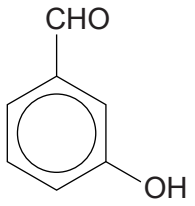
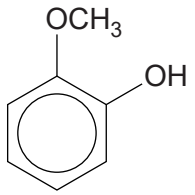
1 A student analysed a mixture of compounds found in red wine using gas chromatography followed by mass spectrometry (GC-MS).

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



compound A



compound B

(a) The column in the gas chromatogram is packed with solid beads coated with a liquid polymer.

How does gas chromatography (GC) separate the compounds in the mixture?

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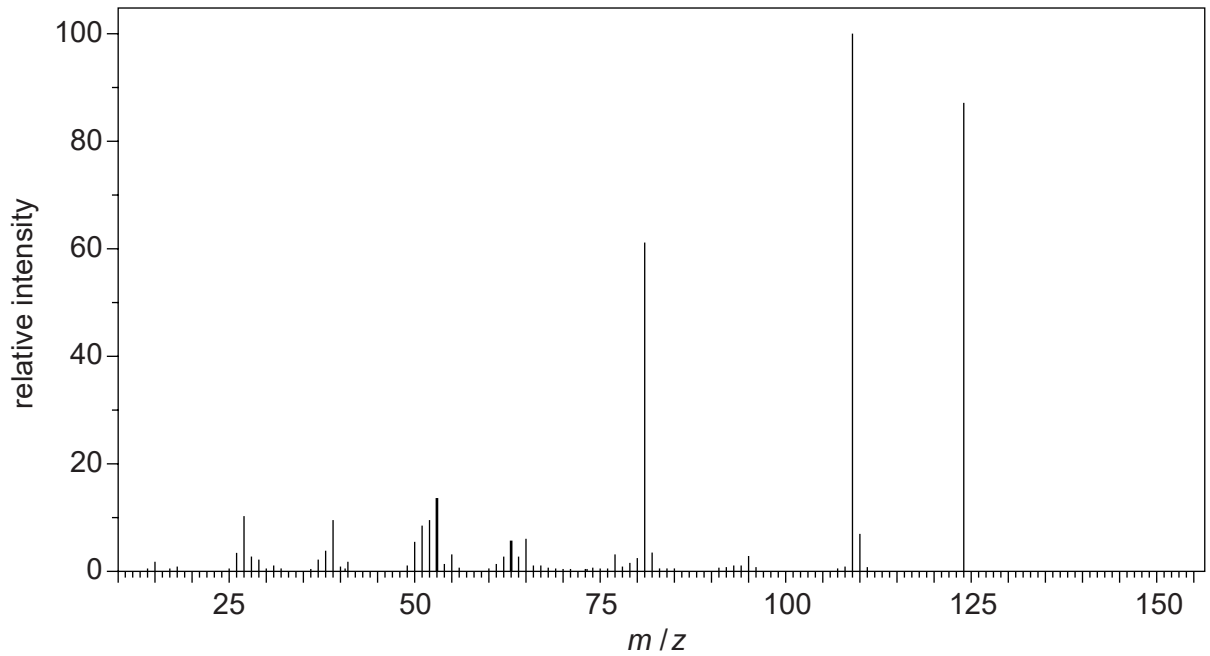
..... **[1]**

(b) The mass spectrum (MS) of the **first** compound to emerge from the column is shown below.



(i) Identify the compound responsible for this spectrum.

Give a reason for your answer.

.....

..... **[1]**

(ii) What does your answer to **(b)(i)** suggest about the interaction of this compound with the phases present in the column?

