1. Which volume of oxygen gas, at room temperature and pressure, is required for complete combustion of 1.25×10^{-3} mol of propan-1-ol?

A. 105 cm^3
B. 120 cm^3
C. 135 cm^3
D. 120 cm^3

Your answer ☐

[1]

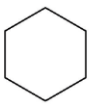
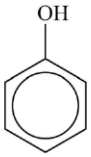
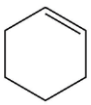
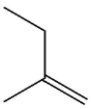
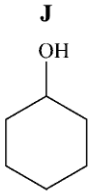
2. Which alcohol will **not** react with potassium dichromate(VI) in sulfuric acid?

A. $CH_3CH_2CH(OH)CH_2CH_3$
B. $CH_3CH_2CH(CH_3)CH_2OH$
C. $(CH_3)_2CHCH(CH_3)OH$
D. $(CH_3CH_2)_2C(CH_3)OH$

Your answer ☐

[1]

3(a). The organic compounds in the table below can be termed, aliphatic, alicyclic or aromatic.

E	**F**	**G**
		
H	**I**	**J**
		

Identify, using letters **E**, **F**, **G**, **H**, **I**, **J**, the compound(s) which are the following types.

Each response may contain more than one letter.

aliphatic .....

alicyclic .....

aromatic .....

[3]

(b). Compound **I** has one alkyl group.

What is the general formula of alkyl groups?

[1]

(c). Compound **H** can be prepared in an elimination reaction by heating compound **J** with an acid catalyst.

A student carries out this preparation using 7.65 g of compound **J**.

The student obtains 2.05 g of compound **H**.

i. Write an equation for this reaction, using molecular formulae.

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

Give your answer to **one** decimal place.

percentage yield = ... % **[4]**

ii. Describe a simple test that the student could carry out to confirm the presence of the functional group in compound **H**.

Draw the structure of the organic product from the test.

test: ----------

organic product =

[2]

4. * You are provided with three alcohols that are structural isomers: $CH_3CH_2CH_2CH_2OH$, $CH_3CH_2CHOHCH_3$ and $(CH_3)_3COH$. You do not know which is which.

You have access to normal laboratory apparatus and chemicals, Quickfit apparatus, and an infrared spectrometer.

Describe a plan that would allow you to identify the three alcohols using the same experimental set up and method.

You should provide

- equations using structural formulae for any reactions
- a description of how you will identify the three alcohols from any observations and results.

[6]

5. Molecules with more than one functional group are useful chemical 'building blocks'.

Compound **D**, $CH_3CH(OH)CH_2NH_2$, is an intermediate in the synthesis of a variety of drugs.

i. Compound **D** can be synthesised from ethanal, CH_3CHO.

Devise a **two-step** synthesis of compound **D** from ethanal.

- Give details of appropriate reagents and relevant conditions.
- Write an equation for each step, showing clearly all organic compounds.

[4]

ii. Explain why compound **D** is very soluble in water.

Use a diagram in your answer.

[3]

iii. Compound **D** reacts with propanedioic acid, $HOOCCH_2COOH$, to form a condensation polymer.

Draw a possible repeat unit of this condensation polymer.

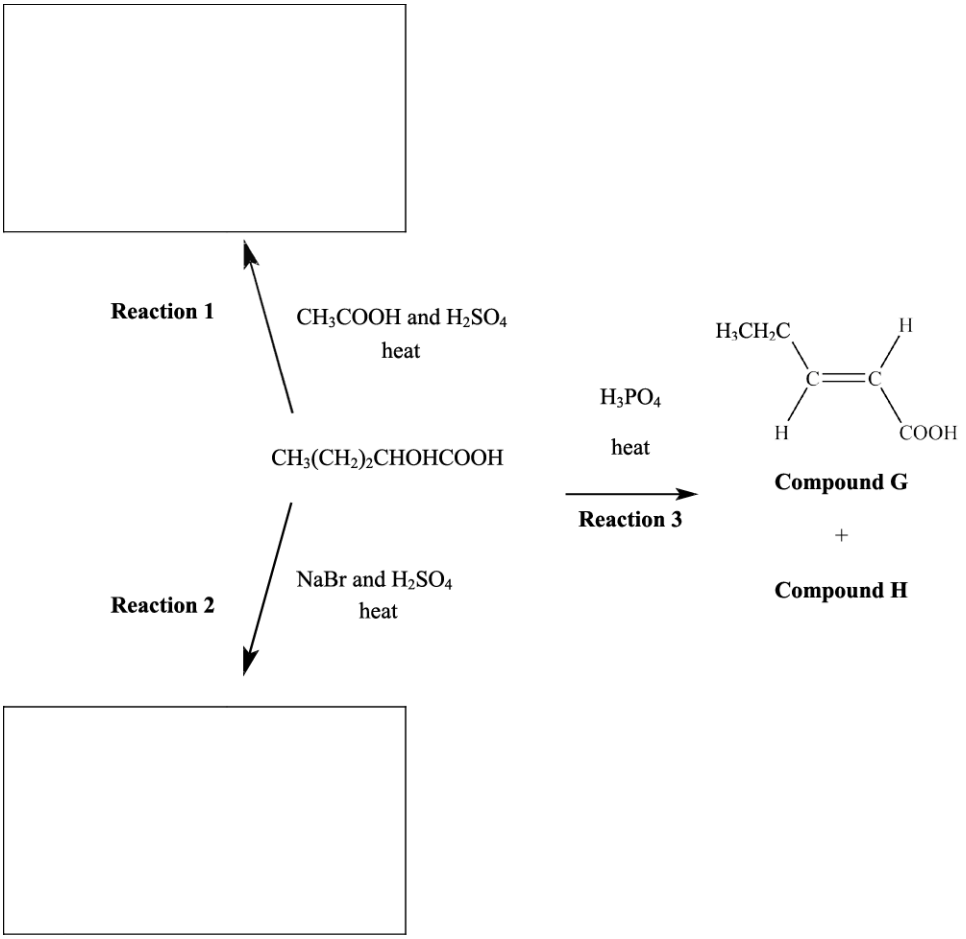
Show clearly any functional group present in the repeat unit.

[2]

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

The flowchart below shows some reactions of an AHA, $CH_3(CH_2)_2CHOHCOOH$.

i. Fill in the boxes to show the organic products of **Reactions 1** and **2**, clearly showing the relevant functional groups.



[2]

ii. Give the **full** systematic name for compound **G**.

[1]

iii. Compound **H** is a stereoisomer of compound **G**.
- Suggest a structure for compound **H**.
- Draw the repeat unit of the addition polymer that can be formed from compound **H**.

Compound H	addition polymer

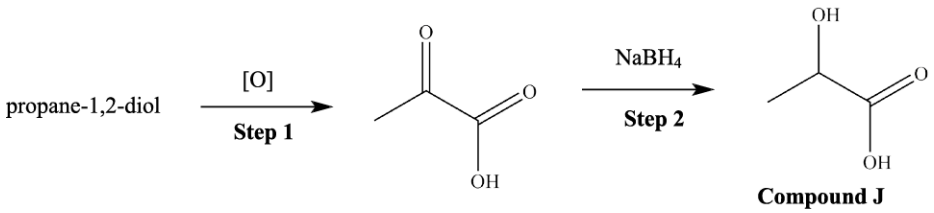
[2]

iv. The addition polymer in (**iii**) is used widely in industry. Increasingly, waste polymers are being processed as a more sustainable option than disposal.

Apart from recycling, state **two** methods for usefully processing waste polymers.

[2]

(b). 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 $[BH_4]^-$.

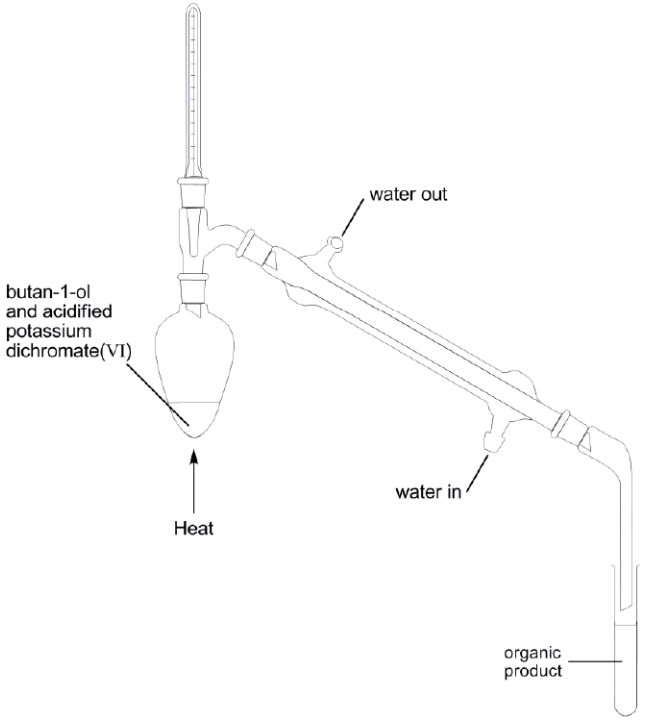
Draw a '*dot-and-cross*' diagram of $NaBH_4$ and give the **full** electron configuration of Na^+.

Show outer shells of electrons only.

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

[2]

7. Butan-1-ol is reacted with acidified potassium dichromate(VI) using the apparatus shown below.



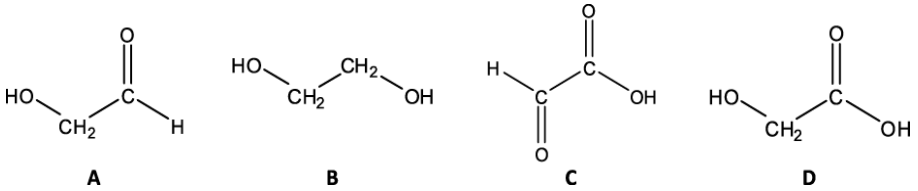
What is the organic product of this reaction?

A. But-1-ene
B. Butanone
C. Butanal
D. Butanoic acid

Your answer ☐

[1]

8. Which molecule is the most soluble in water?



Your answer ☐

[1]

9. This question is about alkenes.

When alcohol **A** is heated with an acid catalyst, a reaction takes place forming alkene **B**.

The equation for this reaction is shown below as **Equation 16.1**.

$CH_3CH(CH_3)CH_2CHOHCH_3 \rightarrow CH_3CH(CH_3)CHCHCH_3 + H_2O$ **Equation 16.1**

alcohol A **alkene B**

i. State the type of reaction in **Equation 16.1**.

[1]

ii. Alkene **B** has two stereoisomers.

Explain what is meant by the term *stereoisomers*, and draw the **skeletal** formulae of the two stereoisomers of alkene **B**.

[3]

iii. The reaction of **A** with an acid catalyst also forms another alkene, **C**.

Alkene **C** is a structural isomer of alkene **B**.

Suggest the structure of alkene **C**.

[1]

iv. * A student carries out the reaction in **Equation 16.1** using 9.26 g of alcohol **A**.

The student obtains a liquid reaction mixture containing a mixture of organic products and the acid catalyst.

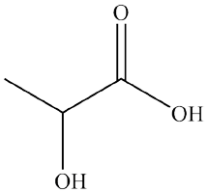
The student purifies the reaction mixture to obtain the liquid alkene **B** with a percentage yield of 75.0%.

Describe a method to obtain a pure, dry sample of alkene **B** from the reaction mixture and calculate the mass of alkene **B** that the student produced.

[6]

10. This question is about organic acids.

Lactic acid, shown below, has two functional groups.



Lactic acid reacts with bases and with many metals.

- An aqueous solution containing 1.125 g of lactic acid is reacted with an excess of magnesium producing hydrogen gas.
- The excess magnesium is removed.
  The water is evaporated, leaving a white solid, **A**.

i. Name the type of reaction of lactic acid with bases and with metals.

reaction with bases:

reaction with metals:

[1]

ii. Calculate the volume of $H_2(g)$ produced, measured at room temperature and pressure.

volume of H_2 = ... **[2]**

i. What is the empirical formula of the white solid **A**?

[1]

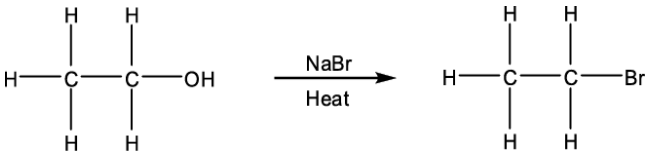
ii. Predict **two** reactions of lactic acid, each involving a different functional group.

Do **not** include reactions with bases or metals.

For each reaction,
- state the type of reaction, the reagents and conditions
- draw the structures of any organic products formed.

[4]

11. Bromoethane can be prepared by heating ethanol with NaBr.



What are the conditions for this reaction?

A. Acid catalyst
B. Ultraviolet radiation
C. Halogen carrier
D. Nickel catalyst

Your answer ☐

[1]

12(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]

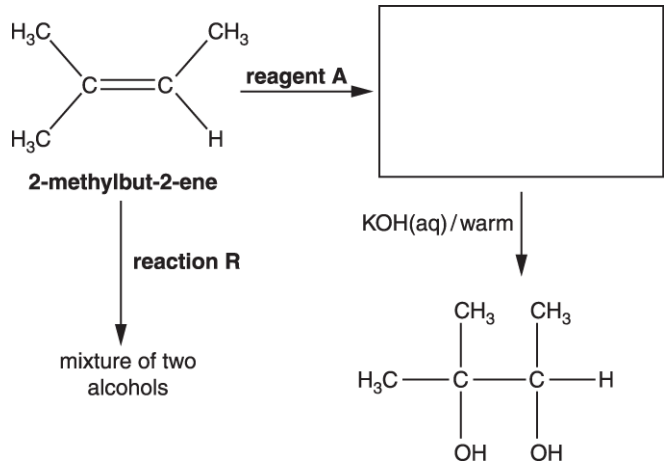
(b). Explain, with reference to a suitable chemical test, how compound **J** could be identified.

Your answer should **not** include spectroscopy.

[3]

13(a). The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

Complete the flowchart by drawing an organic structure in the box below.



[1]

(b). Identify reagent **A**.

[1]

(c). In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

i. State the reagents and conditions needed for **reaction R**.

[1]

ii. What is meant by the term *structural isomers*?

[1]

iii. Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

[2]

iv. Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

[2]

(d). Describe the oxidation reactions of propan-1-ol when using a suitable oxidising agent.

Indicate how the use of different reaction conditions can control which organic product forms.

Include reagents, observations and equations in your answer.

In your equations, use structural formulae and use [O] to represent the oxidising agent.

[6]

14. Compound **B**, C_xH_yO, can be oxidised to form a ketone **C**.

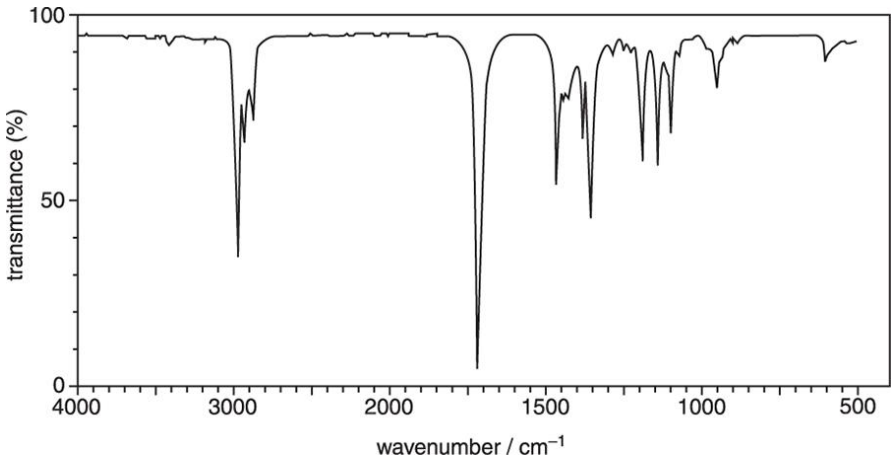
0.035 mol of **B** has a mass of 2.59 g.

Compound **B** reacts with compound **D**, $C_3H_6O_2$, in the presence of an acid catalyst to form two compounds **E** and **F**.

- Calculate the molar mass of compound **B**.
- Give the structures of compounds **B**, **C**, **D**, **E** and **F**.

[6]

15(a). The branched-chain alcohol **J**, $C_5H_{12}O$, was heated under reflux with excess H_2SO_4 / $K_2Cr_2O_7$ to form an organic compound **K** with the infrared spectrum below.



- Determine the structures for the branched-chain alcohol **J** and compound **K**.
  Your answer should explain all your reasoning using the evidence given.
- Write an equation for the reaction of **J** when heated under reflux with excess H_2SO_4 / $K_2Cr_2O_7$ to form **K**.
  Use [O] to represent the oxidising agent.

Your answer needs to be clear and well organised using the correct terminology.

[6]

(b). The alcohol **J** is soluble in water.

Explain why alcohol **J** is soluble in water.

Use a labelled diagram to support your answer.

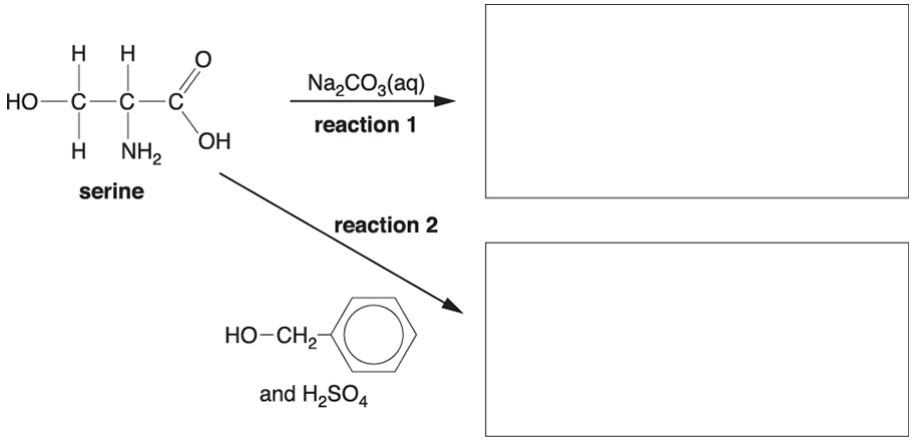
Include relevant dipoles and lone pairs.

[1]

16. Many α-amino acids have several functional groups.

Serine, shown below, is a naturally occurring α-amino acid.

i. In the boxes below, draw the structure of the organic compounds formed by each reaction.



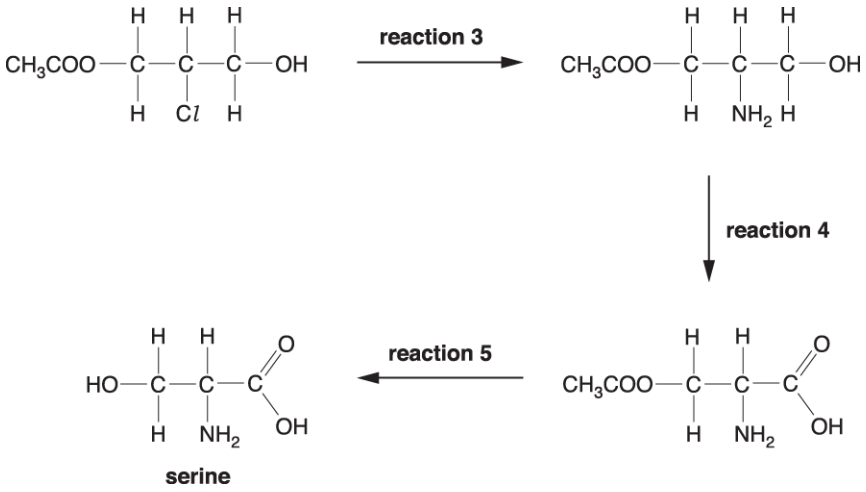
[3]

ii. Suggest a use for the organic compound formed by **reaction 2**.

[1]

iii. Serine is commonly used in organic synthesis.

One possible method of synthesising serine is shown below.



Complete the following:

Reagent and conditions used for **reaction 3**.

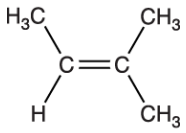
Type of reaction for:

reaction 4 .....

reaction 5 .....

[3]

17. Compound **A** is an alkene.



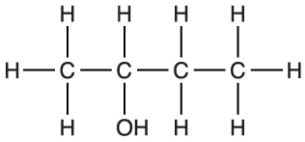
compound **A**

Compound **A** can be made from alcohol **B** by heating with an acid catalyst.

Suggest **two** possible structures for alcohol **B** .

[2]

18(a). This question is about the properties and reactions of butan-2-ol.



Some properties of butan-2-ol are listed in the table.

Melting point	−115 °C
Boiling point	99.5 °C

Why is butan-2-ol classified as a secondary alcohol?

[1]

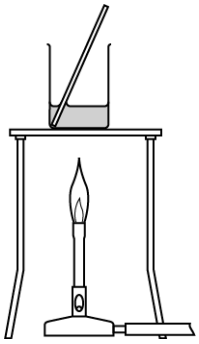
(b). Butan-2-ol can be oxidised by heating with an oxidising agent.

i. Write an equation for the reaction.

Use [O] to represent the oxidising agent and show the structure of the organic product.

[2]

ii. A student plans to carry out this oxidation using the apparatus shown in the diagram.

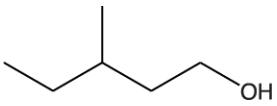


Give **one** reason why the apparatus is **not** suitable and describe a more suitable way of carrying out this oxidation.

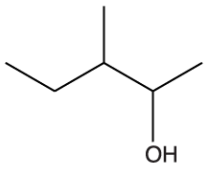
[2]

19. Which alcohol can be oxidised by $K_2Cr_2O_7$ and H_2SO_4 to form a ketone?

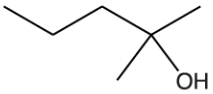
A



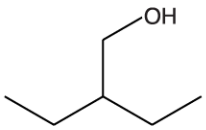
B



C



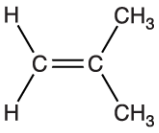
D



Your answer ☐

[1]

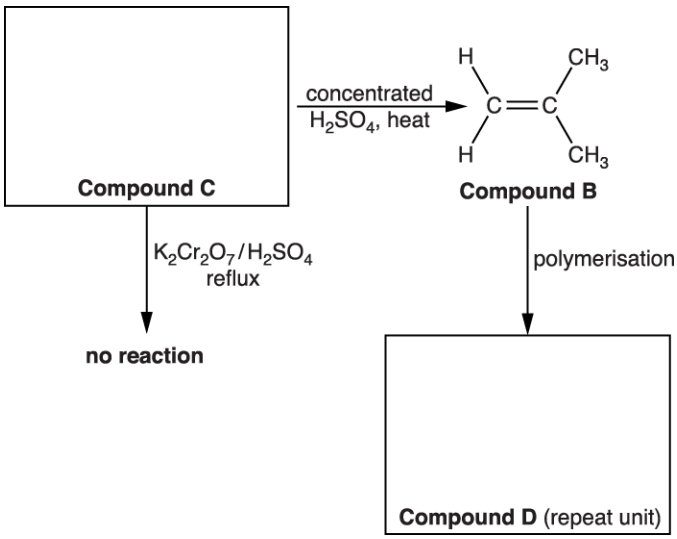
20. Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



Compound B

Some reactions involving compound **B** are shown in the flowchart below.

Complete the flowchart, showing the structures of organic compounds **C** and **D**.



[2]

21(a). At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

[2]

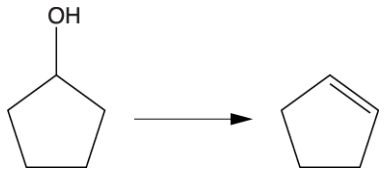
(b). The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

Alcohol	Boiling point / °C
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different.

