1. 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.

_____

_____

_____

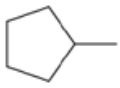
_____

Extra answer space if required.

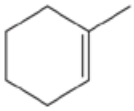
[6]

2. This question is about hydrocarbons.

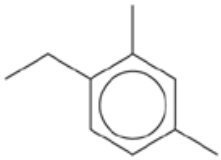
The structures of hydrocarbons **A–E** are shown below.



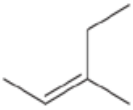
A



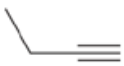
B



C



D



E

Explain why hydrocarbon **D** is a Z-stereoisomer.

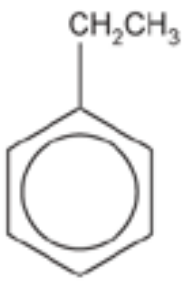
[2]

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

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

[6]

4. Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, CH_3CH_2Cl, in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.



Ethylbenzene

Ethylbenzene

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

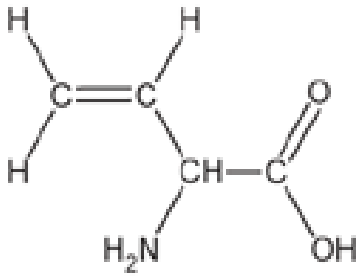
i. What is meant by the term **electrophile**?

[1]

ii. Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

[5]

5. The amino acid below can form addition and condensation polymers.



Draw **2** repeat units of these polymers.
Display the sections linking the monomers together.

addition polymer (2 repeat units)

condensation polymer (2 repeat units)

[3]

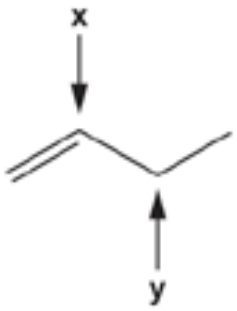
6. Hydrogen reacts much more readily with alkenes than with alkanes.

Why is this?

A Alkenes are polar molecules whereas alkanes are not.
B All atoms in an alkane have a full outer shell of electrons.
C The bond enthalpy of C–C σ bonds is **higher** than that of **π** bonds.
D The bond enthalpy of C–C σ bonds is **lower** than that of **π** bonds.

Your answer ☐ **[1]**

7. The structure of but-1-ene is shown below.

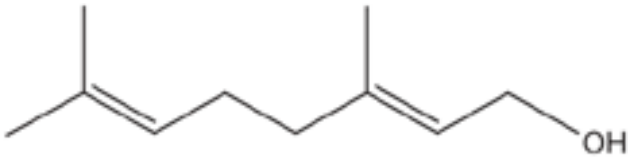


Which row has the correct **shape** around carbon atoms labelled **x** and **y**?

	x	y
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

Your answer ☐ **[1]**

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



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.
B Bromine water and 2,4-dinitrophenylhydrazine.
C Bromine water and acidified dichromate(VI).
D Tollens' reagent and aqueous silver nitrate in ethanol.

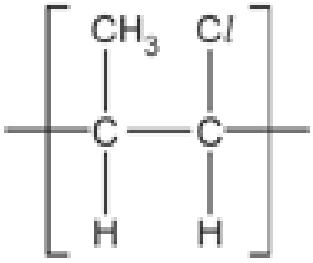
Your answer ☐ **[1]**

9. Which property explains the low reactivity of alkanes?

A Low C–C bond enthalpy.
B Low bond enthalpy of π- bonds.
C Low polarity of σ- bonds.
D Low reactivity of carbon and hydrogen.

Your answer ☐ **[1]**

10. The repeat unit of an addition polymer is shown below.



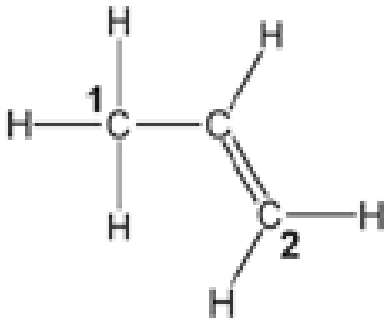
Which statement about this addition polymer is correct?

A Combustion produces toxic alkaline fumes.
B The addition polymer is biodegradable.
C The monomer is $H_3CCH{=}CHCl$.
D The repeat unit above is shown as a displayed formula.

Your answer ☐ **[1]**

11. This question is about hydrocarbons.

Propene, C_3H_6, has different bond angles and shapes around the carbon atoms. The displayed formula of a propene molecule is shown below.



Predict the bond angles and the names of the shapes around the C atoms **1** and **2** above, and explain why the bond angles and shapes are different.

