1. The functional group in an organic compound, **W**, was identified by carrying out two chemical tests. The results of the tests are shown below.

Heating with acidified sodium dichromate(VI)(aq)	**Addition of 2,4-dinitrophenylhydrazine(aq)**
orange solution turns green	yellow / orange precipitate formed

Which compound could be **W**?

A. $CH_3CH_2CH_2OH$
B. CH_3COCH_3
C. $CH_3CH(OH)CH_3$
D. CH_3CH_2CHO

Your answer ☐

[1]

2. CN^- ions react with haloalkanes and with carbonyl compounds.

Which row gives the correct mechanisms for the reactions?

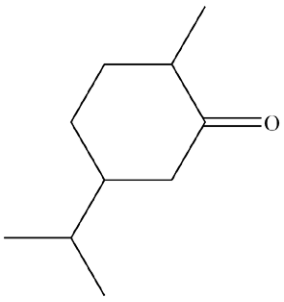
	Reaction of CN^- with haloalkanes	Reaction of CN^- with carbonyl compounds
A	Electrophilic substitution	Electrophilic addition
B	Electrophilic substitution	Nucleophilic addition
C	Nucleophilic substitution	Electrophilic addition
D	Nucleophilic substitution	Nucleophilic addition

Your answer ☐

[1]

3. Carbonyl compounds have distinctive smells.

Menthone smells of peppermint.



Menthone

Menthone is reacted in a two-step synthesis shown below.

Step 1: A sample of menthone is added to hot acidified aqueous dichromate(VI) ions.

Step 2: The resulting mixture from **Step 1** is added to $NaBH_4$ in water.

What happens to the smell of the reaction mixture during the process?

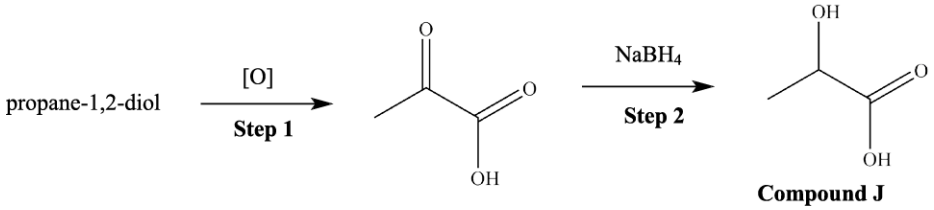
	Step 1	Step 2
A	Smell of peppermint remains	Smell of peppermint is lost
B	Smell of peppermint is lost	Smell of peppermint returns
C	Smell of peppermint remains	Smell of peppermint remains
D	Smell of peppermint is lost	Smell of peppermint does not return

Your answer ☐

[1]

4. α-Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

A student synthesises a sample of the AHA **J** using the following reaction scheme, starting from propane-1, 2-diol.



Compound J

i. In the space below:
- state a suitable oxidising agent for **Step 1**
- write an equation for **Step 1**
- outline the mechanism for **Step 2**, showing curly arrows and relevant dipoles.

[5]

ii. The reagent used in **Step 2** of the synthesis in (**i**) was $NaBH_4$. $NaBH_4$ contains the ions Na^+ and $[BH_4]^-$.

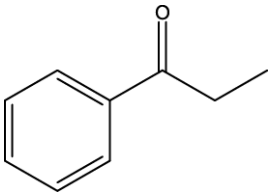
Draw a '*dot-and-cross*' diagram of $NaBH_4$ and give the **full** electron configuration of Na^+.

Show outer shells of electrons only.

full electronic configuration of Na^+: .....

[2]

5. A chemist reacts the following molecule with sodium borohydride, $NaBH_4$.



Which functional group is formed in the reaction?

A. Carboxylic acid
B. Secondary alcohol
C. Primary alcohol
D. Aldehyde

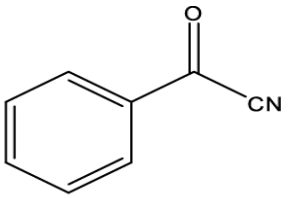
Your answer ☐

[1]

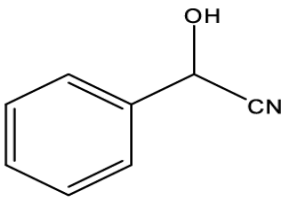
6. Benzaldehyde, C_6H_5CHO, reacts with $NaCN(aq)/H^+(aq)$.

What is the organic product of this reaction?

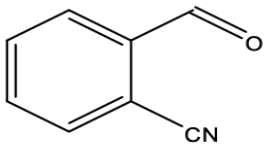
A



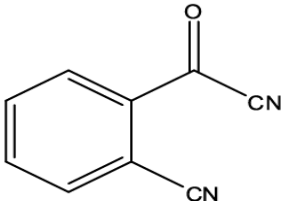
B



C



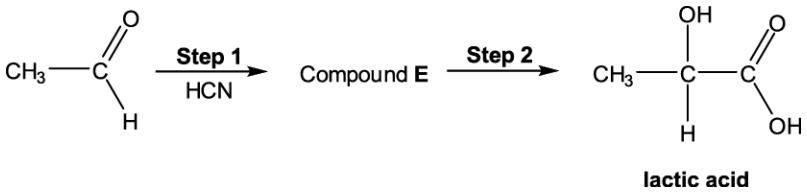
D



Your answer ☐

[1]

7(a). Lactic acid is a naturally occurring chemical, which can be synthesised from ethanal, CH_3CHO, as shown in the steps below.



lactic acid

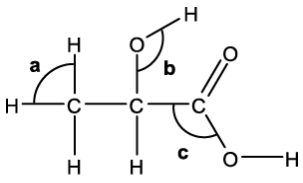
i. Draw the structure for compound **E**.

[1]

ii. Suggest a reagent that could be used for **Step 2**.

[1]

iii. The displayed formula of lactic acid is shown below.



lactic acid

Suggest a value for each bond angle **a**–**c**.

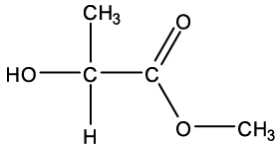
Bond angle **a**: .....

Bond angle **b**: .....

Bond angle **c**: .....

[2]

(b). Methyl lactate is an ester of lactic acid which is used as a solvent.



methyl lactate

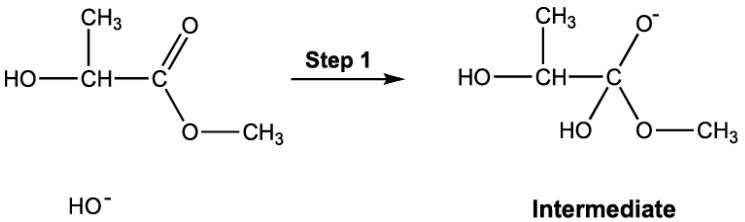
Methyl lactate can be hydrolysed by refluxing with sodium hydroxide solution.

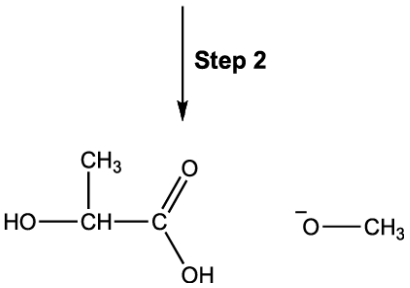
In this reaction the hydroxide ion acts as a nucleophile.

i. Suggest how the hydroxide ion can act as a nucleophile.

[1]

ii. Part of the mechanism for the hydrolysis is shown below.



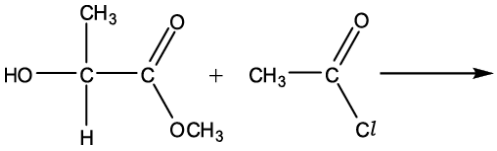


- Add relevant dipoles and curly arrows to show how the intermediate is formed in **Step 1** of the mechanism.
- Add curly arrows to show how the carboxylic acid and $^{-}OCH_3$ ion are formed from the intermediate in **Step 2** of the mechanism.

[4]

iii. Methyl lactate can also react with ethanoyl chloride.

Complete the equation for this reaction.



[2]

8(a). Compound **F** has the molecular formula C_4H_8.

Compound **F** is reacted with steam in the presence of an acid catalyst, to form a mixture of three alcohols, **G**, **H** and **I**.

Compound **G** is oxidised with acidified potassium dichromate(VI) to form compound **J**.

Compound **J** reacts with Tollens' reagent to form compound **K**.

Compounds **H** and **I** are optical isomers.

Draw the structures of the compounds **F**, **G**, **H**, **I**, **J** and **K**.

[6]

(b). Explain, with reference to a suitable chemical test, how compound **J** could be identified.

Your answer should **not** include spectroscopy.

[3]

9(a). Cyclohexanone can be prepared in the laboratory by reacting cyclohexanol with concentrated sulfuric acid and sodium dichromate.

Ethanedioic acid is added to the reaction mixture to react with any excess dichromate.
The mixture is then distilled. The impure distillate is a mixture of cyclohexanone and water.

You will need to refer to some or all of the following data to answer these questions.

	Boiling point / °C	**Density / g cm^{-3}**	***M*$_r$**
Cyclohexanol	161	0.962	100.0
Cyclohexanone	156	0.948	98.0

* Draw a labelled diagram to show how you would safely set up apparatus for distillation and describe a method to obtain a pure sample of cyclohexanone from the distillate.

[6]

(b). Ethanedioic acid removes excess dichromate ions, $Cr_2O_7^{2-}$, as in the equation below.

$$3(COOH)_2 + Cr_2O_7^{2-} + 8H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O$$

Suggest how you could tell when the excess dichromate has completely reacted with the ethanedioic acid.

[1]

(c). A student monitors the course of this reaction using thin-layer chromatography (TLC).

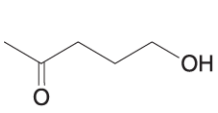
Outline how TLC could be used to monitor the course of the reaction.

[2]

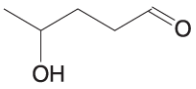
(d). Plan an experiment that would allow the student to confirm the identity of the pure organic product by means of a chemical test.

[3]

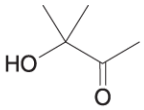
10. The following three carbonyl compounds are structural isomers of $C_5H_{10}O_2$.



compound C



compound D



compound E

Aldehydes and ketones are both reduced by $NaBH_4$. When used in the presence of a $CeCl_3$ catalyst, $NaBH_4$ only reduces ketones.

Compound **F** has the structural formula $CH_3COCH_2CH_2CHO$. It is reduced by $NaBH_4$ in the presence of a $CeCl_3$ catalyst to form one of the compounds **C**, **D** or **E**.

Show the mechanism for this reduction of compound **F** and identify the product that is formed.

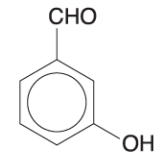
Use curly arrows and show relevant dipoles.

You do not need to show the role of the $CeCl_3$ catalyst.

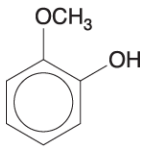
[4]

11. A student analysed a mixture of compounds found in red wine using gas chromatography followed by mass spectrometry (GC-MS).

Two of the compounds found to be present in the mixture are shown below.



compound A

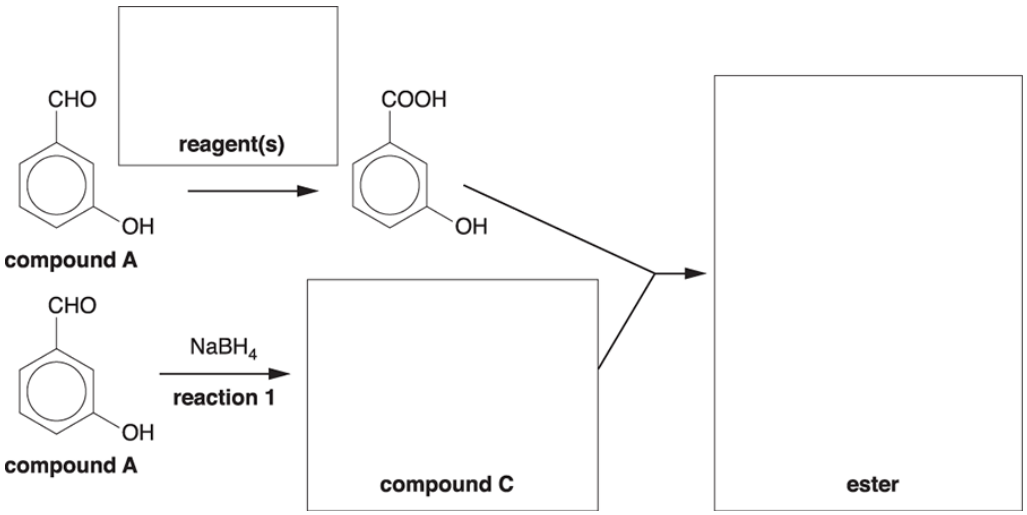


compound B

In red wine, compound **A** slowly forms an ester.

The formation of the ester can also be done in the laboratory, as shown in the flowchart below. Separate portions of compound **A** are used in the formation of the ester.

i. Complete the boxes in the flowchart below.



[3]

ii. Give the mechanism to show the formation of compound **C** in **reaction 1**.
Use curly arrows and relevant dipoles.

[3]

12(a). There are several isomeric alcohols with the formula $C_5H_{11}OH$.

Pentan-1-ol, $CH_3(CH_2)_3CH_2OH$, can be prepared in the laboratory by the reduction of an aldehyde.

State a suitable reducing agent for this reaction and write an equation to show the preparation of pentan-1-ol.
Use [H] to represent the reducing agent in the equation.

Reducing agent .....

Equation .....

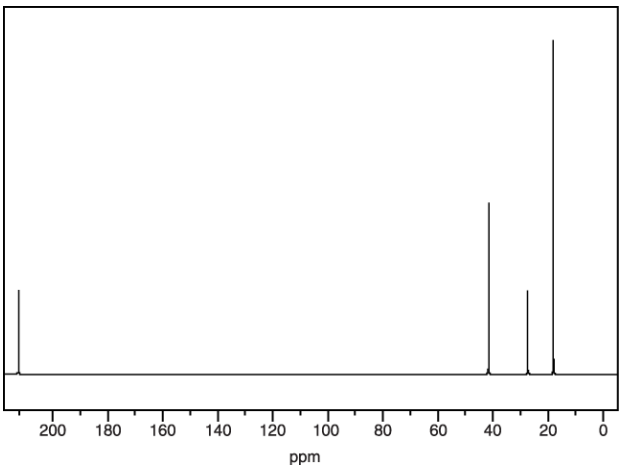
[2]

(b). Compound **F** is a structural isomer of $C_5H_{11}OH$.

Compound **F** is converted to compound **G** when heated under reflux with acidified potassium dichromate(VI) solution.

Compound **G** reacts with 2,4-dinitrophenylhydrazine to form an orange solid but compound **G** does not react with Tollens' reagent.

The ^{13}C NMR spectrum of compound **G** is shown below.



Compound **H** is a carboxylic acid. In a titration, 0.211 g of carboxylic acid **H** requires 22.8 cm^3 of 0.125 mol dm^{-3} NaOH for neutralisation.

Compound **F** reacts with compound **H** in the presence of concentrated sulfuric acid to form organic compound **I**.

Identify compounds **F**, **G**, **H** and **I** and draw their structures in the boxes below.

Show your working **only** for the identification of compound **H**.

F

G

H

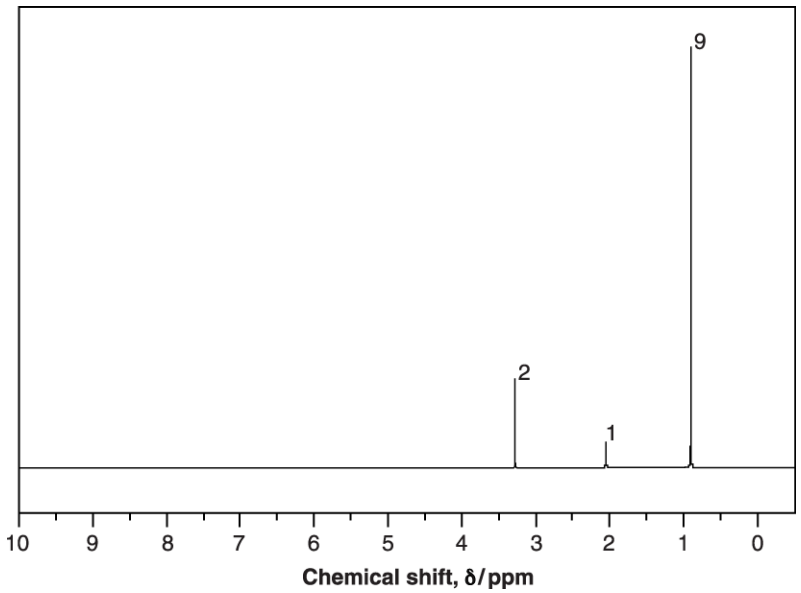
I

[7]

(c). Compound **J** is another structural isomer of $C_5H_{11}OH$.