[2]

(c). Alkenes can be prepared from alcohols. Cyclopentene can be prepared from cyclopentanol as shown in the equation below.



A student plans to prepare 5.00 g of cyclopentene from cyclopentanol. The percentage yield of this reaction is 45.0%.

i. What is the name of this type of reaction?

[1]

ii. Calculate the mass of cyclopentanol that the student should use.

Show your working.

mass of cyclopentanol = ... g **[3]**

22(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 .....

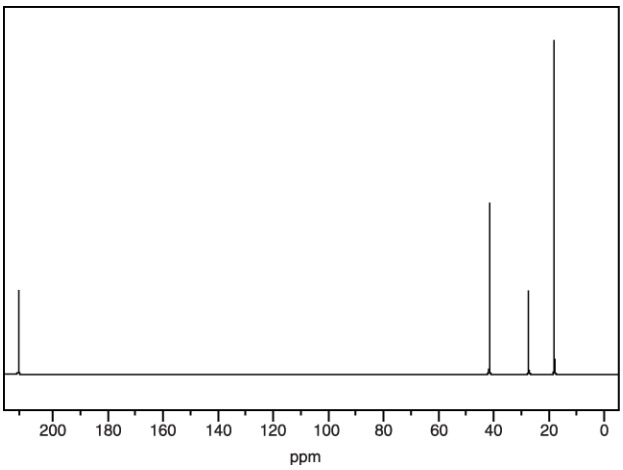
[2]

(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

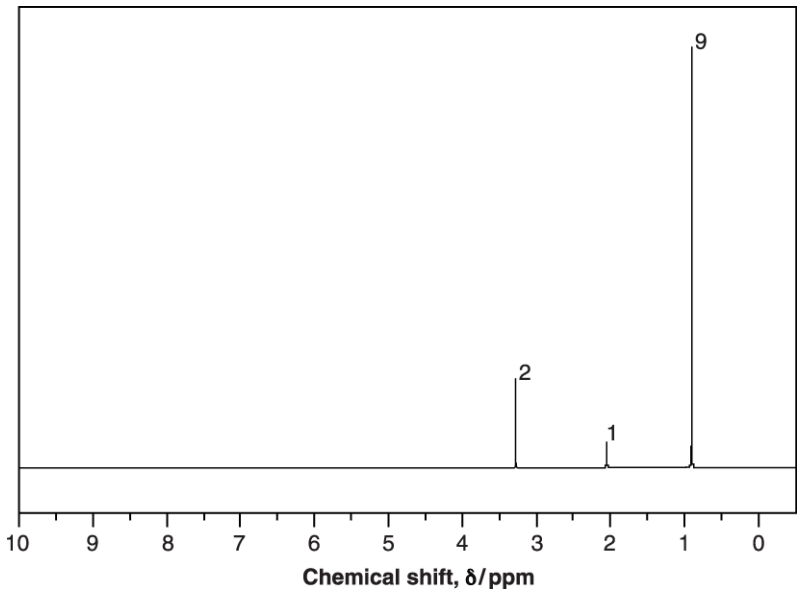
I

[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.

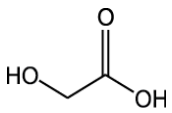


Identify compound **J** and draw its structure in the box below.

J

[1]

23. The compound shown below reacts with a mixture of NaBr and H_2SO_4.



What is the relative molecular mass of the organic product?

A 138.9

B 155.9

C 201.8

D 235.8

Your answer ☐

[1]

24. A student plans the two-step synthesis below.

$HOCH_2CH=CHCH_2OH$ → **intermediate** → $HOOCCH_2COCOOH$

Which compound could be the student's intermediate?

A $HOOCCH=CHCOOH$

B $HOCH_2CH_2CHICOOH$

C $HOCH_2CH_2CH(OH)CH_2OH$

D $HOCH_2CH(OH)CH(OH)CH_2OH$

Your answer ☐

[1]

25. *Five compounds **B**–**F** have the boiling points shown below.

Compound	Boiling point / °C
B	−12
C	0
D	35
E	48
F	97

The structural formulae of compounds **B**–**F** are shown below in no particular order.

$CH_3CH_2CH_2CH_3$, $CH_3CH_2CH_2NH_2$, $CH_3CH_2CH_2OH$, $CH_3CH(CH_3)CH_3$, $CH_3CHC/\ CH_3$

Using this information, identify compounds **B**–**F**.

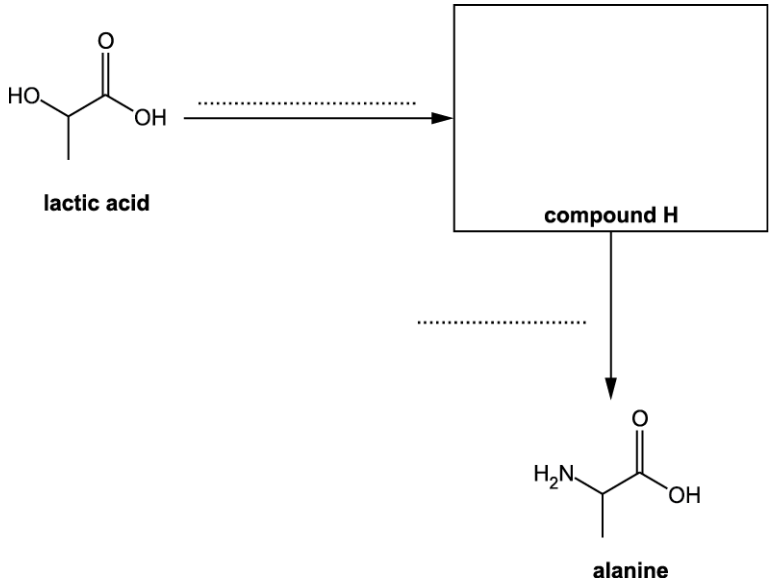
Explain your reasoning.

[6]

26. A student plans a two-stage synthesis of alanine from lactic acid, $CH_3CH(OH)COOH$.

The synthesis first prepared compound **H**, as shown in the flowchart.

Draw the structure of compound **H** in the box and add the formulae of the reagents for each stage on the dotted lines.

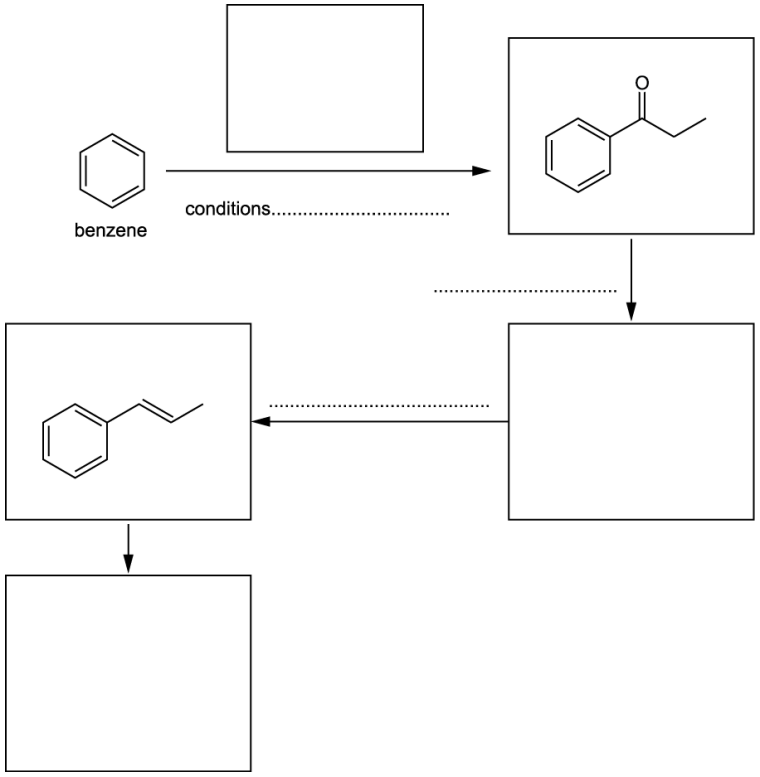


[3]

27(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]

28(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.

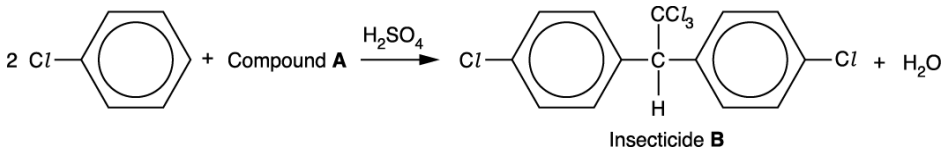
Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

[5]

29. Concentrated sulfuric acid is often used to catalyse organic reactions.

An insecticide, **B**, can be made by the reaction below, using H_2SO_4 as a catalyst.



Insecticide **B**

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

[1]

ii. Sulfuric acid is a catalyst in many reactions.

State **one** other example of an organic reaction in which sulfuric acid is a catalyst.

[1]

30. Which alcohol reacts with an acid catalyst to form *E* and *Z* stereoisomers?

A pentan-3-ol

B pentan-1-ol

C 2-methylbutan-2-ol

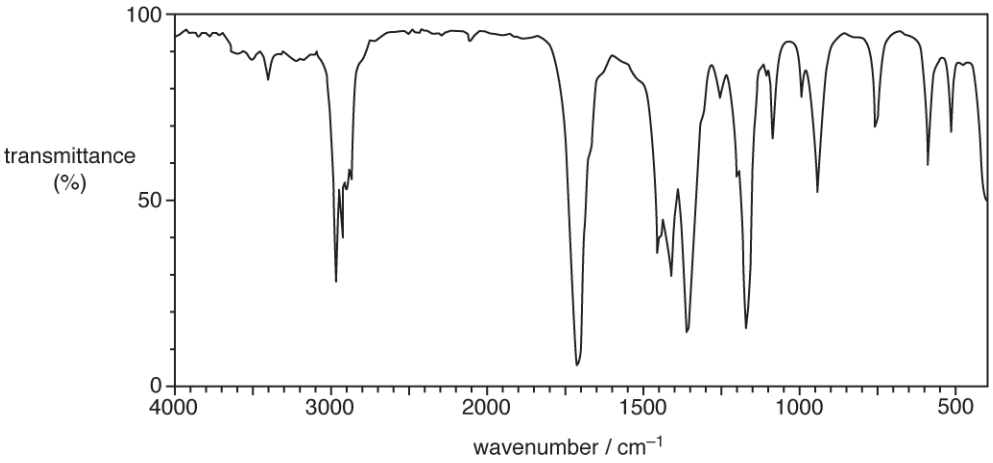
D 2,2-dimethylpropan-1-ol

Your answer ☐

[1]

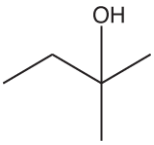
31. An alcohol **A** is heated under reflux with sulfuric acid and potassium dichromate(VI).

The organic compound formed produces the infrared spectrum below.

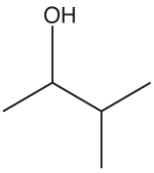


Which compound could be alcohol **A**?

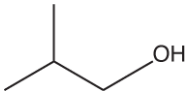
A



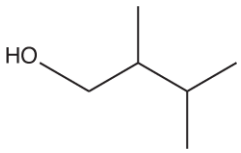
B



C



D



Your answer ☐

[1]

32(a). This question is about alcohols.

Construct an equation for the complete combustion of an unsaturated alcohol with 5 carbon atoms.

[1]

(b). Many alcohols, including ethanol, are soluble in water.

i. Explain, with the aid of a diagram, why ethanol is soluble in water.
Include relevant dipoles and lone pairs.

[2]

ii. The solubility of hexan-1-ol and hexane-1,6-diol in water is shown below in **Table 19.1**.

Alcohol	**Solubility in water / g dm^{-3}**
hexan-1-ol	5.9
hexane-1,6-diol	500

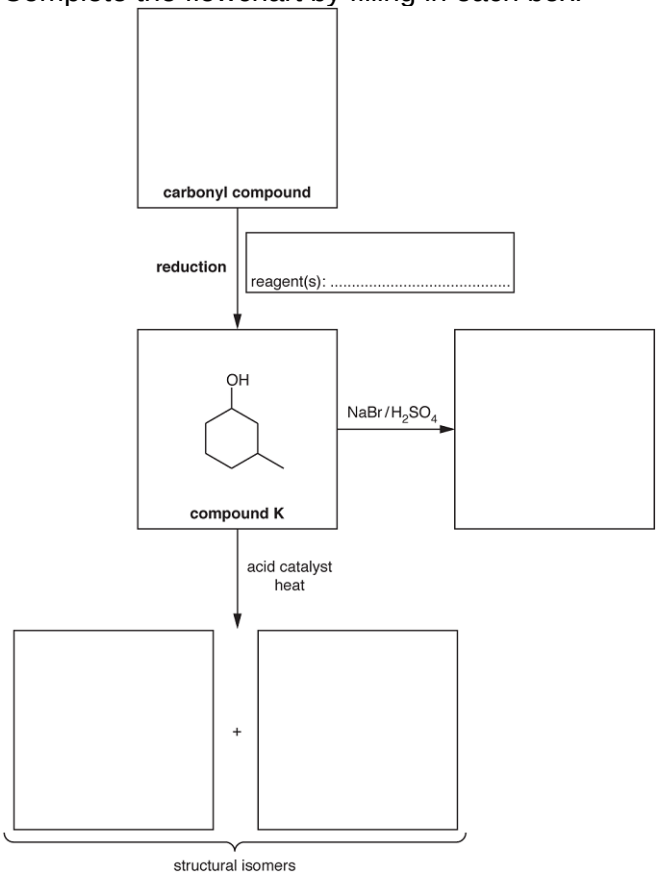
Table 19.1

Explain the difference in solubility of hexan-1-ol and hexane-1,6-diol.

[1]

(c). 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]

(d). Butan-1-ol can be oxidised to form two different organic products, depending on the reaction conditions used.

Describe both oxidation reactions of butan-1-ol.

For each reaction include

- the structure of the organic product
- a balanced equation
- the essential reaction conditions.

In your equations you may use [O] to represent the oxidising agent.

[5]

33(a). The hydroxyl group, –OH, is responsible for many properties of alcohols.

Methanol, CH_3OH, is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges δ+ and δ – to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

[2]

(b). Describe the oxidation reactions of butan-1-ol forming an aldehyde and a carboxylic acid.

Explain, using a diagram, how the aldehyde can be produced in the laboratory by controlling the reaction conditions.

[6]

34. Organic compounds can be prepared in the laboratory using synthetic routes with two or more stages.

A student devises a two-stage synthesis of cyclohexene from bromocyclohexane.

i. Suggest the structure of **intermediate E** and the reagent(s) and conditions for **step 2**.

reagent(s) and conditions

[2]

ii. The student carries out this synthesis and obtains 1.23 g of pure cyclohexene from 5.50 g of bromocyclohexane.

Calculate the percentage yield of cyclohexene.

Give your final answer to an **appropriate** number of significant figures.

percentage yield = ... % **[3]**

35(a). Alcohols can be converted into haloalkanes in a substitution reaction.

Plan an experiment to prepare approximately 0.1 mol of 2-bromopentane, $CH_3CHBrCH_2CH_2CH_3$, from pentan-2-ol, $CH_3CH(OH)CH_2CH_2CH_3$.

Your plan should include a calculation of the mass of alcohol required and details of the chemicals to be used in the reaction.

[2]

(b). * Alcohols can be converted into alkenes in an elimination reaction.

The elimination of H_2O from pentan-2-ol forms a mixture of organic products.

Give the names and structures of all the organic products in the mixture.

Your answer should explain how the reaction leads to the different isomers.

[6]

36.

1-Bromobutane is an organic liquid with a boiling point of 102 °C.

A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.

The equation is shown below.

$$CH_3CH_2CH_2CH_2OH + H^+ + Br^- \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm^{-3}) and an aqueous layer (density = 1.00 g cm^{-3}).

i. * Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.

[6]

ii. The student used 0.150 mol of butan-1-ol. The student obtained a 61.4% percentage yield of 1-bromobutane.

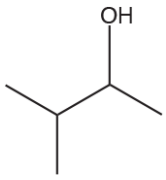
Calculate the mass of 1-bromobutane obtained.

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

mass = g **[2]**

37(a). This question is about reactions of organic compounds containing carbon, hydrogen and oxygen.

A chemist investigates two reactions of alcohol **A**, shown below.



alcohol A

i. What is the systematic name of alcohol **A**?

[1]

ii. What is the structural formula of alcohol **A**?

[1]

iii. The chemist heats alcohol **A** with an acid catalyst to form a mixture containing **two** alkenes.

Draw the structures of the **two** alkenes formed in this reaction.

[2]

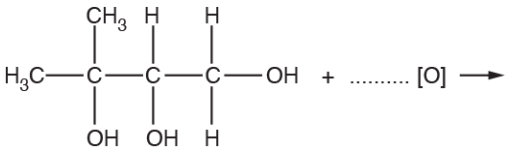
iv. The chemist heats alcohol **A** with sodium chloride and sulfuric acid.

Construct a balanced equation for this reaction.
Show structures for the organic compounds in your equation.

[2]

(b). Compound **B**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product.

Complete the equation for this reaction.



compound B

[2]

38. The relative molecular masses and boiling points of some fuels are shown in **Table 22.1**.

Fuel	Relative molecular mass	Boiling point / °C
hexane	86	69
pentan-1-ol	88	138
heptane	100	98

Table 22.1

Explain the difference in the boiling points of the fuels in **Table 22.1**.

[4]

39. This question is about reactions involving alcohols.

Three reactions of an alcohol **E** are shown in **Fig. 25.1**.

i. Complete **Fig. 25.1** to show the structures of the organic products formed in the reactions.

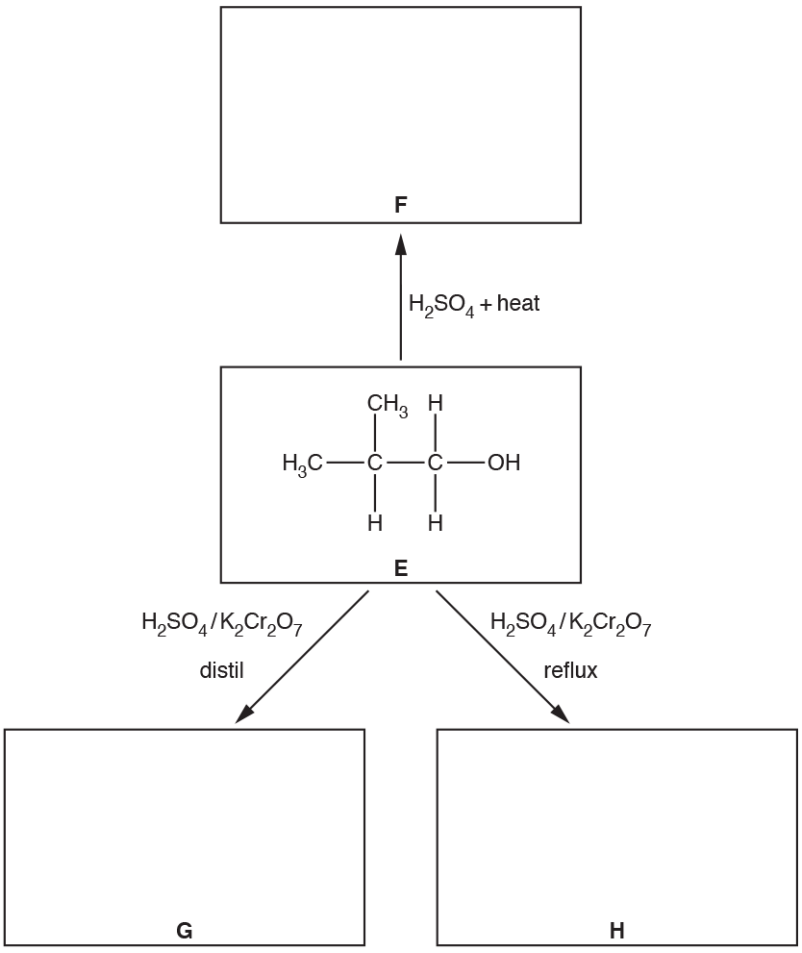


Fig. 25.1

[3]

ii. What is the systematic name of alcohol **E**?

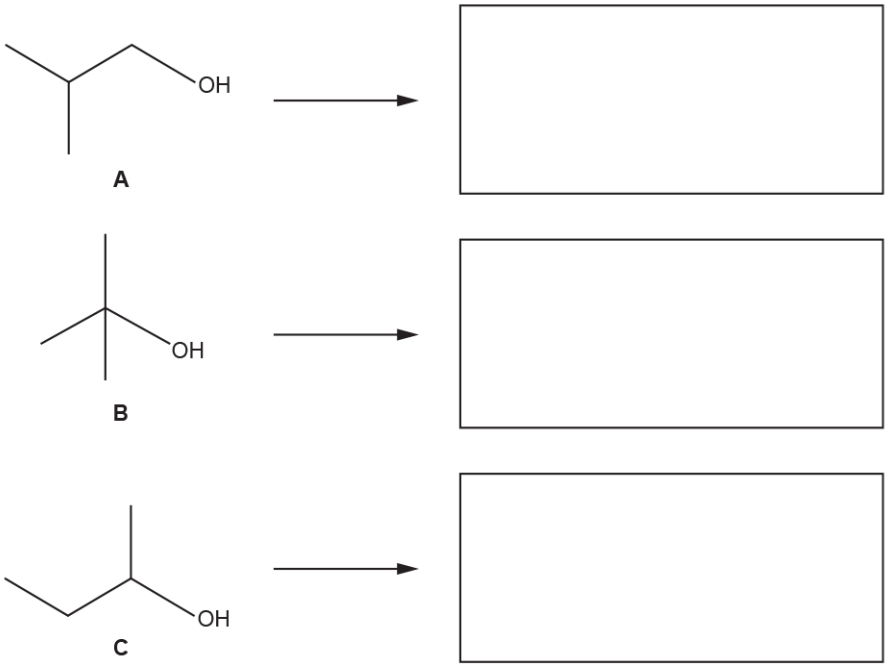
[1]

40. This question is about alcohols and alkanes.

Three alcohols **A**, **B** and **C** are structural isomers of $C_4H_{10}O$.

Each alcohol is refluxed with acidified dichromate(VI), $H^+/Cr_2O_7^{2-}$.

i. Draw the structures for the organic products.
If there is no reaction, write **'NONE'**.



[3]

ii. Write the systematic name for alcohol **C**.

[1]

iii. Complete the equation below for the complete combustion of alcohol **A**.

$C_4H_{10}O$ ..... → ..... **[1]**

41.

What are the correct reagents for the conversion below?

$CH_3CH_2CHOHCH_3$ $CH_3CH_2CHBrCH_3$

A Br_2 and H_2SO_4

B Br_2 and NaOH

C NaBr and H_2SO_4

D NaBr and NaOH

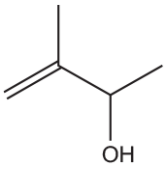
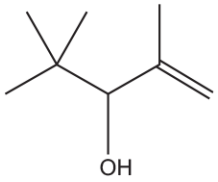
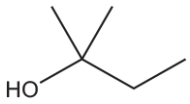
Your answer ☐ **[1]**

42.