Carbon atom	Bond angle	Name of shape
1		
2		

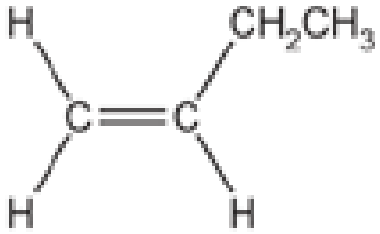
Explanation:

[5]

12. HBr reacts readily with alkenes.

i. Outline the mechanism for the reaction of but-1-ene with HBr to form **2-bromobutane**.

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



[4]

ii. During this reaction, a small amount of **1-bromobutane** is also produced.

Explain why **2-bromobutane** is the major product.

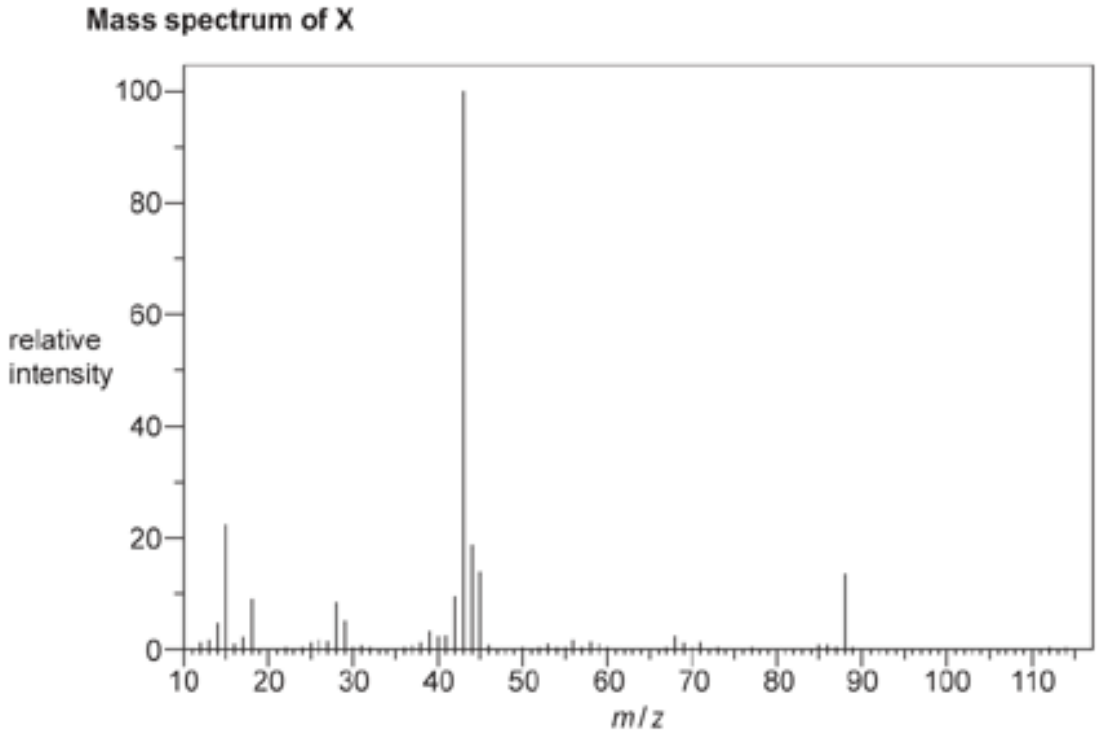
[2]

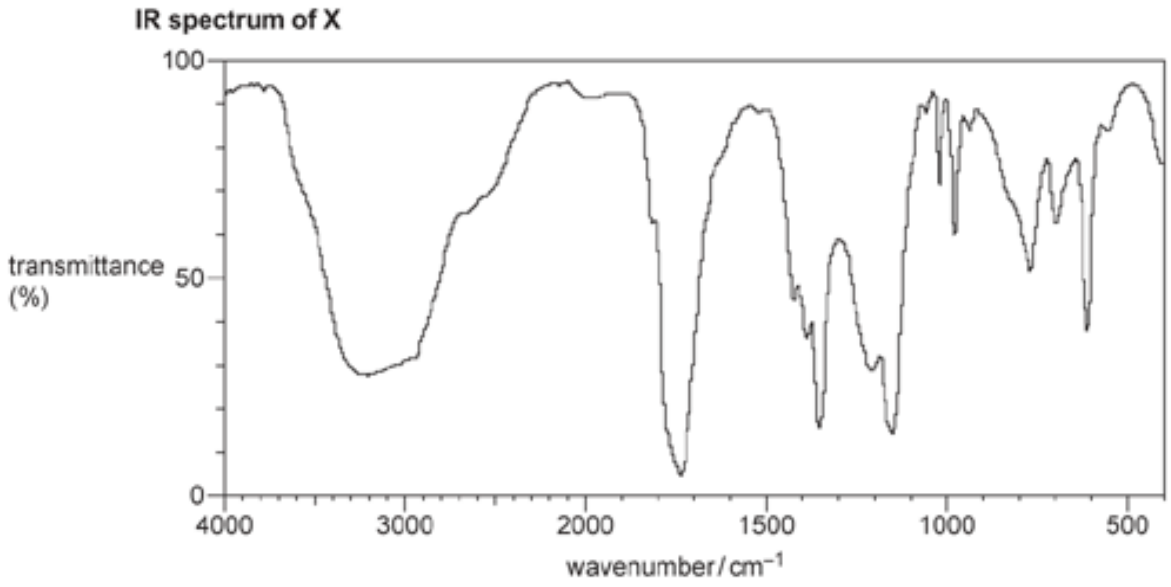
13. Compound **X** is an organic compound with **two** functional groups.