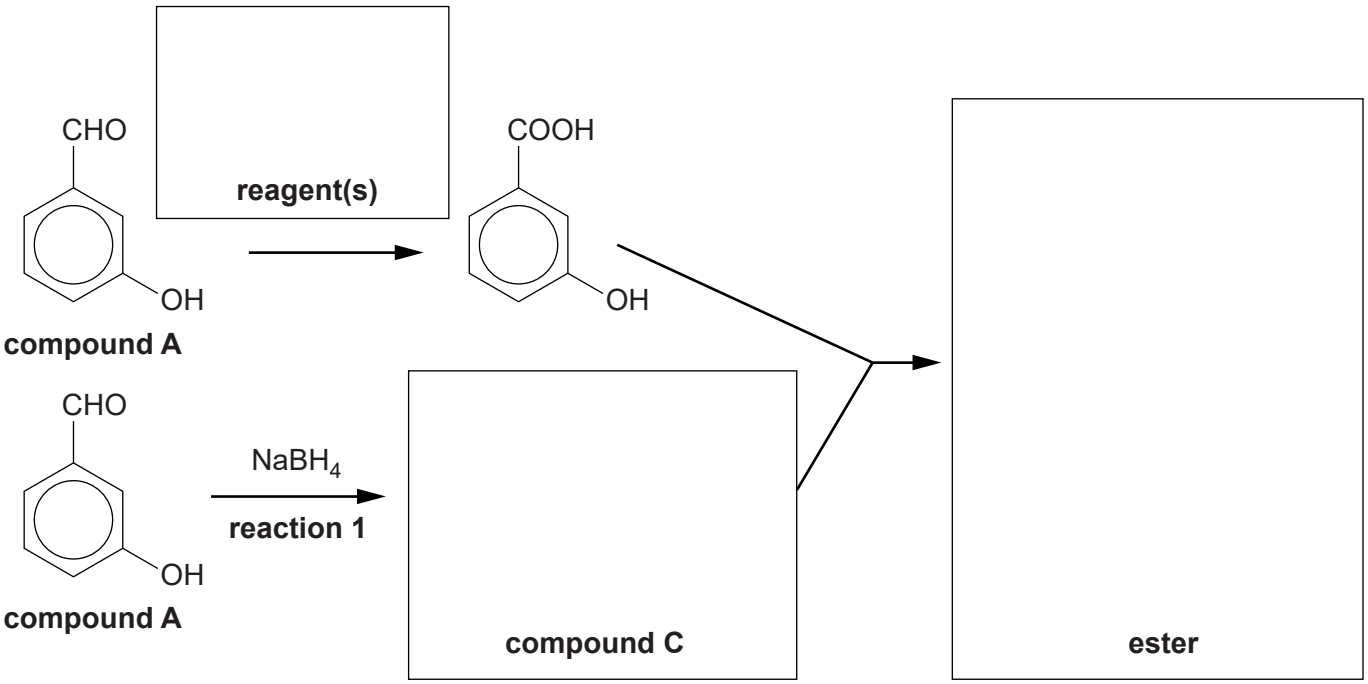
.....

..... **[1]**

(c) 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.

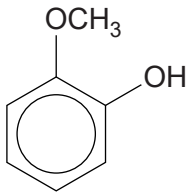
(i) Complete the boxes in the flowchart below.



[3]

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

(d) 1 mol of compound **B** reacts with 2 mol of bromine, Br_2 by electrophilic substitution.



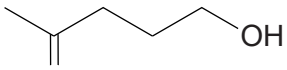
compound B

Write a balanced equation for this reaction, showing clearly the structure of the organic compound.

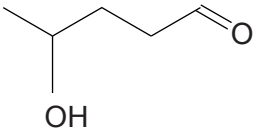
[1]

[Total: 10]

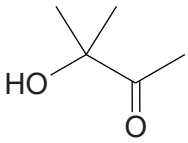
2 The following three carbonyl compounds are structural isomers of $C_5H_{10}O_2$.



compound C



compound D



compound E

(a) Describe chemical tests that you could carry out in test-tubes to distinguish between compounds **C**, **D** and **E**.

Include appropriate reagents and any relevant observations. Also include equations showing structures for the organic compounds involved.

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..... **[4]**

(b) 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]

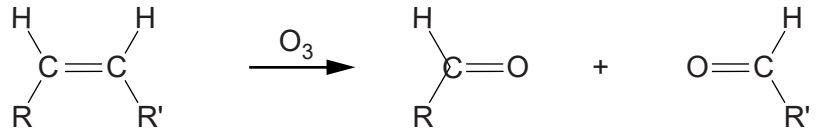
(c) Predict the number of peaks in the ^{13}C NMR spectra of compounds **C**, **D** and **E**.

