bond angles Allow (1) for 4 correct displayed / structural formulae	(2)

Question Number	Answer	Additional Guidance	Mark
(c)(iii)	• displayed formula of **F** (1) • carbon atoms labelled (1)	Example of displayed formula:  Allow CH_3 Allow other unambiguous labels for the carbon atoms Allow M2 for labels on structural / skeletal formulae, including labels on formulae in (c)(ii) Ignore reference to singlet / splitting patterns	(2)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>(d)*</td>
<td>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.
<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.</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, 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).</td>
<td>(6)</td>
</tr>
</table>

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	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

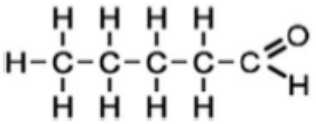
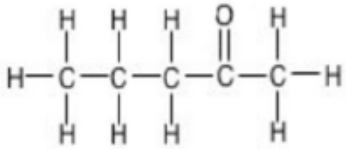
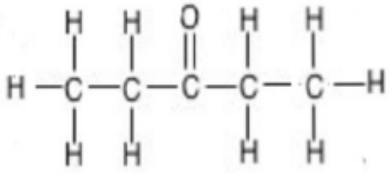
Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

Additional incorrect chemistry loses a structure and lines of reasoning mark (if 1 or 2 have been awarded).

	Indicative content • **IP1 London forces** Pentane (only) has London forces / all have London forces • **IP2 Butanal** Butanal (also) has (permanent) dipole-dipole interactions • **IP3 Propanoic acid** Propanoic acid (also) has (dipole-dipole and) hydrogen bonding • **IP4 Intermolecular forces** The London forces have about the same strength as they have a similar number of electrons / pentane has 42, butanal has 40 (and propanoic acid has 40 electrons) **or** butanal has dipole-dipole interactions because it is polar / has a dipole on C=O **or** propanoic acid has hydrogen bonding because it contains OH / COOH group • **IP5 Butanal and pentane** Dipole-dipole interactions are stronger than London forces **or** more energy is needed to overcome the dipole-dipole interactions than London forces • **IP6 Butanal and propanoic acid** Hydrogen bonding is stronger than dipole-dipole interactions **or** more energy is needed to overcome hydrogen bonding than dipole-dipole interactions	Allow dispersion forces / van der Waals' forces / forces between an instantaneous dipole and an induced dipole for London forces throughout answer Do not award IP1 if any other forces mentioned Allow dipole-dipole forces / attractions / bonds Do not award IP2 if hydrogen bonding included Allow similar relative molecular masses (butanal 72, pentane 72, propanoic acid 74) Do not award incorrect numbers of electrons / relative molecular masses Allow dipole-dipole interactions linked to C=O Allow diagram of hydrogen bond between two molecules Ignore formation of dimer Allow London forces are the weakest (intermolecular force) Do not award if covalent bonds broken or explanation is about intermolecular forces with water Allow hydrogen bonding is the strongest (intermolecular force) Do not award if covalent bonds broken or explanation is about intermolecular forces with water	**(6)**

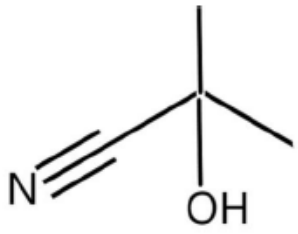
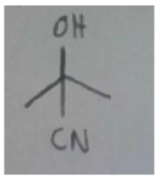
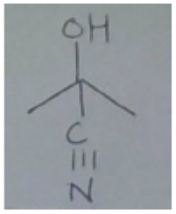
Q3.

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)

Q4.

<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 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.
</td>
<td>6</td>
</tr>
</table>

	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	

Q5.