Compound **X** has the percentage composition by mass:
C, 40.91%; H, 4.54%; O, 54.55%.

Compound **X** does **not** decolourise bromine water.

A scientist analyses compound **X** using mass spectrometry and infrared spectroscopy.



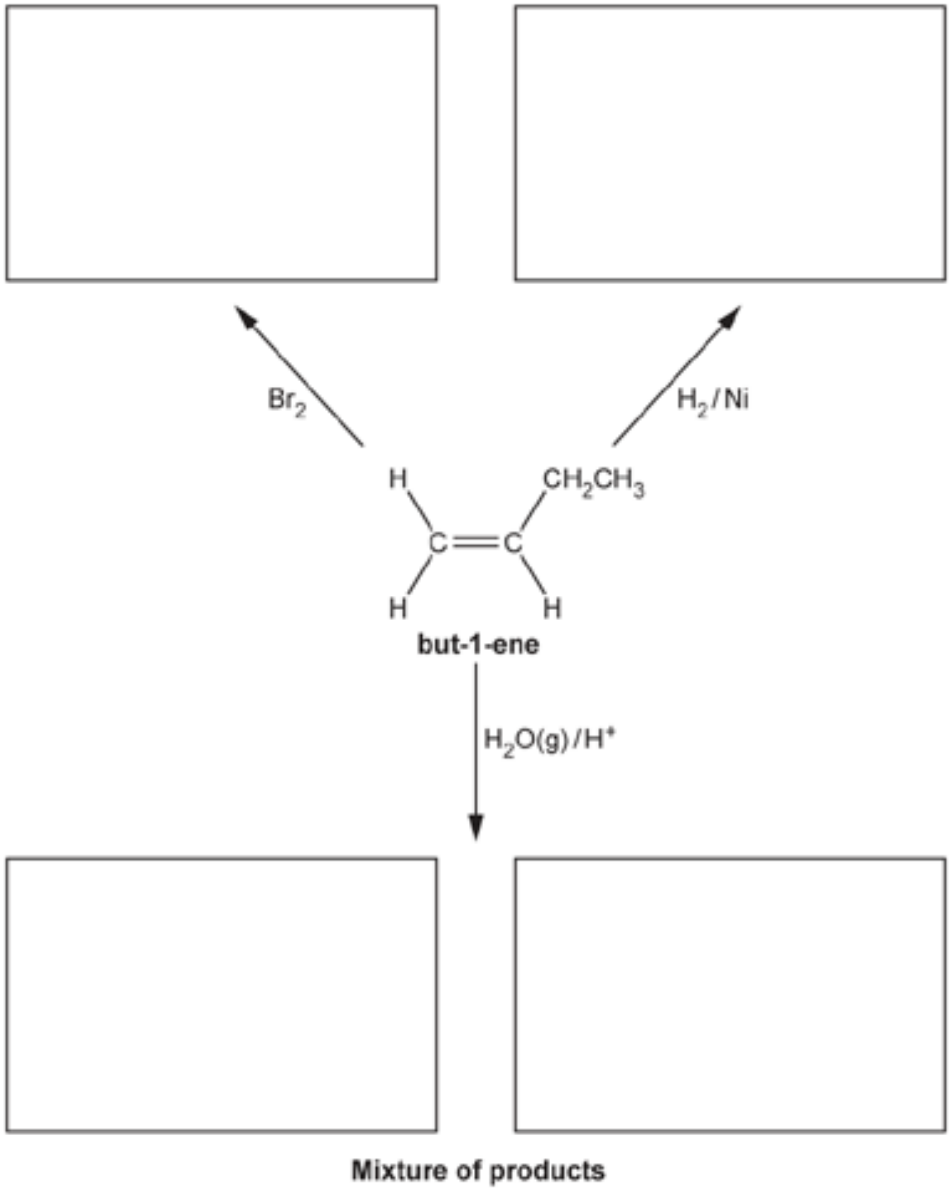


Use all the information to determine a possible structure of compound **X**.