Compound	**C**	**D**	**E**
Number of peaks			

[1]

(d) 'Ozonolysis' is a technique used in organic chemistry to break open a C=C double bond.

During ozonolysis, an alkene reacts with ozone, O_3. The products are carbonyl compounds, as shown below.



(i) Draw the structures of the products you would expect from the complete ozonolysis of the following alkenes.

- pent-2-ene

- hexa-2,4-diene

[3]

(ii) In another ozonolysis reaction, organic compound **G** reacted to form **only** hexane-1,6-dial.

Compound **G** has six carbon atoms.

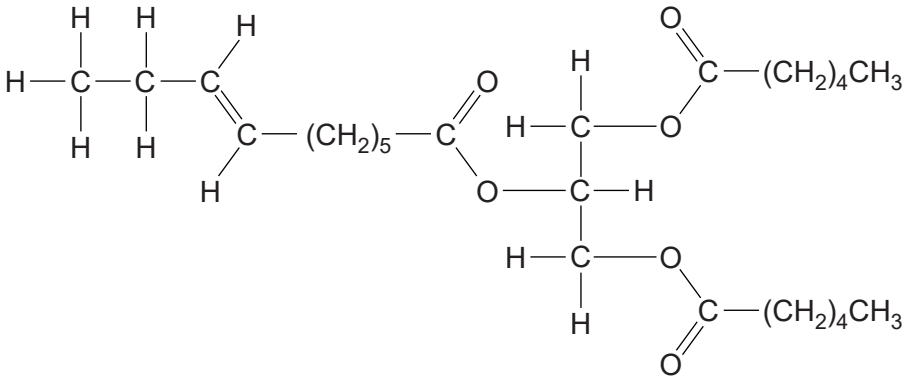
Draw the structure of compound **G**.

[1]

[Total: 13]

3 Triglycerides are triesters and are found in fats and oils.

The structure of a triglyceride found in some goats' milk is shown below.



(a) This triglyceride is hydrolysed with hot aqueous sodium hydroxide.

(i) Give the systematic name of the alcohol that is formed by this hydrolysis.

..... **[1]**

(ii) Draw the structures of the other organic products of this hydrolysis.

[3]

(b) Suggest why people who consume a large quantity of this type of goats' milk might be more at risk of suffering from coronary heart disease.

In your answer, you should use appropriate technical terms, spelled correctly.

.....

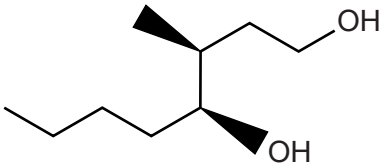
.....

.....

..... **[2]**

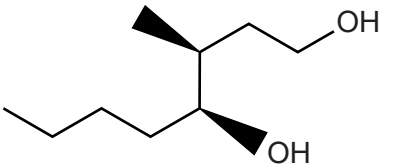
[Total: 6]

4 Compound **E**, shown below, is an alcohol that is found in oak wood. It is formed by the breakdown of cellulose.



compound E

Compound **E** can be converted into compound **G** as shown in the flowchart below.



compound E

excess $K_2Cr_2O_7/H_2SO_4$

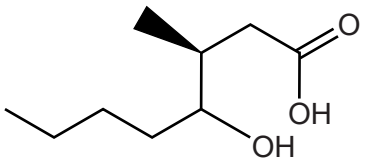
reflux

reaction 1

compound F

reaction 2

reagent .....



compound G

(a) (i) Complete the flowchart to show the structure of the organic compound **F** and the reagent needed for **reaction 2**. **[1]**

(ii) What would you observe during **reaction 1**?

.....

..... **[1]**

(iii) In **reaction 1**, compound **E** was heated under reflux with excess $K_2Cr_2O_7/H_2SO_4$.