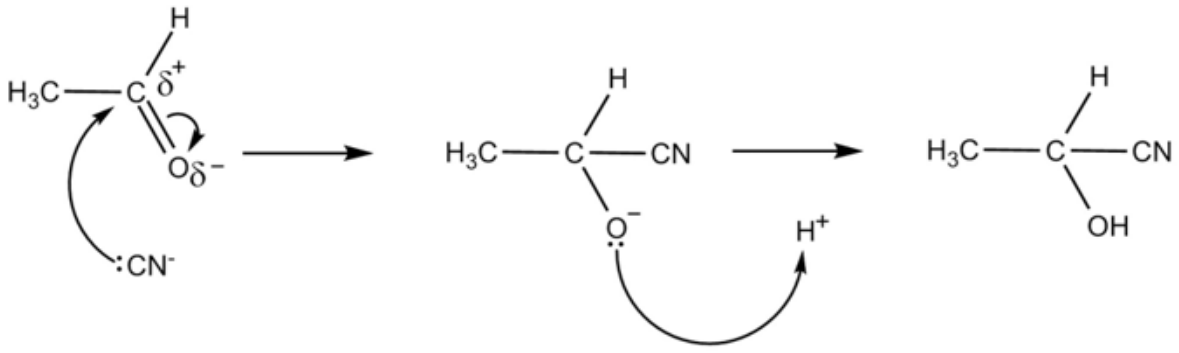
Question Number	Answer	Mark
(a)	**The only correct answer is C** (add 2,4-dinitrophenylhydrazine (Brady's reagent) to each compound) *A is incorrect because neither would react* *B is incorrect because neither would react* *D is incorrect because neither would react*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is B** (warm each compound with acidified potassium dichromate(VI) solution) *A is incorrect because neither would react* *C is incorrect because neither would react* *D is incorrect because neither would react*	(1)

Question Number	Answer	Mark
(c)	**The only correct answer is D** (add a few drops of each compound, drop by drop, to water) *A is incorrect because as butanal would react but 2-methylpropan-2-ol would not* *B is incorrect because as butanal would react but 2-methylpropan-2-ol would not* *C is incorrect because as butanal would react but 2-methylpropan-2-ol would not*	(1)

Q6.

Q	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• arrow from lone pair on carbon of cyanide ion to carbonyl carbon **(1)** • dipoles on carbon and oxygen in carbonyl bond **and** arrow from carbonyl bond to oxygen or just beyond **(1)** • structure of intermediate, including charge **(1)** • arrow from lone pair of oxygen in intermediate to hydrogen ion / H in HCN **(1)**	Penalise absence of lone pair only once in M1, M3 and M4 If HCN used to protonate in step 2, dipole on HCN and curly arrow to break HCN bond are **not** required Ignore product	4



Q	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	The prediction is incorrect because • ethanal is planar around the carbonyl carbon atom / planar around the CHO **(1)** • (so in Step 1) the (carbonyl) carbon can be attacked from above or below **(1)** • hence both stereoisomers (of intermediate / product) will form in equal amounts **or** so product mixture is racemic / rotates the plane of plane-polarised light equally in both directions **(1)**	Accept planar at the site of the nucleophilic attack / planar about C=O Do not award planar molecule / cation / intermediate Allow attack from any direction / either side Ignore 'has no effect on the plane of plane-polarised light' Ignore comments related to SN1 or SN2 If no other mark scored allow 1 mark for idea that product will rotate plane of plane polarised light as it has a chiral centre / carbon	**3**

Q	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• hydrolysis **(1)** • (dilute) hydrochloric acid / HCl((aq)) **(1)** • heat (under reflux) / reflux **(1)** • $CH_3CH(OH)CN + 2H_2O + H^+ \rightarrow CH_3CH(OH)COOH + NH_4^+$ **(1)** OR $CH_3CH(OH)CN + 2H_2O \rightarrow CH_3CH(OH)COOH + NH_3$ OR $CH_3CH(OH)CN + 2H_2O + HCl \rightarrow CH_3CH(OH)COOH + NH_4Cl$ OR $CH_3CH(OH)CN + H_2O + OH^- \rightarrow CH_3CH(OH)COO^- + NH_3$ **and** $CH_3CH(OH)COO^- + H^+ \rightarrow CH_3CH(OH)COOH$	Allow any strong acid by name or formula Allow sodium hydroxide **followed by** any (strong) acid Ignore conc / concentrated Allow 'boil' for heat Allow NaOH for OH^- Allow HCl for H^+ Ignore state symbols even if incorrect	**4**

Q	Acceptable Answers	Additional Guidance	Mark
(b)	• $CH_3CH(OH)COOH + NaHCO_3 \rightarrow CH_3CH(OH)COO^-Na^+ + H_2O + CO_2$ OR $H^+ + HCO_3^- \rightarrow H_2O + CO_2$	Allow $CH_3CH(OH)COONa$ Allow H_2CO_3 Ignore state symbols even if incorrect Do not award if covalent bond shown between O and Na	**1**