The ^1H NMR spectrum of **J** is shown below.

The numbers next to each peak are the relative peak areas.



Identify compound **J** and draw its structure in the box below.

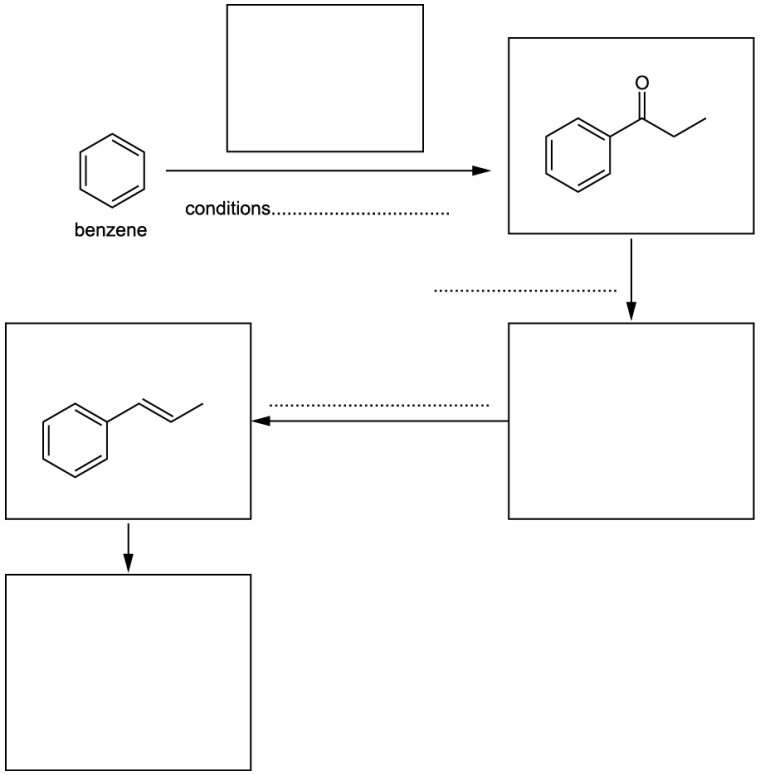
J

[1]

13(a). This question is about the synthesis of a polymer.

The flowchart below shows the synthesis of polymer **I** starting from benzene.

Draw the structures of the missing compounds in the boxes and add the missing reagents on the dotted lines.



repeat unit of polymer **I**

[6]

(b). Polymer **I** cannot be disposed of in landfill sites as it is not biodegradable.

Suggest **one** way of processing waste polymer **I** other than landfill and recycling.

[1]

14(a). A student was provided with five compounds: an aldehyde, a ketone, a carboxylic acid and two esters. The student decides to identify the type of compound by carrying out some chemical tests.

Suggest chemical tests to identify the carboxylic acid and aldehyde.

For each test, include essential reagent(s), observation(s) and a balanced equation.

In your equations, use 'R' for the alkyl group.

i. Test for carboxylic acid.

Reagent(s)
.....

Observation(s)
.....

Equation

[2]

ii. Test for aldehyde.

Reagent(s)
.....

Observation(s)
.....

Equation

[2]

(b). Suggest a chemical test to distinguish the ketone from the two esters.

Reagent(s) .....

Observation(s) .....

[1]

(c). The student wants to confirm that the other two compounds are esters. Unfortunately there is no direct test for an ester group.

The esters are $CH_3COOC(CH_3)_3$ and $(CH_3)_3CCOOCH_3$.

The student plans the following:

- hydrolyse the two esters using aqueous sodium hydroxide.
- separate the hydrolysis products.
- carry out tests on the hydrolysis products.

i. Write an equation for the hydrolysis of one of the two esters with aqueous sodium hydroxide.

Show the structures for the organic compounds.

[2]

ii. Suggest a chemical test on the hydrolysis products that would allow the two esters to be identified.

Write an equation for one reaction that takes place.

Show the structures for the organic compounds.

Reagent(s)
.....

Observation(s)
.....

Equation

[2]

iii. The student thought that NMR spectroscopy could be used to identify the two esters without the need to carry out chemical tests.

The esters are $CH_3COOC(CH_3)_3$ and $(CH_3)_3CCOOCH_3$.

Explain whether the student is correct for ^{13}C and ^{1}H NMR spectroscopy. Your answer should also clearly state any differences between the spectra of the two esters.

[3]

(d). The ketone and aldehyde provided to the student both contain five carbon atoms.

The ^{1}H NMR spectrum of the aldehyde contains two singlet peaks only:
a large peak at δ = 1.2 ppm and smaller peak at δ = 9.6 ppm.

Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

[5]

15. This question is about organic compounds containing nitrogen.

Sodium cyanide, NaCN, can be reacted with many organic compounds to increase the length of a carbon chain.

i. 1-Chloropropane, $CH_3CH_2CH_2Cl$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

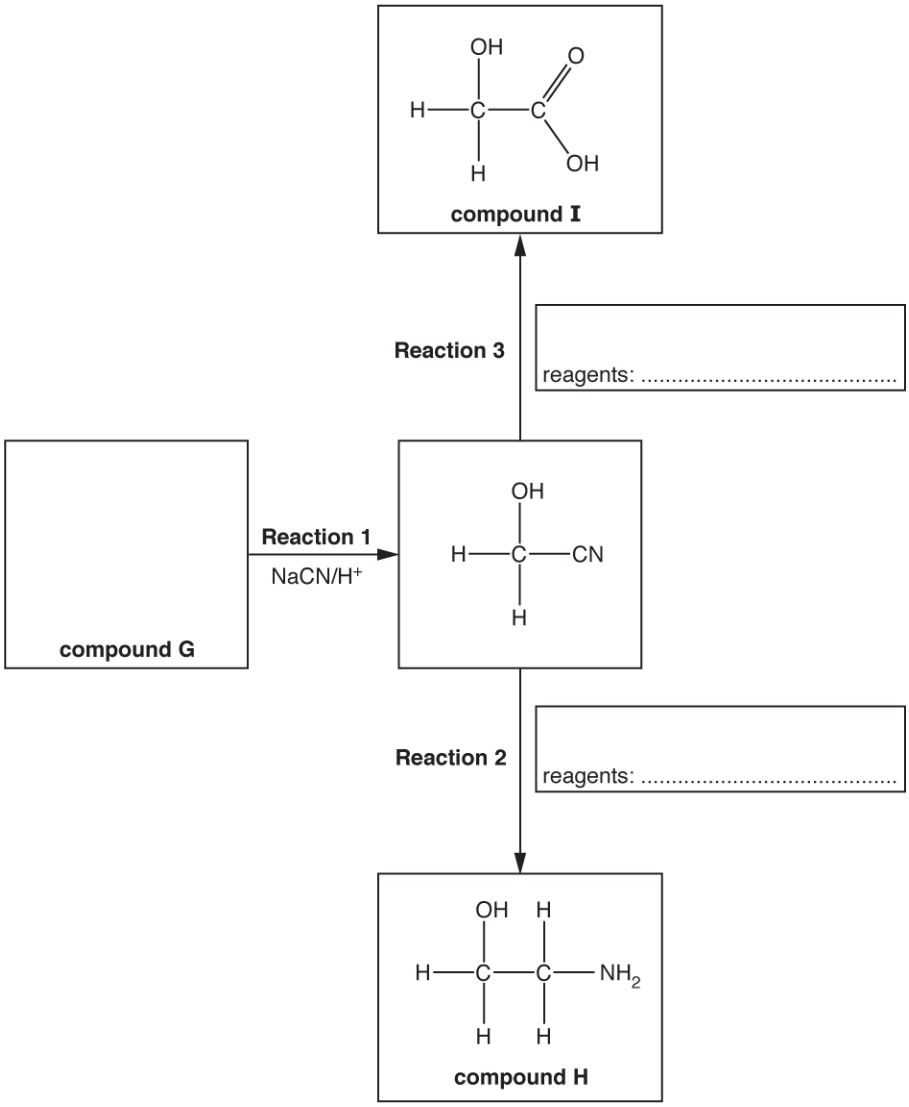
Outline the mechanism for this reaction.

Include curly arrows, relevant dipoles and the structure of the organic product.

[3]

ii. Compound **G** is used to synthesise compounds **H** and **I** as shown in the flowchart below.

Complete the flowchart showing the structure of compound **G** and the **formulae** of the reagents for **Reaction 2** and **Reaction 3**.



[3]

iii. Compound **H** reacts with dilute hydrochloric acid to form a salt.

Explain why compound **H** can react with dilute hydrochloric acid and suggest a structure for the salt formed.

Explanation

Structure

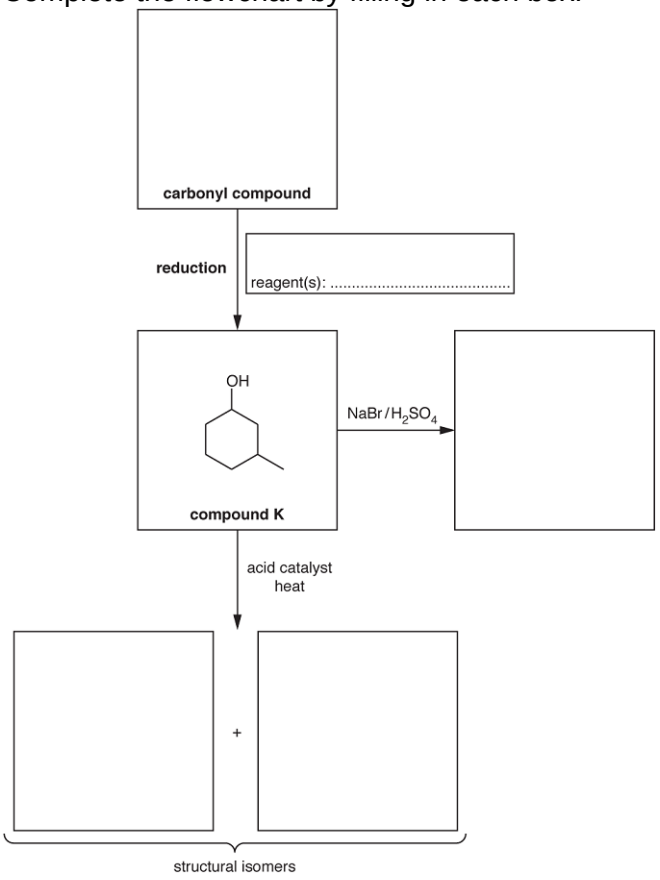
[2]

iv. Compound **I** is the monomer for the biodegradable polymer **J**.
Draw **two** repeat units of polymer **J** and suggest a reason why it is biodegradable.

[3]

16. Alcohols are important in organic synthesis and can be formed by the reduction of carbonyl compounds.

i. Complete the flowchart by filling in each box.

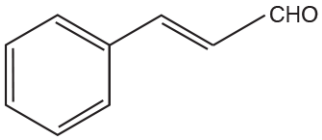


[5]

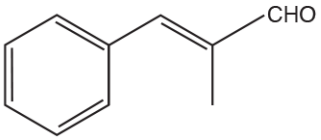
ii. What is the name of compound **K**?

[1]

17(a). A student plans to carry out some chemical tests on both cinnamaldehyde and methylcinnamaldehyde.



cinnamaldehyde



methylcinnamaldehyde

i. Suggest a suitable chemical test to confirm that both compounds contain an unsaturated carbon chain.

Your answer should include the reagent and observations.

[1]

ii. Describe a chemical test to confirm that both compounds contain an aldehyde functional group.

Your answer should include the reagent and observations.

[1]

iii. Describe a chemical test to confirm that cinnamaldehyde and methylcinnamaldehyde contain a carbonyl group.

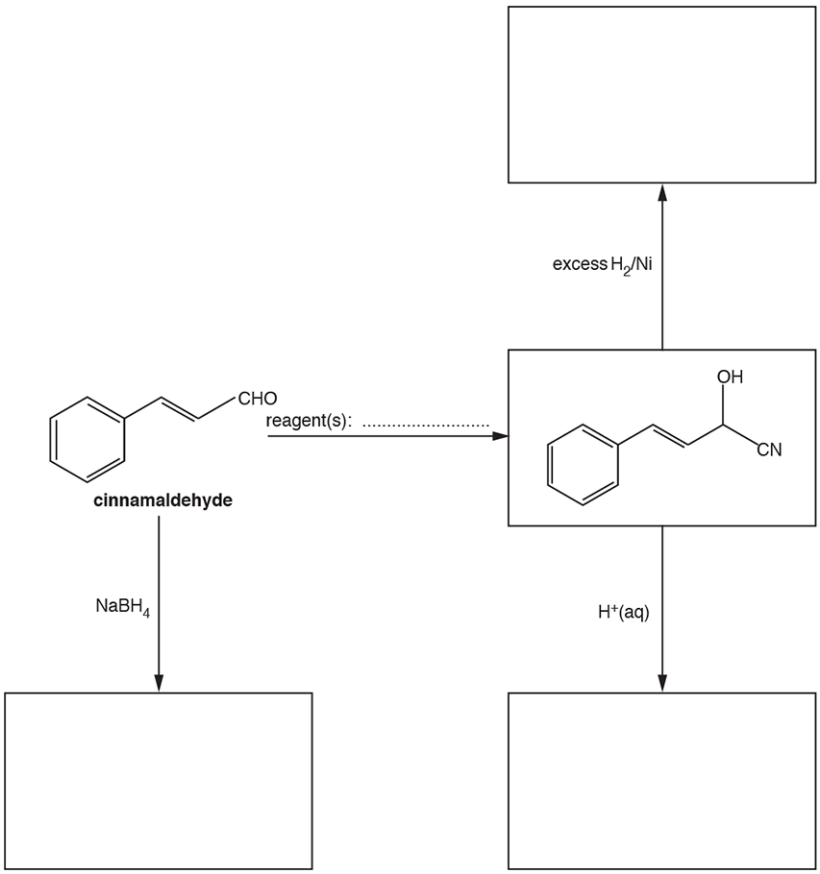
How could the products of this test be used to distinguish between the two compounds?

Your answer should **not** include spectroscopy.

[3]

(b). The flowchart below shows some reactions starting with cinnamaldehyde.

Draw the structures of the missing organic compounds in the boxes and add the missing reagent(s) on the dotted line.



[5]

18. A carbonyl compound is reacted with $NaBH_4$. Which compound(s) could be formed?

1 2-Methylpentan-2-ol

2 2-Methylpentan-1-ol

3 3-Methylpentan-2-ol

A 1, 2 and 3

B Only 1 and 2

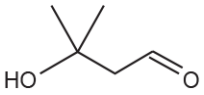
C Only 2 and 3

D Only 1

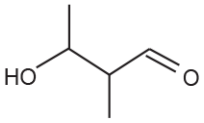
Your answer ☐ **[1]**

19. Which compound can be refluxed with acidified potassium dichromate (VI) to form an organic product with molecular formula $C_5H_8O_2$?

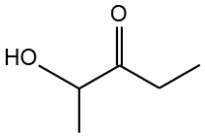
A



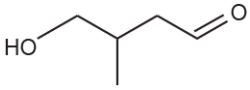
B



C

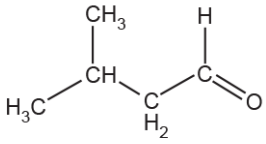


D

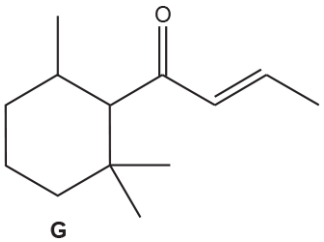


Your answer ☐ **[1]**

20(a). The carbonyl compounds, **F** and **G**, shown below, contribute to the flavour of coffee.