Which compound could react with **both**

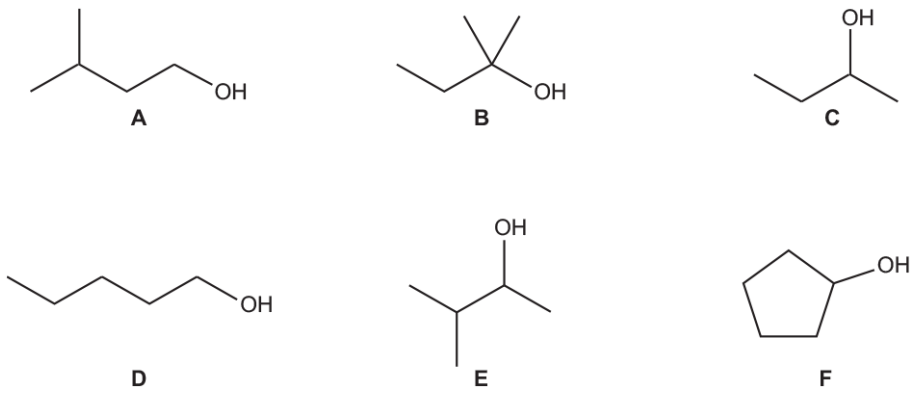
$K_2Cr_2O_7/H_2SO_4$ in an oxidation reaction **and**

an acid catalyst (e.g. H_2SO_4) in an elimination reaction?

A	
B	
C	
D	

Your answer ☐ **[1]**

43(a). This question is about the alcohols **A–F** shown below.



Which of the alcohols **A–F** are secondary alcohols?

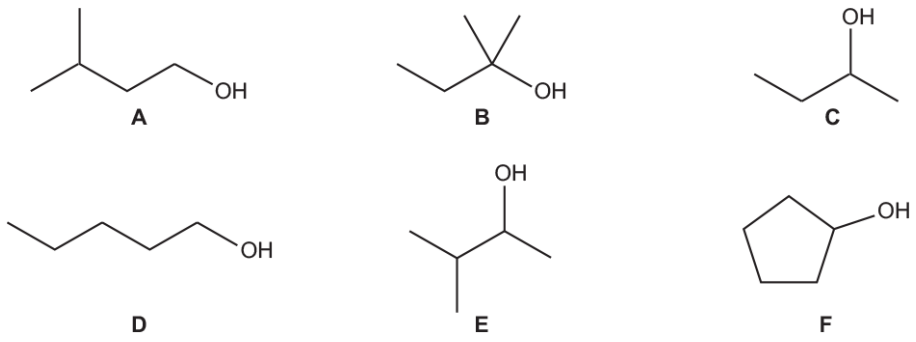
[2]

(b). Complete a balanced equation for the complete combustion of alcohol **C**.

$CH_3CH_2CH(OH)CH_3$ + ... → ..... + ...

[1]

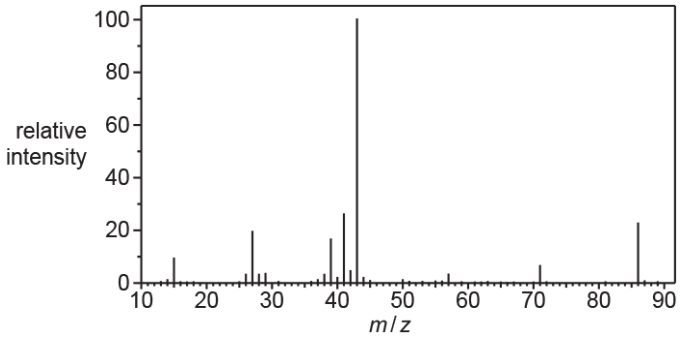
(c). * The structures A–F are repeated below.



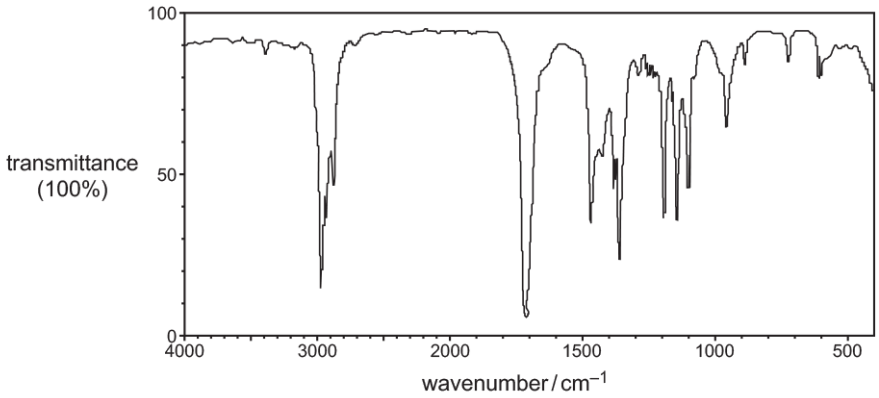
Compound **X** is one of the alcohols **A–F**.

A student refluxes compound **X** with acidified potassium dichromate(VI) as an oxidising agent. A pure sample of the organic product **Y** is obtained from the resulting mixture. The mass spectrum and IR spectrum of **Y** are shown below.

Mass spectrum of Y



IR spectrum of Y



Using this information, identify compound **X** and product **Y**, and write an equation for the formation of product **Y** from compound **X**. You may use [O] to represent the oxidising agent.

In your answer you should make clear how your conclusions are linked to the evidence.

[6]

44. Which of these reagent(s) will **not** react with $HOCH_2CH_2CH_2COOH$?

A NaCN in ethanol

B C_2H_5OH in the presence of an acid catalyst

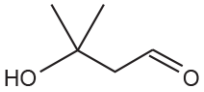
C $(CH_3CO)_2O$

D concentrated H_2SO_4

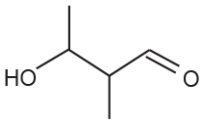
Your answer ☐ **[1]**

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

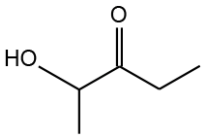
A



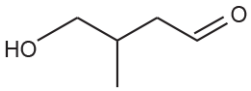
B



C



D



Your answer ☐ **[1]**

46. Which alcohol reacts with an acid catalyst to form a mixture of stereoisomers?

A 3-methylbutan-2-ol

B pentan-1-ol

C 2-methylhexan-2-ol

D heptan-4-ol

Your answer ☐ **[1]**

47. Alcohols can be used to prepare organic compounds with different functional groups.

$HO(CH_2)_4OH$ can be oxidised to form $HOOC(CH_2)_2COOH$.

i. State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions:

Equation:

[3]

ii. $HOOC(CH_2)_2COOH$ is soluble in water.

Explain, using a labelled diagram, why $HOOC(CH_2)_2COOH$ is soluble in water.

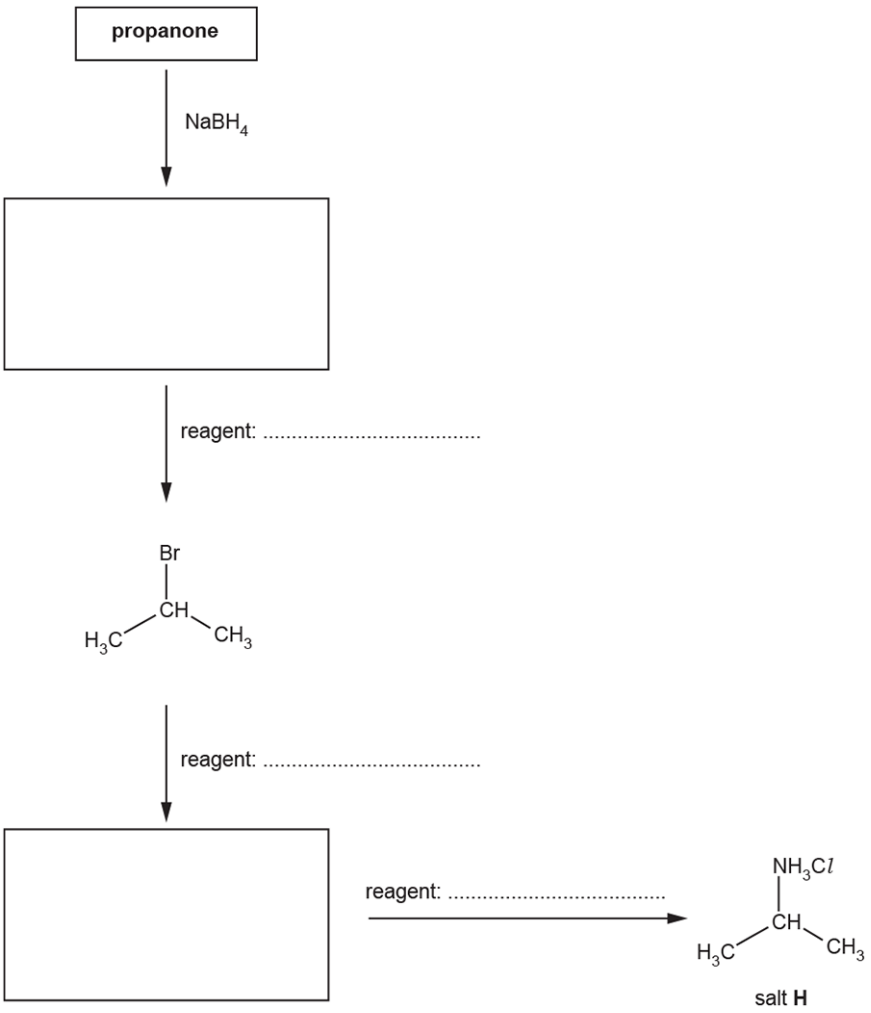
[2]

48. 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]

49(a). 2-Chloro-2-methylpropane, $(CH_3)_3CCl$, is an organic liquid with a boiling point of 50 °C.

A student prepares $(CH_3)_3CCl$ by reacting 2-methylpropan-2-ol, $(CH_3)_3COH$, with concentrated hydrochloric acid.

Write a balanced equation for this reaction.

Use skeletal formulae for organic compounds.

[2]

(b). Compounds **A** and **B** are structural isomers of $(CH_3)_3COH$.

i. Compound **A** is a secondary alcohol.

What is the systematic name of compound **A**?

[1]

ii. Compound **B** is a branched primary alcohol.

Compound **B** is refluxed with acidified potassium dichromate(VI) as an oxidising agent.

Write the equation for the reaction that takes place.

Use structures for organic compounds and [O] for the oxidising agent.

[3]

50. What is the correct equation for the incomplete combustion of butan-1-ol?

A $CH_3CH_2CH_2CH_2OH + 1½O_2 \rightarrow 4CO + 5H_2$

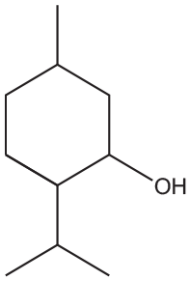
B $CH_3CH_2CH_2CH_2OH + 2O_2 \rightarrow 4CO + 5H_2$

C $CH_3CH_2CH_2CH_2OH + 4O_2 \rightarrow 4CO + 5H_2O$

D $CH_3CH_2CH_2CH_2OH + 4½O_2 \rightarrow 4CO + 5H_2O$

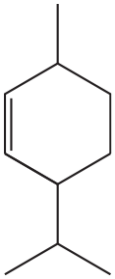
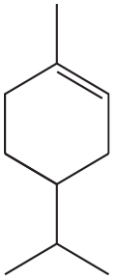
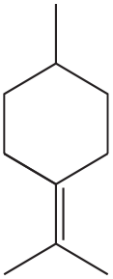
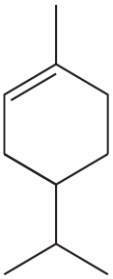
Your answer ☐ **[1]**

51. Menthol, shown below, is heated with an acid catalyst.



menthol

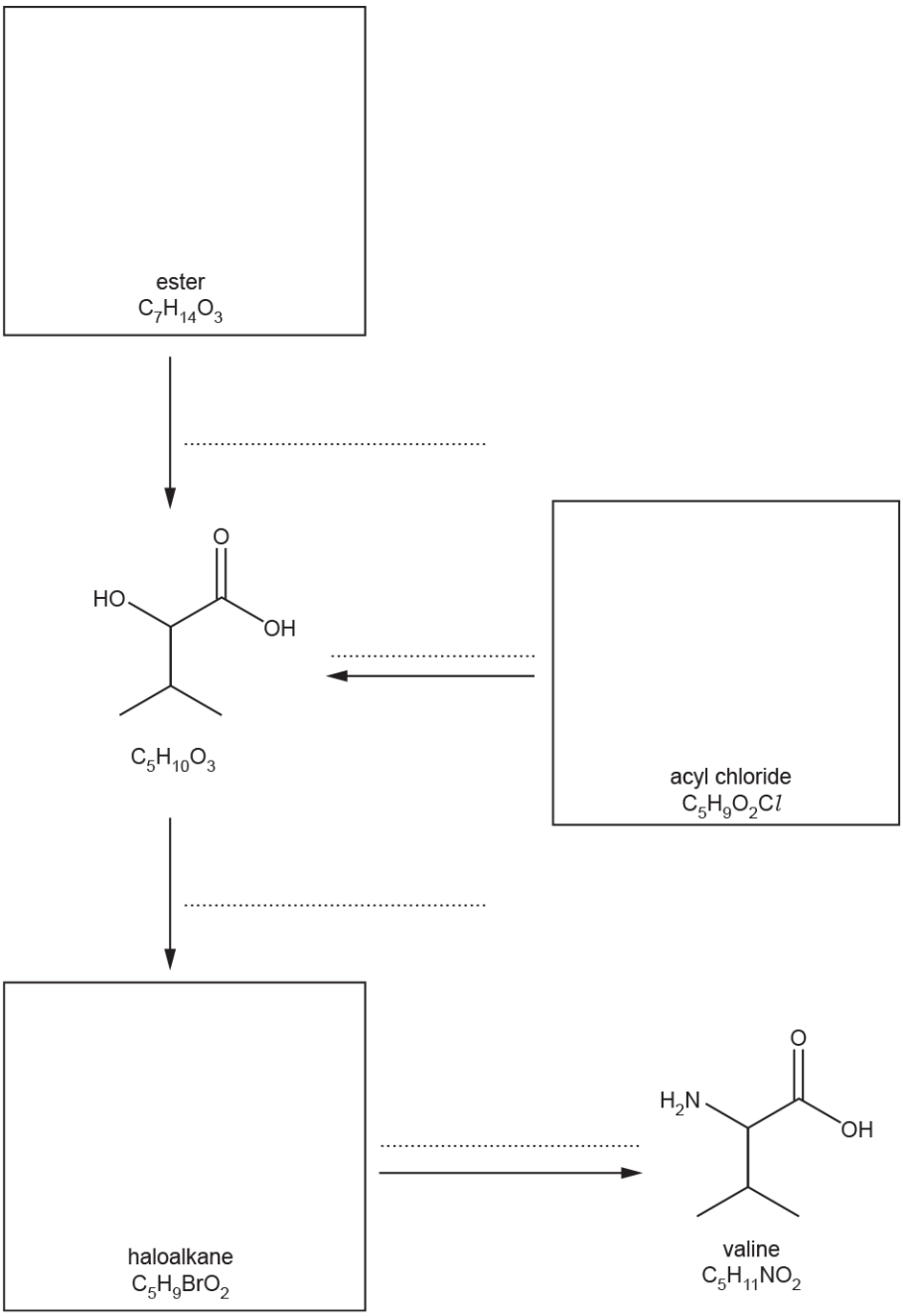
Which structure could be formed?

			
A	**B**	**C**	**D**

Your answer ☐ **[1]**

52. This question is about organic acids.

Complete the flowchart for two synthetic routes to the amino acid valine.



[7]

53. 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

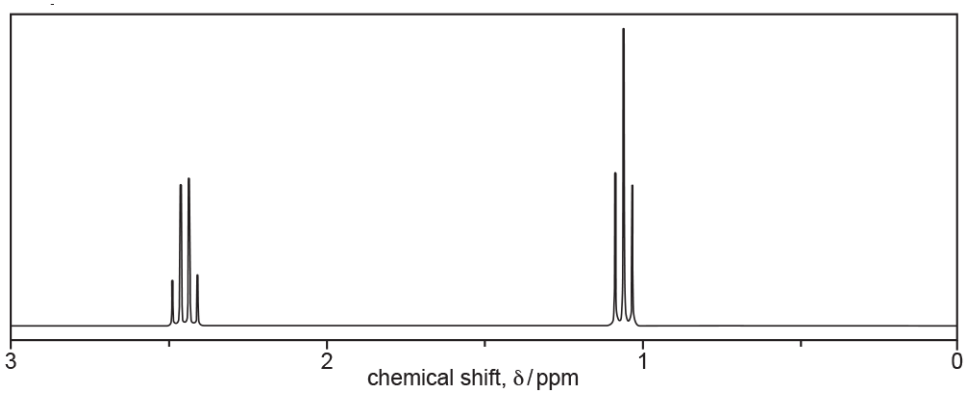
^{13}C NMR spectrum of D

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

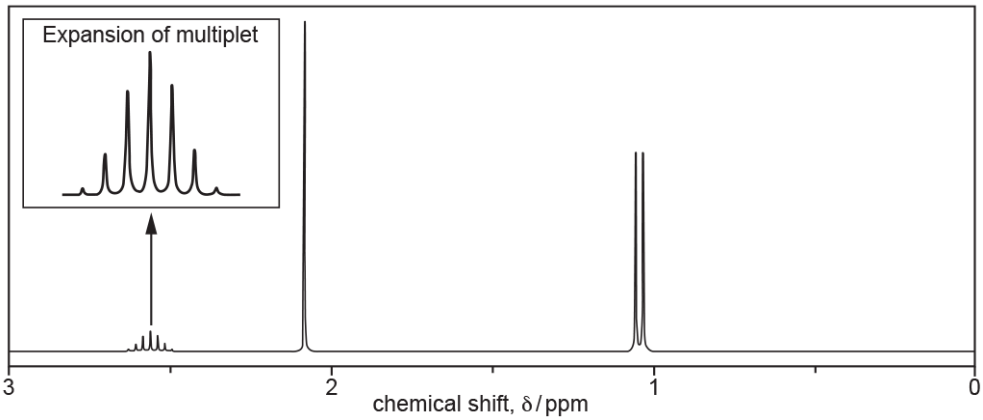
^{1}H NMR spectra of E and F

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]

54. Internal combustion engines have historically used fuels obtained from crude oil as a source of power.

The environmental effects of fossil fuel use can be reduced by blending petrol with biofuels such as ethanol.

A fuel is being developed using a 1:1 molar ratio of octane and ethanol.

i. Write the equation for the complete combustion of this fuel.

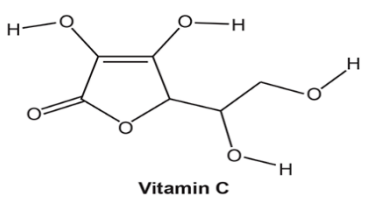
[1]

ii. Calculate the energy released, in kJ, by the complete combustion of 8.00 kg of this fuel.
$\Delta_c H(C_8H_{18})$ = -5470 kJ mol^{-1} ; $\Delta_c H(C_2H_5OH)$ = -1367 kJ mol^{-1}.

energy released = ... kJ **[3]**

55(a). A student carries out an investigation on vitamin C, $C_6H_8O_6$.

The structure of vitamin C is shown below. Vitamin C is an optical isomer.



Vitamin C

What is the total number of optical isomers with the structure of vitamin C?

total number of optical isomers = ... **[1]**

(b). Vitamin C is extremely soluble in water. This means that vitamin C is removed rapidly from the body. 'Vitamin C ester' is available in tablet form as a less soluble source of vitamin C which stays in the body for longer.

i. Suggest why vitamin C is extremely soluble in water.

_____

_____

[1]

ii. A 'vitamin C ester' tablet contains an ester with the molecular formula $C_{22}H_{38}O_7$.

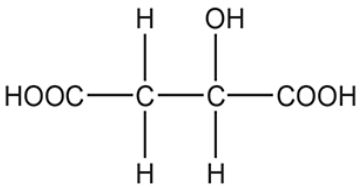
This ester can be prepared by reacting vitamin C with a long chain carboxylic acid, $C_x H_y COOH$, in the presence of an acid catalyst.

Vitamin C and the long chain carboxylic acid react in a 1:1 molar ratio.

Determine *x* and *y* in the formula of this carboxylic acid.

x = ... *y* = ... **[2]**

56. Apple juice contains malic acid which has the following structure.



Malic acid can be oxidised by heating with acidified potassium dichromate(VI).

Write a balanced equation for the reaction, showing the structure of the organic product.

Use [O] to represent the oxidising agent.

[2]

57. 2-Bromobutane, $CH_3CH_2CHBrCH_3$, can be prepared by several different methods.

The relative molecular mass, M_r, of 2-bromobutane is 136.9.

2-Bromobutane can be prepared by reacting butan-2-ol, $CH_3CH_2CHOHCH_3$, with sodium bromide and sulfuric acid (**Reaction 5.3**).

$CH_3CH_2CHOHCH_3 + H^+ + Br^- \rightarrow CH_3CH_2CHBrCH_3 + H_2O$ **Reaction 5.3**

2-Bromobutane is a liquid with a boiling point of 91 °C and does not mix with water.

i. A student plans to prepare 10.0 g of 2-bromobutane using **Reaction 5.3**.

The percentage yield is 67.0%.

Calculate the mass of $CH_3CH_2CHOHCH_3$ needed for this preparation.

Give your answer to **3** significant figures.

mass = ... g **[3]**

ii. The student mixes butan-2-ol, sodium bromide and sulfuric acid in a pear-shaped flask, and refluxes the mixture.

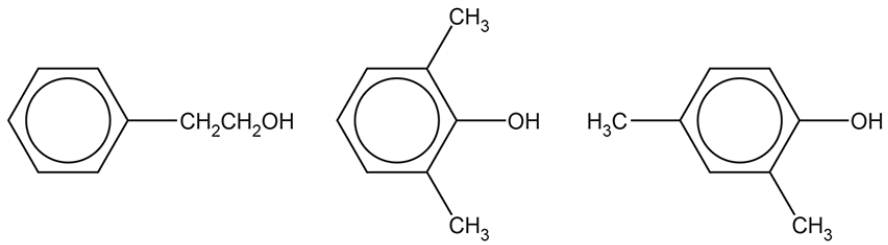
After 1 hour, the mixture in the flask has separated into two layers: an aqueous layer and an organic layer.

Describe the procedures the student would need to carry out to obtain a pure, dry sample of 2-bromobutane from this mixture.

[3]

58(a). This question is about the chemistry of aromatic compounds.

Compounds **J**, **K** and **L**, shown below, are structural isomers.



Compound J **Compound K** **Compound L**

Compound **J**, $C_6H_5CH_2CH_2OH$, is reacted with acidified potassium dichromate(VI) under reflux to form organic product **M**.

Write an equation for this reaction. Use [O] to represent the oxidising agent and show the structure of **M**.

[2]

(b). 1-phenylethanol is a naturally occurring compound found in many vegetables and flowers.

1-phenylethanol can be synthesised from 2-phenylethanol in two stages.

2-phenylethanol 1-phenylethanol

Suggest reagents, conditions and equations for each stage in the synthesis.

Show structures for organic compounds.

Stage 1

reagents and conditions .....

equation:

Stage 2

reagents and conditions .....

equation:

[4]

59. Information about 1-bromobutane and butan-1-ol is shown in the table.

Compound	Melting point /°C	Boiling point / °C	Density / g cm^{-3}
1-bromobutane	-113	102	1.268
butan-1-ol	-90	118	0.810

A student prepares a sample of 1-bromobutane by refluxing 9.25 g of butan-1-ol with sodium bromide and sulfuric acid.

After reflux, the reaction mixture is purified.

The student obtains 6.10 cm^3 of pure 1-bromobutane.

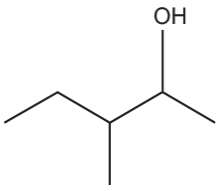
***** Draw a diagram to show how the student would have carried out the reflux and calculate the percentage yield of 1-bromobutane that the student obtains.