Q	Acceptable Answers	Additional Guidance	Mark
(c)(i)	• (large concentration of) HCO_3^- react with (extra) H^+ ions **(1)** • equilibrium 1 moves to the RHS to keep concentration of H^+ ions constant / H_2CO_3 forms to keep concentration of H^+ ions constant **(1)** • equilibrium 2 moves to RHS to form CO_2 (which can be excreted from the body) / H_2CO_3 then forms CO_2 (and water) **(1)**	Allow ratio of $[HCO_3^-]$ to $[H_2CO_3]$ remains constant / ratio of [salt] to [acid] remains constant Allow H_3O^+ for H^+ Allow equilibrium 1 moves to the RHS to remove excess H^+ ions / H_2CO_3 forms to remove excess H^+ ions If no reference to H^+ and CO_2 in M2 and M3 but direction of movement of equilibria are correct in both cases, allow 1 mark	3

Q	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of $[H^+]$ / $[H_3O^+]$ **(1)** • K_a expression **(1)** • rearrangement of K_a expression and calculation of $[HCO_3^-] : [H_2CO_3]$ **(1)** OR • calculation of pK_a **(1)** • Henderson Hasselbach expression **(1)** • rearrangement of K_a expression and calculation of $[HCO_3^-] : [H_2CO_3]$ **(1)**	$[H^+] = 10^{-7.41}$ / = 3.8905×10^{-8} $K_a = \frac{[HCO_3^-][H^+]}{[H_2CO_3]}$ Allow $[H_3O^+]$ in K_a Do not award $[H_2O]$ in K_a expression $[HCO_3^-] : [H_2CO_3]$ $= 4.5 \times 10^{-7} \div 3.8905 \times 10^{-8} = 11.567 : 1 = 11.6 (: 1)$ Ignore SF except 1 Allow correct rounding of $[H^+]$ to 3.9×10^{-8} Allow 1 : 0.086444 if it's clear that 1 relates to $[HCO_3^-]$ p$K_a = -\log 4.5 \times 10^{-7} = 6.3468$ pH = pK_a + log($[HCO_3^-] \circ [H_2CO_3]$) 7.41 - 6.3468 = log($[HCO_3^-] \circ [H_2CO_3]$) $[HCO_3^-] : [H_2CO_3] = 11.567 (: 1)$ Correct answer with no working scores (3) If final answer close, check for and allow correct rounding	3
		(Total for Question = 18 marks)	

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)**

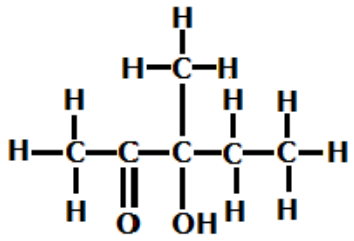
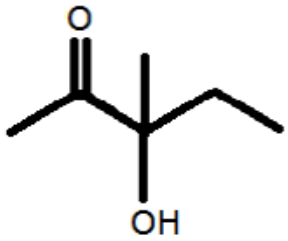
Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculate mass of oxygen **(1)** **(1)** • divides masses by atomic mass • divides by smallest to find the simplest ratio **(1)** **and** correct empirical formula	Example calculation Mass of O = 10 - 6.21 - 1.03 = 2.76(g) Element / Mass / Mass / 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)**

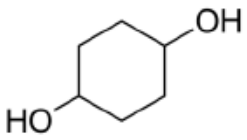
Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • molecular ion peak / peak at highest mass will be at twice the mass of the empirical formula / will be at 116	Ignore references to n.m.r or i.r.	**(1)**

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	

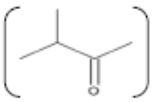
	• **IP4** Acidified potassium dichromate(VI) suggests not a primary, a secondary alcohol or an aldehyde present	Accept just no primary or secondary alcohol present Ignore references to ketone and carboxylic acid giving no result	
	• **IP5** Polarimetry indicates a chiral centre is present / it is a chiral 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)**

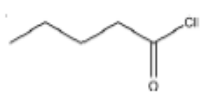
Q8.

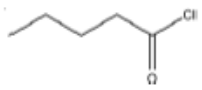
Question number	Answer	Mark
	D butanoic acid	1

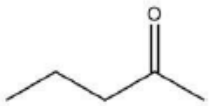
Q9.

Question Number	Answer	Mark
	The only correct answer is D  *A is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent* *B is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent* *C is not correct because this is an aldehyde and it would give a silver mirror with Tollens' reagent*	(1)

Q10.