F



G

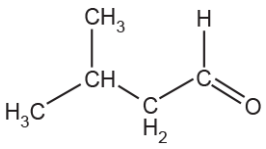
Describe suitable chemical tests, with observations, that would confirm the presence of the functional groups in **F** and **G**.

[4]

(b). Compound **F** reacts with HCN using NaCN(aq) and H_+(aq).

i. Outline the mechanism for the reaction of **F** with NaCN(aq) and H+(aq) and state the name of the mechanism. The structure of **F** has been provided.

Include relevant dipoles, lone pairs and the structure of the organic product.



Name of mechanism: **[5]**

ii. Explain why the mechanism in **(i)** involves heterolytic fission.

[2]

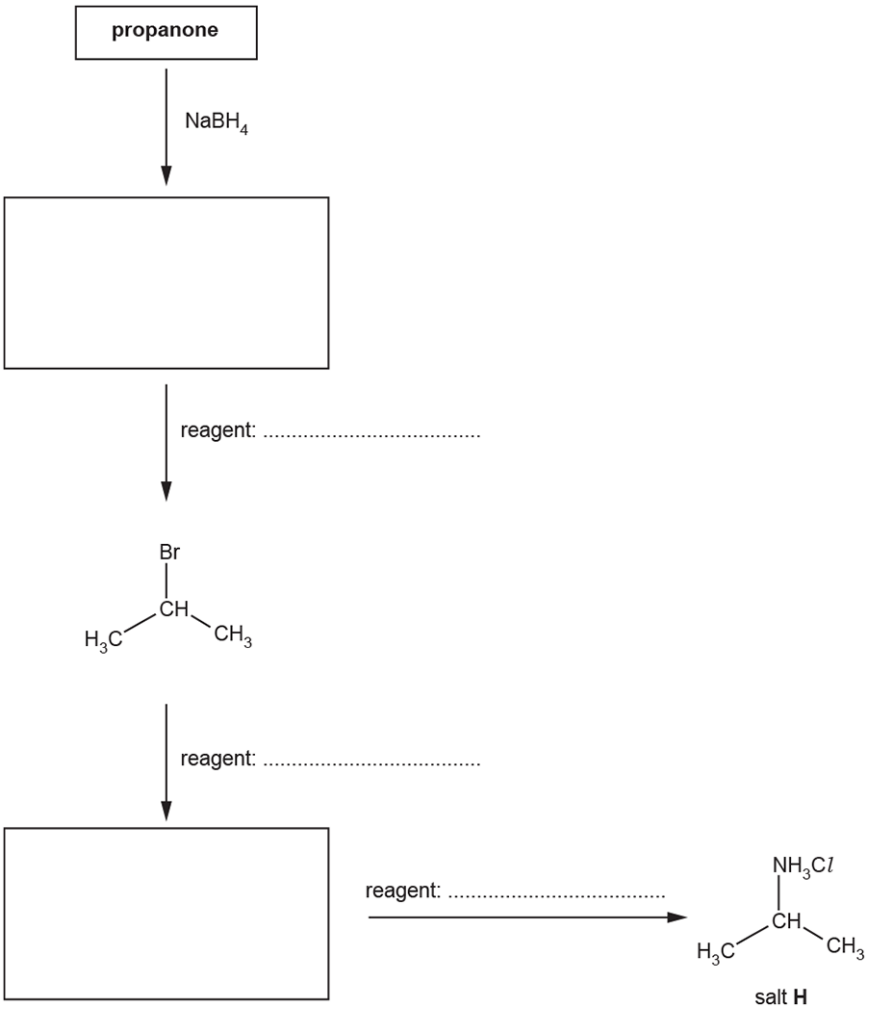
21. This question is about organic compounds containing nitrogen.

Salt **H**, $(CH_3)_2CHNH_3Cl$, is used in the manufacture of garden weedkillers.

The flowchart shows the synthesis of the salt **H** from propanone.

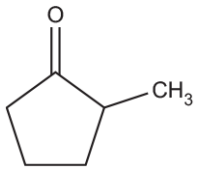
Complete the flowchart.

Show structures for organic compounds.



[5]

22. 2-Methylcyclopentanone, shown below, is reacted with NaCN(aq)/H^+(aq) to form an organic product.



2-methylcyclopentanone

Which statement is correct?

A In the mechanism, a CN^- ion accepts an electron pair.

B The mechanism is electrophilic addition.

C The organic product has one chiral centre.

D The organic product has the molecular formula $C_7H_{11}NO$.

Your answer ☐ **[1]**

23. Which reaction is **not** a reduction?

A $C_6H_5NO_2 \rightarrow C_6H_5NH_2$

B $CH_3CN \rightarrow CH_3CH_2NH_2$

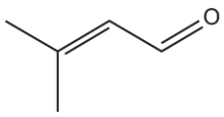
C $CH_3CH_2Cl \rightarrow CH_3CH_2NH_2$

D $CH_3COCH_3 \rightarrow CH_3CHOHCH_3$

Your answer ☐ **[1]**

24. This question is about organic synthesis.

Prenal, shown below, is used in the synthesis of some pharmaceuticals.

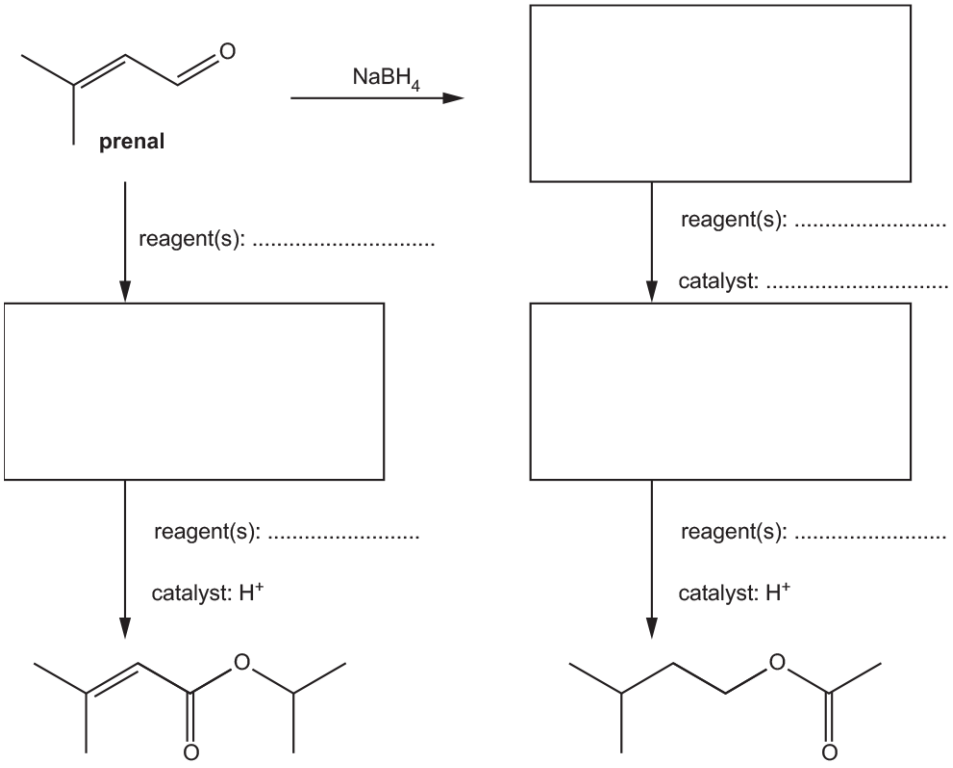


prenal

i. What is the systematic name for prenal?

[1]

ii. Complete the flowchart below for the synthesis of two compounds starting from prenal.



[7]

25. Compounds **D**, **E** and **F** are isomers with the molecular formula $C_5H_{10}O$.

One of the compounds is alicyclic.

A student carries out test-tube tests on the compounds.

The observations are shown below.

Compound	2,4-DNP	$H^+/Cr_2O_7^{2-}$, reflux	Bromine water
D	No change	Green solution	No colour change
E	Orange precipitate	No colour change	No colour change
F	Orange precipitate	No colour change	No colour change

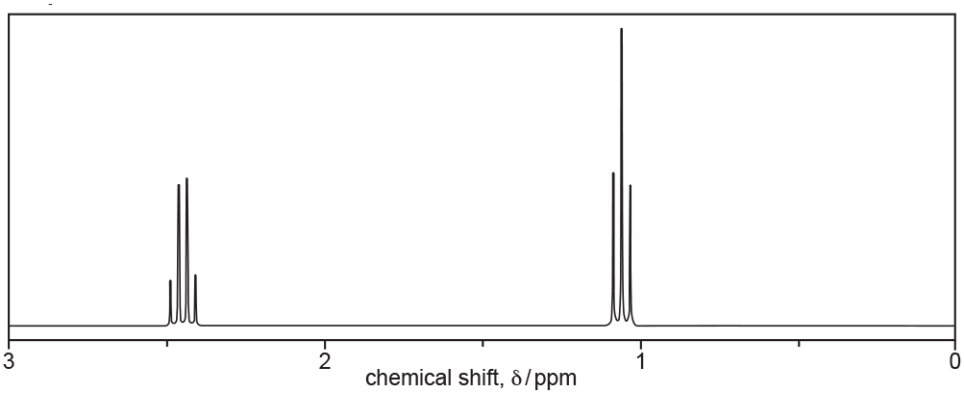
^{13}C NMR spectrum of D

Compound **D** has 3 peaks at δ / ppm: 24, 36, 73.

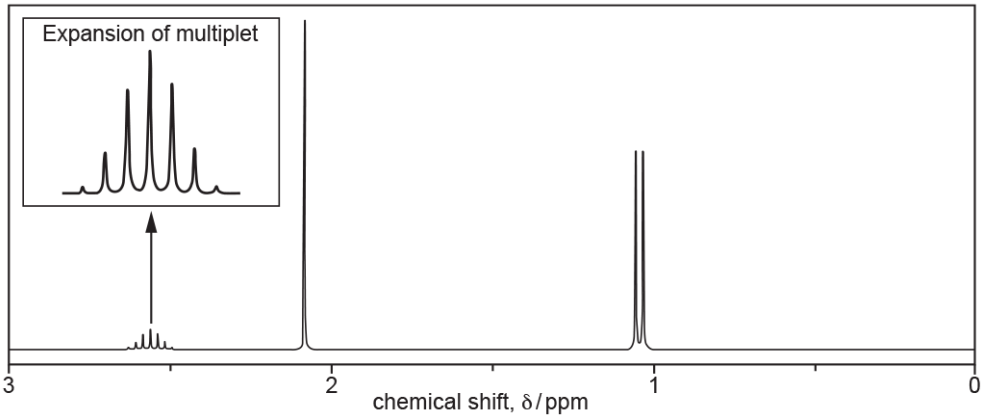
^{1}H NMR spectra of E and F

The integration data has been omitted.

Compound E



Compound F



Analyse the observations and results to identify the structures of **D**, **E** and **F**.

Explain your reasoning.

[6]

26. This question is about carbonyl compounds.

i. Describe a chemical test to confirm the presence of a carbonyl group.

How could the product of this test be used to identify the carbonyl compound?

Your answer should **not** include spectroscopy.

[3]

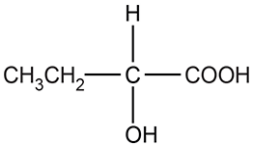
ii. Describe a chemical test that would identify whether a carbonyl compound is an aldehyde.

Your answer **should** include the reagent and observations.

[1]

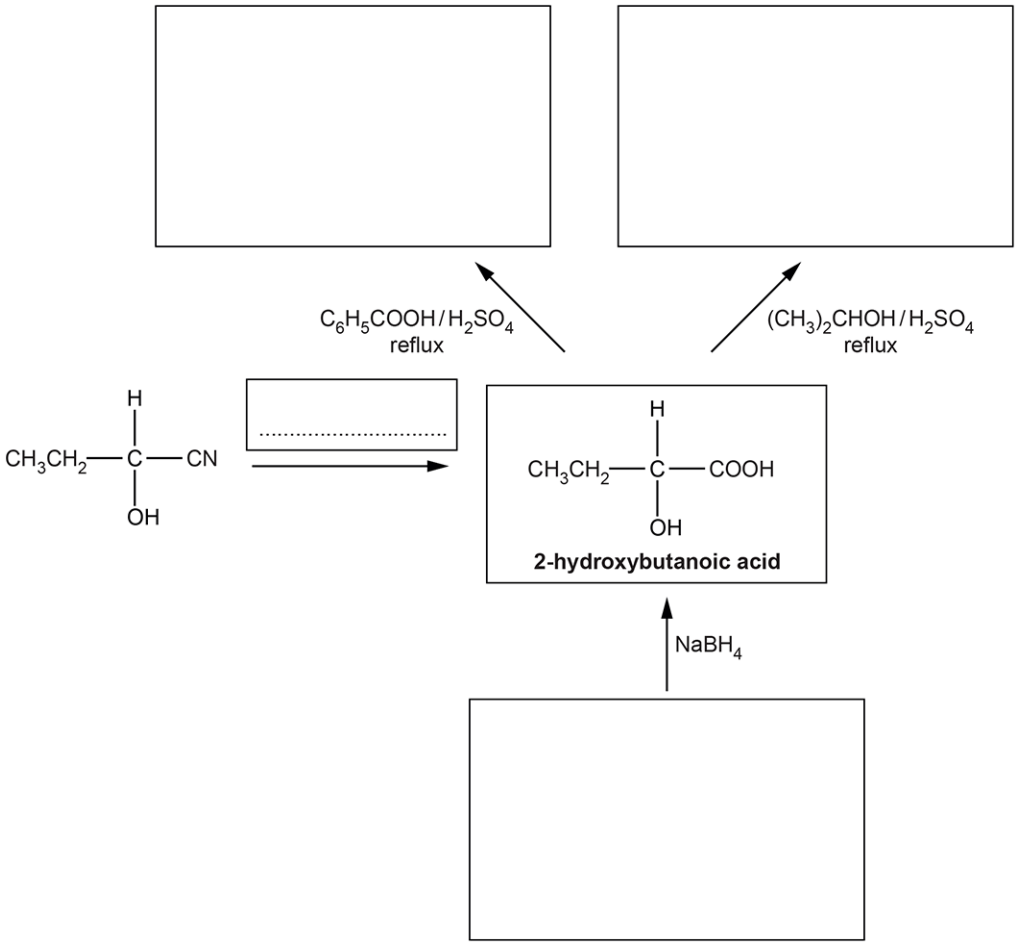
27. This question is about compounds that contain the carboxylic acid functional group.

The structure of 2-hydroxybutanoic acid is shown below.



2-hydroxybutanoic acid

Fill in the flowchart for reactions involving 2-hydroxybutanoic acid.



[4]

28. * Carbon-carbon bond formation is used in synthesis to increase the length of a carbon chain.

Describe the formation of carbon−carbon bonds in aliphatic compounds by **two** different mechanisms.

Your answer should include mechanisms for each aliphatic compound.

Additional answer space if required.

[6]

29. Which compound reacts with 2,4-dinitrophenylhydrazine but does **not** react with Tollens' reagent?

A $C_6H_5COCOOH$

B $C_6H_5CH(OH)CHO$

C CH_3COCHO

D $CH_3CH_2CH(OH)CH_3$

Your answer ☐ **[1]**

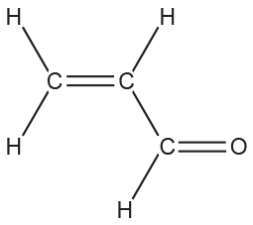
30(a). This question is about reactions of acrolein, $H_2C{=}CHCHO$.

Acrolein reacts with sodium cyanide in acidic conditions, NaCN(aq) / H^+(aq).

i. Outline the reaction mechanism for this reaction, showing the intermediate and the organic product.

The structure of acrolein has been provided.

Include curly arrows and relevant dipoles.