Describe how the student could have obtained pure 1-bromobutane from the reaction mixture obtained after reflux.

[6]

60(a). This question is about alkenes.

A mixture of alkenes is produced when water is eliminated from alcohol **A**.



Alcohol A

i. What is the systematic name of alcohol **A**?

[1]

ii. Alcohol **A** is refluxed with an acid catalyst.

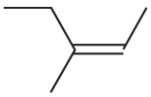
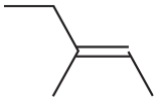
- A mixture of alkene isomers **B**, **C** and **D** is formed.
- Alkenes **B** and **C** show *E*/*Z* isomerism but alkene **D** does not.

Construct the equation for the formation of alkene **D** from alcohol **A**.

Show the structure of the organic product.

[2]

iii. The skeletal formulae of alkenes **B** and **C** are shown below.

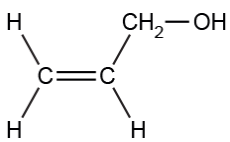
	Alkene B	**Alkene C**
Skeletal formula		
Isomer	*Z*	*E*

Use the Cahn-Ingold-Prelog priority rules to explain why alkene **B** is the *Z* isomer.

[2]

(b). A chemistry company is developing water-soluble polymers.

The chemists decide to use compound **E**, shown below, as the monomer.



Compound E

i. Draw a section of the polymer formed, showing **two** repeat units, and suggest why this polymer is likely to be soluble in water.

Section of polymer (**two** repeat units)

Reason for solubility in water

[2]

ii. Outline **two** ways that waste hydrocarbon polymers can be processed usefully, rather than being disposed of in landfill sites.

1

2

[2]

61(a). This question is about alcohols.

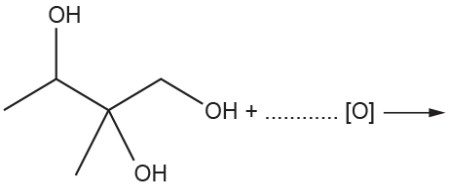
An **unsaturated** alcohol has 6 carbon atoms and contains **one** C=C bond.

Construct an equation for the complete combustion of this alcohol.

[2]

(b). Compound **C**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product and one other product.

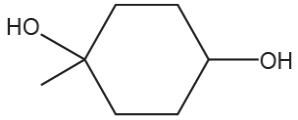
Complete the equation for this reaction.



Compound C

[3]

(c). Compound **D**, shown below, is refluxed with H_2SO_4, as an acid catalyst, to form a mixture of three isomers with the molecular formula C_7H_{10}.



Compound D

i. Draw the structures of the **three** isomers of C_7H_{10} formed from compound **D**.

[3]

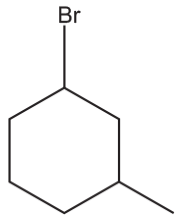
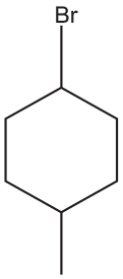
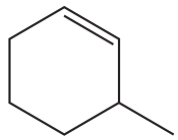
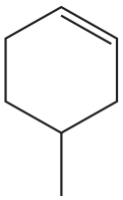
ii. A student converts compound **D** into a diiodoalkane.

Suggest suitable reagents for this reaction.

[1]

62. 3-Methylcyclohexanol is reacted with NaBr and H_2SO_4.

What is the organic product?

A	
B	
C	
D	

Your answer ☐

[1]

63. This question is about the oxidation of two alcohols that are structural isomers of C_3H_8O.

Compare the oxidation of these two structural isomers using different reaction conditions.

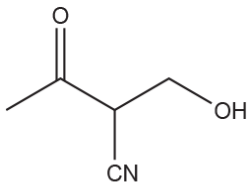
For each reaction include:

- the reaction conditions
- the functional group of any organic product
- a balanced equation.

In your equations, use [O] to represent the oxidising agent and show any organic compounds as structures.

[5]

64. 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]

65. 4.30 g of the alcohol C_5H_9OH, (M_r = 86.0), is burned in oxygen.

$C_5H_9OH(l) + 7O_2(g) \rightarrow 5CO_2(g) + 5H_2O(l)$

Which volume of oxygen gas is needed, in dm^3, for this complete combustion of C_5H_9OH, at RTP?

A 1.2

B 2.4

C 5.8

D 8.4

Your answer ☐ **[1]**

66(a). This question is about reactions of alcohols.

There are 4 structural isomers of $C_4H_{10}O$ that are alcohols:

$CH_3CH_2CH_2CH_2OH$

$CH_3CH_2CHOHCH_3$

$(CH_3)_2CHCH_2OH$

$(CH_3)_3COH$

Alcohols take part in many different types of reaction, including

- elimination
- oxidation
- substitution
- esterification.

For each type of reaction, choose appropriate reagent(s) and/or catalyst, and show the organic product formed.

Elimination reaction of $CH_3CH_2CH_2CH_2OH$

Reagent(s) and/or catalyst

organic product

[2]

(b). Oxidation reaction of $CH_3CH_2CHOHCH_3$

Reagent(s) and/or catalyst

organic product

[2]

(c). Substitution reaction of $(CH_3)_2CHCH_2OH$

Reagent(s) and/or catalyst

organic product

[2]

67. 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. 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]

68(a). Three alcohols, **A**, **B** and **C**, are structural isomers with the molecular formula $C_5H_{12}O$.

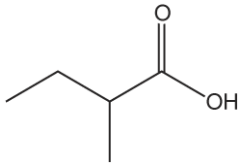
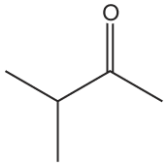
A, **B** and **C** take part in combustion reactions.

Complete the equation for the complete combustion of $C_5H_{12}O$.

$C_5H_{12}O$ + ... **[2]**

(b). Alcohols **A**, **B** and **C** are each refluxed with acidified dichromate(VI), $H^+/Cr_2O_7^{2-}$.
The organic products are shown in the table below.

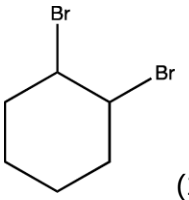
Complete the table to show the structures of alcohols **A**, **B** and **C**.

Alcohol	Structure of alcohol	Organic product after refluxing with $H^+/Cr_2O_7^{2-}$
A		
B		
C		No reaction

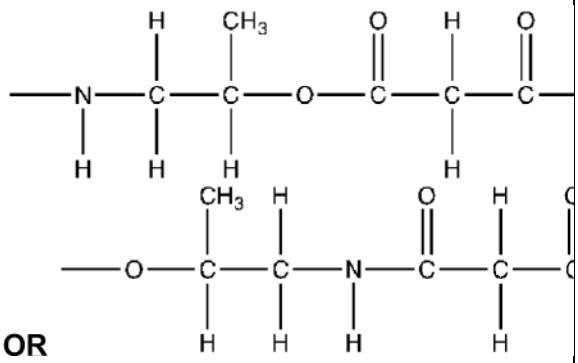
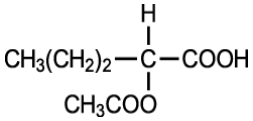
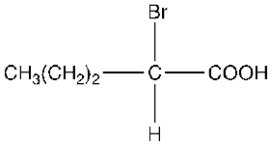
[3]

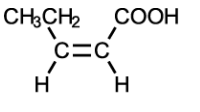
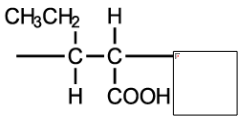
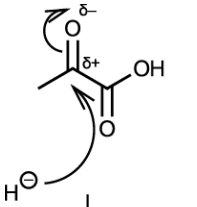
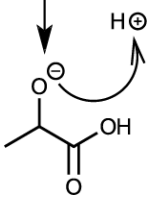
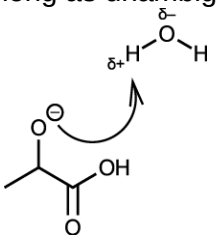
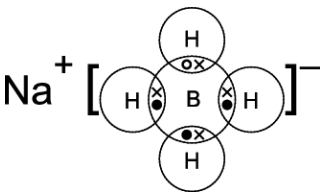
END OF QUESTION PAPER

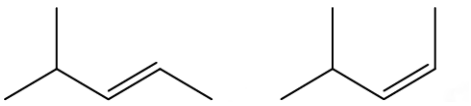
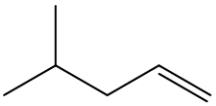
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			D	1	
			Total	**1**	
3	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	**do not allow** C_nH_{2n+} 1
	c	i	*Equation:* $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) *Calculation:* **FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 32.7 (%) award 3 marks theoretical yield = 7.65 / 100 = 0.0765 (mol) (1) actual yield = 2.05 / 82 = 0.025 (mol) (1) % yield = (0.025 / 0.0765) × 100% = 32.7(%) (1)	4	**ignore** state symbols **allow** $C_6H_{11}OH$ for $C_6H_{12}O$ **If there is an alternative answer, check to see if there is any ECF credit possible using working below** % yield **must** be to 1 dp **allow** theoretical and actual yield calculated in mass theoretical yield = 0.0765 × 82 = 6.273 g % yield = (2.05 / 6.273) = 32.7(%) **allow ecf** from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	**allow** bromine water turns colourless **ignore** 'goes clear' **allow** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	**10**	
4			** Please refer to the marking instruction point 10 for guidance on how to mark this question.*	6	**Indicative scientific points may include** **Identification of alcohols**

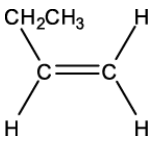
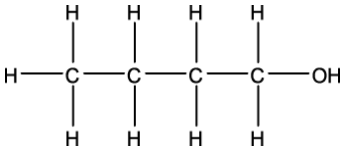
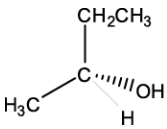
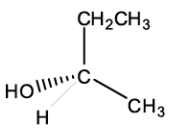
			(Level 3) Candidate provides a method for identifying the alcohols **AND** provides all supporting evidence from IR spectrum **AND** gives details of reagents and conditions and correct equations. *The explanation is detailed and well structured. The information is clearly supported by details of reactions and evidence of oxidation product.* (5–6 marks) **(Level 2)** Candidate provides a basic method **AND** provides some supporting evidence from IR spectrum **AND** gives details of reagents and conditions with some attempt at equations. *The explanation has some structure. The information is supported by some details of reactions and evidence from IR spectrum.* (3–4 marks) **(Level 1)** Candidate attempts to describe a basic method **AND** gives some supporting evidence from IR spectrum **OR** details of reagents and conditions with some attempt at equations. *The explanation is basic and lacks structure. The information is supported by limited evidence from the reactions and oxidation products and would not lead to identification.* (1–2 marks) No response or no response worthy of credit. (0 marks)		Based on recognition of alcohols as primary, secondary and tertiary (stated or implied by method). Basic procedure involves reflux followed by use of IR to identify different oxidation products. **Reactions** • stated reagents ($H^+/Cr_2O_7^{2-}$ and conditions (reflux)) • equations using [O] including structural formulae $CH_3CH_2CHOHCH_3 + [o] \rightarrow CH_3CH_2COCH_3 + H_20$ $CH_3CH_2CH_2CH_2OH + 2[o] \rightarrow CH_3CH_2CH_2COOH + H_2o$ **Identification of oxidation product** • IR: carboxylic acid from broad OH absorption and C=O • IR: carbonyl / ketone from C=O and no OH • tertiary alcohol from lack of C=O and OH peak in IR **OR** no colour change in reflux.
			Total	**6**	

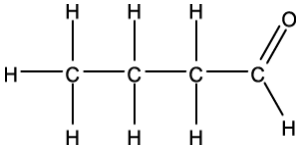
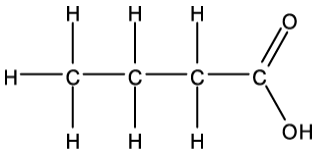
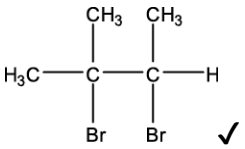
5		i	**Step 1**: add HCN **OR** H_2SO_4/KCN $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ **Step 2**: react with H_2/Ni $CH_3CH(OH)CN + 2H_2 \rightarrow CH_3CH(OH)CH_2NH_2$	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous first mark can be implicit from equation. third mark can be implicit from equation if Ni shown as catalyst (*e.g.* above the reaction arrow) **ALLOW** $CH_3CH(OH)CN + 4[H] \rightarrow CH_3CH(OH)CH_2NH_2$
		ii	because (compound **D**) forms hydrogen bonds form **with** water demonstrated through diagram showing: - dashed line between —OH and (:)OH_2 - dashed line between —NH_2 and (:)OH_2	3	dipole and lone pair are **not** required **IGNORE** bond angles Diagram does **not** need to show all of Compound **D** (and **IGNORE** if wrong)
		iii	 **OR** ester **AND** amide link rest of structure	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous 'End bonds' **MUST** be shown (solid or dotted) **IGNORE** brackets and / or *n*
			Total	**9**	
6	a		Enter text here.		
		i	**Product from reaction 1**:  **Product from reaction 2**: 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous.
		ii	(*E*)-pent-2-enoic acid	1	**ALLOW** "*E*" with or without brackets

		iii	compound **H** =  addition polymer = 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous. 'End bonds' **MUST** be shown (solid or dotted) **IGNORE** brackets and / or *n*
		iv	combustion for energy production use as an organic feedstock for the production of plastics and other organic chemicals	2	
	b	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	**14**	

7			C	1	
			Total	**1**	
8			D	1	
			Total	**1**	
9		i	Elimination	1	**ALLOW** Dehydration
		ii	Same structural formula **AND** Different arrangement (of atoms) in **space** **OR** different **spatial** arrangement 	3	**ALLOW** have the same structure / displayed formula / skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula Stereoisomers have the same formula or molecular formula is **not** sufficient Reference to *E*/*Z* isomerism or optical isomerism is **not** sufficient **IGNORE** names **IF** skeletal formula is not used **ALLOW** one mark if both stereoisomers of alkene **B** are shown clearly.
		iii		1	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names
		iv	** Please refer to the marking instruction point 10 for guidance on how to mark this question.* **Level 3 (5–6 marks)** Outlines full details of how a pure sample of **B** is obtained from the reaction mixture. **AND** Correctly calculates mass of **B** • *Purification steps are clear, in the correct order, using appropriate scientific terms.* • *Calculation shows all relevant steps and mass given to 3 significant figures.* **Level 2 (3–4 marks)** Some details of how a sample of **B** is	6	**Indicative scientific points, with bulleted elements, may include:** **1. Purification** • Use of a **separating funnel** to separate organic and aqueous layers • **Drying** with an anhydrous salt, e.g. $MgSO_4$, $CaCl_2$, etc. • **Redistillation** Incorrect purification method is **NOT** worthy of credit. **2. Mass of B obtained**

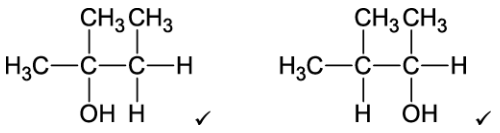
			obtained from the reaction mixture. **AND** Attempts a calculation which is mostly correct. • *Purification steps lack detail, e.g. no drying agent or no explanation of separation, or only some scientific terms used.* • *Calculation can be followed but unclear.* **Level 1 (1–2 marks)** Few or imprecise details of how a sample of **B** is obtained from the reaction mixture. **AND** Attempts to calculate the mass of B using mole approach but makes little progress with only 1 step correct. • *Purification step is unclear with few scientific terms and little detail, e.g. just 'separate the layers and dry'.* • *Calculation is difficult to follow and lacking clarity* **0 marks** No response or no response worthy of credit.		• n(**A**) used = $\frac{9.26}{102}$ = 0.0908 (mol) = theoretical n(**B**) • **Actual** n(**B**) obtained = $n(0.908) \times \frac{75}{100}$ = 0.0681 (mol) • mass **B** = 84 × 0.0681 = **5.72 g** **CHECK** for extent of errors by **ECF** Alternative correct calculation may calculate the mass of **B** as 0.0908 × 84 = 7.63 g, followed by $7.63 \times \frac{75}{100}$ = 5.72 g Calculation must attempt to calculate n(***A***) in mol. Simply finding 75% of the initial mass of alcohol A, 9.26, is **NOT** worthy of credit.
			Total	**11**	
10		i	reaction with bases: neutralisation **AND** reaction with metals: redox	1	Enter text here.
		ii	correctly calculates n(**A**) = $\frac{1.125}{90}$ = 0.0125 (mol) volume of H_2 = $\frac{0.0125}{2}$ x 24,000 = 150 cm^3 **units** required	2	**ALLOW** 0.15 dm^3 **ALLOW ECF** from n(**A**)
		iii	$C_6H_{12}O_6Mg$	1	**DO NOT ALLOW** $(C_3H_6O_3)_2Mg$
		iv	Type of reaction of COOH: e.g. esterification **AND** reagents and conditions e.g. CH_3OH **AND** H_2SO_4	4	**ALLOW** esterification with any stated alcohol e.g. product from CH_3OH/H_2SO_4 → $CH_3(CHOH)COOCH_3$

			Organic product of COOH reaction Type of reaction of −OH **AND** reagents and conditions Organic product of −OH reaction		Many possible reactions of secondary alcohol possible, e.g. oxidation with $K_2Cr_2O_7$ / H_2SO_4 + heat → $CH_3(CO)COOH$ elimination with H_2SO_4 / H_3PO_4 + heat → $CH_2 = CHCOOH$ esterification with CH_3COOH / H_2SO_4 **OR** CH_3COCl → $CH_3(CHOOCCH_3)COOH$ bromination with NaBr / H_2SO_4 → $CH_3(CHBr)COOH$ **ALLOW** self-polymerisation as reaction for either group (if another reaction example given) condensation polymerisation with H_2SO_4 → $[OCH(CH_3)CO]_n$
			Total	**8**	
11			A	1	
			Total	**1**	
12	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

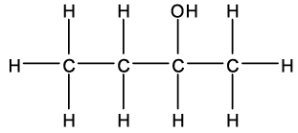
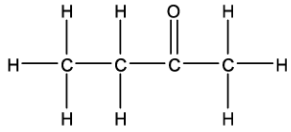
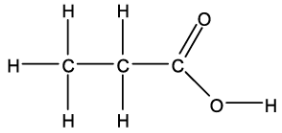
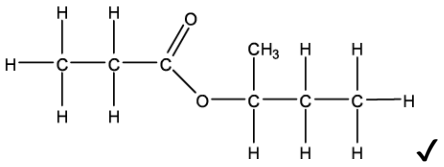
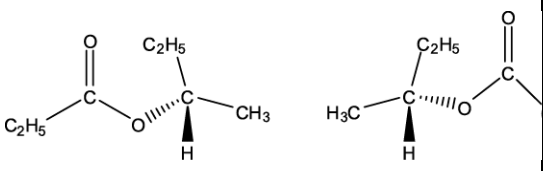
			Compound J:  **Compound K:** 		
	b		(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate Take melting point of crystals Compare to known values	3	**NOTE: (b)** is marked completely independently of **(a)** ALLOW errors in spelling **ALLOW** 2,4(−)DNP **OR** 2,4(−)DNPH **ALLOW** Brady's 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**	
13	a		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **DO NOT ALLOW** molecular formula **ALLOW** dichloro or diiodo compound instead of the dibromo compound as the **only** alternatives. **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this

					scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).
	b		Reagent **A**: correct halogen✓ e.g. Br_2 / bromine	1	**ALLOW** Cl_2 if dichloro compound drawn **ALLOW** I_2 if diiodo compound drawn **IGNORE** state symbols Answer must match box from **(a)** to score **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b),

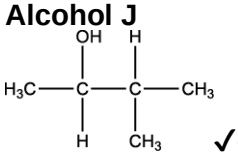
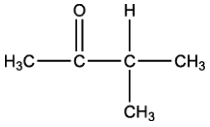
					as this was essentially dependant on part (a).
	c	i	Steam **AND** acid catalyst ✓	1	**ALLOW** H^+ / named acid / H_2SO_4 / H_3PO_4 **ALLOW** $H_2O(g)$ **ALLOW** water only if a temperature of 100 °C or above is quoted. **IGNORE** any temperature given with steam **IGNORE** pressure **Examiner's Comments** One would expect the majority of candidates to do well in a question which required them to state the reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100 °C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure Same formula is **not** sufficient Different arrangement of atoms is **not** sufficient **Examiner's Comments** The majority of candidates were able to explain the term structural isomers.