In your answer, make it clear how your conclusions are linked to the evidence.

[6]

14. Complete the flowchart for the reactions of but-1-ene, by adding the structures of the organic products in each box.

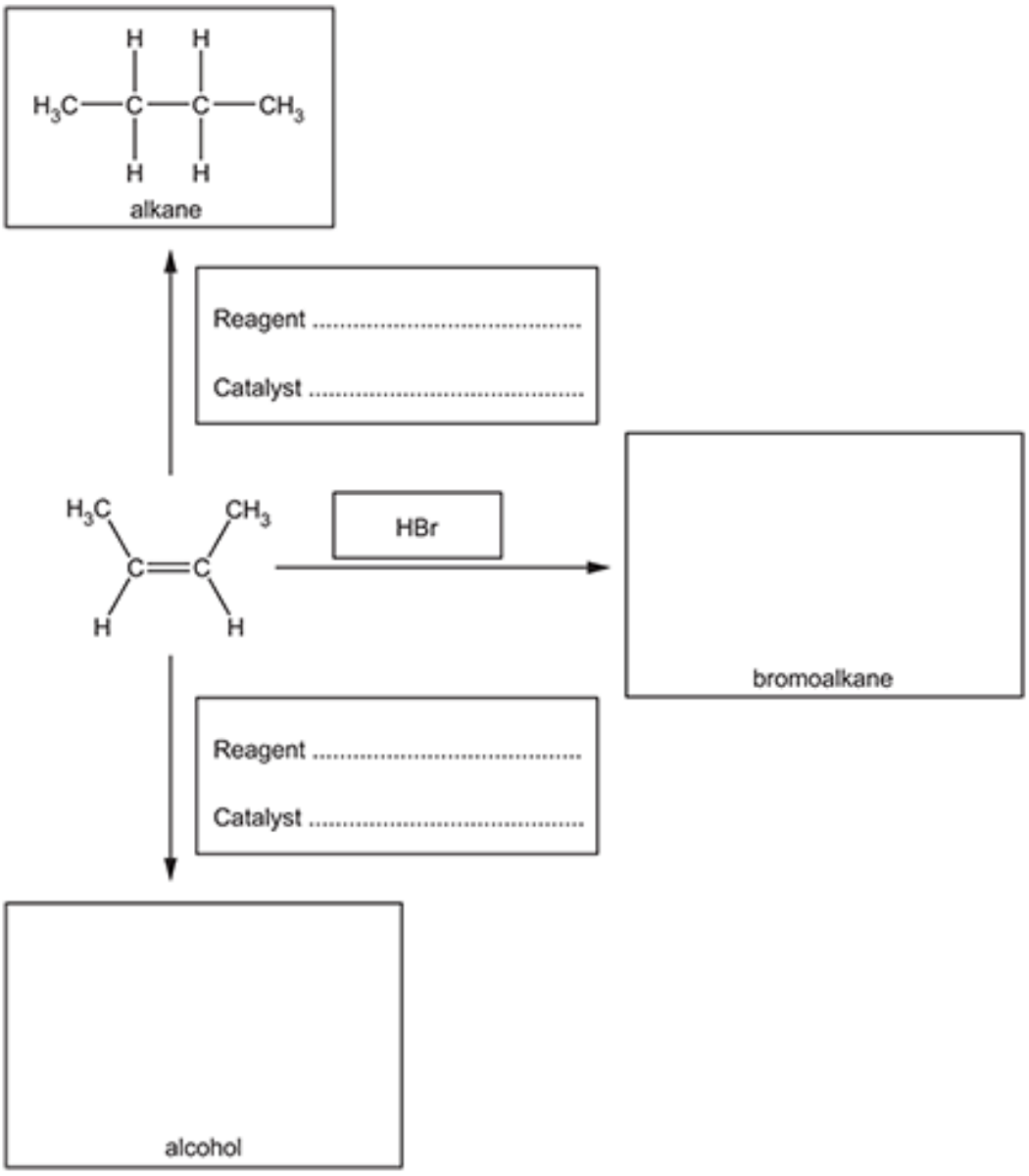


[4]