Suggest why these conditions were used, rather than the reaction mixture being distilled during the process.

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.....

..... **[1]**

(iv) Name the type of reaction taking place in **reaction 2**.

..... **[1]**

(b) Describe a chemical test that you could use to detect the presence of a carbonyl group in an organic compound.

Reagent .....

Observation .....

.....

..... **[2]**

(c) Compound **E** is a single stereoisomer.

(i) Draw the skeletal formula of one other stereoisomer of compound **E** and state the type of stereoisomerism.

type of stereoisomerism ..... **[2]**

(ii) 4.56 g of compound **E** was converted into compound **G** using the method shown in the flowchart on page 12.

3.15 g of compound **G** was formed.

Calculate the percentage yield of compound **G**.

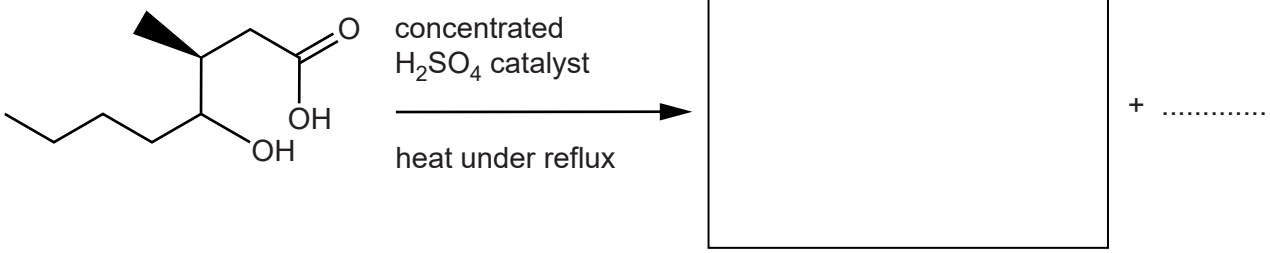
Give your answer to **three** significant figures.

The M_r of compound **E** is 160.0.

percentage yield of compound **G** = ... % **[3]**

(iii) Compound **G** is heated for several hours under reflux, in the presence of a concentrated sulfuric acid catalyst. An ester and a small inorganic molecule are formed.

Complete the equation below to show the **two** products formed by this reaction.



[2]

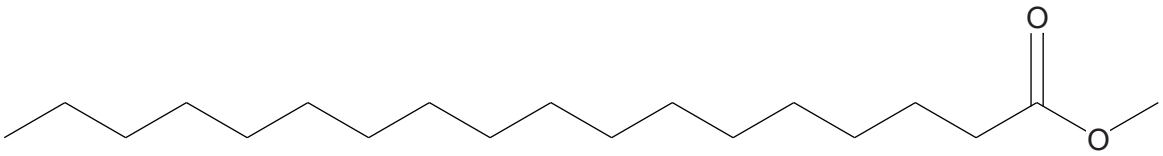
[Total: 13]

5 Fats and oils are mixtures of organic compounds. Some fats contain glycerides and steroids

(a) Some processed foods contain *trans* oils which have been linked to health risks.

(i) The incomplete structure below shows an octadeca-12-enoate section of a *trans* oil.

- Add the double bond to the structure
- State how the *trans*-isomer is different from the *cis*-isomer.



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..... **[2]**

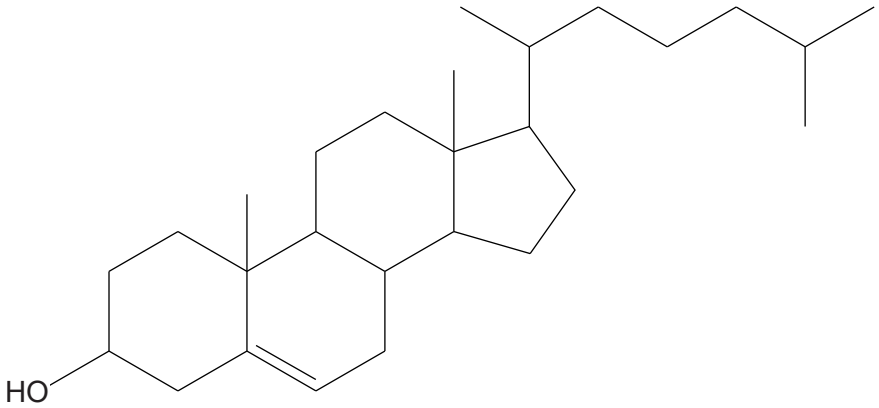
(ii) State **one** possible health risk of a diet that is high in *trans* oils.