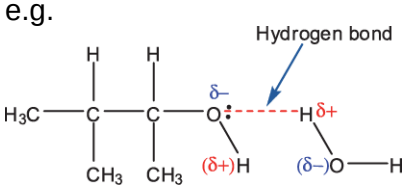
		iii	 ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** any vertical bond to OH **DO NOT ALLOW** OH− **Examiner's Comments** Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula $C_5H_{12}O$, but that could not be formed from 2- methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1- ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methlybut-2-ene. Candidates should be reminded to check that any structures they suggest are consistent with the context of the question.
		iv	Does not contain OH group(s) **OR** does not contain hydroxyl group(s) **OR** is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	**ALLOW ORA** throughout **DO NOT ALLOW** OH^- (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is **not** sufficient **Examiner's Comments** The majority of candidates were able to recognise that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.
	d		Reagents: Acid / H^+ and (potassium or sodium) dichromate / $Cr_2O_7^{2-}$ seen **once**✓ Observations: Orange to Green **OR** Orange to Blue✓ Distillation / Distil produces aldehyde /	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** H_2SO_4 and $K_2Cr_2O_7$ **ALLOW** correct displayed formula **OR** correct structural formula **OR** skeletal

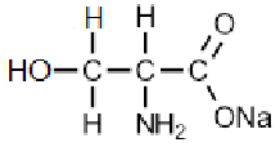
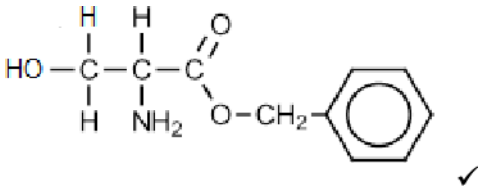
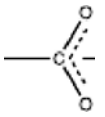
			CH_3CH_2CHO: ✓ $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓ Reflux (of propan-1-ol) produces carboxylic acid / CH_3CH_2COOH✓ $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		formula **OR** a mixture of the above **DO NOT ALLOW** molecular formulae **ALLOW** C_3H_7OH for propan-1-ol in equations **DO NOT ALLOW** CH_3CH_2COH for aldehyde **IGNORE** further oxidation of aldehyde **ALLOW** $CH_3CH_2CO_2H$ for carboxylic acid **Examiner's Comments** This question differentiated well with some very good answers but also some weak responses. The most able candidates provided succinct and well-structured responses which demonstrated a good understanding of the oxidation of primary alcohols. Frequently, good candidates picked up five or six marks. The most common approach was to state the oxidising agent first and whilst most candidates were able recall that potassium dichromate was required, a significant proportion failed to state that an acid was also needed. Many candidates were able to give the colour change but a large number did not mention this. Candidates often referred to the production of the aldehyde and then the carboxylic acid and the majority of candidates were able to provide the correct conditions for these processes. Providing balanced equations for each reaction proved to be the most challenging aspect of this question. A large proportion of candidates included hydrogen as the by-product rather than water, or specified no by-product at all. Another common error was the incorrect balancing of the complete oxidation equation. A significant proportion of responses did not use the correct amount of the oxidising agent when

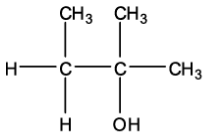
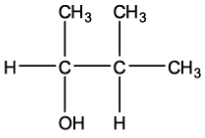
					converting propan-1-ol to propanoic acid. The examiners were encouraged by the candidates' ability to provide correct structural formulae, however some candidates showed the aldehyde group as –COH. Candidates should be reminded that an aldehyde group is expected to be represented as –CHO in this type of formula.
			Total	**14**	
14			Molar mass of **B** = 74 ✓ **B-F** clearly identified **B/alcohol:**  ✓ **C/ketone:**  ✓ **D/carboxylic acid:**  ✓ **E and F:**  ✓ H_2O/water ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Check and annotate page 19 below this response** Molar mass = $\frac{2.59}{0.035}$ = 74 For structure of **B**, **C**, **D** or **E / F ALLOW** correct displayed **OR** correct structural formula **OR** correct skeletal formula **OR** mixture of the above as long as unambiguous. **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structures. **IGNORE** names of organic compounds **E** and **F** can be identified either way round **ALLOW** H_2O or displayed formula for mark For **E** and **F** – **ALLOW** the two optical isomers 

					Examiner's Comments Candidate were required to apply their knowledge of the reactions of alcohols to suggest the structures of the five compound **B–F**. Generally this question was answered well and most candidates scored three or more marks. The majority of candidates chose to use displayed formula. Other candidates opted to use skeletal formula and only a small proportion showed structural formulae. Almost all of the candidates were able to correctly calculate the molar mass of **B** as 74 g mol^{-1} which allowed most to suggest a structure for the compound. Many candidates used the information that **B** forms a ketone and provided the correct structure of butan-2-ol, although a significant proportion of candidates suggested **B** was butan-1-ol. The more able candidates identified the structure of **C** as butanone, but a large proportion of the cohort did not suggest a structure. Some candidates who used displayed formula for **C** often included an extra hydrogen atom on the carbonyl group. Most candidates were able to suggest a correct structure of carboxylic acid **D** and therefore deduced that the reaction between **B** and **D** was an esterification reaction. The most difficult part of this question was identifying **E** and **F**. The most able candidates provided a correct structure for the ester, however some candidates often missed of one of the hydrogen atoms from their displayed formula. The most common incorrect response was to the structure of butyl propanoaoate. Some candidates identified the other compound formed in the reaction of **B** and **D** as water but a large proportion gave a second ester. In general the structures given by candidates were accurately drawn but candidates should be reminded to check

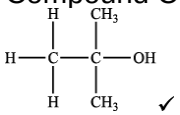
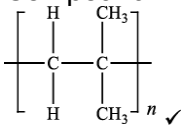
					their work carefully to ensure the correct number of atoms and bonds are present if using displayed formula.
			Total	**6**	
15	a		**QWC**: Evidence of the **IR** absorption at 1720 (cm^{-1}) for presence of C=O / carbonyl group ✓ **QWC**: No carboxylic acid OH absorption in IR **OR** no peak between 2500–3300 cm^{-1} **AND** so **J** is a secondary alcohol **OR** so **K** is a ketone ✓ **Alcohol J**  ✓✓ **Compound K** Structure of a carbonyl compound that could be obtained from alcohol **J** ✓ **Equation** Balanced equation for conversion of **J** to **K** ✓ e.g. $CH_3CHOHCH(CH_3)_2 + [O] \rightarrow CH_3COCH(CH_3)_2 + H_2O$	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **BOTH IR** at ~ 1720 (cm^{-1}) **AND** C=O required **ALLOW** ranges from *Data Sheet*, i.e. C=O within range 1640–1750 cm^{-1}; **IGNORE** any reference to C-O absorption For structures of **J** and **K**, **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** any names given for **J** and **K** **ALLOW** 1 mark for the structure of an alcohol with the molecular formula $C_5H_{12}O$ **DO NOT ALLOW** pentan-1-ol (*primary and unbranched*) or 2-methylbutan-2-ol (*branched but tertiary*) **DO NOT ALLOW** any marks for **J** and **K** if more than one structure is given for **J** **Note:** 'sticks' in either **J** and / or **K** will lose only 1 mark **ALLOW** 1 mark for:  **IF** a structure is not given for **J** **NOTE:** structures for **J** and **K** could be awarded from the equation, even if not labelled. **ALLOW** molecular formulae in equation i.e. $C_5H_{12}O + [O] \rightarrow C_5H_{10}O + H_2O$ **DO NOT ALLOW** equations that form a carboxylic acid **Examiner's Comments**

					This question discriminated well and most candidates were able to score at least one mark, by identifying the C=O peak in the IR spectrum provided. The most able candidates gave succinct responses that included both the correct structures of **J** and **K** as well as a balanced equation. In addition, they included reference to the absence of a carboxylic acid O-H peak in the IR spectrum concluding that **K** must be a ketone. This marking point was missed by a large proportion of the cohort and often a branched primary alcohol for **J** and corresponding aldehyde for **K** were suggested. Some candidates incorrectly identified the C—H peak in the spectrum as an O—H and suggested that **K** was a carboxylic acid.
	b		**Labelled** diagram showing at least one H-bond between alcohol molecule and water ✓ e.g.  	1	**IF** diagram is not labelled **ALLOW** Hydrogen bonds / H bonds from text Diagram should include role of an O lone pair and dipole charges on each end of H bond. **IGNORE** alcohol R group, even if wrong **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **Examiner's Comments** The majority of candidates were able to draw a diagram to show the hydrogen bond between an alcohol and water. However, a significant proportion lacked the accuracy required at this level and failed to show the role of the lone pair. It was also common to see responses that omitted the relevant dipoles. The question asked for the inclusion of relevant dipoles and lone pairs and candidates are advised to double check diagrams to ensure these key features are not neglected.
			Total	**7**	

16		i	 ✓  ✓ —NH_3^+ in second product ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** —O^-Na^+ **OR** —O^- (cation not required) **DO NOT ALLOW** —O—Na (covalent bond) **DO NOT ALLOW** —O (without the sodium) **ALLOW** delocalised carboxylate  **Examiner's Comments** The majority scored two marks here. The question had a three mark total for drawing two structures and this may have prompted some candidates to incorrectly form a salt with the alcohol group in **reaction 1**. Many were able to draw a correct structure for the ester formed in **reaction 2**, but very few protonated the amine group in acidic conditions. The protonation of hydrolysis products has been well represented in recent papers.
		ii	perfume / fragrance / flavouring ✓	1	**IGNORE** solvent **OR** food additive **Examiner's Comments** Well answered with most of the correct responses referring to perfumes and flavourings which are the uses listed in the specification. Common responses marked as incorrect were suggestions that this ester could be used for making dyes, polymers or textiles.
		iii	Reaction 3: (hot) ethanolic ammonia ✓ Reaction 4: oxidation ✓ Reaction 5: hydrolysis ✓	3	**ALLOW** NH_3 (dissolved) in ethanol **IGNORE** other conditions **ALLOW** oxidisation / oxidised **DO NOT ALLOW** redox **ALLOW** nucleophilic addition-elimination **DO NOT ALLOW** nucleophilic

					substitution **IGNORE** acid / base **Examiner's Comments** Most candidates were able to score at least one mark here, usually for correctly identifying **reaction 4** as an oxidation reaction. Although the use of excess reagent was not required for **reaction 3**, some missed ethanol as an essential solvent and **reaction 5** was occasionally described as a reduction.
			Total	**7**	
17			 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW any** vertical bond to OH, e.g. **ALLOW** OH **OR** OH **DO NOT ALLOW** OH– **Examiner's Comments** Many candidates found it difficult to draw the structures for the two alcohols that could be dehydrated to produce compound A. This was surprising as it was a simple task to add water across the double bond of compound "A" resulting in two branched chained isomers. The most common incorrect answers were pentan-1-ol and pentan-2-ol, although some candidates shortened the chain length resulting in compounds containing only four carbon atoms.
			Total	**2**	
18	a		The –OH group is attached to a carbon that is attached to one hydrogen atom **OR** The –OH group is attached to a carbon that is attached to two C atoms / alkyl groups/R groups ✓	1	**ALLOW** alcohol / hydroxyl / functional group for –OH **Examiner's Comments** The definition of a secondary alcohol was well known with most candidates being to express this to gain the mark available.

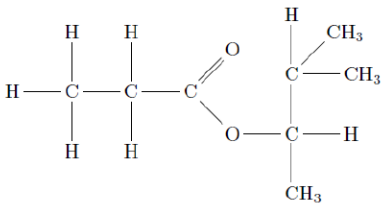
	b	i	**Equation** $CH_3CH(OH)CH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$ ✓ **Structure of product could be allowed from equation** $CH_3COCH_2CH_3$ ✓	2	**ALLOW** molecular formulae: $C_4H_{10}O$ and C_4H_8O **ALLOW** C_4H_9OH **ALLOW** C_2H_5 for CH_3CH_2 **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **Examiner's Comments** The majority of candidates were able to identify the structure of the ketone formed in the oxidation of butan-2-ol but many were not able to construct a suitable equation. Water was often omitted from the equation on the right hand side whilst sometimes the equation was incorrectly balanced with a 2 being placed in front of the [O]. The most able candidates normally scored both marks.
		ii	Butan-2-ol/butanone is flammable **OR** Butan-2-ol / butanone is volatile / low boiling point **OR**	1	**IGNORE** vague answers about health and safety **ALLOW** alcohol for butan-2-ol **ALLOW** ketone for butanone
		ii	Butan-2-ol / butanone will evaporate / boil away ✓		**DO NOT ALLOW** the product or reactant. **DO NOT ALLOW** distillation
		ii	(Heat under) reflux **OR** a description of reflux with vertical condenser and a round bottomed or pear shaped flask with source of heat. ✓	1	**DO NOT ALLOW** any reference to closed system. **Examiner's Comments** Another question requiring candidates to evaluate a practical activity where responses were on the whole disappointing. Very few candidates were able to access both of the marks with the harder of the two marks being for suggesting why the apparatus was not suitable for the experiment. Clearly many candidates were able to suggest a better method of carrying out the experiment with reflux being often quoted.
			Total	**5**	

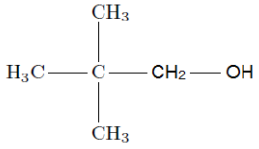
19			B	1	**Examiner's Comments** Generally scored well.
			Total	**1**	
20			Compound C:  ✓ **CARE**: Tertiary alcohol Compound **D**: (repeat unit)  ✓	2	**For structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above ***Connectivity*** **IGNORE** connectivity of bonds to CH_3 e.g. **ALLOW** CH_3- **ALLOW any** vertical bond to OH, e.g. **ALLOW** OH **OR** OH | | **DO NOT ALLOW** OH– **DO NOT ALLOW** more than one repeat unit **REQUIRED:** Side links (dotted lines fine) **NOT REQUIRED:** Brackets and '*n*' **Examiner's Comments** This part was answered well. If a mark was lost, it was almost always due to compound C, especially at the low scoring end of the range. Many struggled with the structure of a tertiary alcohol or omitted H atoms from the structure. Compound D was generally drawn correctly by candidates of all abilities. If the mark was not credited, it was usually due to not removing the double bond, or drawing more than one repeat unit.

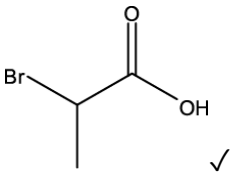
			Total	2	
21	a		Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** reference to specific compounds e.g. comparing methane and methanol Second marking point requires **BOTH** types of intermolecular forces in response i.e comparison of hydrogen bonds **AND** van der Waals is **essential** **DO NOT ALLOW** the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water **ALLOW** more energy required to break hydrogen bonds than van der Waals' forces **ALLOW** it is harder to overcome the hydrogen bonds than van der Waals' forces **IGNORE** more energy is needed to break bonds **Examiner's Comments** Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.
	b		2-methylpropan-1-ol has less surface (area of) contact **OR** fewer points of contact ✓ 2-methylpropan-1-ol has fewer / weaker	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Both answers need to be comparisons** **ALLOW ORA** throughout Reference to just surface area / closeness of molecules is **not** sufficient

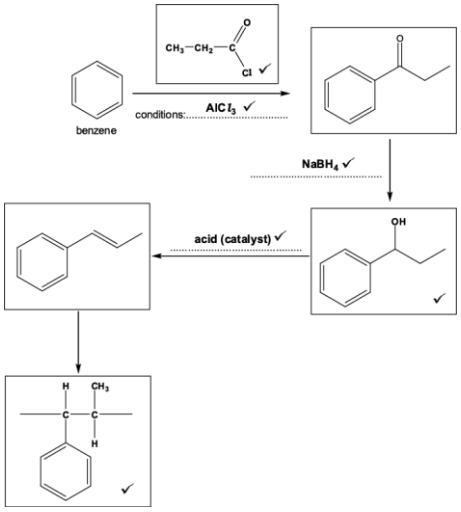
			van der Waals' forces **OR** less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓		**IGNORE** reference to H bonds **IGNORE** less energy is needed to break bonds **Examiner's Comments** Most candidates recognised that 2-methylpropan-1-ol is branched and communicated both marking points succinctly. Weaker responses identified that 2-methypropan-1-ol would have weaker intermolecular forces, but failed to specify these as van der Waals' forces.
	c	i	Elimination **OR** dehydration ✓	1	**Examiner's Comments** Many candidates correctly named the type of reaction. There were a significant number of incorrect responses, the most common of which included hydrolysis, dehydrogenation and condensation.
		ii	**IF answer = 14.0 OR 14.1 g award 3 marks** ..... **actual** $n(C_5H_8)$ produced = $\frac{5.00}{68.0}$ = 0.0735 (mol) ✓ **theoretical** $n(C_5H_9OH) = n(C_5H_8) = 0.0735 \times \frac{100}{45.0}$ = 0.163 (mol) ✓ Mass of C_5H_9OH = 0.163 × 86.0 = 14.0 (g) **OR** 14 g **OR** 14.1 g ✓ (*use of unrounded values in calculator throughout*)	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW ECF** at each stage **ALLOW 3 SF** up to calculator value correctly rounded for intermediate values **ALLOW** expected mass $C_5H_8 = 5.00 \times \frac{100}{45.0} = 11.111$ **ALLOW** Mass C_5H_9OH reacted = 0.0735 × 86.0 = 6.321 (g) **ALLOW** Mass of C_5H_9OH used = $6.321 \times \frac{100}{45.0}$ = 14.0 **O** **ALLOW 2 SF** up to calculator value correctly rounded for mass of C_5H_9OH **Note:** 2.84 **OR** 2.85 g would get 2 marks *(use of 45.0/100 instead of 100/45.0)*

					13.76 **OR** 13.8 would get 2 marks *(use of 0.16 for moles C_5H_9OH)* **Examiner's Comments** Candidates coped well with this calculation based on percentage yield. Most were able to calculate the moles of cyclopentene produced and the strongest scaled this correctly to give the moles of cyclopentanol required. A common mistake was to scale by a factor of 45/100, rather than 100/45. However, error carried forward marks were awarded and the majority of candidates scored two or three marks. Answer: 14.1 g
			Total	**8**	
22	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** $C_4H_9CHO + 2[H] \rightarrow C_5H_{11}OH$ **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 $C_5H_{11}OH$ ✓	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

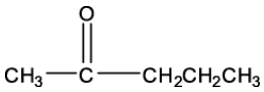
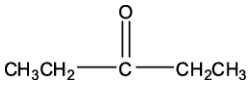
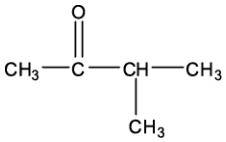
			M2 Compound **F** = $CH_3CH(OH)CH(CH_3)CH_3$ ✓ **M3** Compound **G** = $CH_3COCH(CH_3)CH_3$ ✓ **M4** n(NaOH) = (0.125 x 22.8/1000) = 0.00285 (mol) ✓ **M5** M(compound H) = (0.211/0.00285 =) 74(.0) (g mol^{-1}) ✓ **M6** Compound **H** = / CH_3CH_2COOH ✓ **M7** Compound **I** =  ✓		**ALLOW ECF** from an 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 **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

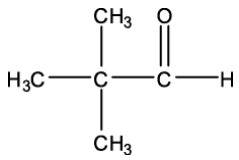
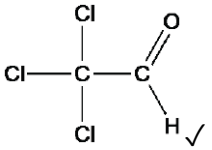
			 ✓		**OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 2,2-dimethylpropan-1-ol **Examiner's Comments** A good discriminator but many correct structures were seen.
			Total	**10**	
23			**A**	1	
			Total	**1**	
24			**C**	1	
			Total	**1**	
25			**Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Identifies most of the compounds. **AND** A comprehensive explanation with most of the scientific points and few omissions. *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)** Identifies some of the compounds. **AND** Explanation covers some of the scientific points and few omissions. *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)** Attempts to identify a few of the compounds. **AND** A basic explanation based on intermolecular forces.	6	**Indicative scientific points may include:** **<u>Compounds B-F</u>** • **B** is $CH_3CH(CH_3)CH_3$ • **C** is $CH_3CH_2CH_2CH_3$ • **D** is $CH_3CHClCH_3$ • **E** is $CH_3CH_2CH_2NH_2$ • **F** is $CH_3CH_2CH_2OH$ **<u>Intermolecular forces</u>** • $CH_3CH(CH_3)CH_3$ and $CH_3CH_2CH_2CH_3$ have London dispersion/induced dipole-dipole forces. • $CH_3CHClCH_3$ has permanent dipole-dipole (and London dispersion/induced dipole-dipole forces). • $CH_3CH_2CH_2NH_2$ and $CH_3CH_2CH_2OH$ have hydrogen bonding (and London dispersion/induced dipole-dipole forces). • The stronger the intermolecular force, the higher the boiling point as more energy is required to overcome intermolecular forces.

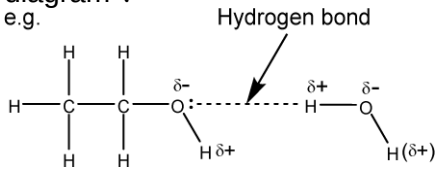
			The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear. **0 marks** No response or no response worthy of credit.		• Relative strength: hydrogen bonds > permanent dipole-dipole > London dispersion forces. **<u>Affect of structure</u>** • $CH_3CH(CH_3)CH_3$ is branched and $CH_3CH_2CH_2CH_3$ is straight chain. • $CH_3CH(CH_3)CH_3$ has less points of contact. • London dispersion/induced dipole-dipole forces are weaker in branched structures. • $CH_3CH_2CH_2OH$ has stronger H bonds than $CH_3CH_2CH_2NH_2$ **OR** more H bonds than $CH_3CH_2CH_2NH_2$ • O is more electronegative than N **OR** O has two lone pairs (and N has one)
			Total	**6**	
26			**Reagents for first stage** $NaBr/H_2SO_4$ ✓ **Compound H**  ✓ **Reagent for second stage** (excess ethanolic) NH_3 ✓	3	**ALLOW** any suitable halide salt/sulfuric acid combination **ALLOW** HC*l* **OR** HBr **OR** HI **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** the halogen in compound **H** can be C*l*, Br or I, but **must** be consistent with halide salt used
			Total	**3**	
27	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

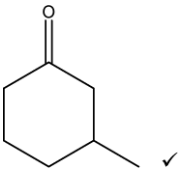
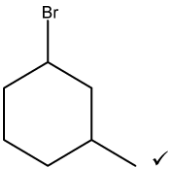
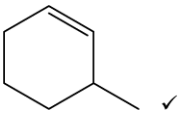
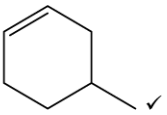
					**IGNORE** names of organic compounds *(question asks for structures)* **ALLOW** aluminium(III) chloride **OR** aluminium trichloride **ALLOW** $FeCl_3$ **OR** Fe as halogen carrier in first step. **ALLOW** sodium borohydride **OR** sodium tetrahydridoborate **IGNORE** [H] for reducing agent in second 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**	
28	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**	2	**Note:** both reagent and observation are required for first mark

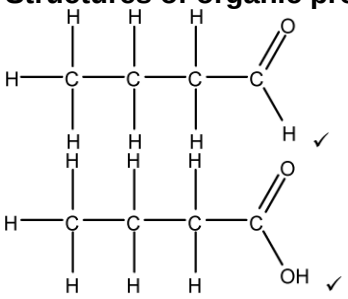
			Silver (mirror) ✓ **Equation** RCHO + [O] → RCOOH ✓		**ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** $H^+/Cr_2O_7^{2-}$ **OR** acidified (potassium/sodium) dichromate **AND** Orange to green *(this would identify the aldehyde from the carboxylic acid, ketone and esters)*
	b		2,4−dinitrophenylhydrazine **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)** (It is) not possible to identify (the esters) with ^{13}C NMR	3	

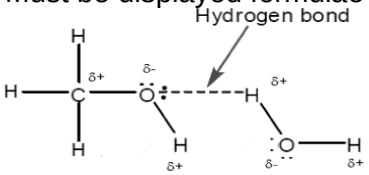
			AND (both) spectra would contain four peaks (with similar chemical shifts) ✓ **^{1}H NMR (2 marks)** (It is) possible to identify (the esters) with ^{1}H NMR (^{1}H NMR spectrum of) $CH_3COOC(CH_3)_3$ has a singlet/peak between 2.0−3.0 (ppm) (^{1}H NMR spectrum of) $(CH_3)_3CCOOCH_3$ has a singlet/peak 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** No H on adjacent C atom as peak is singlet	5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names of ketones

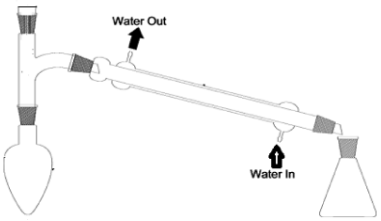
			✓  **OR** (2,2−)dimethylpropanal ✓		
			Total	**17**	
29		i		1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
		ii	Any **organic** reaction in which sulfuric acid is a catalyst e.g: Elimination of (H_2O from) alcohols Nitration of benzene Esterification Hydrolysis of esters/amides	1	The answer needs to refer to the reaction: i.e. 'Elimination', 'hydrolysis' are insufficient but 'Esterification' describes the reaction **DO NOT ALLOW** oxidation for alcohols/ aldehydes
			Total	**2**	
30			A	**1**	**Examiner's Comments** Candidates found this question challenging, with only the more able candidates obtaining the correct alcohol. Answer option C was a common incorrect answer.
			Total	**1**	
31			B	**1**	**Examiner's Comments** Just over half of the candidates identified the correct alcohol. The common incorrect answer was C.
			Total	**1**	
32	a		$C_5H_{10}O + 7O_2 \longrightarrow 5CO_2 + 5H_2O$ ✓	**1**	**ALLOW** multiples e.g. $2C_5H_{10}O + 14O_2 \longrightarrow 10CO_2 + 10H_2O$ **ALLOW** any equation involving an unsaturated alcohol with correct balancing

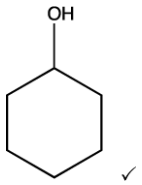
					e.g. $C_5H_8O + 6.5O_2 \longrightarrow 5CO_2 + 4H_2O$ $C_5H_6O + 6O_2 \longrightarrow 5CO_2 + 3H_2O$ $C_5H_4O + 5.5O_2 \longrightarrow 5CO_2 + 2H_2O$ $C_5H_2O + 5O_2 \longrightarrow 5CO_2 + H_2O$ **IGNORE** state symbols **Examiner Comments** The more able candidates were able to balance this combustion equation. Those who failed to be awarded the mark either used the molecular formula of a saturated alcohol or did not consider the presence of the oxygen atom in the alcohol when balancing the equation.
	b	i	Diagram showing a water molecule and an ethanol molecule with at least one $H^{\delta+}$ and one $O^{\delta-}$ on **BOTH** molecules ✓ Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another. **AND** Hydrogen bonding stated or labelled on diagram ✓ e.g.  	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** δ+ on H atoms of alkyl group **DO NOT ALLOW** any marks for a diagram containing O_2H If more than one hydrogen bond is shown they must **all** be correct to award the mark. **Examiner Comments** The examiners were surprised that more of the candidates did not achieve both marks on a question that many would have experienced before from legacy past papers. Candidates often failed to include dipoles and lone pairs even though this was indicated in the stem of the question. Candidates should recognise the involvement of the lone pair in any hydrogen bonds drawn. Where candidates gave more than one hydrogen bond in their diagrams they had to be correct for a mark to be awarded.
		ii	Hexane-1,6-diol has more OH groups (than hexan-1-ol) **AND**	**1**	Statements **MUST** be comparative e.g. hexane-1,6-diol has two –OH groups and hexan-1-ol has one −OH group **ALLOW** hydroxyl or hydroxy

			(hexane-1,6-diol) forms more hydrogen bonds **with water** ✓		**DO NOT ALLOW** hydroxide/OH^- **ALLOW ORA** **Examiner Comments** The best answers here stated that that hexane-1,6-diol had more OH groups than hexan-1-ol and so more hydrogen bonds could be formed with water molecules. Weaker answers did not compare the two compounds simply stating that hexan-1,6-diol had two OH groups or that it formed two hydrogen bonds with water. Candidates who did include a comparison frequently failed to state that solubility was due to hydrogen bonds being formed with water.
	c	i	**Starting material from reduction reaction**  ✓ **Reagent for reduction** $NaBH_4$ ✓ **Product from reaction with $NaBr/H_2SO_4$**  ✓ **Structural isomers**  ✓  ✓	**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 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.