Question Number	Answer	Mark
(a)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not change the pH of water C is incorrect as ketones do not change the pH of water D is incorrect as amides do not change the pH of water*	1

Question Number	Answer	Mark
(b)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not react with amines to form an N-substituted amide C is incorrect as ketones do not react with amines* *D is incorrect as amides do not react with amines*	1

Question Number	Answer	Mark
(c)	The only correct answer is **C** (compound 3)  *A is incorrect as it does not form iodoform* *B is incorrect as it does not form iodoform D is incorrect as it does not form iodoform*	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 ☒.

Ethanal and propane have the same molar mass but ethanal has a much higher boiling temperature.

Ethanal is fully miscible in water but propane is almost insoluble.

Which intermolecular forces of ethanal are mainly responsible for the differences in these properties?

		Higher boiling temperature	Greater solubility in water
☒	**A**	hydrogen bonds	hydrogen bonds
☒	**B**	permanent dipole forces	permanent dipole forces
☒	**C**	hydrogen bonds	permanent dipole forces
☒	**D**	permanent dipole forces	hydrogen bonds

(Total for question = 1 mark)

Q2.

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.

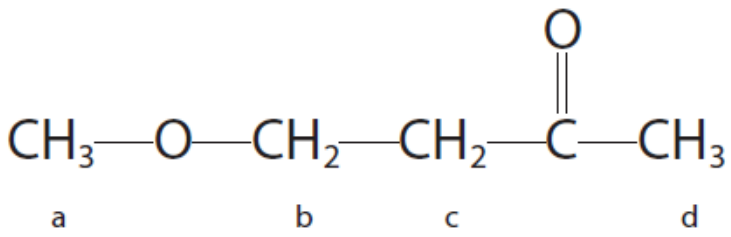
Give the structures of these **four** isomers.

(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)

.....

(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)

.....

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

Justify your answer.

(3)

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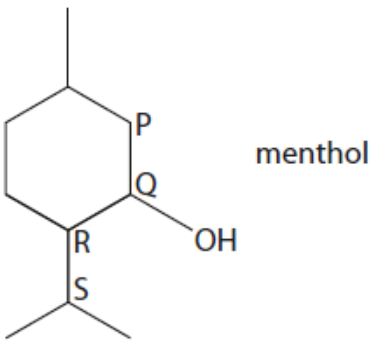
.....

(Total for question = 17 marks)

Q3.

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

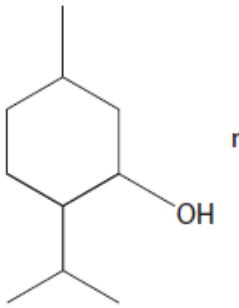
☒ **B** Q

☒ **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

	Qualitative test		
Group	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

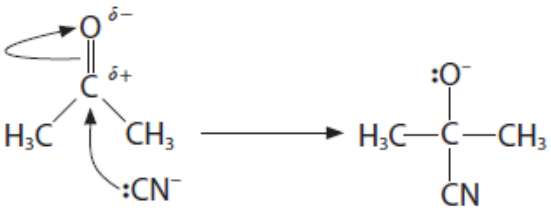
(Total for question = 3 marks)

Q4.

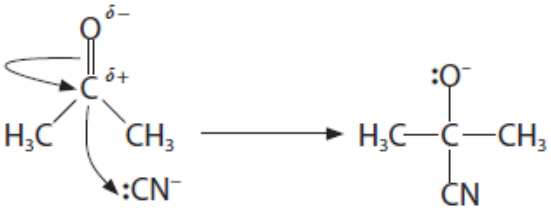
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which diagram shows the first step of the mechanism for the nucleophilic addition of hydrogen cyanide to propanone in the presence of potassium cyanide?

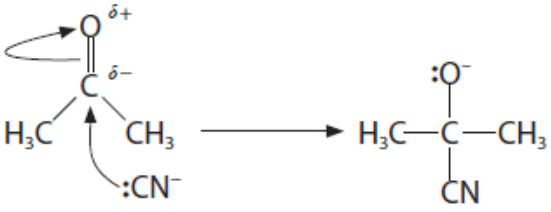
☒ **A**



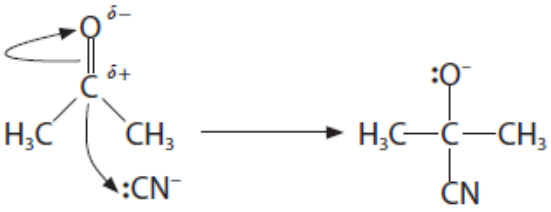
☒ **B**



☒ **C**



☒ **D**



Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

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 ☒.