.....

..... **[1]**

(b) Cholesterol is part of a family of compounds called steroids.

The structure of cholesterol is shown below.



(i) How many carbon atoms are there in a molecule of cholesterol?

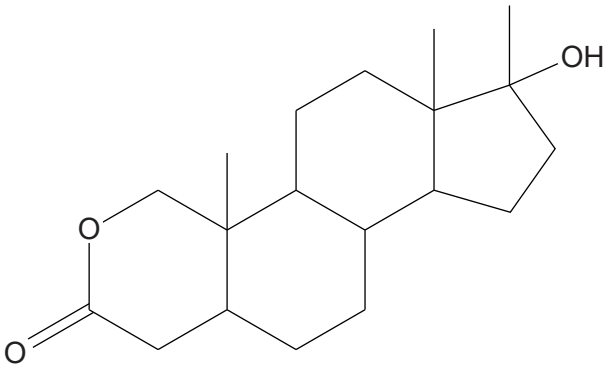
..... **[1]**

(ii) How many chiral centres are there in a molecule of cholesterol?

..... **[1]**

(c) Oxandrolone is a type of synthetic drug called an 'anabolic steroid', prescribed to promote muscle growth.

The structure of oxandrolone is shown below.



(i) What are the functional groups in oxandrolone?

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..... **[2]**

(ii) Oxandrolone is synthesised from naturally occurring steroids.

Suggest an advantage of developing a synthetic route to oxandrolone starting from a natural steroid.

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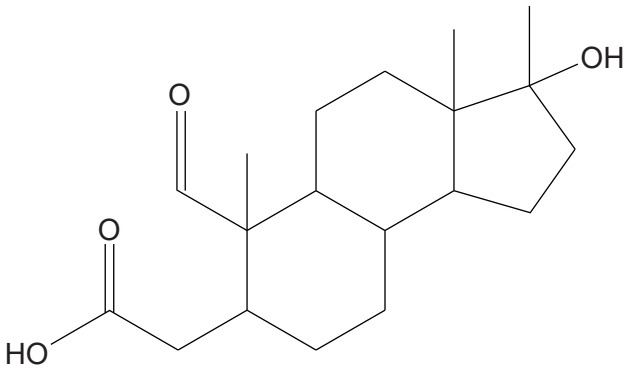
.....

..... **[1]**

(iii) Compound **C** below is an intermediate formed during the synthesis of oxandrolone.



compound C

Suggest a two-step synthesis of oxandrolone from compound **C**.

For each step of the synthesis,

- state the reagents and any conditions
- state the functional groups that would react and those that would form.

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.....

..... **[4]**

[Total: 12]

6 Benzaldehyde, C_6H_5CHO, is the simplest aromatic aldehyde and has a characteristic smell of almonds.

(a) Benzaldehyde can be nitrated with a mixture of concentrated nitric acid and concentrated sulfuric acid to form 3-nitrobenzaldehyde.

Explain, with the aid of curly arrows, the mechanism for the formation of 3-nitrobenzaldehyde.

Your answer should clearly show the role of sulfuric acid as a catalyst.

