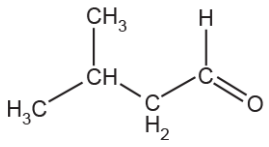
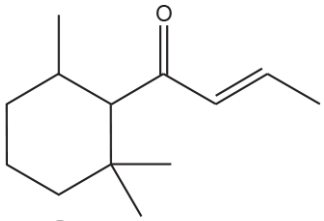
Carbonyl Compounds

1(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**.

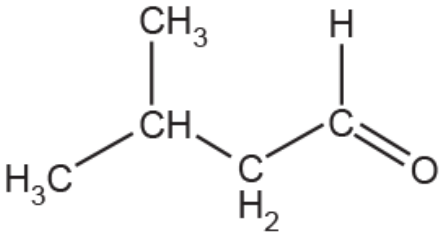
---

[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.

_____

_____

_____

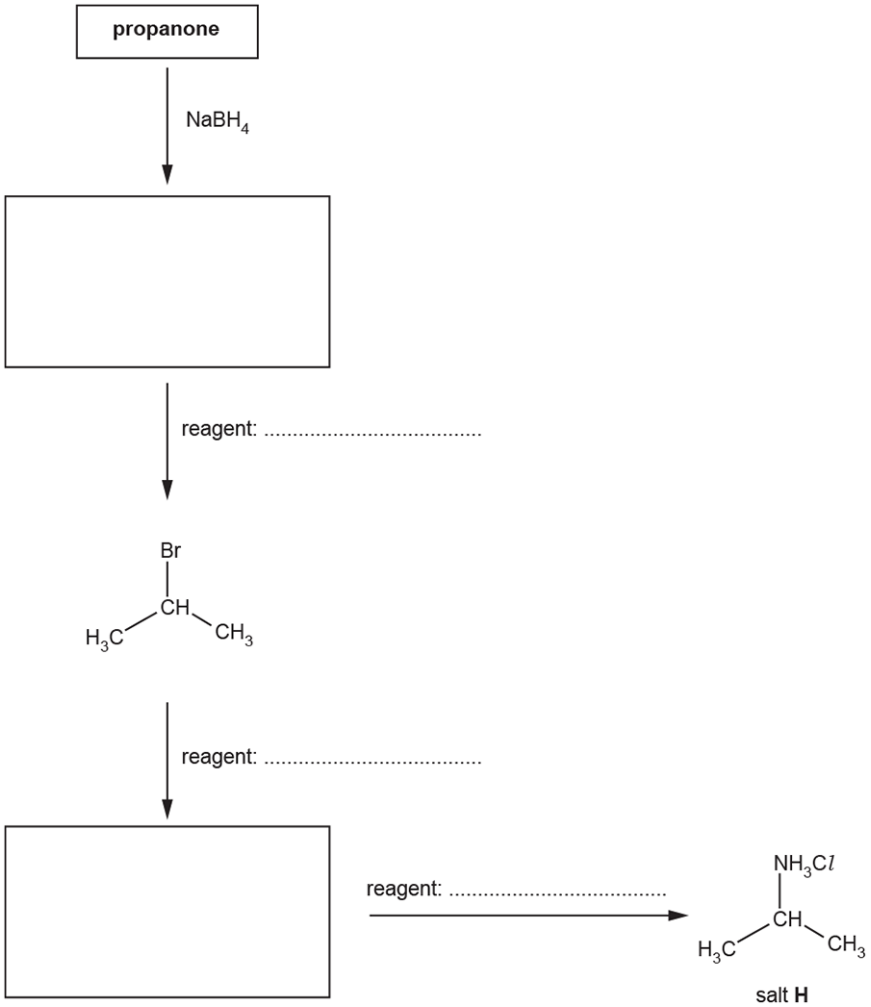
_____ **[2]**

2. 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.

