1. Alcohol E is one of the following alcohols.

- butan-2-ol
- 2-methylpentan-3-ol
- propan-1-ol
- ethane-1,2-diol
- 2-methylpropan-2-ol
- propan-2-ol

A student oxidises alcohol E by heating under reflux with excess acidified potassium dichromate(VI). An organic product F is isolated.

The mass spectrum of the alcohol E is shown below.

![Mass spectrum of alcohol E](image)

The infrared spectrum of the organic product F is shown below.

![Infrared spectrum of product F](image)
• Name or draw the structures of the alcohol E and the organic product F.

• Write an equation for the reaction of alcohol E with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).

In your answer, you should make clear how each structure fits with the information given above.

[Total 7 marks]

2. Alcohols A, B, C and D are shown below.

(\ \text{CH}_3\text{CH}_2\text{OH})

(a) Compound A is ethanol, a very useful alcohol.

Identify the two main methods used in the industrial production of ethanol. Write an equation for each method.

method 1 .........................................................................................................

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equation ..........................................................................................................

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method 2 .........................................................................................................

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equation ..........................................................................................................

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[4]
(b) A student heated each alcohol, A–D, with acidified potassium dichromate(VI) as the oxidising agent. With alcohols A, B and C, the colour turned from orange to green.

(i) Identify the organic product and write a balanced equation for the reaction of alcohol B with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).

organic product:

balanced equation:

(ii) The organic product obtained from C was analysed by infrared (IR) spectroscopy.

The IR spectrum of the product is shown below.
Use your *Data Sheet* to identify the organic product. Explain your reasoning.

organic product:

reasoning ................................................................................................................
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(c) The student heated alcohol D with ethanoic acid in the presence of an acid catalyst. An organic product E was formed with a fruity smell.

(i) Name alcohol D.

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(ii) Name the functional group in the organic product E.

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(iii) Draw the structure of the organic product E.

[Total 13 marks]
3. A student carried out an investigation to compare the rates of hydrolysis of 1-iodopropane and 1-bromopropane. The student heated hot aqueous sodium hydroxide with each halogenoalkane and found that 1-iodopropane was hydrolysed faster.

The equation for the reaction with 1-iodopropane is shown below.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{I} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{I}^-
\]

(a) (i) Outline the mechanism for this hydrolysis of 1-iodopropane.

Show curly arrows and relevant dipoles.

(b) Explain why 1-iodopropane is hydrolysed faster than 1-bromopropane.

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[Total 6 marks]
4. An analytical chemist was provided with a compound J which has an unbranched carbon skeleton. After analysis, the chemist obtained the following results.

<table>
<thead>
<tr>
<th>type of analysis</th>
<th>evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>infrared spectroscopy</td>
<td>broad absorption at 3350 cm(^{-1})</td>
</tr>
<tr>
<td>percentage composition by mass</td>
<td>C, 70.59%; H, 13.72%; O, 15.69%</td>
</tr>
<tr>
<td>mass spectrometry</td>
<td>molecular ion peak at (m/z = 102.0)</td>
</tr>
</tbody>
</table>

Use this information to suggest all the possible structures for the unbranched compound J.

In your answer you should make clear how your explanation is linked to the evidence.

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[Total 8 marks]
5. Bromobutane, CH₃CH₂CH₂CH₂Br, can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Br}^- 
\]

The butan-1-ol produced can be analysed by mass spectrometry.

(i) Predict two fragment ions that you would expect to see in the mass spectrum of butan-1-ol and state the \( m/z \) value of each ion.

...........................................................................................................................................
...........................................................................................................................................

[2]

(ii) State a use of mass spectrometry outside of the laboratory.

...........................................................................................................................................

[1]

[Total 3 marks]

6. Compound X is an atmospheric pollutant emitted from fuel combustion of petrol and diesel vehicles. Compound X is a potent human carcinogen.

• Analysis of compound X showed the following percentage composition by mass: C, 88.89%; H, 11.1%.

• Mass spectrometry showed a molecular ion peak at \( m/z = 54 \).

• Compound X reacts with H2 in the presence of a nickel catalyst in a 1 : 2 molar ratio.

Analyse and interpret this information to determine a possible structure for compound X.

Show all your working.

[Total 5 marks]
7. (a) Butan-1-ol can be oxidised to form butanal.
   (i) State a suitable oxidising mixture for this reaction.
       .................................................................................................................. [2]
   (ii) State the colour change you would see during this oxidation.
       from .................................................. to .................................................. [1]

   (b) A sample of the butanal from (a) was analysed using infra-red spectroscopy. The infra-red spectrum contained an absorption in the region 1680–1750 cm\(^{-1}\) but did not contain a broad absorption in the region 2500–3300 cm\(^{-1}\).

       Refer to the Data Sheet for Chemistry provided.

       (i) What does the absorption in the region 1680–1750 cm\(^{-1}\) indicate?
           .................................................................................................................. [1]

       (ii) What does the absence of a broad absorption in the region 2500–3300 cm\(^{-1}\) indicate?
           .................................................................................................................. [1]

       (iii) The reaction in (a) was carried out using distillation and not reflux.
           Explain why.
           ..................................................................................................................
           .................................................................................................................. [2]

     [Total 7 marks]

8. Compound E can be oxidised to form a carboxylic acid.
   (i) State a suitable oxidising mixture for this reaction.
       .................................................................................................................. [2]
(ii) Write a balanced equation for this oxidation of compound E.

Use [O] to represent the oxidising mixture.