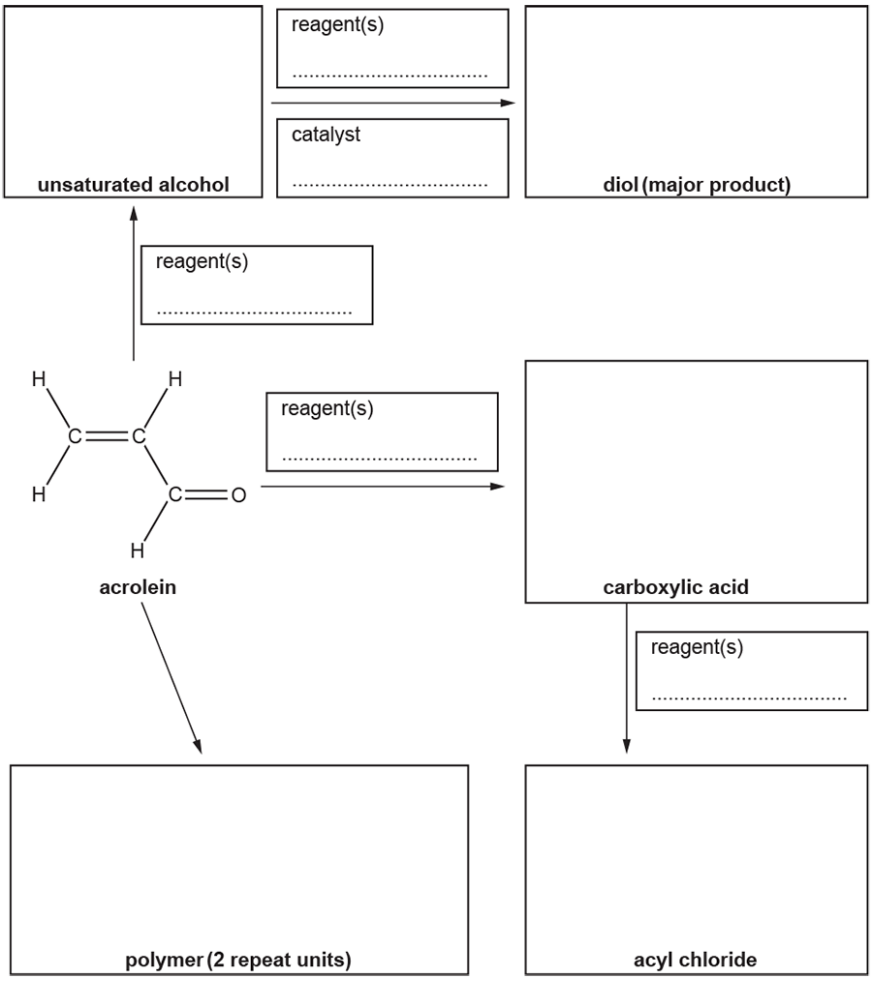


[4]

ii. Name this type of mechanism.

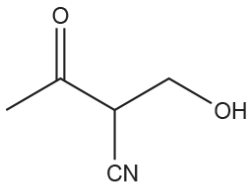
[1]

(b). Complete the flowchart by filling in each box.



[9]

31. A chemist is investigating compound **A**, shown below, as a potential organic intermediate.



Compound A

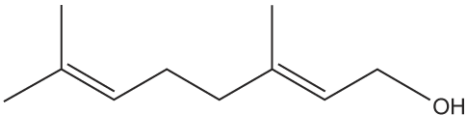
Describe the type of stereoisomerism shown by compound **A** and suggest three reactions of compound **A**, one for each of the **three** functional groups using reagents of your choice.

In your answer, show stereoisomers of compound **A**, your chosen reactants and conditions, and the structures for the organic products produced.

Mechanisms and equations are **not** required.

[6]

32. Geraniol, shown below, is a component in many natural oils.



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.

B Bromine water and 2,4-dinitrophenylhydrazine.

C Bromine water and acidified dichromate(VI).

D Tollens' reagent and aqueous silver nitrate in ethanol.

Your answer ☐ **[1]**

33. Alkenes and carbonyl compounds take part in addition reactions.

Describe **one** addition reaction of an alkene and **one** addition reaction of a carbonyl compound.
Include reagents and reaction mechanisms.

[6]

34. This question is about the analysis of organic compounds.

Compounds **F, G, H** and **I** are structural isomers.

A student carries out test-tube tests on the compounds.
The student records the observations after carrying out each test.
These are shown in **Table 5.1**.

In **Table 5.1**, 2,4-dintrophenylhydrazine has been abbreviated to 2,4−DNP.

Table 5.1

Compound	Test			
	2,4-DNP	**Acidified dichromate(VI) reflux**	**Bromine water**	**Tollens' reagent**
F	Orange solution	Green solution	Colourless solution	Colourless solution
G	Orange solution	Green solution	Orange solution	Colourless solution
H	Orange precipitate	Orange solution	Orange solution	Colourless solution
I	Orange precipitate	Green solution	Orange solution	Silver mirror

i. Write the formula of the species causing the colours after refluxing with acidified dichromate(VI).

Green solution

Orange solution **[2]**

ii.

iii. The student is provided with further information about compounds **F–I**.

- They all have the molecular formula $C_5H_{10}O$.
- One of the compounds is alicyclic.
- The other compounds are unbranched.

Use this further information and the student's observations in **Table 5.1** to answer the following.

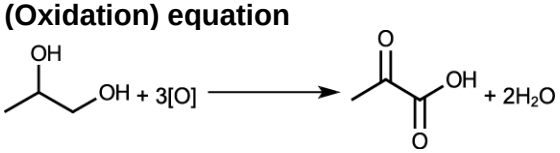
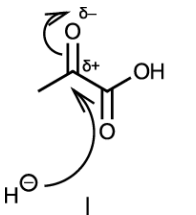
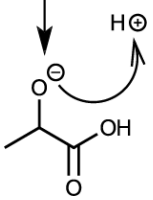
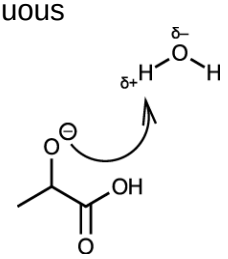
- How do the observations provide evidence for the possible functional groups in compounds **F–I**?
- Suggest a possible structure for each of the compounds **F–I**.

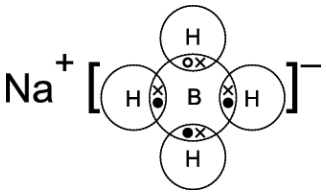
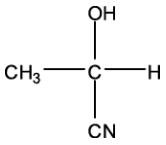
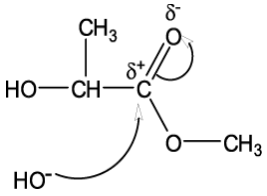
Show your reasoning.

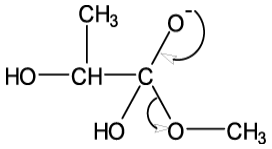
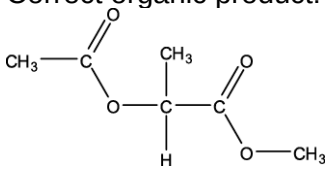
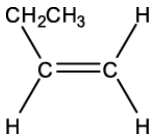
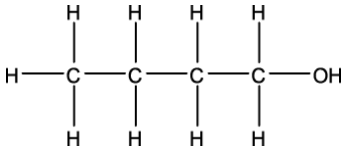
[6]

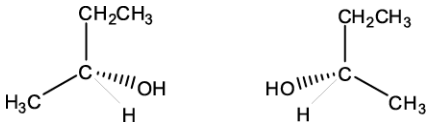
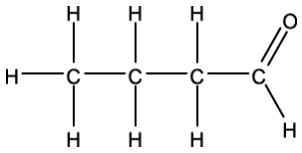
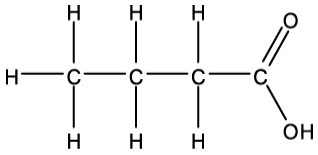
END OF QUESTION PAPER

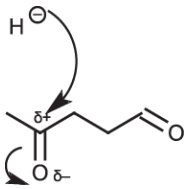
Mark scheme

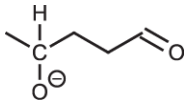
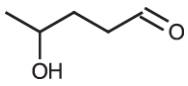
Question			Answer/Indicative content	Marks	Guidance
1			D	1	
			Total	**1**	
2			D	1	
			Total	**1**	
3			A	1	
			Total	**1**	
4		i	Oxidising agent = acidified (potassium / sodium) dichromate(VI) **(Oxidation) equation**  **(Reduction) mechanism**  curly arrow from H^- to $C^{\delta+}$ dipole **AND** curly arrow from C=O bond to O  intermediate **AND** curly arrow to H^+	5	**ALLOW** $Cr_2O_7^{2-}$ **OR** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ for dichromate **ALLOW** H^+ **OR** (conc.) sulfuric acid for "acidified" **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous  **ALLOW** for second stage **IF** H_2O is used it **MUST** show the curly arrow from the intermediate to $H^{\delta+}$ in H_2O **AND** from the O—H bond to the O **IGNORE** product **IGNORE** stereochemistry of intermediate

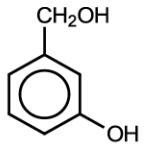
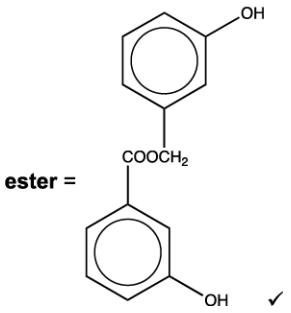
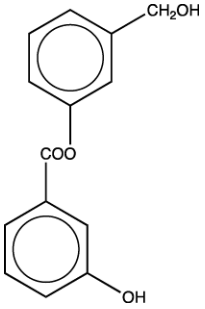
		ii	 $1s^2\ 2s^2\ 2p^6$	2	**IGNORE** inner electron shells for both ions Three different symbols required to identify electrons from different elements **DO NOT ALLOW** [Ne] **OR** [He] $2s^2\ 2p^6$
			Total	**7**	
5			B	1	
			Total	**1**	
6			B	1	
			Total	**1**	
7	a	i		1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
		ii	**aqueous** acid **OR** H^+ / **H_2O**	1	**ALLOW** $H^+(aq)$ / $H_2SO_4(aq)$ / HCl(aq)
		iii	Angle a = 109.5° Angle b = 104.5° Angle c = 120° **Two** correct All **three** correct	2	**ALLOW** 109–110° **ALLOW** 104–105°
	b	i	It is an electron pair donor **OR** donates a lone pair	1	
		ii	 Curly arrow from HO^- to carbon atom of C=O bond Correct dipole **AND** curly arrow from C=O bond to $O^{\delta-}$	4	Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No need to

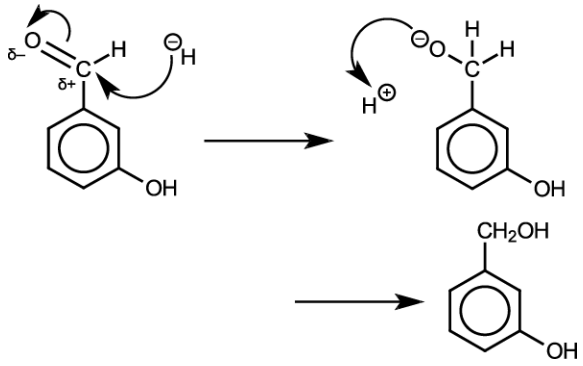
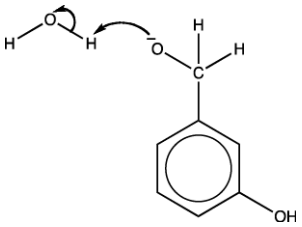
			.....  Curly arrow from negative charge on oxygen to C–O bond (to reform carbonyl π-bond) Curly arrow from C–O single bond to oxygen atom (to form methoxide ion)		show lone pair if curly arrow came from negative charge on O) **IGNORE** dipole on C–O single bond Curly arrow must come from lone pair on O **OR** from minus sign on O^- ion (No need to show lone pair if curly arrow came from negative charge on O)
		iii	Correct organic product:  HC*l*	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**11**	
8	a		**F–K** clearly identified **Compound F:**  **Compound G:**  **Compounds H and I:**	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names **H** and **I** can be identified either way round

			 **Compound J:**  **Compound K:** 		
	b		(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate Take melting point of crystals Compare to known values	3	**NOTE: (b)** is marked completely independently of **(a)** ALLOW errors in spelling **ALLOW** 2,4(−)DNP **OR** 2,4(−)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **Mark second and third points independently of response for first marking point** **DO NOT ALLOW** 2nd and 3rd marks for taking and comparing boiling points **OR** chromatograms
			Total	**9**	
9	a		** Please refer to the marking instruction point 10 for guidance on how to mark this question.* **Level 3 (5–6 marks)** Correctly labelled diagram of apparatus that works, with no safety problems **AND** Full appreciation of further two steps required to gain pure sample *There is a well-developed diagram which is clear and structured. The information on further purification is detailed and relevant.* **Level 2 (3–4 marks)**	6	**Indicative scientific points may include: Diagram** Includes following components: distillation flask heat source thermometer at outlet (bulb **level** with outlet) still-head water condenser (**correct direction** of water flow) receiving vessel **open** system. **Further purification** Shake and leave to settle in a separating funnel

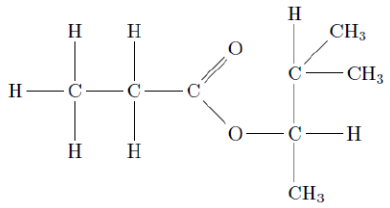
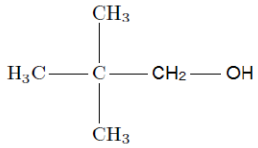
			Labelled diagram of apparatus but with safety / procedural problems **OR** clear diagram of functional apparatus without labelling **AND** Some details of further purification steps *The diagram presents apparatus that is in the most-part relevant with some correct labelling, and supported by some details of further purification steps.* **Level 1 (1–2 marks)** Diagram of apparatus drawn with no labelling **OR** labelled diagram with significant safety / procedural problems **AND** Few or imprecise details about further purification stages *The diagram is basic and unstructured. Any mention of purification steps is limited to generic term, e.g. 'drying', without relevant detail.* **0 marks** No response or no response worthy of credit.		Separate layers by tapping off Add (a small amount of) anhydrous magnesium sulfate / anhydrous calcium chloride to organic layer (in a dry conical flask) (Re)distil the organic layer Collect fraction distilling at (between 150 °C and) 156 °C.
	b		Lack of (further) effervescence	1	**ALLOW** fizzing / bubbling stops
	c		Take samples from reaction mixture at regular intervals Spot / run on a TLC plate, alongside cyclohexanol (and cyclohexanone) controls	2	**ALLOW** "frequent" for "regular" **ALLOW** measure / compare R_f value to cyclohexanol **IGNORE** reference to solvent or visualising chemicals / UV
	d		React (sample of distillate) with 2,4-dinitrophenylhydrazine recrystallise **AND** determine the melting point Compare melting point to known / library value for cyclohexanone (derivative)	3	**ALLOW** (2,4-)DNPH / Brady's reagent
			Total	**12**	
10			 curly arrow from H^- to C(δ^+) of correct C=O group ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous First curly arrow must come from either a lone pair on H or negative charge on H **IF** aldehyde reduced **OR** both carbonyls reduced **DO NOT AWARD** first mark