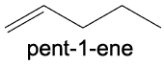
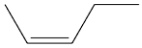
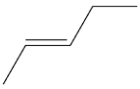
		ii	3-methylcyclohexanol ✓	**1**	**ALLOW** 3-methylcyclohexan-1-ol **ALLOW** 1-methylcyclohexan-3-ol **IGNORE** lack of hyphens, or addition of commas **Examiner Comments** Just over half of candidates managed to name the structure as 3-methylcyclohexanol. The most common errors included 3-methylphenol, 3-methylcyclichexanol and 3-methylhexanol.
	d		**Structures of organic products**  ✓ ✓ **Equations** $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$ ✓ $CH_3CH_2CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2CH_2COOH + H_2O$ ✓ **Reaction conditions** Distillation to produce aldehyde/$CH_3CH_2CH_2CHO$ **AND** Reflux to produce carboxylic acid/$CH_3CH_2CH_2COOH$ ✓	**5**	**ANNOTATE WITH TICKS AND CROSSES** Use of any primary alcohol containing 3, 5 or more carbons can be awarded up to 4 marks. **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names **DO NOT ALLOW** $CH_3CH_2CH_2COH$ for the structure of the aldehyde. **ALLOW** $CH_3CH_2CH_2CO_2H$ for the structure of the carboxylic acid. **ALLOW** marks for structures from equations as long as unambiguous. **ALLOW** molecular formulae in equations e.g. $C_4H_{10}O + [O] \longrightarrow C_4H_8O + H_2O$ $C_4H_{10}O + 2[O] \longrightarrow C_4H_8O_2 + H_2O$ $C_4H_9OH + [O] \longrightarrow C_3H_7CHO + H_2O$ $C_4H_9OH + 2[O] \longrightarrow C_3H_7CO_2H + H_2O$ **IGNORE** incorrect structures in equations i.e. $C_4H_{10}O + [O] \longrightarrow C_3H_7COH + H_2O$ scores equation mark Conditions **must** be linked to aldehyde/carboxylic acid or correct products. Conditions may be written above arrow of equation. **Examiner Comments** A very well answered question. Candidates had obviously been well prepared as even the weakest candidates gained a number of marks

					here. The most common mark lost was a failure to include H_2O in the balanced equations. In the preparation of the carboxylic acid, a number of Candidates balanced the equation with $2H_2O$.
			Total	**15**	
33	a		Displayed formulae of CH_3OH and H_2O **AND** C–O **AND** O–H polar bonds shown on CH_3OH molecule with δ+ and δ- **AND** Both O–H polar bonds shown on H_2O molecule with δ+ and δ- ✓ **Two** lone pairs shown on both oxygen atoms **AND** Hydrogen bond / H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	**2**	Must be displayed formulae  **IGNORE** δ+ shown on other H atoms **ALLOW** hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water **Examiner's Comment:** Candidates did not cope well with the requirement to produce a hydrogen bonding diagram that was expected to match the content of all four of the bullet points listed in the question. Perhaps candidates did not read the question carefully enough but some diagrams did not include displayed formulae, dipoles were often missing from the methanol molecule, lone pairs were absent from oxygen atoms and the hydrogen bond was marked in an incorrect position. This resulted in a low scoring question for a diagram that had produced much higher scores when asked on papers from the legacy specification.
	b		*Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive explanation with all three scientific points covered thoroughly. *There is a well-developed description with a logical structure including correct chemical equations and an explanation with a clear line of reasoning including a fully labelled diagram.*	**6**	**Indicative scientific points** **<u>1. Oxidation reaction forming aldehyde</u>** • acid / H+ **AND** dichromate / $Cr_2O_7^{2-}$ • heat **AND** distillation • organic product is butanal / $CH_3CH_2CH_2CHO$ • $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H2O$

			Level 2 (3–4 marks) The candidate attempts all three scientific points but explanations are incomplete. **OR** Explains two scientific points thoroughly with no omissions. *The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.* **Level 1 (1–2 marks)** A simple explanation based on at least two of the main scientific points **OR** The candidate explains one scientific point thoroughly with few omissions. *The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde.* *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.*		**2. Oxidation reaction forming carboxylic acid** • acid / H+ **AND** dichromate / $Cr_2O_7^{2-}$ • heat under reflux • organic product is butanoic acid / $CH_3CH_2CH_2COOH$ • $CH_3CH_2CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$ **3. Distillation** • diagram of apparatus with condenser • condenser has water flow • collection of organic product • product is separated to prevent further oxidation (to carboxylic acid)  **Examiner's Comment:** A very wide range of responses was seen in the second question marked using a level of response mark scheme and a greater proportion of candidates were able to access the highest level in this question. Diagrams of a distillation apparatus were often disappointing and many poor answers failed to identify the oxidation products. A Level 1 response usually named the oxidising agent and included a crude diagram of a distillation apparatus. Diagrams in Level two responses often included more detail with a condenser cooled by water flow and an indication of where butanal can be collected. A Level three response was expected to include balanced equations for the oxidation reactions.
			Total	**8**	

34		i	 ✓ Acid (catalyst) **AND** heat ✓	**2**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** (heat under) reflux **ALLOW** H_3PO_4 OR H_2SO_4 OR H+ **DO NOT ALLOW** other named acids **IGNORE** concentration / pressure **IGNORE** water / steam **Examiner's Comments** Candidates who were able to give the structure of the intermediate were not always able to state the conditions for the elimination of water from an alcohol. The presence of an acid catalyst and heat are stated in the specification. Some candidates confused this reaction with addition reactions of alkenes suggesting that a Ni catalyst or the presence of steam is required.
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 44.4(%) award all 3 marks for calculation *Amount cyclohexene (m / M)* = 1.23/82 **OR** 0.0150 mol ✓ *Amount of brnmocyclohexane (m / M)* = 5.50/162.9 **OR** 0.0338 mol ✓ % yield = (0.0150/0.0338) × 100 = 44.4(%) ✓ Final answer **must** be to 3 significant figures	**3**	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW 3 SF**: 0.0338 up to calculator value of 0.033763044 correctly rounded **Common ECFs** (2 marks) • Incorrect M_r → incorrect moles of cyclohexene • Incorrect M_r → incorrect moles of 2- bromocyclohexane e.g. **ALLOW two marks** for use of incorrect mass of bromocyclohexane with other calculations correct e.g. (5.50/163) = 0.033742331 → 44.5% **ALLOW** calculation in mass *Theoretical mass yield:*

					$m(C_6H_{10})$ = 0.0338 × 82 = 2.77 g % yield = (1.23/2.77) × 100 = 44.4% **Examiner's Comment:** Although some candidates simply calculated 1.23/5.50, most followed an effective strategy for the calculation of percentage yield. Many gained full marks but a large number of candidates relied on the application of error carried forward when they made one or more careless errors during the calculation of molar mass and / or moles. Intermediate answers were sometimes rounded to 2 significant figures and marks were lost by candidates who presented their final answer to 2 or 4 significant figures.
			Total	**5**	
35	a		(Minimum) *n*(pentan-2-ol) required = 0.1 × 88 = 8.8 g (1) React the alcohol with a mixture of NaBr **AND** H_2SO_4 **AND** warm (to distil off the product) (1)	2	**allow** HBr
	b		** Please refer to the marking instruction point 10 for guidance on how to mark this question.* **(Level 3)** Applies knowledge of elimination reactions to provide the correct names and structures of all three alkenes. **AND** Full, detailed explanation of formation of both types of isomers linked to the reaction, with clear understanding of both types of isomerism. *The explanations show a well-developed line of reasoning which is clear and logically structured. The information presented is relevant to the compounds drawn / named.* (5–6 marks) **(Level 2)** Applies knowledge of elimination reactions to provide the correct name and structure	6	**Indicative scientific points may include:** • the elimination can produce a double bond in either the 1- or the 2- position (through combination of the hydroxyl group with a hydrogen from either the 1st or the 3rd carbon) • this leads to the formation of structural isomers (pent-1-ene and pent-2-ene) • pent-2-ene exhibits stereoisomerism / *E*/*Z* isomerism / *cis–trans* isomerism because it has two different groups attached to each carbon atom • there are two possible isomers of pent-2-ene and three in total.

			for pent-1-ene. **AND** Correct structures of stereoisomers of pent-2-ene but full names missing or incorrect. **AND** Explanation of formation of at least one type of isomers in some detail. *The explanations show a line of reasoning presented with some structure. The information presented is in the most-part relevant to the compounds drawn / named.* (3–4 marks) **(Level 1)** Applies knowledge of elimination reactions to name and draw the structures of organic products. Either name **OR** structure should be correct for two compounds. **AND** Attempts to explain formation of one type of isomer. *The information about isomerism is basic and communicated in an unstructured way. The relationship to the compounds drawn / named may not be clear.* (1–2 marks) **(0 marks)** No response or no response worthy of credit.		**Names and structures of alkenes**  pent-1-ene  *Z* or *cis*-pent-2-ene  *E* or *trans*-pent-2-ene
			Total	**8**	
3 6		i	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Correctly labelled diagram of reflux apparatus that works, with no safety problems **AND** An appreciation of most of the purification steps required to gain a pure sample *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	6	**Indicative scientific points may include:** **Apparatus set up for reflux:** • round-bottom/pear shaped flask • heat source • condenser *Detail: water flow in condenser bottom to top; open system.* **Purification**

Level 2 (3–4 marks)
Labelled diagram of apparatus (either reflux or distillation) but with safety/procedural problems **OR** clear diagram of reflux apparatus without labelling
AND
Some details of further purification steps

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)
Diagram of apparatus (**reflux OR separation OR distillation**) drawn with no labelling **OR** labelled diagram with significant safety/procedural
AND / OR
Few or imprecise details about further purification stages

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.

- Use of a **separating funnel** to separate organic and aqueous layers
- *Detail: Collect lower organic layer density greater*
- **Drying** with an anhydrous salt,
- *Detail: e.g. $MgSO_4$, $CaCl_2$, etc.*

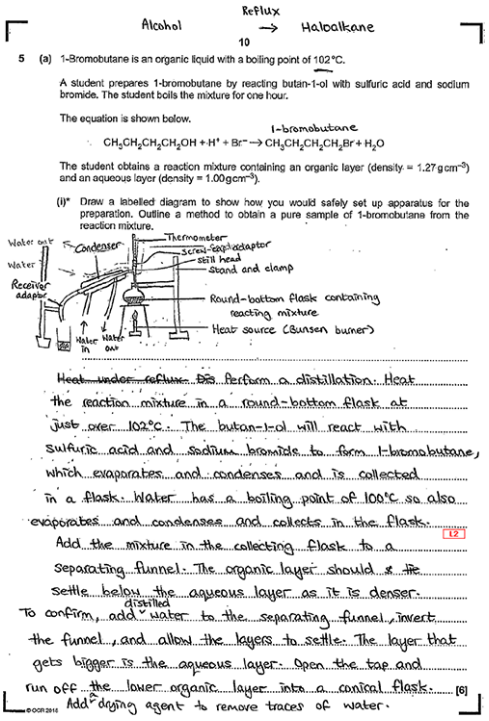
Redistillation

- *Detail: Collect fraction distilling at 102°C.*

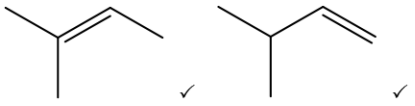
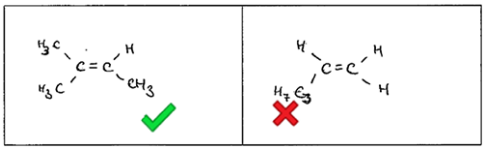
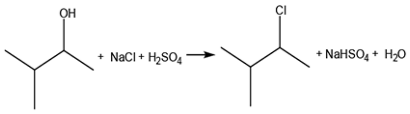
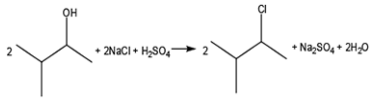
Examiner's Comments

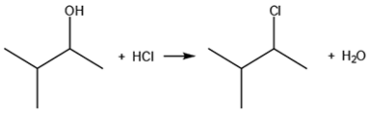
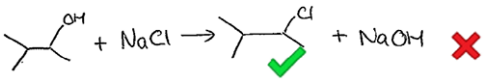
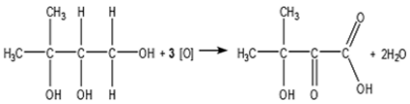
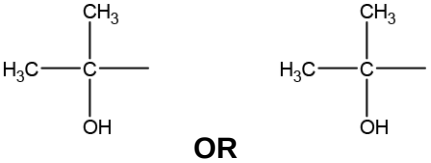
Candidates were not prepared to answer this type of question and the diagrams were hard to give credit to. Many had significant safety implications such as open beakers of butan-1-ol being heated by a Bunsen burner. Most mis-read the question and just outlined the method for purification and struggled to recall the practical details. Very few candidates mentioned the use of anhydrous salts, referring instead to 'boiling off' the water.

Exemplar 4

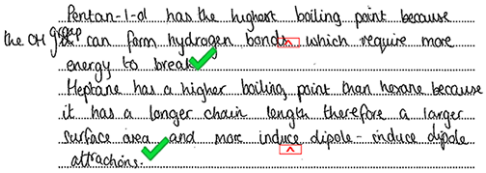
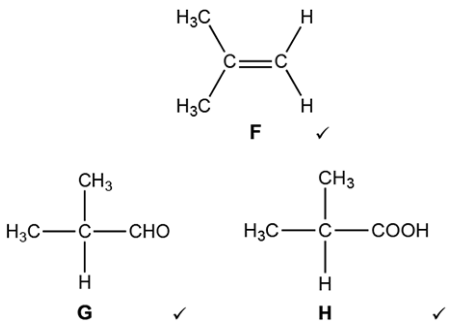
					 Reflux Alcohol → Halkalkane 10 5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102 °C. A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour. The equation is shown below. 1-bromobutane $CH_3CH_2CH_2CH_2OH + H^+ + Br^- \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$ The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm^{-3}) and an aqueous layer (density = 1.00 g cm^{-3}). (i)* Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture. Water out Condenser Thermometer Screw-top adapter Still head Water Stand and clamp Receiver adapter Round-bottom flask containing reacting mixture Heat source (Bunsen burner) Water in Water out Heat under reflux. Do perform a distillation. Heat the reaction mixture in a round-bottom flask at just over 102°C. The butan-1-ol will react with sulfuric acid and sodium bromide to form 1-bromobutane, which evaporates and condenses and is collected in a flask. Water has a boiling point of 100°C so also evaporates and condenses and collects in the flask. 12 Add the mixture in the collecting flask to a separating funnel. The organic layer should sit the settle below the aqueous layer as it is denser. To confirm, add distilled water to the separating funnel, invert the funnel, and allow the layers to settle. The layer that gets bigger is the aqueous layer. Open the tap and run off the lower organic layer into a conical flask. [6] Add drying agent to remove traces of water. This candidate was credited 4 marks for this level 2 answer. Although they have drawn distillation apparatus instead of reflux, they have considered the boiling point of the product, detailed using a separating funnel, a drying agent and that the lower organic layer would be drawn off first.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 12.6 (g) award 2 marks** • n(1-bromobutane) = $0.150 \times \frac{61.4}{100}$ = 0.0921 (mol) ✓ • **Mass 1-bromobutane = 0.0921 × 136.9 = 12.6 (g) ✓** **3 SF required**	2	**Common errors:** 33.4 (0.150 × 100/61.4 = 0.244 × 136.9) 1 mark **ALLOW ECF** for incorrect moles or incorrect M_r **of 1-bromobutane** (provided answer is to 3 SF) **DO NOT ALLOW** 6.82 (using M_r of butan-1-ol) **ALLOW** calculation using masses, e.g. • **Theoretical = 0.150 × 136.9 = 20.535 (g) ✓** ***(ALLOW 20.535 rounded back to 20.5)***

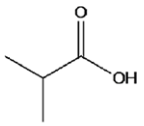
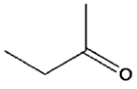
					Actual mass = $20.535 \times \frac{61.4}{100} = 12.6$ (g) ✓ • *(20.5 also gives 12.6)* **Examiner's Comments** This question was well answered, but a significant number of candidates incorrectly used the Mr of butan-1-ol when calculating the mass of 1-bromobutane.
			Total	**8**	
37	a	i	3-methylbutan-2-ol ✓	**1**	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylbutane-2-ol **DO NOT ALLOW** 2-methylbutan-3-ol **OR** 3-methylbut-2-ol **OR** 3-methbutan-2-ol **OR** 3-methybutan-2-ol **OR** 3-methlybutan-2-ol **Examiner's Comments** The majority of candidates were able to correctly name alcohol A as 3-methylbutan-2-ol. A significant number of responses used incorrect numbering and suggested 2-methylbutan-3-ol as the name.
		ii	$(CH_3)_2CHCHOHCH_3$ ✓	**1**	**ALLOW** brackets around OH e.g. $(CH_3)_2CHCH(OH)CH_3$ **ALLOW** any unambiguous structural formula e.g. $CH_3CH(CH_3)CHOHCH_3$ $CH_3CH(CH_3)CH(CH_3)OH$

					Examiner's Comments Most candidates were able to show a correct structural formula of alcohol A.
		iii	One mark for each correct structure. 	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** in either order **Examiner's Comments** Many candidates correctly identified the two alkenes formed as 2-methylbut-2-ene and 3-methybut-1-ene. Stronger responses used skeletal formula to show the structures clearly. Some candidates preferred to use chemical symbols to represent the atoms present and although this approach is valid, lower ability responses did not show sufficient detail as demonstrated in Exemplar 1. **Exemplar 1**  In this response the alkene 2-methylbut-2-ene has been correctly identified and one mark credited. However, the attempt to show 3-methylbut-1-ene does not score. This is because C_3H_7 has been used instead of $CH(CH_3)_2$. Candidates should be encouraged to show every carbon atom when drawing a structure as the use of ambiguous formulae is not sufficient to gain credit.
		iv	 Correct haloalkane ✓ Correctly balanced equation ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ for H_2SO_4 **ALLOW** equations forming Na_2SO_4  **ALLOW** equations with HCl

					 **DO NOT ALLOW** equations that form NaOH **Examiner's Comments** This question proved difficult for candidates. Although many candidates were able to identify the correct organic product, only the higher ability candidates were able to construct an appropriate balanced equation. A common error was to omit the role of the acid; this is shown in Exemplar 2 below. Lower ability candidates appeared not to recognise this reaction and suggested an alkoxide salt, rather than a haloalkane as the organic product. **Exemplar 2**  This type of response was seen frequently by examiners. The candidate has drawn the correct structure of the haloalkane formed and scores the first mark. However, the response fails to recognise that the reaction occurs under acidic conditions and omits the sulfuric acid from the equation.
	b		 Correct organic product ✓ Rest of equation ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the tertiary OH group e.g. **ALLOW**  **OR**

					Examiner's Comments This question required candidates to apply their knowledge of the oxidation of alcohols to complete the equation for the complete oxidation of compound B. This question discriminated well. Many candidates correctly identified the organic product but only the higher ability candidates could complete the equation. A common error was to omit water as a product of the reaction.
			Total	**8**	
38			**Heptane compared to hexane** heptane (has a longer chain so) has more points of contact / more surface interaction (between molecules) ✓ heptane has stronger/more induced dipole(–dipole) interactions ✓ **Pentan-1-ol compared to heptane and/or hexane** pentan-1-ol has hydrogen bonds that are strong(er than induced dipole–dipole interactions) **OR** (alcohols have) hydrogen bonds and induced dipole(-dipole) interactions/London forces ✓ **Energy required to break forces** More energy is required to break induced dipole(–dipole) interactions in heptane than hexane **OR** More energy is required to break hydrogen bonds ✓	**4**	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW ORA** throughout **ALLOW** heptane has more electrons **IGNORE** IDID **ALLOW** stronger/more London forces **IGNORE** van der Waals' forces/VDW for induced dipole–dipole interactions *(ambiguous as this term refers to both permanent dipole–dipole interactions and induced dipole–dipole interactions)* **IGNORE** 'pentan-1-ol can form hydrogen bonds with water' **ALLOW** 'more energy to break intermolecular forces' if intermolecular forces are not stated. **IGNORE** it is harder to break the intermolecular forces *no reference to energy)* **IGNORE** more energy needed to separate molecules **IGNORE** more energy is needed to break bonds **Examiner's Comments** This question was answered well with most candidates scoring three or four

					marks. Examiners were impressed by the number of responses that accurately referred to induced dipole-dipole interactions or London forces rather than van der Waals' forces, which is ambiguous. Some responses lacked detail, as demonstrated in Exemplar 10. **Exemplar 10**  This response attributes the higher boiling point of pentan-1-ol to the amount energy required to break hydrogen bonds. However, it does not refer the relative strength of this type of interaction. Consequently, the first paragraph only scores marking point four and not marking point three. The higher boiling point of heptane compared to hexane is explained by a correct comparison of the induced dipole-dipole interactions present in these compounds, so marking point two was achieved. However, the justification for the difference in intermolecular forces lacks precision. Candidates should be encouraged to focus on surface contact or surface interaction between molecules rather than referring to surface area alone.
			Total	**4**	
39		i	 	**3**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** mixture of the above (as long as unambiguous) **IGNORE** molecular formula **ALLOW** CH_3– **ALLOW** 1 mark for **G AND H** combined is structures are correct but in wrong boxes