An organic compound that reacts with **both** lithium tetrahydridoaluminate(III) (lithium aluminium hydride) **and** magnesium could be

☒ **A** an aldehyde

☒ **B** a carboxylic acid

☒ **C** a ketone

☒ **D** a tertiary alcohol

(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 ☒.

When propanone reacts with iodine in the presence of sodium hydroxide, the precipitate formed has the formula

☒ **A** CH_3I

☒ **B** CHI_3

☒ **C** CH_3COCH_2I

☒ **D** CH_3COCI_3

(Total for question = 1 mark)

Q7.

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)

Q8.

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 ☒.

Propanone reacts with iodine in both acidic and alkaline conditions.

(a) The products of the reactions under the stated conditions include

(1)

	Acidic conditions	Alkaline conditions
☒ **A**	CH_3I	CH_3COO^-
☒ **B**	CH_3COCI_3	CH_3COO^-
☒ **C**	CH_3COCH_2I	CH_3I
☒ **D**	CH_3COCH_2I	CHI_3

(b) The rate equation for the reaction between propanone and iodine in acidic conditions is

$$\text{rate} = k[H^+][CH_3COCH_3]$$

The reaction was carried out at two different pH values, all other conditions remaining unchanged.

In the first reaction pH = 2.0

In the second reaction the rate was found to be $\frac{1}{3}$ of the original value.

What was the pH of the second reaction, to 1 decimal place?

(1)

☒ **A** 0.7

☒ **B** 1.5

☒ **C** 2.5

☒ **D** 2.7

(Total for question = 2 marks)

Q9.

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 ☒.

An unknown aldehyde may be identified by measuring the melting temperature of the purified precipitate formed in its reaction with

☒ **A** 2,4-dinitrophenylhydrazine

☒ **B** Fehling's solution

☒ **C** potassium dichromate and sulfuric acid

☒ **D** Tollens' reagent

(Total for question = 1 mark)

Q10.

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)

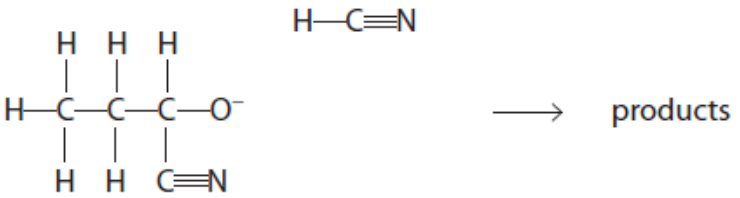
Step **1**



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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.....

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

Justify this description by referring to the mechanism.

(2)

.....

.....

.....

.....

.....

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

Draw the three-dimensional structures of these enantiomers.

(2)

(Total for question = 10 marks)

Q11.

Which compound gives a pale yellow precipitate on warming with a solution of iodine and sodium hydroxide?

(1)

☒ **A** CH_3OH

☒ **B** $CH_3CH_2CH_2CHO$

☒ **C** $CH_3CH_2COCH_3$

☒ **D** $CH_3CH_2COCH_2CH_3$

(Total for question = 1 mark)

Q12.

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 ☒.

How many structural isomers with the molecular formula $C_5H_{10}O$ react with Tollens' reagent?

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

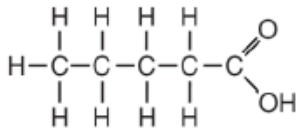
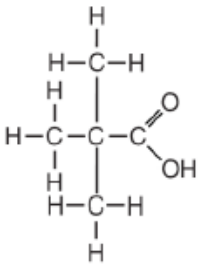
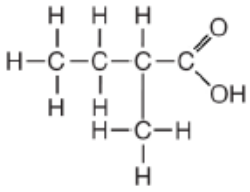
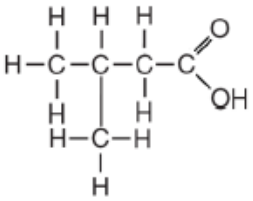
(Total for question = 1 mark)

Mark Scheme

Q1.

Question number	Answer	Mark
	The only correct answer is D(permanent dipole forces, hydrogen bonds) *A* *is incorrect because pure ethanal does not form hydrogen bonds* *B* *is incorrect because permanent dipole forces are less important than hydrogen bonding in the solubility of ethanal in water* *C* *is incorrect because pure ethanal does not form hydrogen bonds and permanent dipole forces are less important than hydrogen bonding in the solubility of ethanal in water*	(1)

Q2.