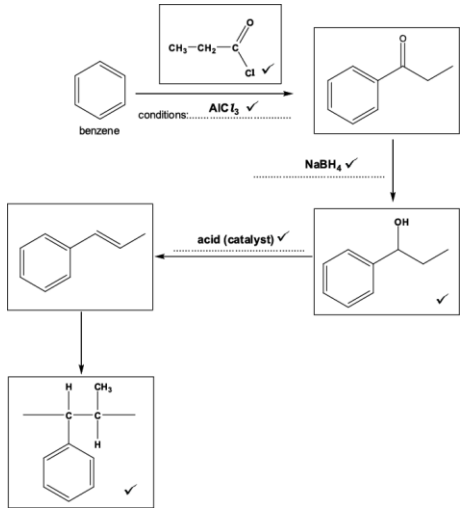
			dipole correct **AND** curly arrow from C=O bond to O($^{\delta-}$) ✓  correct intermediate with negative charge on O ✓  correct product ✓		(second, third and fourth marks can be awarded **ECF**) **IGNORE** lack of C—H if entirely skeletal **IGNORE** curly arrows in second stage Apply ecf to error in structure e.g. CH_2 missing from the chain or —COOH / -COH instead of —CHO **IGNORE** other products **Examiner's Comments** Good candidates had no problem with this reaction mechanism. Some did not read the question carefully and reduced the wrong carbonyl group. Other errors included an incorrect starting position for the first curly arrow, the omission of a CH_2 unit from the carbon chain or changing the aldehyde functional group to a carboxyl group.
			Total	**4**	
11		i	reagent = $K_2Cr_2O_7$ **AND** H_2SO_4 ✓	3	**ALLOW** acidified dichromate **ALLOW** H^+ / any acid **IGNORE** concentration of acid **ALLOW** $Na_2Cr_2O_7$ / $Cr_2O_7^{2-}$ / (potassium **OR** sodium) dichromate((VI)) **ALLOW** acidified MnO_4^- **ALLOW** Tollens' reagent / ammoniacal silver nitrate **IGNORE** conditions **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR**

			compound C =  ✓  ✓		a combination of above as long as unambiguous **ALLOW ECF** from incorrect **compound C** Check positions of OH groups **ALLOW** esterification of phenol group  **Examiner's Comments** A well answered question. Most knew the correct reagents for the oxidation of the aldehyde and the majority were able to show the structure produced when the aldehyde is reduced using $NaBH_4$. Some chose to esterify the phenol group rather than the alcohol group in compound **C** and this was given credit.
		ii	curly arrow from H^- to $C^{\delta+}$ ✓ dipole **AND** curly arrow from C=O bond to O ✓ correct intermediate **AND** curly arrow to H^+ ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** curly arrow must come from lone pair on H or negative charge on H curly arrow must come from the bond, not the carbon atom curly arrow must come from lone pair on O or negative charge on O and go to H or positive charge on H **Where circles have been placed round charges, this is for clarity only and does not indicate a requirement** **ALLOW** correct structural **OR**

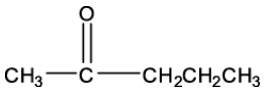
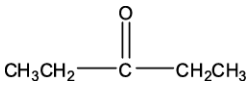
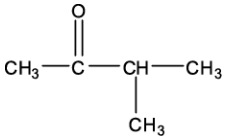
					displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** for second stage  **IF** H_2O is used it **MUST** show the curly arrow from the negative charge or lone pair on the oxygen atom of the intermediate to H in H_2O **AND** from the O—H bond to the O in H_2O. **Dipole not required on water molecule** Penalise missing –OH on intermediate only **IGNORE** product – already given credit in part (i) **Examiner's Comments** The full range of marks was seen. Common errors included missing charges, curly arrows beginning or ending in the wrong place and —OH groups missing or placed in the wrong position on the intermediate structure. Most candidates chose to show the reaction of the intermediate with water rather than with H^+ ions
			Total	**6**	
12	a		<u>Reducing agent</u> $NaBH_4$ / sodium tetrahydridoborate(III) / sodium borohydride✓ <u>Equation</u> $CH_3(CH_2)3CHO + 2[H] \rightarrow CH_3(CH_2)3CH_2OH$ ✓	1	**ALLOW** $LiAlH_4$/lithium tetrahydridoaluminate(III)/lithium aluminium hydride **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above **ALLOW** $C_4H_9CHO + 2[H]$

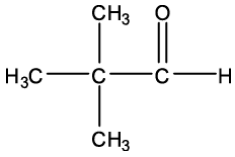
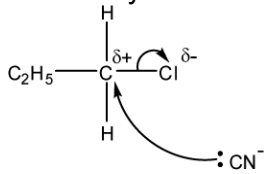
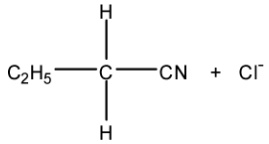
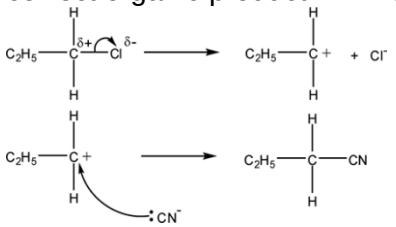
					→ $C_5H_{11}OH$ **ALLOW** molecular formulae: $C_5H_{10}O + 2[H] \rightarrow C_5H_{12}O$ **DO NOT ALLOW** –COH for aldehyde **Examiner's Comments** Very well answered. The most common error was an incorrect formula for the aldehyde.
	b		**M1** Compound **F** structure is a secondary alcohol with the formula $C_5H_{11}OH$ ✓ **M2** Compound **F** = $CH_3CH(OH)CH(CH_3)CH_3$ ✓ **M3** Compound **G** = $CH_3COCH(CH_3)CH_3$ ✓ **M4** n(NaOH) = (0.125 x 22.8/1000) = 0.00285 (mol) ✓ **M5** M(compound H) = (0.211/0.00285 =) 74(.0) (g mol^{-1}) ✓ **M6** Compound **H** = / CH_3CH_2COOH ✓	7	**ANNOTATE WITH TICKS AND CROSSES ETC** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **IGNORE** names if structures are given **ALLOW** 3-methylbutan-2-ol if structure not given **ALLOW ECF** from an incorrect secondary alcohol for **M3** e.g. pentan-2-ol → pentan-2-one e.g. pentan-3-ol → pentan-3-one **ALLOW** (3-)methylbutanone if structure not given **IGNORE** any discussion of the reactions of compound **G** with 2,4-dinitrophenylhydrazine and/or Tollens' reagent. **ALLOW 3 SF** up to calculator value correctly rounded **IF** M(compound H) = 74 award 2 marks (M4 + M5) **ALLOW ECF** from incorrect calculation of amount of NaOH **ALLOW** propanoic acid if structure not given

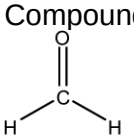
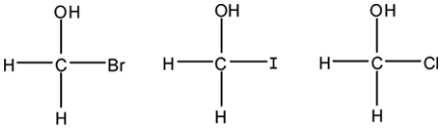
			M7 Compound **I** =  ✓		**ALLOW ECF** from incorrect compound **F** (alcohol) and/or incorrect compound **H** (carboxylic acid) to form compound **I** (ester). Compounds **F**, **G**, **H** and **I** must be placed in the correct box or correctly labelled for **M2**. **M3**, **M6** and **M7** **Examiner's Comments** A high scoring question with many candidates gaining full marks. Although most realised that Compound F was a secondary alcohol, fewer candidates combined this knowledge with the information provided by carbon-13 NMR to deduce the correct structure of the secondary alcohol.
	c		The structural isomer is:  ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 2,2-dimethylpropan-1-ol **Examiner's Comments** A good discriminator but many correct structures were seen.
			Total	**10**	
13	a		One mark for each correct structure/reagent/condition as shown below	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names of organic compounds *(question asks for structures)*

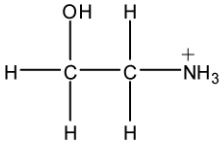
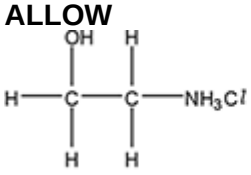
					**ALLOW** aluminium(III) chloride **OR** aluminium trichloride **ALLOW** $FeCl_3$ **OR** Fe as halogen carrier in first step. **ALLOW** sodium borohydride **OR** sodium tetrahydridoborate **IGNORE** [H] for reducing agent in second step **ALLOW** H^+ / H_2SO_4 / H_3PO_4 / named mineral acid for reagent in third step
	b		Use as an organic feedstock ✓ **OR** Combustion for energy production ✓	1	**ALLOW** the production of plastics or monomers or new polymers Combustion alone is **not** sufficient
			Total	**7**	
14	a	i	**Reagent and observation** sodium carbonate **AND** Fizzing/effervescence/bubbling ✓ **Equation** Correctly balanced equation ✓ e.g. $2RCOOH + Na_2CO_3 \rightarrow 2RCOONa + CO_2 + H_2O$	2	**Note:** both reagent and observation are required for first mark **ALLOW** name or formula for any suitable carbonate e.g $NaHCO_3$, potassium carbonate etc. **ALLOW** reagent from equation if not stated elsewhere
		ii	**Reagent and observation** Tollens' (reagent) **AND** Silver (mirror) ✓	2	**Note:** both reagent and observation are required for first mark **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3

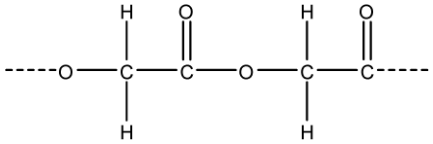
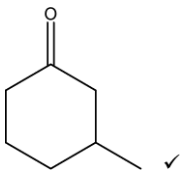
			Equation RCHO + [O] → RCOOH ✓		**ALLOW** $H^+/Cr_2O_7^{2-}$ **OR** acidified (potassium/sodium) dichromate **AND** Orange to green *(this would identify the aldehyde from the carboxylic acid, ketone and esters)*
	b		2,4−dinitrophenylhydrazine **AND** Orange/yellow/red precipitate ✓	1	**ALLOW** errors in spelling **ALLOW** 2,4(−)DNP **OR** 2,4(−)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate
	c	i	$CH_3COOC(CH_3)_3 + NaOH \rightarrow CH_3COONa + (CH_3)_3COH$ CH_3COONa ✓ Rest of equation correct ✓ **OR** $(CH_3)_3CCOOCH_3 + NaOH \rightarrow (CH_3)_3CCOONa + CH_3OH$ $(CH_3)_3CCOONa$ ✓ Rest of equation correct ✓	2	**Note:** the hydrolysis of either ester may be given **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** molecular formulae of products *(question requires structures of products to be shown)*
		ii	**Reagent and observation** $H^+/Cr_2O_7^{2-}$ **OR** acidified (potassium/sodium) dichromate **AND** Orange to green (with CH_3OH) ✓ **Equation** $CH_3OH + [O] \rightarrow HCHO + H_2O$ **OR** $CH_3OH + 2[O] \rightarrow HCOOH + H_2O$ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** molecular formulae *(question requires structures of organic compounds to be shown)*
		iii	**^{13}C NMR (1 mark)**	3	

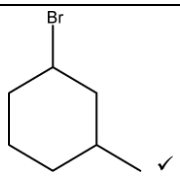
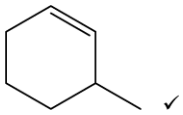
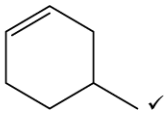
			(It is) not possible to identify (the esters) with ^{13}C NMR **AND** (both) spectra would contain four peaks (with similar chemical shifts) ✓ **^{1}H NMR (2 marks)** (It is) possible to identify (the esters) with ^{1}H NMR (^{1}H NMR spectrum of) $CH_3COOC(CH_3)_3$ has a singlet/peak between 2.0−3.0 (ppm) (^{1}H NMR spectrum of) $(CH_3)_3CCOOCH_3$ has a singlet/peak between 3.0−4.3 (ppm) All **three** correct statements✓✓ Any **two** correct statements ✓		**ALLOW** 'same number of peaks' in place of 'four peaks' **ALLOW** any value or range of values within 2.0−3.0 **ALLOW** any value or range of values within 3.0−4.3
	d		**<u>Possible structures for ketone (2 marks)</u>**    All **three** correct ✓✓ Any **two** correct ✓ **<u>Aldehyde (3 marks)</u>** Peak at (δ) 1.2 shows HC–R **AND** No H on adjacent C atom as peak is singlet ✓ Peak at (δ) 9.6 shows H–C=O **AND**	5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names of ketones

			No H on adjacent C atom as peak is singlet ✓  **OR** (2,2−)dimethylpropanal ✓		
			Total	**17**	
15		i	curly arrow from ⁻CN to carbon atom of C−C*l* bond ✓ Dipole shown on C–C*l* bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−C*l* bond to C*l* atom ✓  correct organic product **AND** Cl^- ✓ 	**2**	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curly arrow must come from lone pair on C of ⁻CN OR CN^- **OR** from minus sign on C of ⁻CN ion (then lone pair on CN^- does not need to be shown) **IGNORE** NaCl **ALLOW** S_N1 mechanism: Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C–C*l* bond to C*l* atom ✓ Correct carbocation **AND** curly arrow from ⁻CN to carbocation. Curly arrow must come from lone pair on C of ⁻CN **OR** CN^- **OR** from minus sign on C of ⁻CN ion (then lone pair on CN^- does not need to be shown) ✓ correct organic product **AND** Cl^- ✓  **Examiner Comments** The mechanism for the reaction of 1-chloropropane was well done with the majority of candidates scoring two or three of the marks. Marks were not awarded when candidates used a negative charge

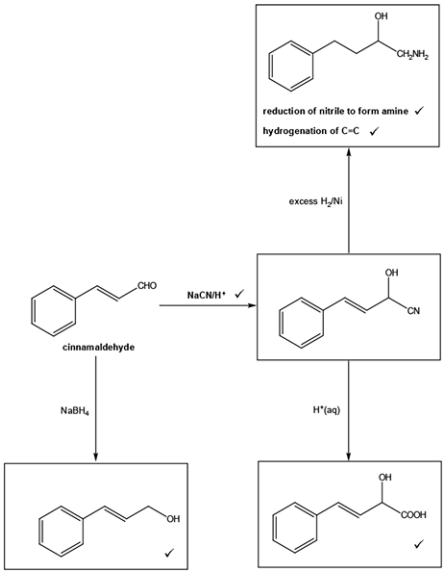
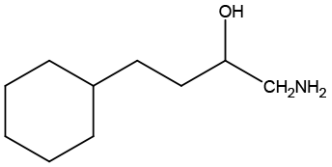
					or a lone pair sited on the nitrogen as the starting point for a curly arrow in the first stage of the reaction mechanism. The final marking point was awarded for the production of a Cl^- ion. The placing of curly arrows, dipoles and lone pairs of electrons are important when communicating by mechanisms.
		ii	Compound **G**  ✓ **Reagents** **Reaction 2:** H_2 **AND** Ni ✓ **Reaction 3:** Correct formula of an aqueous acid e.g. HCl(aq)/H_2SO_4(aq) ✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** name(s) **ALLOW**  **ALLOW** any suitable metal catalyst e.g. Pt **ALLOW** $LiAlH_4$ for reagent in reaction 2 **DO NOT ALLOW** $NaBH_4$ for reagent in reaction 2 **IGNORE** names *(question asks for formulae)* **IGNORE** references to temperature and/or pressure **ALLOW** $H^+(aq)$ **IGNORE** dilute **ALLOW** formula of an acid **AND** water e.g. HCl **AND** H_2O H_2SO_4 **AND** H_2O **Examiner Comments** Although many candidates were able to provide the structure of methanal as the starting material for this synthesis, the structures of chloromethanol, bromomethanol and iodomethanol were accepted as suitable alternatives. It should be noted that hydrolysis is carried out using aqueous acid and that

					dilute acid is not a suitable alternative.
		iii	**Explanation** Nitrogen electron pair **OR** nitrogen lone pair **AND** accepts a proton / H^+✓ **Structure of salt**  **AND** Cl^- ✓	**2**	**IGNORE** NH_2 group donates electron pair **ALLOW** nitrogen donates an electron pair to H^+ **DO NOT ALLOW** nitrogen donates lone pair to acid **IGNORE** comments about the O in the –OH group Compound **H** is a base is **not sufficient** *(role of lone pair required)* **DO NOT ALLOW** nitrogen/N lone pair accepts hydrogen (*proton/H^+ required*) **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  *i.e.* charges **not** requir **IF** charges are shown **both** need to be present **ALLOW** charge either on **N** atom or NH_3^+ **IF** displayed then + charge must be on the nitrogen **Examiner Comments** Only 20% of candidates were awarded both marks for this question. The commonest error was a failure to state that the N atom has a lone pair of electrons that can gain a proton. Answers stating that amines accept protons or that a salt is produced when an acid reacts with a base were not credited. Where a full displayed structure is given the positive charge must be shown on the nitrogen atom, although $-NH_3^+$ is