[6]

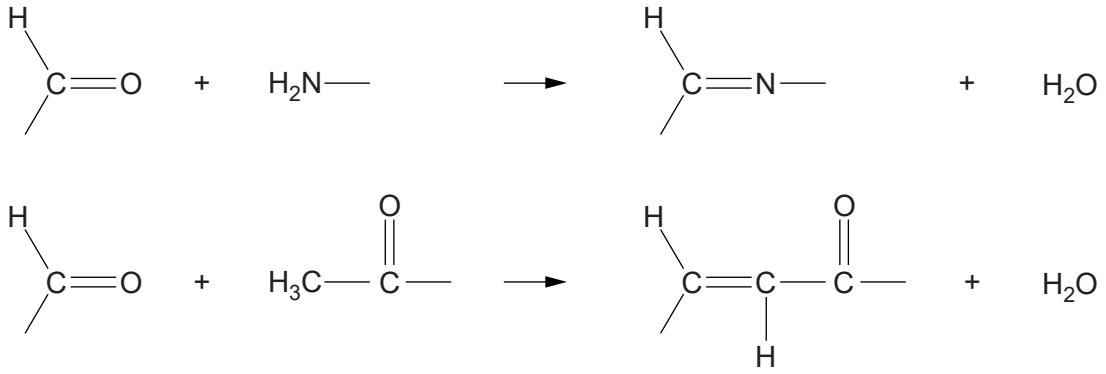
(b) Benzaldehyde reacts with a solution of potassium hydroxide. In this reaction, benzaldehyde is both oxidised and reduced to form two organic products.

Suggest an equation for this reaction, showing clearly the structures of the two organic products.

[3]

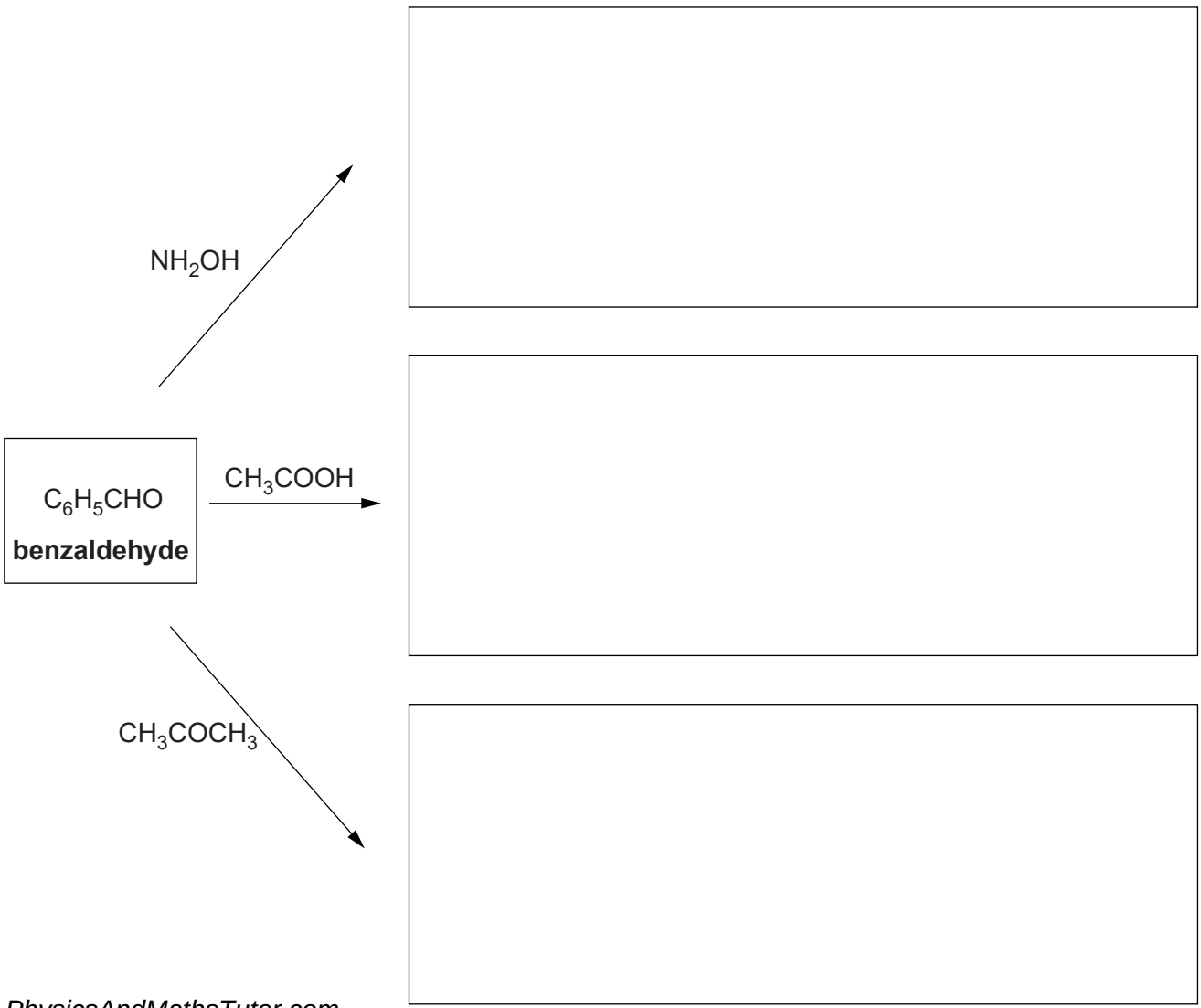
(c) The aldehyde group takes part in 'condensation' reactions with many compounds containing an amine group or a methyl group adjacent to a C=O.