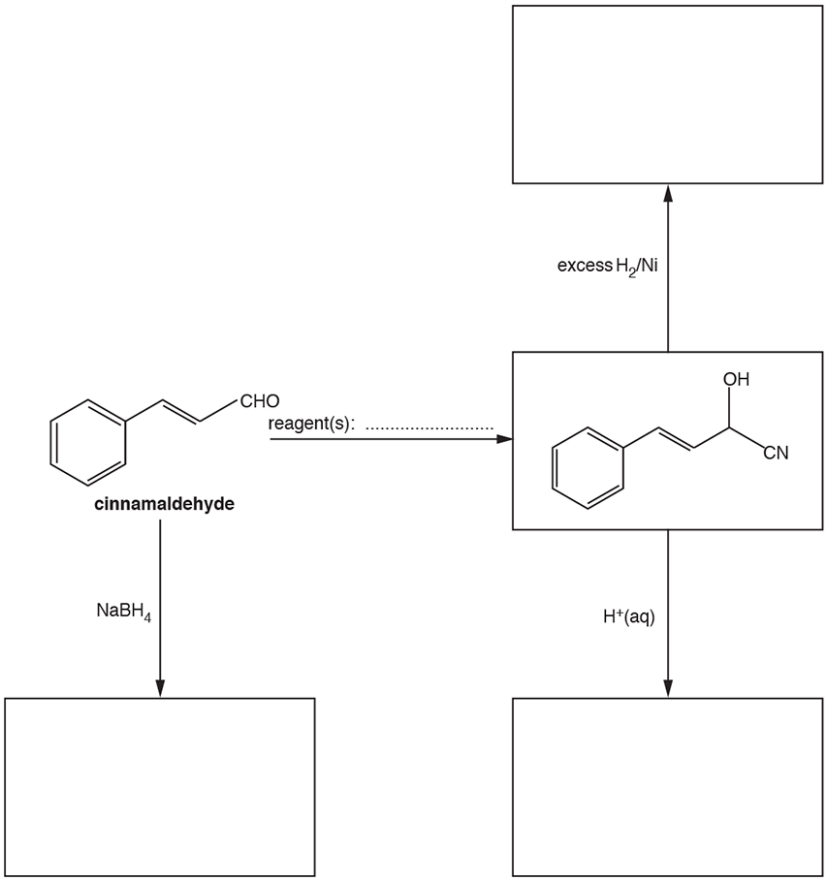
Complete the flowchart.
Show structures for organic compounds.



[5]

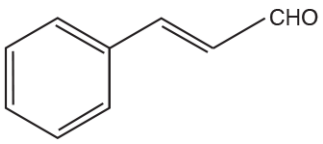
3(a). The flowchart below shows some reactions starting with cinnamaldehyde.

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

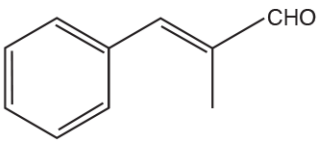


[5]

(b). 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?

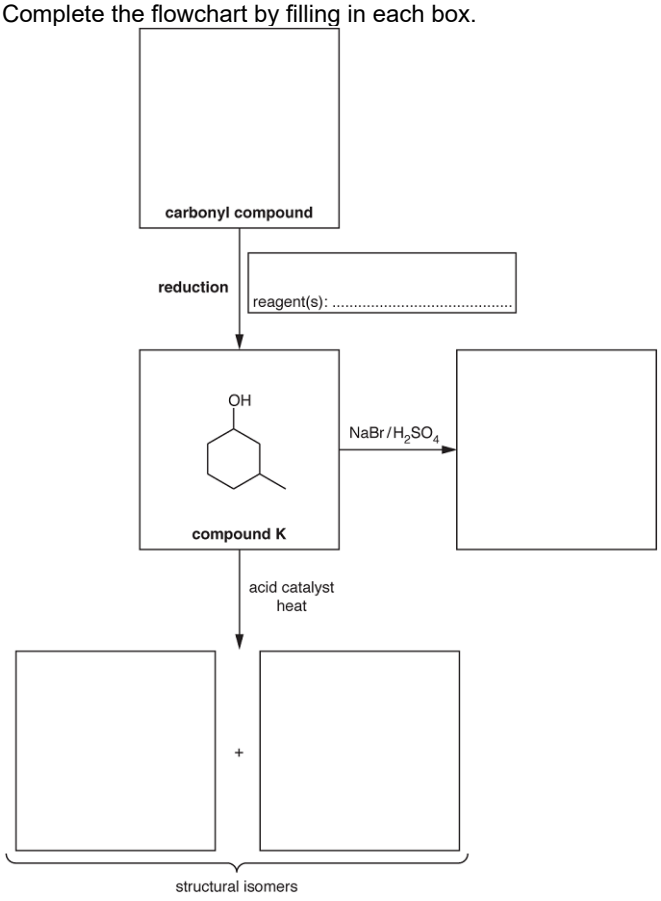
Your answer should **not** include spectroscopy.