15. Alkenes are used in organic synthesis.

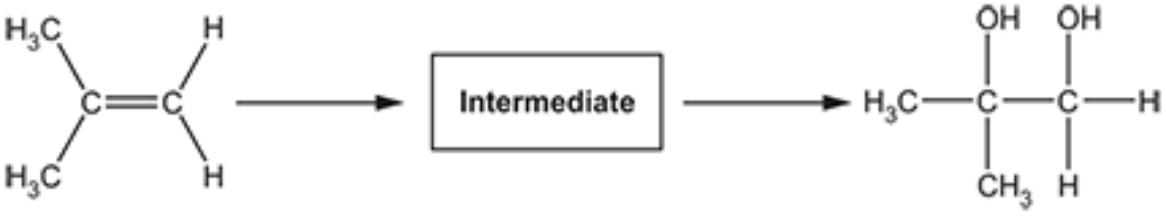
Three reactions of an alkene are shown in the flowchart.

Complete the flowchart to show the missing reagents, catalysts and the structures of organic products.

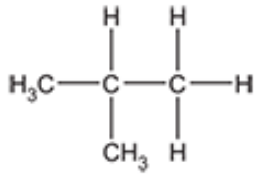
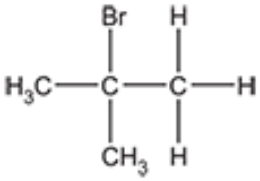
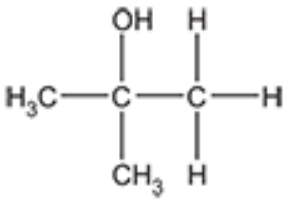
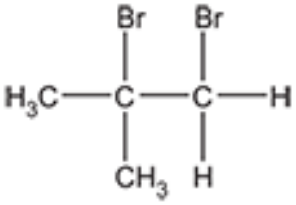


[4]

16. A student has planned the two-stage synthesis shown below.



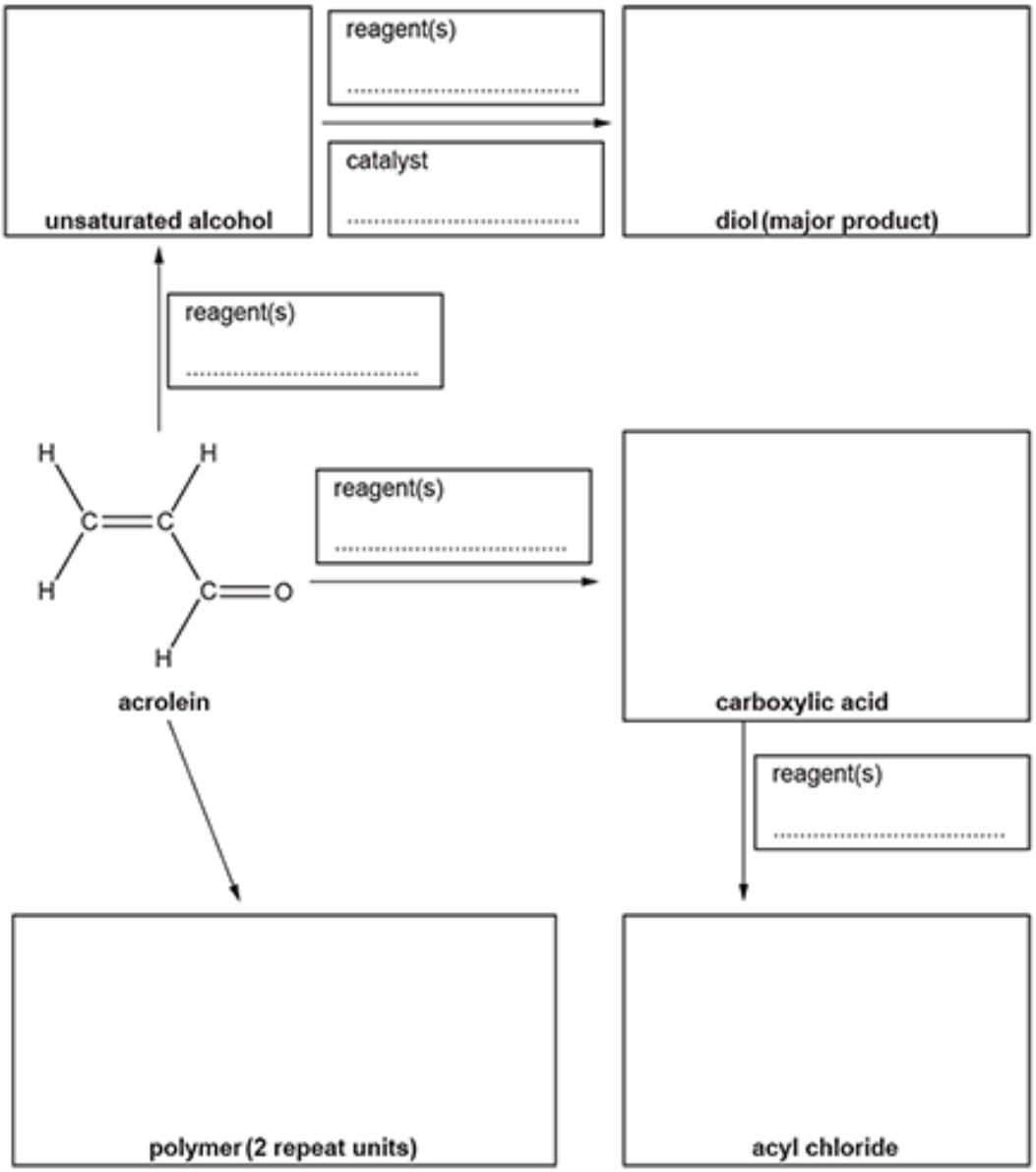
Which compound could be the intermediate for this synthesis?