In these reactions, water is formed as a product. Two examples are shown below.



Predict the organic products formed in the following condensation reactions of benzaldehyde. In each reaction, an excess of benzaldehyde is used.

Draw the structure of each organic product in the boxes.



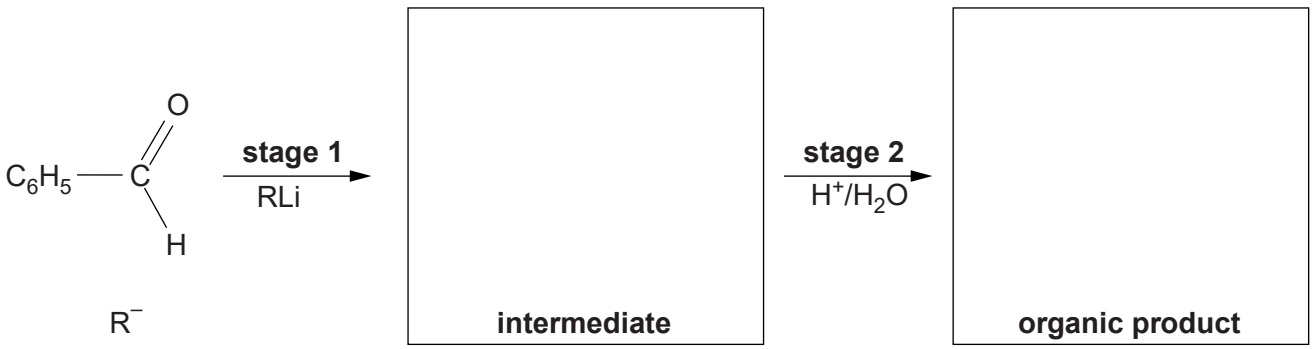
[3]

(d) Alkyllithium compounds, RLi, can be used to increase the number of carbon atoms in an organic compound. Different alkyl groups, R, add carbon chains with different chain lengths.

RLi provides a source of R^- ions, which act as a nucleophile.

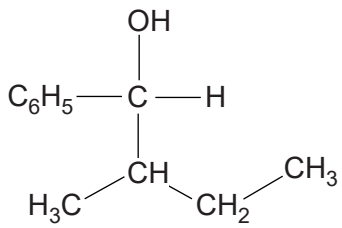
(i) The diagram below shows an incomplete mechanism for the reaction of RLi with benzaldehyde, followed by reaction with aqueous acid.

- Complete, using curly arrows and relevant dipoles, the mechanism for **stage 1**.
- Give the structure of the intermediate and the organic product.



[4]

(ii) A chemist needs to prepare the organic compound below from benzaldehyde.



Draw the structure of the alkyllithium compound needed for this synthesis.

[1]

[Total: 17]