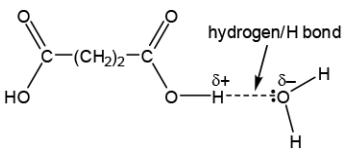
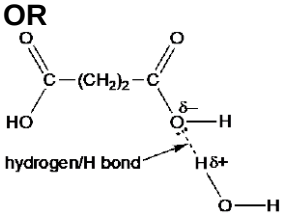
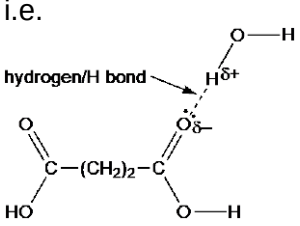
					Examiner's Comments Part (i) discriminated extremely well and rewarded the well-prepared candidate. Compound F proved to be the most difficult option, with a large variety of responses, many appearing to be guesses. Candidates were much more successful with compounds **G** and **H**, although these were sometimes shown in reverse order. A significant number of candidates drew structures containing C=C or C=O bonds in which the carbon atom had five bonds. Candidates should check drawing of organic structures carefully to ensure that all carbon atoms have four bonds. There were some good responses for part (ii), with many clearly shown and correct systematic names.
		ii	2-methylpropan−1−ol ✓ *Both numbers required*	**1**	**IGNORE** absence of hyphen or use of dots or commas as separators **DO NOT ALLOW** 2−methylprop−1−ol **OR** 2−methpropan−1−ol **OR** 2−methypropan−1−ol
			Total	**4**	
4 0		i	A →  ✓ B → NONE ✓ C →  ✓	3 (AO2.5) (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW STICKS IN STRUCTURES** **Examiner's Comments** Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The

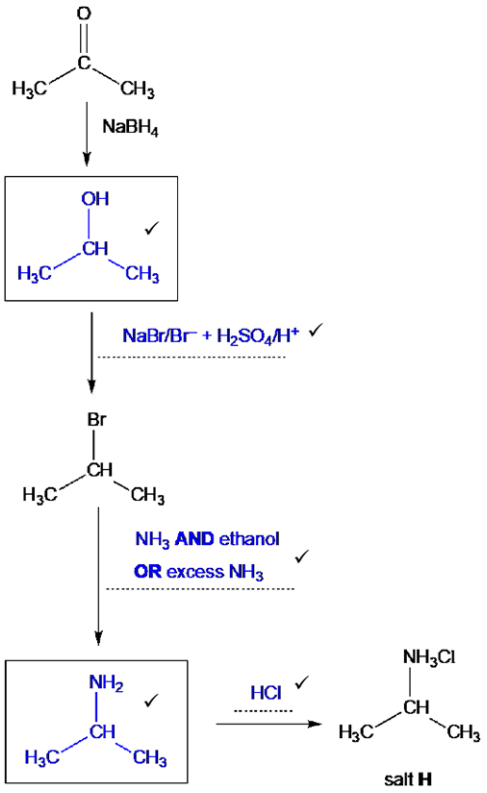
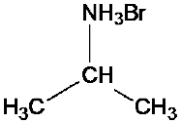
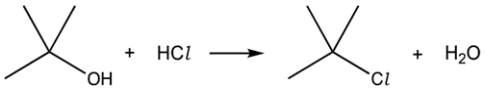
					ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although $4CO_2$ and $5H_2O$ were usually seen for the products, oxygen was usually seen as $6½O_2$, rather than $6O_2$. Candidates need to look very closely at the formula of the organic compound so that the O in $C_4H_{10}O$ is accounted for in the balancing.
		ii	butan-2-ol ✓	1 (AO1.2)	**IGNORE** lack of hyphens, or addition of commas **ALLOW** butane-2-ol **DO NOT ALLOW** butan-3-ol **OR** but-2-ol **Examiner's Comments** Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to

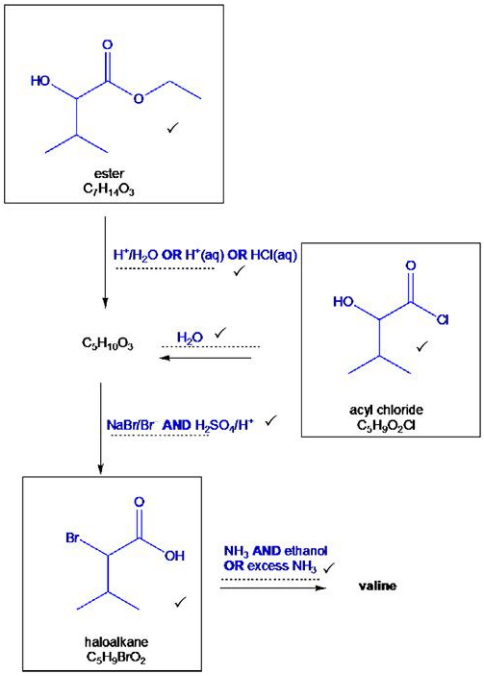
					derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although $4CO_2$ and $5H_2O$ were usually seen for the products, oxygen was usually seen as $6½O_2$, rather than $6O_2$. Candidates need to look very closely at the formula of the organic compound so that the O in $C_4H_{10}O$ is accounted for in the balancing.
		iii	$C_4H_{10}O + 6O_2 \rightarrow 4CO_2 + 5H_2O$ ✓	1 (AO2.6)	**Examiner's Comments** Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although $4CO_2$ and $5H_2O$ were usually seen for the products, oxygen was usually seen as $6½O_2$, rather than $6O_2$. Candidates need to look very closely at the formula of the organic compound so that the O

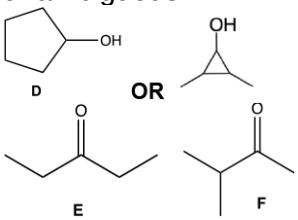
					in $C_4H_{10}O$ is accounted for in the balancing.
			Total	**5**	
4 1			**C**	1 (AO1.1)	
			Total	**1**	
4 2			**A**	1 (AO1.2)	**Examiner's Comments** Success with this question was dependent on knowledge of key reactions and their reagents. B and C proved to be the main distractors from A.
			Total	**1**	
4 3	a		**C, E AND F ✓✓** Three correct alcohols → 2 marks Two correct alcohols → 1 mark	2 (AO1.1× 1) (AO2.1× 1)	**If >2 alcohols are shown lose 1 mark for each incorrect response** **Examiner's Comments** Generally this was well answered. However, some candidates only gave two responses where three were required, presumably because it was worth two marks.
	b		(CH3CH2CHOHCH$_3$ +) $6O_2 \rightarrow 4CO_2 + 5H_2O$ ✓	1 (AO2.6× 1)	**DO NOT ALLOW** [O] **Examiner's Comments** A significant number of candidates did not gain the mark here as they incorrectly balanced the number of oxygens, forgetting that the alcohol contains an O atom i.e. 6.5 O_2 given rather than 6.
	c		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** The candidate gives thorough explanations of both spectra, and correctly identifies **X** and **Y** with a correct equation. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*	6 (AO2.5× 1) (AO3.1× 2) (AO3.2× 3)	**Indicative scientific points** **LOOK AT THE SPECTRA** for labelled peaks <u>Mass Spectrum</u> • M^+ or molecular ion of 86 • *m/z* = 43 shows CH_3CO^+ **OR** $C_3H_7^+$ <u>IR Spectrum</u>

			Level 2 (3–4 marks) The candidate attempts all three scientific points but explanations are incomplete. **OR** Explains two scientific points thoroughly with few omissions. **AND** Attempts a feasible structure based on deduction from correct M_r. *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)** The candidate gives a simple description based on at least two of the main scientific points. **OR** Gives a thorough description and explanation of one of the scientific points. *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.*		• IR shows no broad absorption at 2500–3300 cm^{-1} so no O–H bond **AND** not a carboxylic acid • IR shows absorption at 1700 cm^{-1} for C=O bond **OR** indicates a ketone/aldehyde present <u>Identification and Equation</u> • **X** must be a secondary alcohol, since refluxing a secondary alcohol with acidified potassium dichromate (VI) forms a ketone **OR** primary alcohol → carboxylic acid **AND** tertiary alcohol would not be oxidised. • **X** is $(CH_3)_2CHCHOHCH_3$ **OR** compound **E** **OR** 3-methylbutan-2-ol • **Y** is $(CH_3)_2CHCOCH_3$ **OR** 3-methylbutan-2-one *Equation* $(CH_3)_2CHCHOHCH_3 + [O] \rightarrow (CH_3)_2CHCOCH_3 + H_2O$ **<u>Examiner's Comments</u>** * This was a challenging problem-solving question, relying on candidates to make use of all of the information provided to determine the structure. Very few candidates made no attempt at all at this question. The most common error was incorrectly identifying the peak at 3000 cm^{-1} as O-H from a carboxylic acid, despite it being indicated on the data sheet that this would be a broad peak. It suggested that candidates were not familiar with looking at spectra and understanding what data it gave. Candidates should also be reminded when answering these types of question that they should give the structures, not just molecular formulae, where possible.
			Total	**9**	

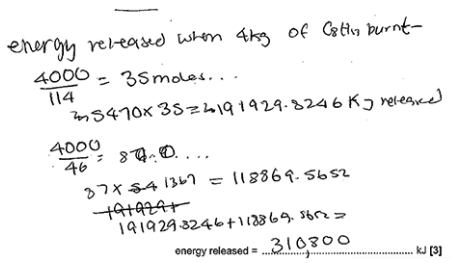
44			**A**	1 (AO1.1)	
			Total	**1**	
45			**C**	1 (AO2.3)	
			Total	**1**	
46			**D**	1 (AO2.1)	
			Total	**1**	
47		i	**Reagents** $K_2Cr_2O_7$ **AND** acid **AND** reflux ✓ **Equation** $HO(CH_2)_4OH + 4[O] \rightarrow HOOC(CH_2)_2COOH + 2H_2O$ [O] **AND** H_2O ✓ Correctly balanced equation ✓	3 (AO1.1) (AO2.5) (AO2.6)	**ALLOW** $Na_2Cr_2O_7$ **OR** $Cr_2O_7^{2-}$ **ALLOW** H_2SO_4 **OR** HCl **OR** H^+ **ALLOW** words. e.g. 'acidified dichromate' **ALLOW** a small slip in formula for dichromate e.g KCr_2O_7, **Examiner's Comments** Many candidates did not correctly balance this equation or missed water as a product entirely.
		ii	 **OR**  Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓ Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another **AND**	2 (AO2.1× 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** δ+ on H atoms of CH_2 group **ALLOW** H-bond for hydrogen bond **ALLOW** H bond between C=O and H_2O, i.e.  **IF** diagram is not labelled, **ALLOW** hydrogen bond/H bond from text

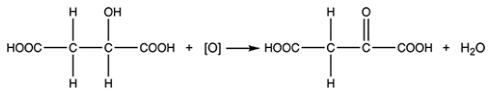
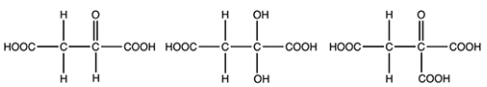
			Hydrogen bonding stated or labelled on diagram		**Examiner's Comments** Candidates who answered this question well had clear, labelled diagrams. Too often, labels, dipoles and lone pairs were missing.
			Total	**5**	
48				5 (AO2.5× 5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** HBr **ALLOW** for the bottom left structure 
			Total	**5**	
49	a		 Correct skeletal formulae for organic compounds ✓ Complete balanced equation ✓	2 (AO2.5 × 2)	Skeletal formulae needed for 1st marking point. For complete balanced equation, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. $(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$
	b	i	Butan-2-ol	1 (AO1.2)	
		ii	$(CH_3)_2CHCH_2OH + 2[O] \rightarrow (CH_3)_2CHCOOH + H_2O$ **B** as reactant: $(CH_2)_2CHCH_2OH$ ✓ $(CH_3)_2CHCOOH$ as product ✓	3 (AO2.5 × 2) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous If structure of **B** is a different primary or secondary alcohol, **ALLOW ECF** for product and equation

			Correct equation with 2[O] and H_2O ✓		
			Total	**6**	
50			**C**	1 (AO2.6)	
			Total	**1**	
51			**A**	1 (AO1.2)	
			Total	**1**	
52				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 **DO NOT ALLOW** OH– for HO– but **ALLOW ECF** for subsequent use in **(b)** For hydrolysis, **ALLOW** dilute acid **ALLOW** alkaline conditions followed by protonation of carboxylate i.e. NaOH(aq)/OH^-(aq) **AND** H^+(aq)/HCl(aq) **ALLOW** HBr for NaBr/H_2SO_4
			Total	**7**	
53			*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	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 $H^+/Cr_2O_7^{2-}$: **D** is primary **OR** secondary alcohol; **E** and **F** are ketones *(negative test shows not aldehydes)* Br_2: **D**, **E** and **F** have no C=C/are saturated

			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 **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.		**^{13}C NMR analysis** **D:** • 3 carbon environments/types of C • δ = 24, 36 ppm **C–C** • δ = 73 ppm, **C**–O **^{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**	

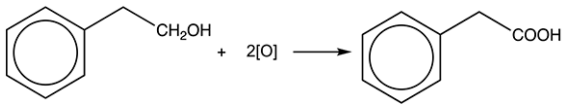
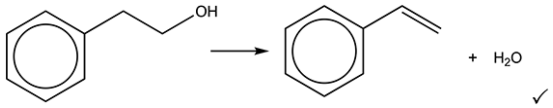
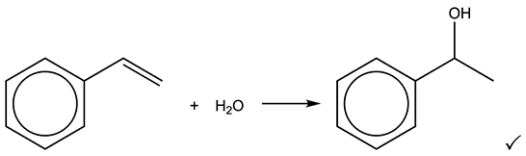
5 4		i	$C_8H_{18} + C_2H_5OH + 15½\ O_2 \rightarrow 10\ CO_2 + 12\ H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples e.g. $2\ C_8H_{18} + 2\ C_2H_5OH + 31\ O_2 \rightarrow 20\ CO_2 + 24\ H_2O$ **ALLOW** $C_{10}H_{24}O$ for $C_8H_{18} + C_2H_5OH$ *Combining ethanol and octane!* **Examiner's Comments** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a 'mixture formula' of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using $15½O_2$ was the hardest part of the equation and many different balancing numbers for O2 were seen ($10CO_2$ and $12H_2O$ where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** --- $M(C_8H_{18})$ = 114 **AND** $M(C_2H_5OH)$ = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark $m(C_8H_{18})$ = (114/160) × 8000 = 5700 g **AND** $m(C_2H_5OH)$ = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded --- **Common errors** **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**

					 **Examiner's Comments** This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**4**	
5 5	a		Number of optical isomers = 4 ✓	1 (AO2.1)	**Examiner's Comments** Most candidates added two asterisks to the diagram of vitamin C for the possible chiral centres. More successful responses usually realised that two chiral centres would give rise to $2^2 = 4$ optical isomers, with 2 optical isomers being the commonest error.
	b	i	Hydrogen bonding **AND** **Many** OH/hydroxyl / hydroxy / alcohol ✓	1 (AO2.1)	**ALLOW** 4 OH **DO NOT ALLOW** OH^- **Examiner's Comments** Most candidates realise that hydrogen bonds would be formed from the OH groups in vitamin C to water. Candidates are advised to read the question carefully as the word 'extremely' was a hint that 'many' OH groups would be needed in the explanation. The most successful responses quoted that hydrogen bonds would form between

					the 4 OH groups in vitamin C and water. Some candidates stated that O atoms in vitamin C would be involved. This was not given marks as not all O atoms in vitamin C are a part of OH groups and capable of hydrogen bonding.
		ii	x = 15 ✓ y = 31 ✓	1 (2 ×AO3.2)	**Examiner's Comments** More successful responses determined that *x* = 15 and *y* = 31. The key to success here was to subtract the formula of vitamin C from the formula of the ester and to add the formula of water: $C_{22}H_{38}O_7$ - $C_6H_8O_6$ + H_2O → $C_{16}H_{32}O_2$ → $C_{15}H_{31}COOH$. A significant number of candidates did obtain one of these values, with 15/16 and 29/30/32 being common incorrect answers. Omitting part(s) of sequence above would result in these incorrect numbers.
			Total	**4**	
5 6			 Correct structure of product ✓ Correctly balanced equation ✓	2 (AO 2.5) (AO 2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** Despite oxidation of alcohols being a topic that has been assessed many times, candidates found this question very tricky with a majority failing to score any marks. Candidates needed to correctly identify this as a secondary alcohol which, when oxidised, will become a ketone. A wide range of errors were seen, including the following: 

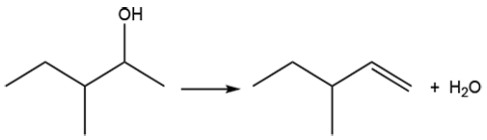
					Other errors included forming C=C or removing COOH. Approximately half of those that got the correct structure were also able to balance the equation gaining both marks. Some forgot that another product was formed or gave H_2 instead. Candidates were given the structure and told to use [O] to represent the oxidising agent. However, some attempted to use structural or molecular formula and/or adding in dichromate to their answers.
			Total	**2**	
5 7		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 8.07 g award 3 marks** **CARE: Intermediate rounding may give 8.06 g which is acceptable for 3 marks** --- *n*(2-bromobutane) $= \frac{10.0}{136.9} = 0.073(0)\ldots.\ (\text{mol})$ ✓ *n*($CH_3CH_2CHOHCH_3$) $= 0.0730\ldots. \times \frac{100}{67.0} = 0.109\ (\text{mol})$ ✓ mass $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **3 SF** required	3 (AO 2.4 × 3)	**ALLOW ECF throughout** **IGNORE** trailing zeroes in intermediate working, e.g. 0.073 for 0.0730 **ALLOW** 3 SF or more, correctly rounded Calculator: 0.7304601899 Calculator: 0.1089552239 **ALLOW alternative method mass** • Theoretical mass of 2-bromobutane $= 100 \times \frac{10.0}{67.0} = 14.9\ldots..\ (\text{g})$ Calculator: 14.925373 • Theoretical *n*($CH_3CH_2CHBrCH_3$) $= \frac{14.923373}{136.9} = 0.1902\ (\text{mol})$ • Mass of $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **Common Errors for 2 marks** 5.41 g (no % yield) 3.62 g (inverted yield)

					Examiner's Comments The most common errors were omitting the yield or inverting the yield, as given on mark scheme, resulting in 2 marks. Clear working was vital here to help marks to be given even if the final answer was incorrect. Many candidates did not gain the final mark due to incorrect significant figures. As with other multi-step calculations, rounding of intermediate values could also cause marks to be lost.
		ii	Separating funnel (to separate aqueous and organic layers) ✓ Dry organic layer with anhydrous salt ✓ Distil and collect fraction at 91°C ✓	3 (AO 3.3 × 3)	**ALLOW** Use a drying agent **ALLOW** appropriate example of an anhydrous salt e.g. $MgSO_4$, $CaCl_2$ **Examiner's Comments** This question was not answered well with over half the candidates failing to score any marks. While some candidates seemed familiar with the techniques required, describing the process to separate the layers, they often struggled to name the separating funnel. Common approaches were to attempt to 'filter' the layers or to use heat (via evaporation or distillation) to drive off the water. Some attempted to use Na_2CO_3 or NaOH to dry the organic layer – perhaps confusing neutralisation of any remaining acid. Although distillation appeared frequently many did not give the temperature so did not gain marks. The order of the procedure was also not always clear with distillation before using a drying agent. Some described attempts to crystallise the organic layer. The range of answers suggests students may need more practical experience with separating organic liquids.

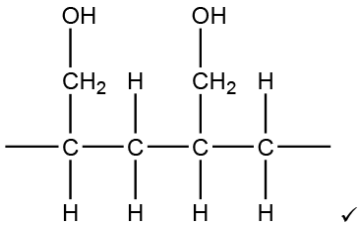
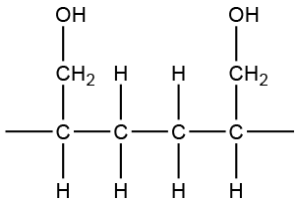
			Total	**6**	
58	a		 organic product ✓ Correct balanced equation ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_6H_5 for phenyl group **Examiner's Comments** Most candidates were able to score at least 1 mark for this question. Common errors included candidates producing two water molecules or failing to balance [O]. A significant proportion of candidates did not score any marks, frequently due to the organic product having too many carbon atoms in it.
	b		**Stage 1** *Reagents*: H_2SO_4 ✓  ✓ **Stage 2** *Reagents*: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓  ✓	4 (AO3.1) (AO2.6) (AO3.1) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam For steam, **ALLOW** H_2O with temperature ≥100°C **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst **DO NOT ALLOW** HCl **IGNORE** pressure **Examiner's Comments** This question proved challenging with only the most able being given full marks. The reagents and conditions were not well known and candidates did not include water in their equations to make sure they were balanced.
			Total	**6**	

5 9			**Level 3 (5-6 marks)** Diagram showing reflux with most labels **AND** A **CORRECT** calculation of the % yield of 1-bromobutane **AND** A **detailed** description of most purification steps. *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)** Diagram showing reflux with some labels **AND** Calculates the % yield of 1-bromobutane with some errors **OR** Diagram showing reflux with most labels **AND** describes some purification steps, with some detail **OR** Calculates the % yield of 1-bromobutane with some errors **AND** describes some purification steps, with some detail *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)** Diagram showing reflux **OR** Attempts to calculate the % yield of 1-bromobutane **OR** Describes few purification steps. *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 (AO2.8 ×2) (AO3.3 ×4)	**Indicative scientific points may include:** <u>Diagram</u> Diagram draw with condenser above flask Labels including • condenser • water in at bottom and out at top • pear-shaped or round-bottom flask ***<u>Calculation of % yield of 1-bromobutane</u>*** • $n(\text{butan-1-ol}) = \frac{9.25}{74.0} = 0.125$ (mol) • mass 1-bromobutane = 6.10 × 1.268 = 7.7348 g • $n(\text{1-bromobutane}) = \frac{7.7348}{136.9} = 0.0565$ (mol) • % yield $= \frac{0.0565}{0.125} \times 100 = 45.2\%$ **ALLOW** 45.2 ± 0.2 for small slip/rounding **NOTE Use of 6.1 g (omission of density)** • $n(\text{1-bromobutane}) = \frac{6.10}{136.9} = 0.044558\ldots$ (mol) • % yield $= \frac{0.044558\ldots}{0.125} \times 100 = 35.6\%$ ***<u>Purification</u>*** • In separating funnel, **organic layer is on bottom** • Drying with an **anhydrous salt by formula or name**, e.g. $MgSO_4$, Na_2SO_4, $CaCl_2$ • Redistil **at 102°C** **Examples** of detail in **bold** (**NOT INCLUSIVE**) **NOTE**: 'Use a separating funnel', dry, and 'redistil' on their own are **NOT**

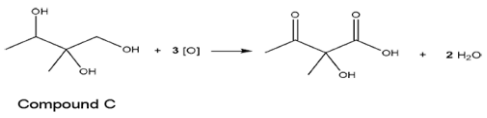
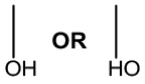
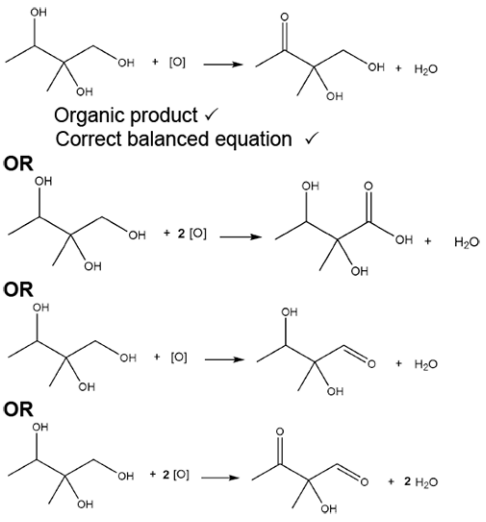
					detailed descriptions **Examiner's Comments** This question was assessed by level of response (LoR). Candidates were required to describe key features in a procedure to prepare a pure organic liquid, including a labelled diagram for reflux, a calculation of the percentage yield and the procedural steps for purification. Levels were determined using these three features. Marks within a level were determined by communication. This question discriminated extremely well. Level 3 candidates would draw a clear diagram with all key items labelled and the set up being capable of being used safely. The percentage yield calculation would be correct, producing a percentage yield close to 45.2%. The steps for the purification: use of a separating funnel, drying and redistillation would be described in the correct order and with some detail. Level 2 candidates would have obtained some of the features required for Level 3 but there would be some key omissions or errors. The diagram may have been drawn clearly but labelling may have been incomplete or a thermometer with bung may have been inserted into the top of the condenser, a very hazardous arrangement. The calculation would be attempted but with some errors, such as omitting to use the density, or using a mixture of moles and masses. The purification steps may have been described but in the wrong order. Purification steps would be incomplete, perhaps only including distillation. Level 1 candidates often drew a diagram resembling a tube above a flask, with water often flowing in the wrong direction. The percentage yield may have been a simple mass ratio with no moles being used. A significant number of candidates