A	
B	
C	
D	

Your answer ☐ **[1]**

17. This question is about reactions of acrolein, $H_2C=CHCHO$.

Complete the flowchart by filling in each box.



[9]

18. This question is about hydrocarbons.

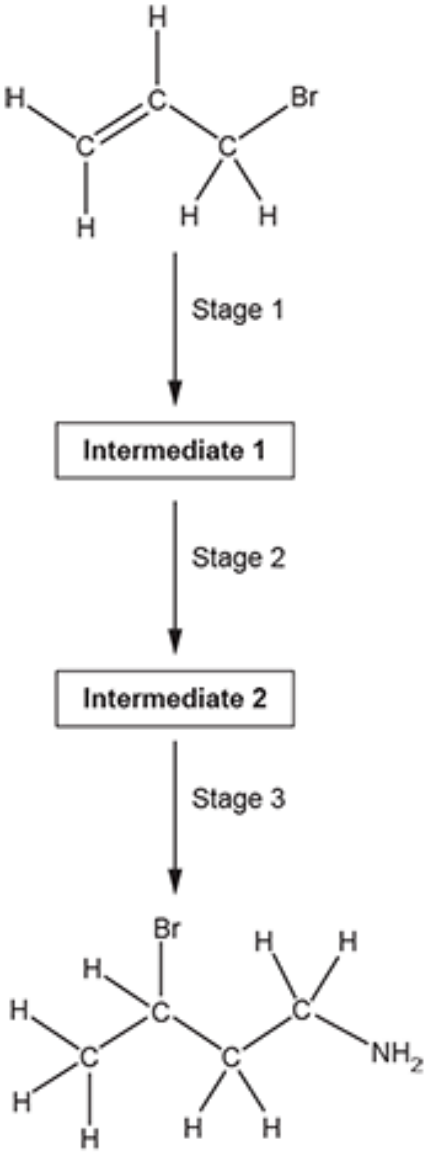
The boiling points of some hydrocarbons containing 6 carbon atoms are shown below.

Hydrocarbon	Boiling point / ºC
2,2-dimethylbutane	50
2-methylpentane	60
hexane	69

State and explain the trend in boiling points shown by these hydrocarbons.

[4]

19. A student intends to synthesise compound **Z**, as shown in the flowchart below.



Compound Z

Plan this synthesis showing reagents, the structures of **intermediate 1** and **intermediate 2**, and equations.

[6]

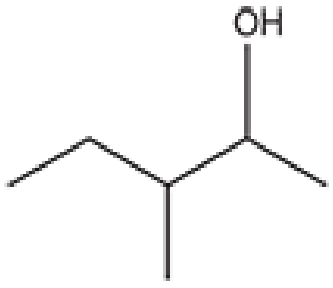
20. Which ion(s) contain(s) bond angles of approximately 120º?

1 CH_3COO^-
2 $C_6H_5O^-$
3 $(CH_3)_3C^+$
A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐ **[1]**

21(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]

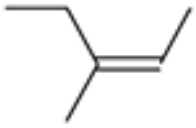
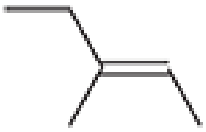
ii. Alcohol **A** is refluxed with an acid catalyst.