---

[3]

4. 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.



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

---

[1]

5. 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.

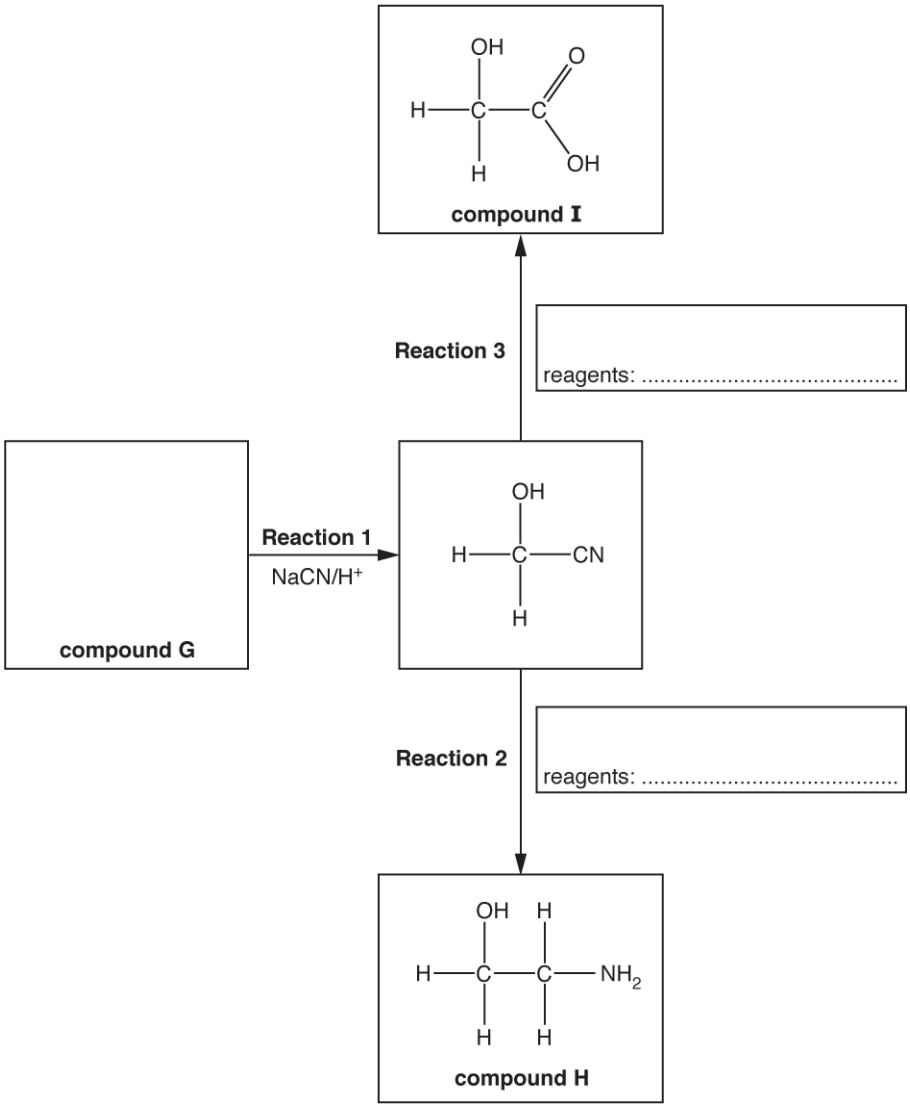
i. 1-Chloropropane, $CH_3CH_2CH_2Cl$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

Outline the mechanism for this reaction.