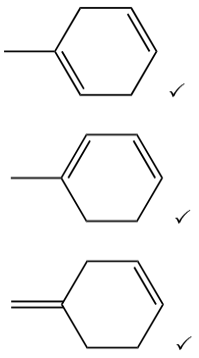
					described the purification steps for an organic solid, including recrystallisation. The preparation of an organic liquid is a key practical procedure that will have been experienced by students during their A Level studies (PAG 5). The overall standard of drawing diagrams was poor, an area that needs improvement.
			Total	**6**	
6 0	a	i	3-methylpentan-2-ol ✓	1 (AO 2.1)	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylpentane-2-ol **DO NOT ALLOW** 2-methylpentan-3-ol 3-methylpent-2-ol 3-methpentan-2-ol 3-methypentan-2-ol 3-methlypentan-2-ol **Examiner's Comments** A significant number of candidates lost the mark for missing -an- in their answer i.e. 3-methylpent-2-ol. Others lost the mark for incorrect spelling of methyl.
		ii	 Correct structure of organic product ✓ Balanced equation ✓	2 (AO 2.7 × 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** additional reactants such as H^+ or [O] in the equation. **ALLOW** incorrect isomer 3-methylpent-2-ene for balancing mark. **Examiner's Comments** Most candidates did not score either mark here, despite the structures for B and C being given in the table below for (iii). Many thought this was oxidation,

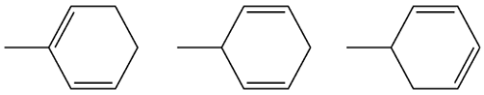
					showing [O] in equations and giving a carbonyl product. Many had alkenes but still with the -OH present. Some attempted to use structural or displayed formulae but errors were made in giving the correct number of H atoms. For those that did have the correct structure, they often did not give an equation, added the acid as a reactant , or missed off the water as a product.
		iii	Priority groups on same side ✓ High(est) priority groups are CH_3CH_2 and CH_3 **OR** Low(est) priority groups are CH_3 and H ✓	2 (AO 3.1 × 2)	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic number or more important groups etc. **ALLOW** priority groups are both on the top **IGNORE** references to relative mass of groups, Ar, Mr, **ALLOW** identification by name e.g. ethyl and methyl, or by circling on the structure. **IF** 'priority' is not mentioned **ALLOW** 1 mark for CH_3CH_2 and CH_3 are on same side **OR** H and CH_3 are on same side **<u>Examiner's Comments</u>** Many responses made no reference to 'priority' and/or discussed alkene C, suggesting that they didn't read the question fully. Candidates often struggled to find the right language to express themselves, such as reference to 'functional groups' or 'molecules' rather than priority groups. Lots discussed using *M*r to assign priority with only a few stating correctly that it is atomic number that is used for CIP rules. Many, despite stating that priority groups are on the same side, didn't identify these groups so didn't get the second mark.
	b	i	**Section of polymer**	2 (AO 2.5) (AO 3.1)	**ALLOW** correct structural **OR** displayed **OR** skeletal formula. **ALLOW** alternating side chains i.e.

			 ✓ - **Reason for solubility in water** <u>OH/alcohol</u> groups form hydrogen bonds <u>with water</u> ✓		 **IGNORE** brackets and use of 'n' **IGNORE** incorrect connectivity for -CH_2OH **DO NOT ALLOW** -HO End bonds **MUST** be shown (solid or dotted) **DO NOT ALLOW** one repeat unit *Question asks for 2 repeat units.* - **DO NOT ALLOW** 'it forms hydrogen bonds' **<u>Examiner's Comments</u>** Most candidates were able to gain credit for their structure, with only a few missing out by only drawing one repeat unit, keeping the C=C, having no end bonds or missing/extra Hs. Lots struggled to gain the second mark for the reason for solubility in water as they didn't refer to H-bonding. There were quite a few misconceptions highlighted in the responses to this question. These included the misunderstanding that a H-bond is an an intermolecular force between -OH on alcohol and water, rather than the covalent bond in the molecule. Some thought the -OH would behave as an alkali, even referring to ions, so would 'fully dissociate'. Some described a reaction with water and breaking apart, perhaps confusing with condensation polymers which can be hydrolysed.
		ii	Any two ✓✓ • Recycled (to make other plastic materials)	2 (AO 1.1 × 2)	**IGNORE** Reused **ALLOW** Used as a fuel to generate energy / electricity

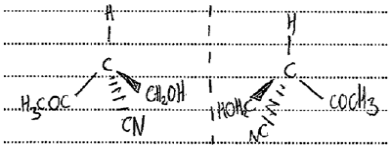
			• Combustion to generate energy / electricity • As (organic) feedstock		**Examiner's Comments** About a quarter of candidates didn't gain any credit here as they struggled to identify useful processes. Lots referred to cracking or breaking down into smaller chains, possibly thinking about fractional distillation of crude oil and how we make better use of larger fractions. Some identified possible use as a fuel but didn't say to generate energy/electricity. We also saw reference made to photodegradable/biodegradable polymers which isn't relevant to hydrocarbon polymers. There was evidence of the misunderstanding of the use as 'feedstock' with reference being made to animals (livestock or animal feed) or as food to eat.
			Total	**9**	
6 1	a		$C_6H_{11}OH$ ✓ Correct balanced equation $C_6H_{11}OH + 8½\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓	2 (AO2.6 ×2)	For $C_6H_{11}OH$, **ALLOW** $C_6H_{12}O$ **OR** any combination of skeletal **OR** structural **OR** displayed formula **ALLOW** multiples **IGNORE** state symbols **ALLOW** multiple OH groups in structure for both marks e.g. $C_6H_{12}O_2$ ✓ $C_6H_{12}O_2 + 8\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓ **Examiner's Comments** Approximately half the candidates gained both marks here but just over a third gained no credit. A very common error was $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$ missing the need for an alcohol group. Another common error was balancing with $9O_2$ i.e. not deducting O from alcohol from their count of O atoms. Some struggled to determine the correct number of Hs when a single C=C bond is introduced so gave $C_6H_{12}OH$ or $C_6H_{13}OH$ instead. Lower attaining candidates did not understand what

					happens during complete combustion. For example, they used [O] instead of molecular oxygen or didn't have CO_2 and water as the products. Some used structural formula which made it easier to get the correct formula of the reactant but often made it trickier to balance the equation.
	b		 Compound C Correct organic product ✓✓ Correct balanced equation ✓	3 (AO2.5 ×2) (AO2.6)	**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**  **ALLOW** 1 mark for partially oxidised organic product and an additional mark for ECF for correct balanced equation for this product. i.e.  **Examiner's Comments** The higher attaining candidates scored well here, with many being able to identify both the primary alcohol being oxidised to the carboxylic acid and the secondary alcohol being oxidised to the

					ketone and obtaining correct balancing. A good strategy adopted by some candidates was labelling the three alcohol groups with their classification, i.e. primary, secondary, and tertiary. Some missed the water by-product or gave H_2 instead. Some gained credit for partial oxidation products as shown in the guidance on the mark scheme. However, more than a third gained no credit here with many attempting to oxidise the tertiary alcohol or removing it entirely. Some made a mistake by adding an extra CH_2 on to the product before COOH group - again demonstrating the importance of counting atoms when balancing equations. Oxidation of alcohols is typically taught in the first year with very simple examples, but candidates need to practise more complex examples. Candidates need to be reminded that every oxidation step requires an [O] and every OH group oxidised produces a water molecule.
	c	i		3 (AO2.5 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **<u>Examiner's Comments</u>** Lots struggled here with just under half of candidates gaining no credit. Only the strongest responses recognised that a carbon-carbon double bond could be formed external to the ring from the methyl branch. A common error was repeating one of the first two isomers as a mirror or rotated image and so lost a mark - candidates need to be able to recognise same structures (especially using skeletal formula) Lower scoring candidates didn't recognise this reaction would result in the elimination of water. So, it was common to see responses with three structures still containing the OH group

					or ketones (possible oxidation products), despite the molecular formula C_7H_{10} being provided twice in the question. Some candidates attempted to give structural isomers of C_7H_{10} that would not form from this reaction (see below) including those with smaller rings and even unsaturated straight chain compounds. Some even gave benzene structures.  This question was particularly problematic to mark if previous structures drawn were then rubbed out. **Drawing structures in exams** Please remind candidates to draw structures clearly in black ink. If incorrect cross them out and redraw them. Drawing in pencil then rubbing out often leads to extra lines showing when exam papers are scanned making it appear that structures are incorrect.
		ii	NaI / KI **AND** H_2SO_4 ✓	1 (AO1.2)	**ALLOW** HI **ALLOW** NaI / KI **AND** H_3PO_4 **OR** HNO_3 **IGNORE** Conc or dilute **Examiner's Comments** Many candidates were unable to provide reagents and conditions for this reaction. Iodo- seemed unfamiliar to some with responses including NaBr or HBr suggesting substitutions with Br are more familiar. The most common errors were to use iodide with no acid or to use iodine, sometimes in conjunction with other reagents such as AlI_3 or FeI_3.
			Total	**9**	
6 2			**A**	1 (AO 2.5)	**Examiner's Comments**

					Candidates had more success with this question with most obtaining the correct option, A.
			Total	**1**	
6 3			**Correct structural isomers of C_3H_8O** *1 mark* $CH_3CH_2CH_2OH$ **AND** $CH_3CHOHCH_3$ ✓ **Reaction conditions** *1 mark* Distillation for aldehyde **AND** reflux for carboxylic acid **OR** ketone ✓ **Functional group of organic product** *2 marks* $CH_3CH_2CH_2OH$ → aldehyde **OR** → carboxylic acid ✓ $CH_3CHOHCH_3$ → ketone ✓ **One correct equation** *1 mark* $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ **OR**		**ANNOTATE WITH TICKS AND CROSSES** **Throughout,** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IF functional group is NOT given,** **ALLOW** propanal / RCHO **ALLOW** propanoic acid / RCOOH **ALLOW**propanone / ..... RCOR **IGNORE** small slips in formulae (assessed in equation) **Examiner's Comments** There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions required to produce the

			$CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ **OR** $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		organic products. The equation proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead. A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.
			Total	**5**	
6 4			**Level 3 (5–6 marks)** Suggests **ALL** of the following • Reagents and conditions for **3** functional groups • Products for **3** functional groups • 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.*	6 (AO 3.1 ×3) (AO 3.2 ×3)	**CHECK TOP OF QUESTION FOR RESPONSES** --- *Indicative scientific points may include:* **Stereoisomerism** • 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.** $NaBH_4$

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.

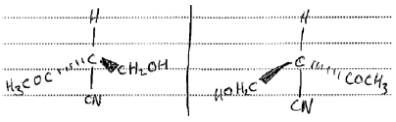
0 mark *No response or no response worthy of credit.*

Key points to check

CHECK TOP OF QUESTION for responses
IGNORE CONNECTIVITY

in 3D isomer structures

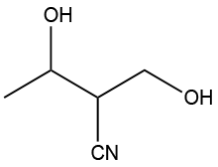
- *IGNORE bond angles*
- *Wedges needed*
- *ALLOW*



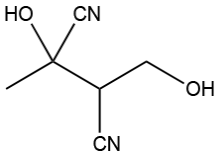
Some responses will not fit into this exact pattern and a best-fit match may be needed

Clear communication
Focus on

- Clear diagrams of 3D optical isomers
- Diagrams of unambiguour structures

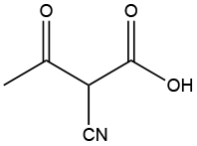


HCN **OR** CN^-/H^+ (e.g. $NaCN/H^+$)

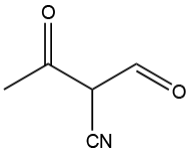


Reactions of –OH, e.g.

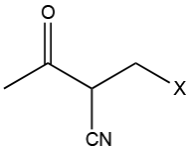
$H^+/Cr_2O_7^{2-}$ **OR** $H_2SO_4/K_2Cr_2O_7$ reflux



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

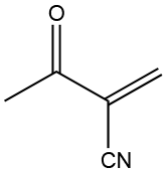
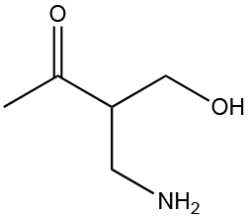
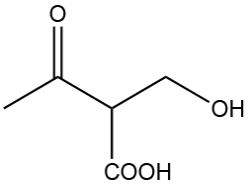


$NaBr/KBr/Br^-$ **AND** $acid/H^+$ **OR** HBr

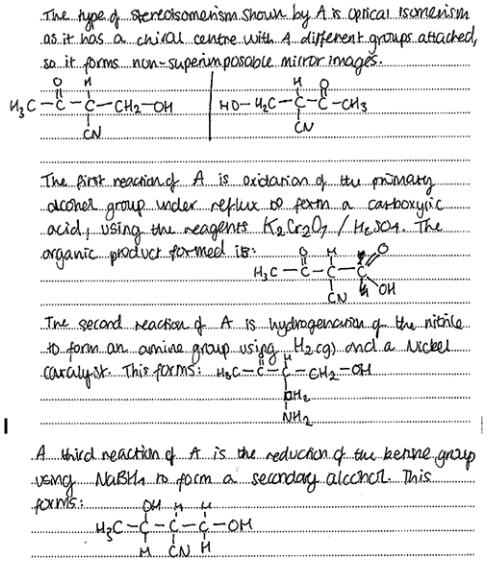


X = halogen

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

			• 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		 **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.

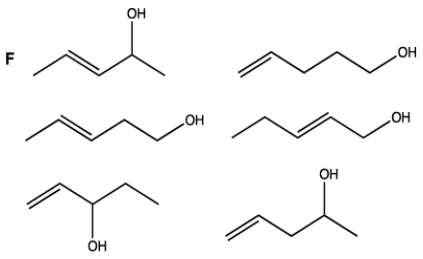
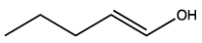
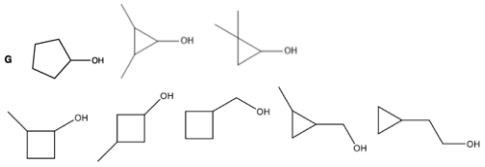
					Optical isomerism was usually identified, with associated diagrams with almost all candidates identifying the chiral centre. Most attempted 3D diagrams but candidates do need to take care that the groups attached to the chiral C atom are those in compound A and that no parts of chains are omitted. Optical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

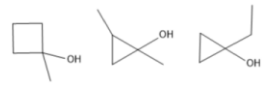
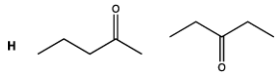
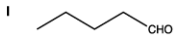
					Exemplar 2  This exemplar shows a good response that lacks 3D diagrams for the optical isomers. The candidate has clearly given reagents and conditions and has shown the organic products. In the response, you can see that the candidate initially showed an extra CH_2 in the –COOH branch, and a mistake 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**	
6 5			**D**	1	**<u>Examiner's Comments</u>** Most were able to correctly calculate the moles of alcohol using the mass and M_r provided and then multiply by 24 dm^3 mol^{-1} to give the correct answer D. All other distractors were seen as incorrect responses from calculations involving the incorrect molar ratio.

			Total	1	
6 6	a		**Reagent and/or catalyst:** H_2SO_4 **OR** H_3PO_4 **OR** H^+ **OR** acid (catalyst) ✓ **Organic product: (mark independently)** $CH_3CH_2CHCH_2$ ✓	2	**DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid as can be used for substitution reaction **DO NOT ALLOW** other additional reagents e.g. H_2O / steam, H_2 / hydrogen **ALLOW** suitable non-specification alternatives e.g. Al_2O_3 **OR** Pumice stone **ALLOW** names of reagents e.g. sulfuric or phosphoric acid, if no formulae given **IGNORE** concentration e.g. dilute/concentrated **IGNORE** (aq) state symbol **IGNORE** conditions e.g. temperature/pressure/reflux **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept but-1-ene **Examiner's Comments** More than half scored both marks here. Common reasons for losing marks included adding water or steam as a reagent, using an incorrect chain length (5 carbons not 4 carbons), missing or adding hydrogens on the structure, e.g. $CH_3CH_2CH_2{=}CH_2$ or giving butane as the product. **OCR support** Useful synthetic route maps for the whole specification, both with and without reagents, can be found on Teach Cambridge.
	b		**Reagent and/or catalyst:** $K_2Cr_2O_7$ **AND** H_2SO_4 **OR** $Cr_2O_7^{2-}/H^+$ ✓	2	**ALLOW** $Na_2Cr_2O_7$ for $K_2Cr_2O_7$ **ALLOW** names for reagents e.g. acidified dichromate, if no formulae given **IGNORE** Roman numerals e.g. (VI),

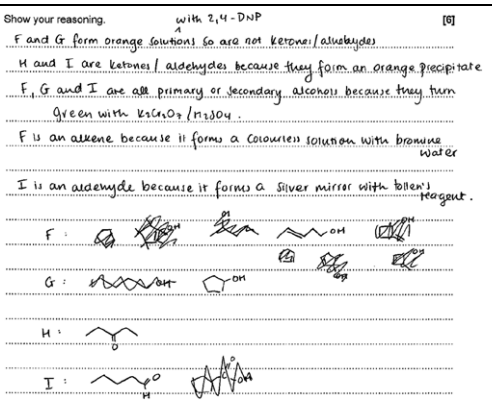
			Organic product: (mark independently) $CH_3CH_2COCH_3$ ✓		unless incorrect **IGNORE** [O] **DO NOT ALLOW** other named acids e.g. HCl / hydrochloric acid **DO NOT ALLOW** other additional reagents e.g. H_2O, steam **ALLOW** suitable non-specification alternative oxidising agents e.g. $KMnO_4/H^+$ **OR** CrO_3/H^+ **OR** H_2CrO_4 (chromic acid) **IGNORE** concentration e.g. dilute/concentrated **IGNORE** conditions e.g. reflux/distillation **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept butanone **<u>Examiner's Comments</u>** This was the most well-known out of the four reactions with more than three quarters of candidates getting both marks. The most common errors included omission of acid catalyst or adding an extra hydrogen on the carbonyl carbon of C=O. Candidates should be reminded to count the number of bonds around each carbon before moving on. A few attempted to oxidise this secondary alcohol to form a carboxylic acid.
	c		**Mark organic product first:** $(CH_3)_2CHCH_2X$ where X is identified as Cl, Br, I ✓ **Reagent and/or catalyst:** Reagent to match organic product NaX / KX / X^- **AND** H_2SO_4 / H^+ / acid Where X is identified as Cl, Br, I ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names unless no structure is given then accept 1-halo-2-methylpropane, where halo is chloro, bromo or iodo (ignore alphabetical order for prefixes) **For 2 marks**, the reagent must be consistent with the product given e.g. $(CH_3)_2CHCH_2Cl$ then correct reagent is NaCl / H_2SO_4 **ALLOW** 1 mark if correct reagents given but no or incorrect organic product

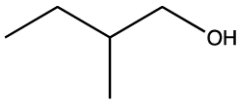
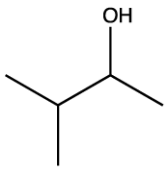
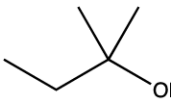
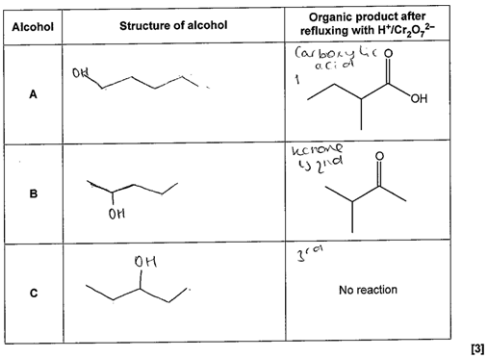
					shown **ALLOW** 1 mark if organic product is given with X i.e. $(CH_3)_2CHCH_2X$ **AND** reagent is consistent e.g. NaX / H^+ **OR** just states 'halide with acid' **ALLOW** HX where X is identified as Cl, Br, I **ALLOW** names of reagents e.g. sodium bromide and sulfuric acid, if no formulae given **DO NOT ALLOW** other additional reagents e.g. $AlCl_3$ **ALLOW** suitable non-specification alternative e.g. PCl_3, PCl_5, (red) phosphorus **AND** bromine **OR** iodine, $SOCl_2$ **IGNORE** concentration e.g. dilute/concentrated **IGNORE** conditions e.g. reflux/distillation **<u>Examiner's Comments</u>** Generally well-answered with very few gaining no marks. Some lost marks for correctly giving sodium halide but forgetting the acid. Some gave the halogen rather than the halide. A few added an additional CH_2 to structure. Some attempted to substitute directly with cyanide to give a nitrile product, e.g. $(CH_3)_2CHCH_2CN$.
			Total	**6**	
67		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 **<u>Examiner's Comments</u>** 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 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	6	Indicative scientific points may include: **<u>Identity of F, G, H and I showing CORRECT structures</u>**  **ALLOW** enols for F, e.g.  For **G**, **DO NOT ALLOW** tertiary -OH. e.g. 

			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.*		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 precipitate 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**	
6 8	a		$C_5H_{12}O^+$ **7½** $O_2 \rightarrow$ **5** CO_2 + **6** H_2O CO_2 **AND** H_2O products ✓ Complete equation balanced ✓	2	**ALLOW** multiples e.g. **2** $C_5H_{12}O$ + **15** $O_2 \rightarrow$ **10** CO_2 + **12** H_2O Watch for 15/2 **OR** 7.5 for 7½ **Examiner's Comments** Most candidates identified the correct products of this combustion as CO_2 and H_2O. The second mark was available for a balanced equation but many balanced O_2 with an 8 rather than with 7½. Candidates need to be very careful when writing equations for the

					combustion of alcohols as it is easy to miss the O atom within the alcohol formula.
	b		<table><tr><th>Alcohol</th><th>Structure</th></tr><tr><td>A</td><td>  ✓</td></tr><tr><td>B</td><td>  ✓</td></tr><tr><td>C</td><td>  ✓</td></tr></table>	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** structure if H(s) are missing from **ONE** structural formula ..... **BUT ALLOW** any further omissions as ECF Take care with numbers of carbons, the branches and the position of branching .... especially for **C** **IGNORE** connectivity, e.g. **ALLOW**  **BUT DO NOT ALLOW −HO** **<u>Examiner's Comments</u>** This question appeared to be straightforward, but many candidates got into a muddle when drawing the alcohol structures. The best tactic is to copy the carbon skeletal and to then add the functional group. Many candidates drew displayed formulae and these often contained too many carbon atoms or missing H atoms. Great care is needed in drawing organic structures. Exemplar 3  [3]

					Exemplar 3 provides some useful lessons. The candidate draws their structures skeletally, but the skeletons do not match the product. Structure C must be a tertiary alcohol, but the candidate has drawn the structure of a secondary alcohol. It should be noted that, even with a correct carbon skeleton, structure A would be rejected. Incorrect connectivity of the OH group is always penalised.
			Total	**5**	