- 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*

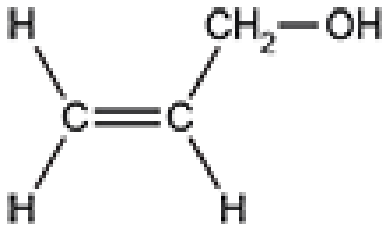
Use the Cahn-Ingold-Prelog priority rules to explain why alkene **B** is the *Z* isomer.

---

[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]

22. This question is about polymers derived from carboxylic acid monomers.

i. Poly(pent-3-enoic acid) is an addition polymer.

Draw the structure of pent-3-enoic acid and **two** repeat units of this polymer.

Pent-3-enoic acid	
Two repeat units of poly(pent-3-enoic acid)	

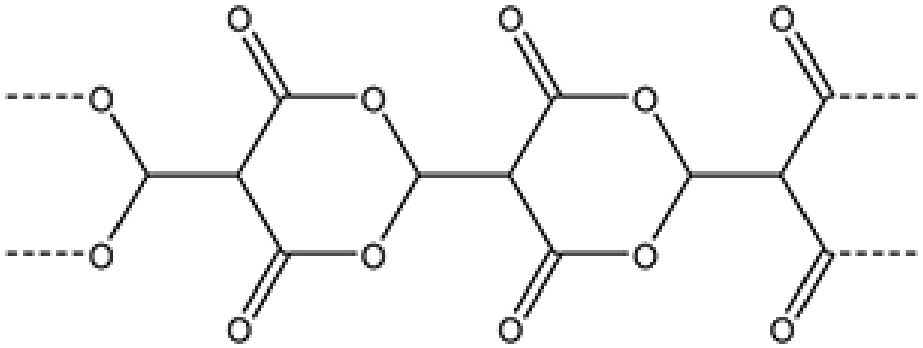
[2]

ii. Butanedicarboxylic acid and 1,4-dihydroxy-2-methylbenzene react to form a condensation polymer.

Draw **one** repeat unit of this condensation polymer.

[2]

iii. Three repeat units of a condensation polymer are shown below.



Draw the structure of the monomer required to form this polymer.

[1]

23. 1-phenylethanol is a naturally occurring compound found in many vegetables and flowers.

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

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

Show structures for organic compounds.

Stage 1

reagents and conditions .....

equation:

Stage 2

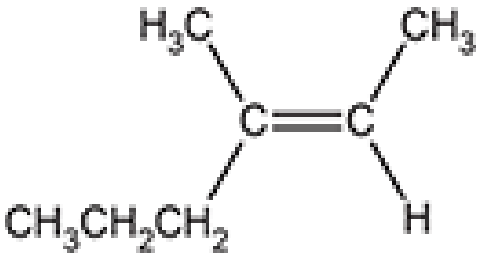
reagents and conditions .....

equation:

[4]

24(a). This question is about unsaturated hydrocarbons.

The unsaturated hydrocarbon **A**, shown below, is reacted with bromine.



Hydrocarbon A

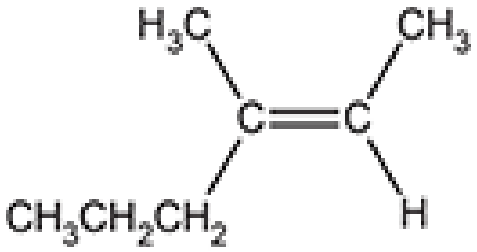
i. What is the systematic name of hydrocarbon **A**?

_____ **[1]**

ii. Outline the mechanism for the reaction of hydrocarbon **A** with bromine.

The structure of hydrocarbon **A** has been provided.

Include curly arrows and relevant dipoles.



[3]

(b). Compounds **B** and **C** are **branched** hydrocarbons that are structural isomers of C_6H_{12}.

Compounds **B** and **C** both have stereoisomers.

• Compound **B** has *cis* and *trans* isomers but does **not** have optical isomers.

• Compound **C** has optical isomers but does **not** have *cis* and *trans* isomers.

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

[1]

ii. What is meant by the term **stereoisomers**?

[1]

iii. Draw structures for the *cis* and *trans* isomers of the branched hydrocarbon **B**.

***cis* isomer**	***trans* isomer**

[2]

iv. Draw 3D structures for the optical isomers of compound **C**.

Optical isomers	

[2]

v. Compounds **D** and **E** are two more structural isomers of C_6H_{12}.

Compounds **D** and **E** do **not** show stereoisomerism.

Table 16.1 shows NMR and infrared (IR) spectral data for **D** and **E**.