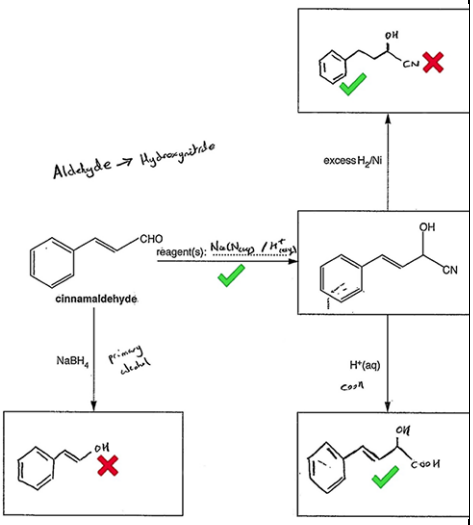
					acceptable. As the question required the formula of the salt, the Cl^- had to be included.
		iv	 Ester link ✓ Rest of structure✓ (polymer **J** is biodegradable because) the ester / ester bond / ester group / polyester can be hydrolysed✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** more than two repeat units for second marking point. 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** ***n*** Broken down by water is **not** sufficient **IGNORE** references to photodegradable **Examiner Comments** The most common mark for this question was two out of the three marks available, with candidates giving a correct structure of the polymer but failing to express that the polymer was biodegradable due the ability of the ester functional group to undergo hydrolysis.
			Total	**11**	
16		i	**Starting material from reduction reaction**  **Reagent for reduction** $NaBH_4$ ✓ **Product from reaction with $NaBr/H_2SO_4$**	**5**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous Watch for missing methyl groups **IGNORE** H^+ / acid or H_2O or

			 ✓ **Structural isomers**  ✓  ✓		ethanol **ALLOW** sodium borohydride **OR** sodium tetrahydridoborate **ALLOW** $LiAlH_4$ **ALLOW** in either order **Examiner Comments** There were many good answers to this synthesis question with about 40% of the cohort scoring full marks. The structure of the carbonyl and the reagent needed for reduction were well known by a majority of candidates however some reacted the alcohol group with sodium bromide to obtain $-O^-Na+$ for the second structure. Weaker candidates did not realise that an alcohol could be dehydrated and thus failed to be awarded the final two marks.
		ii	3-methylcyclohexanol ✓	**1**	**ALLOW** 3-methylcyclohexan-1-ol **ALLOW** 1-methylcyclohexan-3-ol **IGNORE** lack of hyphens, or addition of commas **Examiner Comments** Just over half of candidates managed to name the structure as 3-methylcyclohexanol. The most common errors included 3-methylphenol, 3-methylcyclichexanol and 3-methylhexanol.
			Total	**6**	
17	a	i	Bromine/ Br_2 **AND** goes colourless/decolourised ✓	**1**	**Note:** both reagent and observation are required **ALLOW** bromine water/ $Br_2(aq)$ **Examiner's Comments** Almost all candidates were able to correctly describe the use of bromine as a test for an unsaturated chain.
		ii		**1**	**Note:** both reagent and observation are required for the

			Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓		mark. **ALLOW** ammoniacal silver nitrate **OR** Ag^{+}/NH_3 **ALLOW** black ppt **OR** grey ppt **Examiner's Comments** Almost all candidates were able to correctly describe the use of Tollens' reagent as a test for an aldehyde functional group.
		iii	(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ Take melting point (of crystals) ✓ Compare to known values/database ✓	**3**	**ALLOW** errors in spelling **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **Mark second and third points independently of response for first marking point** **DO NOT ALLOW** 2nd and 3rd marks for taking and comparing boiling points **OR** chromatograms **Examiner's Comments** The use of 2,4-dinitrophenylhydrazine as a test for the carbonyl group is well known by candidates at this level. The majority of the cohort correctly identified this test and the subsequent analysis of the melting point of the products as a method of identifying each compound. Lower ability candidate responses made reference to analysis of the boiling points of the cinnamaldehyde and methylcinnamaldehyde as a means of identification.

	b		Marks for each correct structure/reagent shown below  	**5**	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For reaction with excess H_2/Ni **IGNORE** hydrogenation of benzene ring i.e. the following structure scores two marks  **ALLOW** KCN/H^+ **ALLOW** HCN **ALLOW** H_2SO_4 or HNO_3 or HCl for H^+ **Examiner's Comments** This question proved difficult and although the majority of candidates scored in some parts, only the very best responses secured all five marks. More detailed feedback is discussed with Exemplar 8.

Exemplar 8

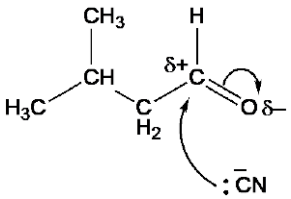
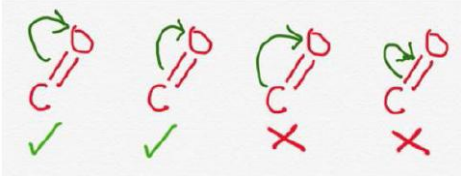
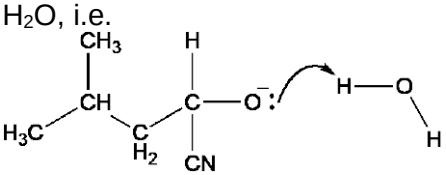


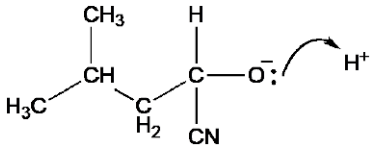
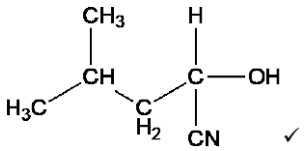
Cinnamaldehyde was the starting point for this flowchart of reactions.

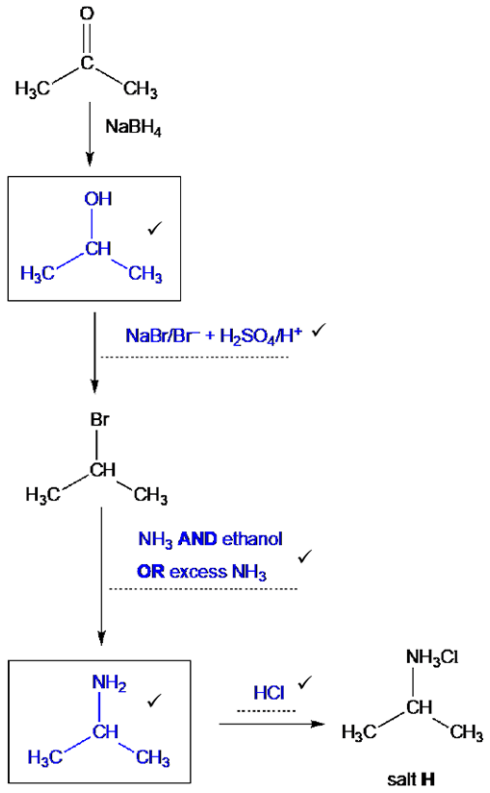
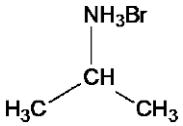
The most frequently scored mark was correct identification of the reagents required for the formation of the hydroxynitrile. This response uses NaCN/H^+. Other candidates used HCN which was also acceptable.

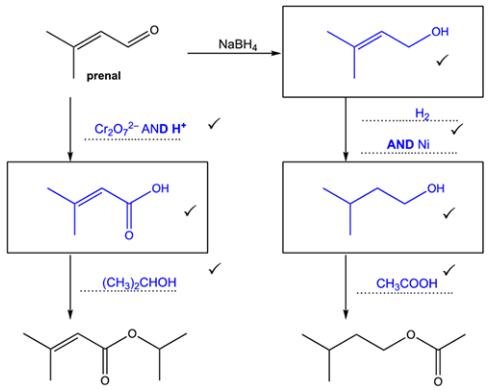
The flowchart shows two different reactions of this hydroxynitrile. The first is the reaction with excess hydrogen in the presence of Ni. Most candidates scored one mark for their product. As in this exemplar, the double bond was often reacted to form a saturated chain. Some candidates identified that the CN group would also react but instead of writing CH_2NH_2 they replaced the CN group with just NH_2, effectivity removing a carbon atom from the chain. The second reaction of the hydroxynitrile is acid hydrolysis of the CN group. This response identifies the correct carboxylic acid. However, this reaction seemed unfamiliar to

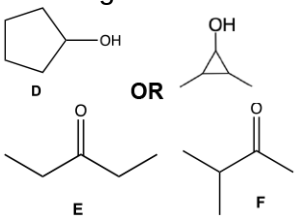
					many candidates and a range of incorrect responses were frequently seen. The final reaction is the reduction of cinnamaldehyde with $NaBH_4$. Many candidates recognised this reaction, but as can be seen in this response the alcohol group is shown on the incorrect carbon atom. This was a common error. Candidates are advised to number carbon atoms present if provided with a complex structure, such as cinnamaldehyde. Numbering will ensure that each carbon is considered when drawing reaction products and would minimise errors, such as those demonstrated in the reduction product.
			Total	**10**	
18			**C**	1 (AO 1.2)	**Examiner's Comments** This question discriminated well, with the higher ability candidates correctly selecting C. The most common incorrect response was A.
			Total	**1**	
19			**C**	1 (AO2.3)	
			Total	**1**	
20	a		F/aldehyde **AND** Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓ G/alkene/C=C **AND** Bromine/Br2 **AND** goes colourless/decolourised ✓ G/ketone **AND** 2,4-dinitrophenylhydrazine	4 (AO2.3) (AO3.3) (AO3.3) (AO3.3)	**IGNORE** use of 2,4-DNP with F **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** bromine water/ $Br_2(aq)$ **ALLOW** errors in spelling for 2,4-DNP **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH

			AND orange/yellow/red precipitate ✓ G/ketone **AND** Tollens' (reagent) **AND** no silver mirror/no change/no reaction ✓		**ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** alterative approach using acidified potassium dichromate for tests with F and/or G, with correct observations, alongside use of 2,4-DNP **Examiner's Comments** Candidates who found this question difficult often did not give a response that would identify all three of the functional groups (aldehyde, ketone and alkene). The use of Tollens' in identifying aldehydes was well demonstrated, however no reaction with Tollens' was less well demonstrated as a result for ketones.
	b	i	**Mechanism** ***3 marks***  Curly arrow from ^-CN to C atom of C=O ✓ Dipole shown on C=O bond, $C^{\delta+}$ and $O^{\delta-}$, **AND** curly arrow from C=O bond to O atom ✓	5 (AO1.2) (AO1.2) (AO2.5) (AO2.5) (AO2.5) (AO1.1)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curly arrow must come from lone pair on C of ^-CN **OR** CN^- **OR** from minus sign on C of ^-CN ion (then lone pair on CN^- does not need to be shown) Curly arrow from C=O bond must start from, OR be traced back to, any part of C=O bond and go to O  --- **ALLOW** curly arrow to H atom of H_2O, i.e. 

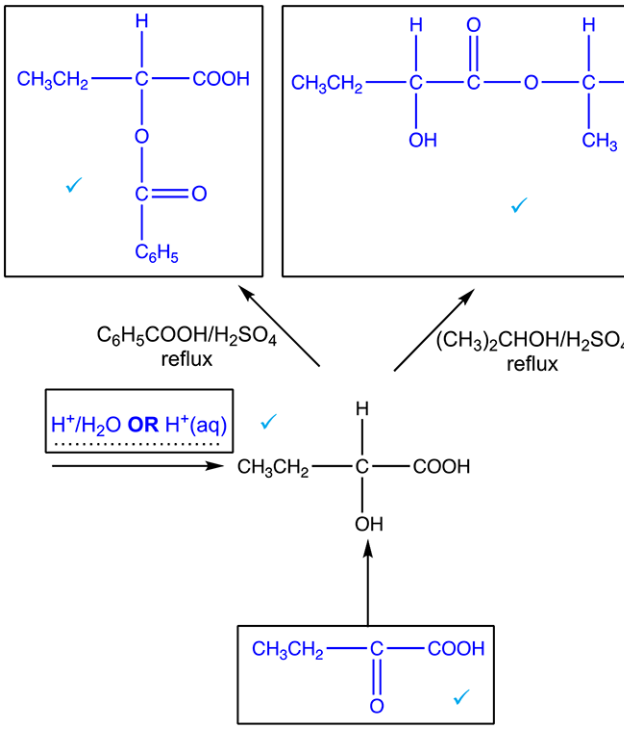
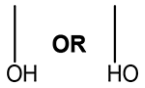
			 Curly arrow from lone pair **OR** – charge on O^- of **correct** intermediate to H^+ ✓ --- **Product** ***1 mark***  ✓ --- **Name of mechanism** ***1 mark*** Nucleophilic addition ✓		**IGNORE** attempt to draw curly arrow showing breaking of H–O in H_2O **IGNORE** lack of dipole on H_2O
		ii	**Heterolytic** One (bonded) atom/O receives both/2 electrons ✓ **Fission** Breaking of a **covalent** bond ✓	2 (AO1.2)	**ALLOW** 2 electrons go to one (bonded) atom/O **DO NOT ALLOW** both pairs of electrons go to O **IGNORE** formation of ions/radicals For O atom, **ALLOW** species **DO NOT ALLOW** element or molecule **ALLOW** π bond in C=O breaks **IGNORE** breaking of C=O bond (no reference to only one bond breaking) 'Bond breaking' is **not** sufficient *(no reference to covalent)* **Examiner's Comments** Candidates often referred to NaCN and HCN in their responses.

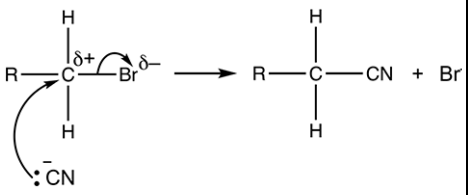
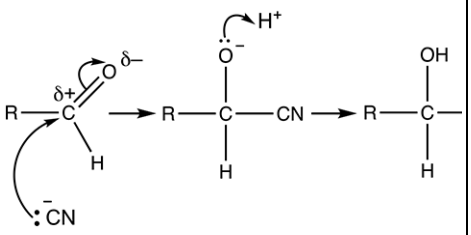
					Candidates who identified the correct bond breaking often then incorrectly wrote that the oxygen atom gained the lone pair of electrons.
			Total	**11**	
21				5 (AO2.5× 5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** HBr **ALLOW** for the bottom left structure 
			Total	**5**	
22			**D**	1 (AO2.1)	
			Total	**1**	
23			**C**	1 (AO1.2)	
			Total	**1**	
24		i	3-methylbut-2-enal ✓	1 (AO1.2)	**IGNORE** lack of hyphens, or addition of commas

		ii		7 (AO1.2× 4) (AO2.5× 3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** names of reagents and catalyst For oxidation, **ALLOW** $K_2Cr_2O_7$ for $Cr_2O_7^{2-}$ **ALLOW** H_2SO_4 for H^+ For left hand side esterification **IGNORE** C_3H_7OH **IF** esterification is given instead of hydrogenation contact your Team Leader
			Total	**8**	
25			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** Compounds **D**, **E AND F** correctly identified **AND** Most of the observations and NMR data analysed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Most of compounds **D**, **E AND F** correctly identified **AND** Some of the observations and NMR data analysed. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Most of compounds **D**, **E AND F** correctly identified **OR** Some of compounds **D**, **E AND F** correctly identified	6 (AO3.1× 4) (AO3.2× 2)	**Indicative scientific points may include:** **<u>Observations from Test-tube tests</u>** 2,4 DNP: **D** has no C=O; **E** and **F** have C=O present **D** is primary **OR** secondary alcohol $H^+/Cr_2O_7^{2-}$: **E** and **F** are ketones *(negative test shows not aldehydes)* Br_2: **D**, **E** and **F** have no C=C/are saturated **<u>^{13}C NMR analysis</u>** **D:** • 3 carbon environments/types of C • δ = 24, 36 ppm **C–C** • δ = 73 ppm, **C**–O

			AND Analyses some of the observations or NMR data **OR** Analyses most of the observations from the test-tube tests. **OR** Analyses most of the NMR data. **OR** Analyses some of the observations and NMR data *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**^{1}H NMR analysis** **E:** • δ = 2.4 ppm, quartet — CH_3–**CH_2**–C=O • δ = 1.1 ppm, triplet — **CH_3**–CH_2– **F:** • δ = 2.6 ppm, heptet/multiplet — $(CH_3)_2$–**CH**–C=O • δ = 2.1 ppm, singlet, — **CH_3**–C=O • δ = 1.1 ppm, doublet — **CH_3**–CH– **Structures** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous  **Examiner's Comments** Most candidates could correctly analyse the observations from the test-tube tests but were unable to link this to the NMR data to suggest structures for D, E and F. This limited their response to Level 1. Those that achieved Level 3 had worked through each piece of data in turn before clearly identifying structures for the three compounds.
			Total	**6**	

26		i	(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ Take melting point (of crystals) ✓ Compare to known values/database ✓	3 (AO1.2 × 3)	**ALLOW** errors in spelling **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **Mark second and third points independently of response for first marking point** **DO NOT ALLOW** 2nd and 3rd marks for taking and comparing boiling points **OR** chromatograms
		ii	Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓	1 (AO1.2)	**ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** $Cr_2O_7^{2-}/H^+$ **AND** Turns green ✓ **IGNORE** reference to conditions, e.g. Heat or reflux --- **IF** other reagents are seen e.g. Fehling's or Benedict's, contact your Team Leader **Examiner's Comments** The use of 2,4-dinitrophenylhydrazine as a test for the carbonyl group is well known by candidates at this level. The majority of the cohort correctly identified this test and the subsequent analysis of the melting point of the products as a method of identifying each compound.