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

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**.


OH
O
H
C
C
OH
H
compound I
Reaction 3
reagents: .....
compound G
Reaction 1
NaCN/H+
OH
H
C
CN
H
Reaction 2
reagents: .....
OH
H
H
C
C
NH2
H
H
compound H

[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

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]

6(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.

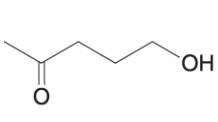
Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

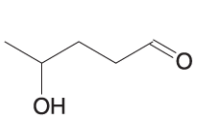
---

[5]

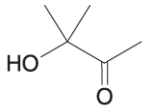
7. The following three carbonyl compounds are structural isomers of $C_5H_{10}O_2$.



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]

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]

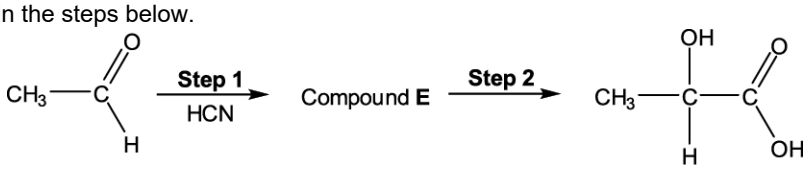
(b). Explain, with reference to a suitable chemical test, how compound **J** could be identified.

Your answer should **not** include spectroscopy.

---

[3]

9(a). 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**.

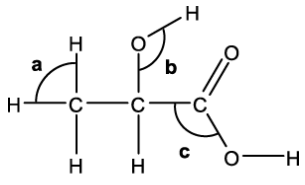
[1]

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**.

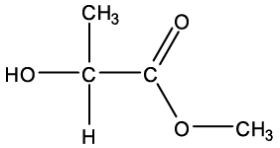
Bond angle **a**: .....

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.

---

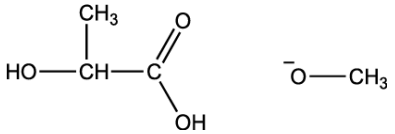
[1]

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

HO^-

Intermediate

Step 2

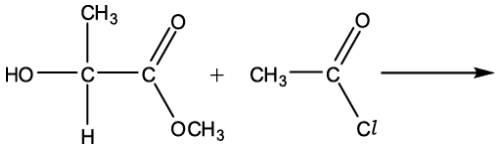


- Add relevant dipoles and curly arrows to show how the intermediate is formed in **Step 1** of the mechanism.
- Add curly arrows to show how the carboxylic acid and $^-OCH_3$ ion are formed from the intermediate in **Step 2** of the mechanism.

[4]

iii. Methyl lactate can also react with ethanoyl chloride.

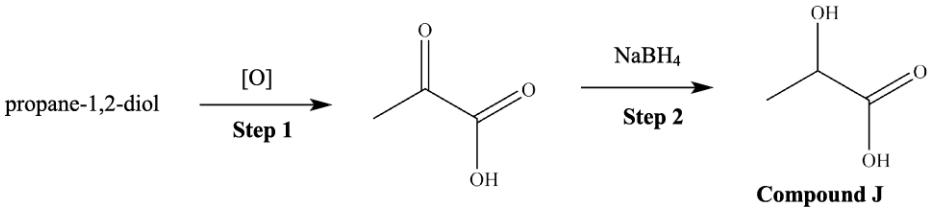
Complete the equation for this reaction.



[2]

10. 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.



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]

END OF QUESTION PAPER