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><td>b</td><td>c</td><td>d</td></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)

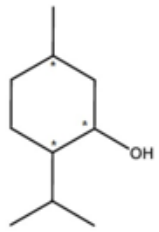
Question Number	Answer	Additional guidance	Mark
(c)(ii)	• (Lithium tetrahydridoalumate(III) / lithium aluminium hydride) / $LiAlH_4$ **AND** in dry ether / diethyl ether / ethoxyethane (solvent)	ALLOW Lithal ALLOW Sodium tetrahydridoborate / sodium borohydride AND Water / ethanol solvent	(1)

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)

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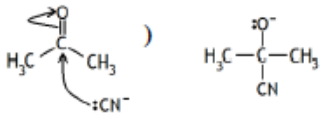
Q3.

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

Q4.

Question Number	Answer	Mark
	The only correct answer is A ( **)** *B is incorrect because the arrow from the C=O should go to O not C* *C is incorrect because the dipole for the C=O has been reversed* ***D** is incorrect because the arrow should go from :CN^- not to it*	(1)

Q5.

Question Number	Answer	Mark
	The only correct answer is B (a carboxylic acid) *A is incorrect because this will not react with magnesium* *C is incorrect because this will not react with magnesium* ***D** is incorrect because this will not react with lithium tetrahydridoaluminate(III) or magnesium*	(1)

Q6.

Question Number	Answer	Mark
	The only correct answer is B (CHI_3) *A is incorrect because there should be 3I not 3H attached to the C* *C is incorrect because this is the product of the reaction between iodine and propanone in acidic conditions* ***D** is incorrect because this is an intermediate during the reaction between iodine and propanone*	(1)

Q7.

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)

Q8.

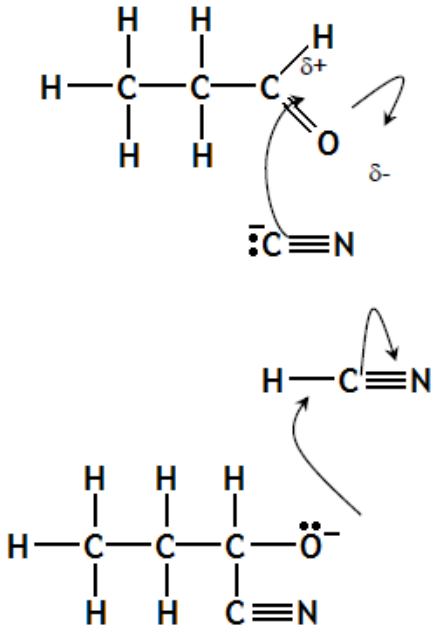
Question Number	Correct Answer	Mark
(a)	**The only correct answer is D** (CH_3COCH_2I CHI_3) ***A*** *is incorrect because* CH_3I *is not formed in acidic conditions* ***B*** *is incorrect because* CH_3COCI_3 *is not formed in acidic conditions* ***C*** *is incorrect because* CH_3I *is not formed in alkaline conditions*	(1)

Question Number	Correct Answer	Mark
(b)	**The only correct answer is C** (2.5) ***A*** *is incorrect because the value of the pH has been divided by 3* ***B*** *is incorrect because the concentration of* H^+ *ions has been multiplied by 3 rather than divided* ***D*** *is incorrect because this value is adding 1/3 of 2 onto 2*	(1)

Q9.

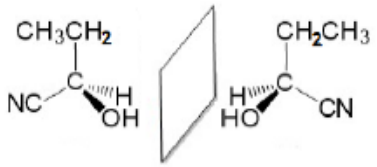
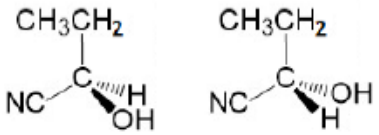
Question number	Answer	Mark
	The only correct answer is A (2,4-dinitrophenylhydrazine) ***B*** *is incorrect because the precipitate is copper(I) oxide for all aldehydes* ***C*** *is incorrect because no precipitate is formed* ***D*** *is incorrect because the precipitate is silver for all aldehydes*	**(1)**

Q10.

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)**

Q11.

Question number	Answer	Mark
	C $CH_3CH_2COCH_3$	1

Q12.

Question Number	Correct Answer	Mark
	The only correct answer is C (4) ***A*** *is incorrect because there are 4 aldehydes with this molecular formula that are structural isomers* ***B*** *is incorrect because there are 4 aldehydes with this molecular formula that are structural isomers* ***D*** *is incorrect because there are 4 aldehydes with this molecular formula that are structural isomers*	(1)