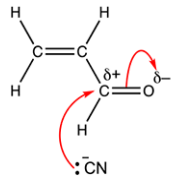
					Lower ability candidate responses made reference to analysis of the boiling points or omitted the reference to analysis of the melting points. Almost all candidates were able to correctly describe the use of Tollens' reagent as a test for an aldehyde fictional group
			Total	**4**	
27				4 (AO2.5× 4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the OH group e.g. **ALLOW**  **IGNORE** connectivity of CH_3CH_2 group **IGNORE** inorganic by-products **ALLOW** HCl/H_2O, H_2SO_4/H_2O **IGNORE** dilute **Examiner's Comments** The majority of candidates were able to identify at least one of the structures. A significant number of candidates did not check the number of bonds of each atom in their structures and frequently had too many or too few hydrogen atoms attached. Most candidates identified that acidic conditions were required but some missed the

					aqueous condition that was also required for the mark.
			Total	**4**	
28			**Level 3 (5–6 marks)** Describes, in detail, reactions of **two** aliphatic compounds that form a C–C bond **AND** mechanisms for the **two** aliphatic reactions. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Describes a reaction of **one** aliphatic compound that forms a C–C bond with few omissions/errors. **AND** mechanism for **one** aliphatic reaction. **OR** Describes reactions of **two** compounds that forms a C–C bond **AND** attempts a mechanism for **one** of the reactions *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Selects suitable reagents for reactions of **two** compounds that form a C–C bond. **OR** Attempts to describe a reaction and mechanism of **one** compound that forms a C–C bond, with omissions/errors. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit*.	6 (AO1.2× 4) (AO2.5× 2)	**Indicative scientific points may include:** **<u>Reactions of aliphatic compounds and mechanisms</u>** • Haloalkane, RX and CN^- → RCN + X^- Reagents: NaCN and ethanol Reaction: Nucleophilic substitution Mechanism:  • Aldehyde or ketone and HCN e.g. RCHO + HCN → RCH(OH)CN Reagents: NaCN and H^+ Reaction: Nucleophilic addition Mechanism:  OR H_2O instead of H^+ for 2nd stage

					If alternative reactions are shown contact your TL e.g. radical substitution, polymerisation **Examiner's Comments** This question differentiated well. Candidates who were given Level 3 (5-6 marks) understood the term aliphatic and were able to provide two different mechanisms that produced a C-C bond. The most common responses seen involved the nucleophilic substitution of a halogenoalkane and a cyanide ion and the nucleophilic addition of a carbonyl with a cyanide ion. Some candidates offered radical substitution mechanisms, detailing initiation, propagation and termination steps, with the termination step producing a C-C bond. Candidates who scored Level 2 (3-4 marks) frequently detailed a reaction involving aromatic compounds or polymerisation of alkenes for which they were unable to give a mechanism.
			Total	**6**	
29			**A**	1 (AO1.2)	**Examiner's Comments** Drawing out the structures often helped candidates to identify each functional group and therefore spot the ketone which is key to correctly answering this question.
			Total	**1**	
30	a	i	**NOTE**: curly arrows can be straight, snake-like, etc.	4 (AO1.2 ×2) (AO2.5 ×2)	**ANNOTATIONS MUST BE USED** --- **1st curly arrow must**

but **NOT** double headed or half headed arrows

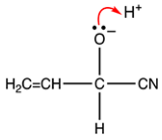
Nucleophilic attack *2 marks*



Curly arrow from $^{-}$CN to C of C=O ✓

Correct dipole shown on C=O
AND
curly arrow showing breaking of C=O ✓

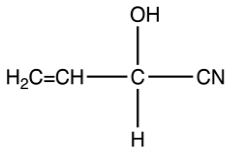
Intermediate *1 mark*



Correct intermediate
AND curly arrow from O^{-} to H^{+} ✓

DO NOT ALLOW δ– on O of intermediate
IGNORE connectivity of H_2C=CH–

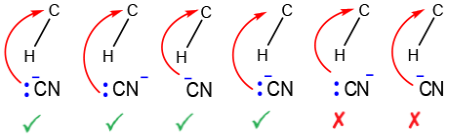
Product *1 mark*



Correct product ✓

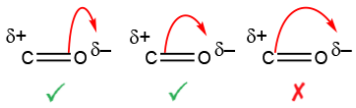
Possible alternative 1,4 (conjugate) addition can be credited as follows (not in

- go to the C atom of C=O
  AND
- start from, **OR** be traced back to any point across width of lone pair on C of $^{-}$:CN **OR** :CN^{-}
- **OR** start from – charge on C of $^{-}$CN (then lone pair on CN^{-} does not need to be shown)



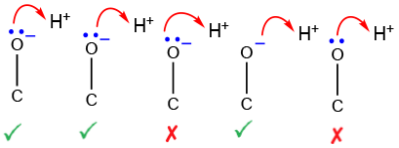
2nd curly arrow must

- start from, **OR** be traced back to any part of $^{\delta+}$C=O $^{\delta-}$ bond
  AND
- go to $O^{\delta-}$ (across width of $O^{\delta-}$)



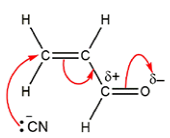
3rd curly arrow must

- go to H^{+}
  AND
- start from, **OR** be traced back to any point across width of lone pair on :O^{-}
- **OR** start from – charge of O^{-} of intermediate (then lone pair on O^{-} does not need to be shown)



specification):

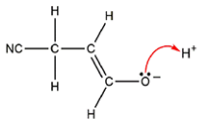
Nucleophilic attack *2 marks*



Curly arrow from ^{-}CN to C of CH_2 of C=C ✓

Curly arrow from C=C to C-C
AND
curly arrow showing breaking of C=O ✓

Intermediate *1 mark*

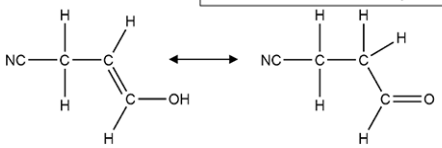


Correct intermediate
AND curly arrow from O^{-} to H^{+} ✓

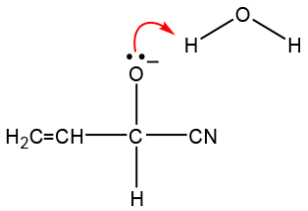
DO NOT ALLOW δ– on O of intermediate

Product *1 mark*

Either tautomer as correct product ✓



NOTE: For arrow to H^{+}
ALLOW arrow to H of H_2O
i.e.



IGNORE attempt to draw curly arrow showing breaking of H–O in H_2O

IGNORE lack of dipole on H_2O

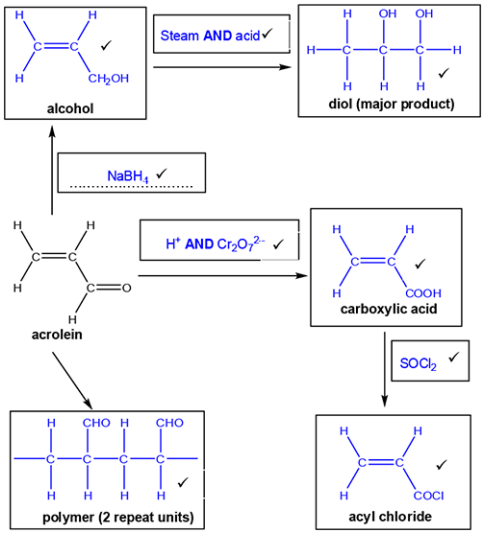
IGNORE absence of OH^{-} as 2nd product
Otherwise this more difficult mechanism could cost 2 marks

Product mark can only be given here if clear from mechanism that there is nucleophilic attack of CH_2 in C=C.
Same product could be seen with an attempt at electrophilic addition across C=C.

Examiner's Comments

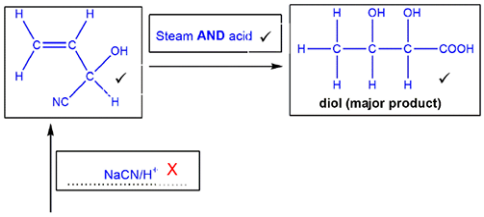
There were many excellent examples of precisely drawn mechanisms for the reaction of acrolein with sodium cyanide in acidic conditions and so most candidates gained at least 3 marks. The importance of accuracy when drawing curly arrows needs to be emphasised when teaching mechanisms - arrows must start at

					lone pairs or negative charges or come from bonds. Many candidates lost marks due to incorrect arrows. Common errors included the use of NaCN or HCN rather than the cyanide ion, the first curly arrow coming from the N of CN-, omission of partial charge across the C=O double bond and addition of partially charges to hydrogen or oxygen. Lower scoring responses often included an intermediate and/or product containing sodium. Some attempted electrophilic addition using HCN across the double bond. A few gained some credit for the mechanism for a competing reaction with nucleophilic addition on CH_2 of C=C. This is not covered in the A Level specification and no candidates scored full marks for this alternative.
		ii	Nucleophilic addition ✓	1 (AO1.1)	**IGNORE** just 'addition' **Examiner's Comments** Most candidates were able to recall the correct response here, especially for those more confident with drawing out the mechanism. The most common incorrect response was nucleophilic substitution. Some suggested reduction or nucleophilic addition elimination. Misspellings of 'nucleophilic' were often seen.
	b			9 (AO1.2 ×4) (AO2.5 ×5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** Correct names instead of formula for all reagents throughout e.g. For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate For Steam and acid



Only possible alternative that can gain credit:

Reaction with $NaCN/H^+$



- For steam, **ALLOW** $H_2O(g)$ **OR** H_2O with $T \geq 100°C$
- For acid, **ALLOW** H^+ **OR** H_2SO_4 **OR** H_3PO_4
- Note both needed for 1 mark. **ALLOW** either way round.

For $NaBH_4$

- **IGNORE** water / aqueous /acid
- **ALLOW** $LiAlH_4$

For $SOCl_2$, **ALLOW** PCl_5 **OR** $COCl_2$

- **IGNORE** H^+ OR HCl

For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 **AND** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **ALLOW** Tollens' reagent

IGNORE connectivity except **DO NOT ALLOW** -COH for aldehyde

For polymer **ALLOW** alternating side chains.
IGNORE brackets and use of 'n'
'End bonds' **MUST** be shown (solid or dotted)

IF $NaCN/H^+$ reacted with acrolein instead of $NaBH_4$

- No mark for NaCN/H+ **OR** HCN
- Unsaturated alcohol award mark for product as shown
- Final product must have CN hydrolysed as shown

Examiner's Comments

This question discriminated well. Many candidates were able to demonstrate an excellent knowledge of organic reactions

					and it was not uncommon to see scores of at least 7 marks. This question identified which candidates had learned their synthetic routes including necessary reagents and conditions. Marks were often lost for small details such as missing Hs (check all Cs have four bonds) or not specifying that steam is required for hydration of alkenes or missing the acid needed for oxidation. Many suggested the use of NaOH or just a mixture of acids to product the diol. The minor 1,3-diol or 1,1-diol product was often seen. The sequence leading to an acyl chloride from acrolein was usually the most well answered. However, quite a few tried to use HCl to make the acyl chloride. Many lost marks for the polymer for incorrect connectivity on the aldehyde, e.g. -COH or attempting to make a polymer via connection of the aldehyde group. **OCR support** This topic guide provides a summary of synthetic routes. Copies of the summary posters without the conditions can be found on Teach Cambridge. This should be used in conjunction with the organic synthesis topic exploration pack.
			Total	**14**	
3 1			**Level 3 (5–6 marks)** Suggests **ALL** of the following • Reagents and conditions for **3** functional groups • Products for **3** functional groups	6 (AO 3.1 ×3) (AO 3.2 ×3)	**CHECK TOP OF QUESTION FOR RESPONSES** --- *Indicative scientific points may include:* **Stereoisomerism**

- Optical isomerism with description and 3D optical isomers shown

There is a well-developed line of reasoning which is clear and logically structured.
The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Suggests **two** of the following

- Reagents and conditions for **2** functional groups
- Products for **2** functional groups
- Optical isomerism with description **OR** an attempt to show 3D optical isomers

There is a line of reasoning presented with some structure.
The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
Suggests **two** of the following

- Reagents and conditions for **1** functional group
- Products for **1** functional group
- Identifies optical isomerism with description **OR** an attempt to show 3D optical isomers

There is an attempt at a logical structure with a line of reasoning.
The information is in the most part relevant.

0 mark *No response or no response worthy of credit.*

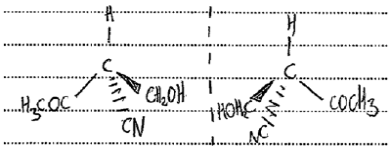
Key points to check

CHECK TOP OF QUESTION for responses
IGNORE CONNECTIVITY

in 3D isomer structures

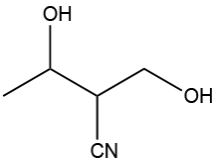
- *IGNORE bond angles*
- *Wedges needed*

- Optical isomerism identified with description: e.g. chiral centre /non-superimposable mirror images
- 3D Optical isomers drawn, e.g.

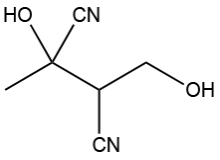


Description is subsumed in 3D diagrams

Reactions of ketone/carbonyl e.g.
$NaBH_4$

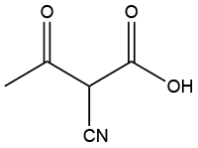


HCN **OR** CN^-/H^+ (e.g. $NaCN/H^+$)

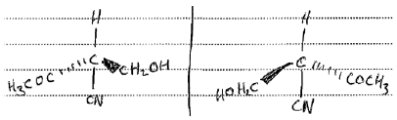


Reactions of –OH, e.g.

$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$
reflux



- *ALLOW*



Some responses will not fit into this exact pattern and a best-fit match may be needed

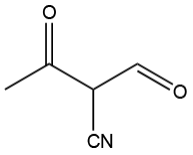
Clear communication
Focus on

- Clear diagrams of 3D optical isomers
- Diagrams of unambiguour structures
- Reagents and functional group formed are linked
- Communication is more a general feel for the quality of theresponses.