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{C}==\text{C}==\text{H} \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}
\]

compound E

[3]

(iii) Explain how compound E and the carboxylic acid could be distinguished by infra-red spectroscopy.

..........................................................................................................................
..........................................................................................................................

[1]

[Total 6 marks]

9. (a) When ethanol is heated with acidified potassium dichromate(VI) solution, it can be oxidised to form either ethanal, CH\text{\textsubscript{3}}\text{CHO} (Fig. 1), or ethanoic acid, CH\text{\textsubscript{3}}\text{COOH} (Fig. 2).

Fig. 1

Fig. 2
The boiling points of ethanol, ethanal and ethanoic acid are given in the table below.

<table>
<thead>
<tr>
<th></th>
<th>CH$_3$CH$_2$OH</th>
<th>CH$_3$CHO</th>
<th>CH$_3$COOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>boiling point/ °C</td>
<td>78</td>
<td>21</td>
<td>118</td>
</tr>
</tbody>
</table>

Use this table of boiling points to explain

(i) why the organic product is likely to be ethanal if the apparatus shown in Fig. 1 is used,

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

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

(ii) why the organic product is likely to be ethanoic acid if the apparatus shown in Fig. 2 is used.

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

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

(b) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use (O) to represent the oxidising agent.

........................................................................................................................................ [2]
The ethanal collected using the apparatus shown in Fig. 1 was analysed by infra-red spectroscopy. Use your Data Sheet to justify which of the three spectra shown below is most likely to be that of ethanal.

![Spectrum A](image)

Absorbance / %

Wavenumber / cm⁻¹

![Spectrum B](image)

Absorbance / %

Wavenumber / cm⁻¹

![Spectrum C](image)

Absorbance / %

Wavenumber / cm⁻¹

The organic product collected when using the apparatus shown in Fig. 1 is most likely to be that shown by spectrum .......... because........................................

..........................................................................................................................

..........................................................................................................................

[3]

[Total 9 marks]
10. A sample of prop-2-en-1-ol was oxidised and an infra-red spectrum of the organic product was obtained.

![Infra-red spectrum](image)

By referring to your Data Sheet, decide whether acrolein, CH$_2$==CHCHO, or acrylic acid, CH$_2$==CHCOOH, was formed.

The infra-red spectrum above is of ...........................................................................................................

because .............................................................................................................................................
.........................................................................................................................................................
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[Total 3 marks]

11. Citronellol, C$_{10}$H$_{20}$O, occurs naturally in both rose and geranium oils. The structural and skeletal formulae of citronellol are shown below.

![Structural and skeletal formulae](image)

(a) Name the **two** functional groups present in citronellol.

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[2]
(b) The functional groups in citronellol can be identified either by chemical tests or by infrared spectroscopy.

(i) State which of the two functional groups you named in (a) is:

1. identified when bromine is added to citronellol, .........................
2. more easily identified from the infra-red spectrum. ......................

(ii) State what you would see when bromine is added to citronellol.

................................................................................................................

(iii) Draw the skeletal formula of the organic product formed when bromine is added to citronellol.

(iv) The infra-red spectrum of citronellol is shown below. Mark on this spectrum, with the letter X, the absorption that confirms the presence of the functional group that is most easily identified from this spectrum.

![Infra-red spectrum of citronellol](image-url)
(c) Reaction of a sample of citronellol, C\textsubscript{10}H\textsubscript{20}O, with hydrogen in the presence of a catalyst results in the formation of a saturated compound C.

(i) Suggest a catalyst for this reaction.

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

(ii) Determine the molecular formula of the saturated compound C.

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

(iii) Construct a balanced equation for this reaction.

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

[Total 9 marks]

12. Lavandulol, C\textsubscript{10}H\textsubscript{18}O, is a fragrant oil which is found in lavender. The structural and the skeletal formulae of lavandulol are shown below.

\begin{center}
\textbf{structural formula} \hspace{1cm} \textbf{skeletal formula}
\end{center}

(a) (i) Identify two different functional groups in lavandulol.

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

(ii) Why does lavandulol not have cis-trans isomerism?

................................................................................................................................. [1]
(b) Lavandulol, C\textsubscript{10}H\textsubscript{18}O, also reacts with bromine to form a saturated organic product.

State what you would see in this reaction and deduce the molecular formula of the organic product.

observation ........................................................................................................ [1]

molecular formula ............................................................................................ [2]

(c) Lavandulol could be converted into an ester $\text{X}$, which is also found in lavender oil.

酯 $\text{X}$

State a reagent and a catalyst that could be used to form ester $\text{X}$ from lavandulol.

reagent ............................................................................................................. [1]

catalyst ............................................................................................................. [1]
(d) Lavandulol can be oxidised to produce either compound Y or compound Z.

![Chemical structures of lavandulol, compound Y, and compound Z](image)

(i) Write a balanced equation for the oxidation of lavandulol to produce compound Z. Use the molecular formulae given above and use \([\text{O}]\) to represent the oxidising agent.

................................................................................................................

[2]

(ii) An infra-red spectrum of either compound Y or compound Z was obtained and was found to contain an absorption between 1680 – 1750 cm\(^{-1}\). However, there was no broad absorption between 2500 – 3300 cm\(^{-1}\).

By referring to your Data Sheet, use this information to deduce whether the infra-red spectrum was of compound Y or of compound Z. Show your reasoning.

The infra-red spectrum was of compound .......... because ............... 

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................................................................................................................

[2]

[Total 12 marks]