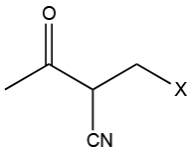
Slips and minor errors in structures

- Do not penalise the odd slip or omission, e.g. An extra C in a chain; a C short in a chain, C shown instead of CH_2 or skeletal
- You need to judge the extent of any slip based on the whole response. Remember that each candidate

$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ distil

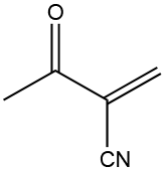


$NaBr/KBr/Br^-$ **AND** $acid/H^+$ **OR** HBr



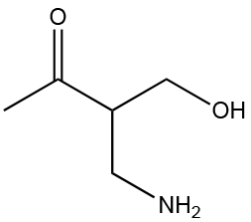
X = halogen

$Acid/H^+$ (catalyst) (e.g. H_2SO_4)

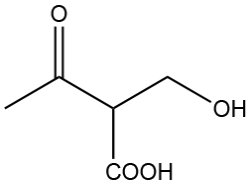


Reactions of C–CN, e.g.

H_2 **AND** metal catalyst e.g. Ni, Pt, Pd



H^+/H_2O e.g. HCl(aq) or H_2SO_4(aq)



OTHER REAGENTS, CONDITIONS AND PRODUCTS e.g. $LiAlH_4$ as reagent

Check with Team Leader

Examiner's Comments

Overall, candidates performed well when answering this question. They were required to identify that compound **A** shows optical isomerism and to choose a reaction for each of the three functional groups. Candidates were also expected to use structures for the organic products.

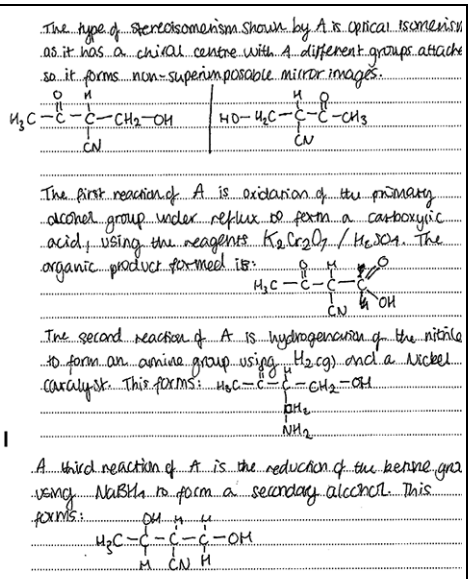
To achieve the highest level of response, a description of optical isomerism should be accompanied by 3D diagrams of the optical isomers.

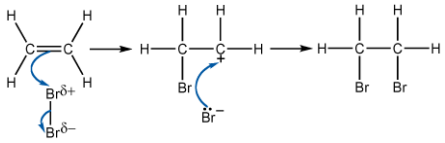
Optical isomerism was usually identified, with associated diagrams with almost all candidates identifying the chiral centre. Most attempted 3D diagrams but candidates do need to take care that the groups attached to the chiral C atom are those in compound A and that no parts of chains are omitted. Optical isomers do also require use bold and dashed wedges to be used.

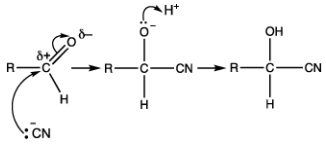
Most candidates showed good knowledge and understanding of reactions for the three functional groups.

- For the primary alcohol, most chose $H^+/Cr_2O_7^{2-}$, with

					distil (→ aldehyde) or reflux (→ carboxylic acid); a significant number chose a concentrated acid (→ alkene) or Br–/H+ (→ haloalkane) • For the ketone, most chose $NaBH_4$ (→ secondary alcohol) • For the nitrile, most chose either H_2/Ni (→ amine) or H^+(aq) (→ carboxylic acid). Clear diagrams of the products were usually seen although many omitted a CH_2 from the amine branch for hydrolysis of the nitrile or an extra CH_2 in the aldehyde or carboxylic acid branch from oxidation of the primary alcohol. Some candidates chose 2,4-DNP for a reaction of the ketone and treated the question as one requiring tests, and then proving that the compound was a ketone from no reaction with Tollens' reagent. The question asked for the organic product and the 2,4-DNP product is beyond the demands of this specification (although this was seen very rarely). Candidates adopting this reaction were limiting the extent of their response and candidate should have considered this requirement before selecting 2.4-DNP. Exemplar 2

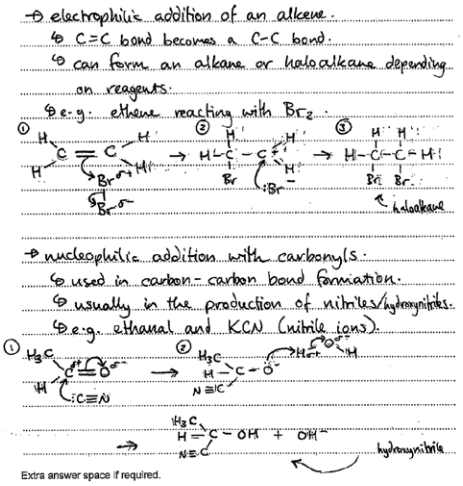
					 The type of stereoisomerism shown by A is optical isomerism as it has a chiral centre with 4 different groups attached so it forms non-superimposable mirror images. The first reaction of A is oxidation of the primary alcohol group under reflux to form a carboxylic acid, using the reagents $K_2Cr_2O_7$ / H_2SO_4. The organic product formed is: The second reaction of A is hydrogenation of the nitrile to form an amine group using $H_2(g)$ and a Nickel catalyst. This forms: A third reaction of A is the reduction of the ketone group using $NaBH_4$ to form a secondary alcohol. This forms: This exemplar shows a good response that lacks 3D diagrams for the optical isomers. The candidate has clearly given reagents and conditions and has shown the organic products. In the response, you can see that the candidate initially showed an extra CH_2 in the –COOH branch, and a mistake in the amine branch. The absence of 3D structures limits the response to Level 2 and 4 marks have been awarded for choosing correct and relevant reagents and conditions, and for the clear communication of the structures.
			Total	**6**	
32			**C**	1	**Examiner's Comments** The majority of candidates were able to correctly identify the two functional groups and the correct corresponding test i.e. alkene using bromine water and primary alcohol using 2,4-dinitrophenylhydrazine. The most common incorrect response was B.
			Total	**1**	

3 3			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks)** Describes addition reactions including the mechanisms of **one** alkene **AND one** carbonyl compound **AND** some additional details *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Describes an addition reaction including the mechanism of **one** alkene **OR one** carbonyl compound **AND** some additional details **OR** Describes addition reactions including an attempt to give the mechanisms of **one** alkene **AND one** carbonyl compound *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Selects suitable reagents for addition reactions of **one** alkene **AND one** carbonyl compound. **OR** Attempts to describe an addition reaction including an attempt to give the mechanism of **one** alkene **OR one** carbonyl compound. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	6	**Indicative scientific points may include:** **<u>Reaction of alkene and mechanism</u>** • Suitable reaction, e.g. alkene and Br_2 **OR** X_2 **OR** HX **OR** H_2O **OR** H_2 **OR** polymerisation *May be shown within mechanism* • Mechanism, e.g.  **ALLOW** mechanism for H_2 **AND** H_2O to be shown as electrophilic addition even though incorrect - consider impact on communication statement. **ALLOW** suitable non-specification alternative e.g. HCN **Additional details (NOT INCLUSIVE)** • Electrophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. alkene to dibromo • Details on reagents required e.g. - H_2 with Ni Catalyst - $H_2O(g)$ with H_3PO_4 catalyst • Explanation of major and minor product from

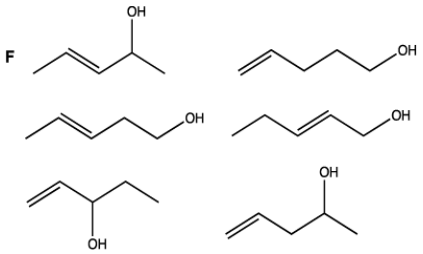
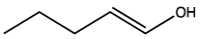
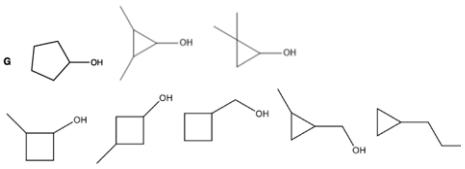
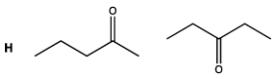
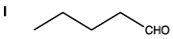
					electrophilic addition of HX with unsymmetrical alkene • Explanation of carbocation intermediate stability • Heterolytic fission **<u>Reaction of carbonyl compound and mechanism</u>** Suitable reactions, e.g. • Aldehyde or ketone and HCN **OR** H^- e.g. RCHO + HCN → RCH(OH)CN *May be shown within mechanism* • Mechanisms, e.g.  **OR** H_2O instead of H^+ for 2nd stage **ALLOW** suitable non-specification alternative e.g. H_2O, NH_3, 1° amine **IGNORE** reactions with carboxylic acids (or derivatives) i.e. addition-elimination mechanism (condensation reaction) **Additional details (NOT INCLUSIVE)** • Nucleophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. aldehyde to hydroxynitrile • In reduction, aldehydes form 1° alcohols and ketones form 2° alcohols

					• Details on reagents required e.g. - formation of hydroxynitriles with $NaCN/H^+(aq)$ - formation of alcohols with $NaBH_4$ • Heterolytic fission Aspects of the **communication statement** being met might typically include: • Curly arrows starting from lone pairs / negative charges / bonds. • All reactants and intermediates have relevant charges and dipoles. • Mechanisms given are chemically feasible for the reactions. • No additional incorrect reactants have been included. **Examiner's Comments** A very good proportion of candidates scored all 6 marks, giving well-drawn mechanisms with some additional details such as mechanism names, functional group interconversions or other additional reaction information. Some attempted to 'describe' the mechanism using only words rather than drawing it out with a conventional curly arrow mechanism. Candidates may need more clarity on what 'describe' means in an organic chemistry

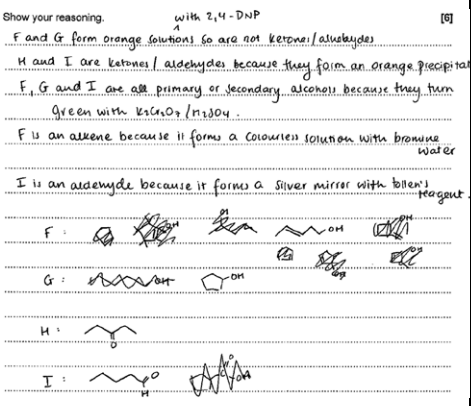
					context. Equally, a few gave just the mechanisms with no additional details, limiting themselves to Level 2. Candidates were usually more confident with the addition to alkenes using an electrophilic addition mechanism. Some gave additional details about major and minor products, although not always relevant as for a symmetrical alkene. Some represented the addition of hydrogen or water to alkenes via an electrophilic addition mechanism. While not correct it showed an understanding of mechanisms and a correct addition reaction for alkenes, so credit was given. Some candidates included incorrect reagents for reactions, such as acid catalysts with addition of a hydrogen halide, or incorrect conditions, such as the requirement for ultraviolet light on addition of a halogen. The addition to carbonyl compounds was not always as well-described. Some candidates struggled to identify carbonyl compounds, selecting carboxylic acids or their derivatives, with attempts at addition-elimination mechanism i.e. condensation reactions. Some gave incorrect reagents for carbonyls, including H_2O and HBr. However, some used off-specification reactions such as the addition of H_2O to form a geminal diol which was given but as the mechanism differs from the nucleophilic addition mechanism taught in this specification, full credit was rarely achieved. Some also considered oxidation of aldehyde or ketone to be an addition reaction. Most who presented a correct mechanism for addition to a

					carbonyl used the reaction with cyanide rather than reduction with $NaBH_4$. Common errors included arrows coming from the N of CN^-, a lack of putting dipoles on carbonyl bonds, missing charges on O in intermediates or showing the wrong direction of arrows. **OCR support** The OCR Guide to Level of Response questions can be found on Teach Cambridge and can be used to help your students better understand this type of question. Exemplar 1  Level 3 – 6 marks Two correct addition mechanisms have been shown, one for an alkene and one for a carbonyl compound. Additional details include the names of the mechanisms, names of the functional groups in the products, and the fact that a C-C bond is formed in the second mechanism. All curly arrows, charges and dipoles are correctly positioned so

					this response was also given the communication mark.
			Total	**6**	
34		i	Green solution Cr^{3+} **OR** $[Cr(H_2O)_6]^{3+}$ ✓ Orange solution $Cr_2O_7^{2-}$ ✓ Formulae **AND** charges must be correct	2	**Green solution** **IGNORE** H^+ **ALLOW** $Cr_2(SO_4)_3$ **OR** $CrCl_3$ **OR** Cr^{+3} Orange solution **IGNORE** H^+ **ALLOW** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **DO NOT ALLOW** Cr^{6+} **ALLOW** 1 mark for correct formulae but wrong way round **Examiner's Comments** Although high attaining candidates responded with the formulae of chromium-containing species, it was common to see organic compounds being suggested. Consequently, a large proportion of candidates did not score either of the 2 marks. Many candidates seem to expect to only give organic species in their responses on this paper and would benefit from understanding that inorganic species may also need to be provided.
		ii	**Level 3 (5-6 marks)** Reaches a comprehensive conclusion to determine possible correct structures for **ALL** of **F**, **G**, **H** and **I** **AND ALL** functional groups of **F**, **G**, **H** and **I** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and*	6	Indicative scientific points may include: **Identity of F, G, H and I showing CORRECT structures**

			substantiated. **Level 2 (3-4 marks)** Reaches a conclusion to determine possible **correct** structures for two of **F**, **G**, **H** and **I** **AND most** functional groups of **F**, **G**, **H** and **I** *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Reaches a simple conclusion to determine a possible correct structure for one of **F**, **G**, **H** and **I** **OR** some functional groups of **F**, **G**, **H** and **I** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		 **ALLOW** enols for F, e.g.  For **G**, **DO NOT ALLOW** tertiary -OH. e.g.  For **G, DO NOT ALLOW** tertiary -OH. e.g.    **IGNORE** names, even if incorrect For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g. **2,4-DNP**

					H and **I** have carbonyl group/aldehyde or ketone **$H^+/Cr_2O_7^{2-}$** **F**, **G** and **I** are primary or secondary alcohols or aldehydes **Bromine** **F** is unsaturated/has C=C **Tollens** **I** is aldehyde ***Correct functional groups may be shown in correct structures*** **Examiner's Comments** This Level of Response question was answered well with many candidates identifying compounds **F-I** correctly to reach Level 3. Structures were usually shown skeletally and this practice is to be recommended. Not only is it far quicker and clearer, it eliminates writing every atom in a displayed or structural formula. Some candidates were not given marks for missing hydrogen atoms or for 'sticks' being shown. In these structures, the chemical meaning of a stick is a terminal CH_3 group. Candidates were also asked to show how the results of the chemical tests helped the identification of the unknown compounds and this formed the basis of the communication strand of the LOR mark. Candidates answered this part of the analysis extremely well and most were given marks for their good communication skills. This question differentiated very well between well-prepared and less confident candidates. The latter often did not know how the results of these organic tests can be used to identify the functional groups present. It was common for such candidates to identify only

					one of the four compounds, scoring within Level 1 only. **OCR Support** To better prepare candidates, we recommend using either the digital multiple choice quizzes on Teach Cambridge or creating targeted practise materials using ExamBuilder. If you are unsure of how to access these or ways to make the most of them, get in touch via science@ocr.org.uk. Exemplar 3  Show your reasoning. with 2,4-DNP [6] F and G form orange solutions so are not ketones/aldehydes H and I are ketones / aldehydes because they form an orange precipitat F, G and I are all primary or secondary alcohols because they turn green with $K_2Cr_2O_7/H_2SO_4$ F is an alkene because it forms a colourless solution with bromine water I is an aldehyde because it forms a silver mirror with Tollen's reagent F : G : H : I : This exemplar is concise and very clear. The candidate has clearly linked the result of each test to the functional groups that must be present. The candidate has drawn skeletal formulae and clearly has experimented with many possible structures before deciding on which must be correct. Notice that the candidate has crossed out the structures that they have rejected. This is an important exam technique - if two structures are drawn, with one correct and the other incorrect, the correct structure cannot be given marks.

					The response is clearly at Level 3 for the four correct structures and the good communication ensures that the communication strand can be given. This response received all 6 marks.
			Total	**8**	