	Number of peaks in ^{1}H NMR spectrum	**Number of peaks in ^{13}C NMR spectrum**	**IR peak at 1620–1680 cm^{-1}**
D	1	1	No
E	1	2	Yes

Table 16.1

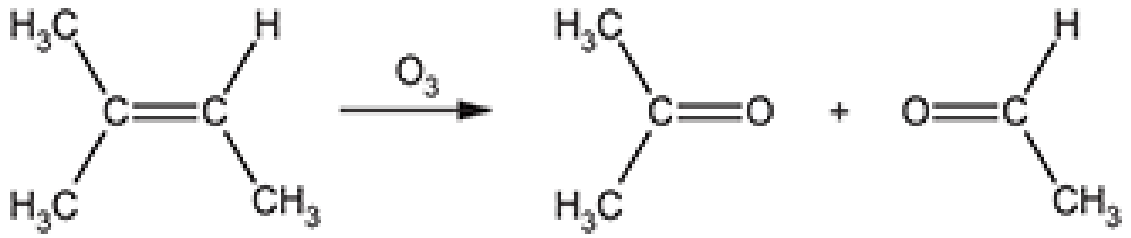
Draw the structures of **D** and **E** and explain how the spectral data in **Table 16.1** provides evidence for the structures.

D	**E**

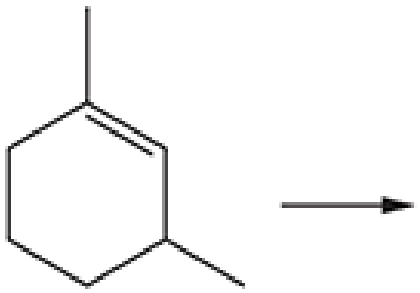
[4]

(c). 'Ozonolysis' is used in organic synthesis. Ozone breaks C=C bonds to form carbonyl compounds.

For example, the complete ozonolysis of methylbut-2-ene is shown below.



i. Draw the structures of the products you would expect from the ozonolysis of the **two** compounds below.

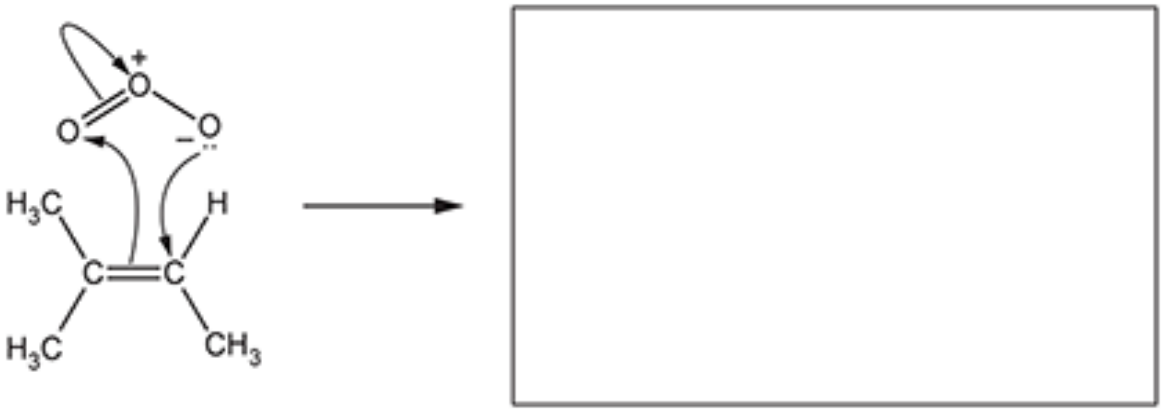


[2]

ii. The mechanism for ozonolysis takes place in several steps.

The curly arrows in the first step in the ozonolysis of methylbut-2-ene are shown below.

In the box, draw the structure(s) for the product(s) of this step.



[1]

25. Which statement about absorption of radiation is correct?

A Infrared radiation can result in the breakdown of the ozone layer.
B Ultraviolet radiation can cause some polymers to photodegrade to benefit the environment.
C Ultraviolet radiation is linked to global warming.
D Ultraviolet radiation is used in modern breathalysers to measure ethanol in the breath.

Your answer ☐ **[1]**

26. What is the number of sigma bonds in a molecule of methylbenzene?

A 7
B 10
C 12
D 15

Your answer ☐ **[1]**

27(a). The alkene, $(CH_3)_3CCH=CH_2$, is used to make some perfumes.

i. What is the systematic name for $(CH_3)_3CCH=CH_2$?

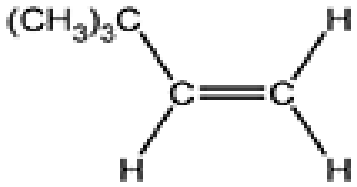
_____ **[1]**

$(CH_3)_3CCH=CH_2$ decolourises bromine.

Outline the reaction mechanism for the reaction of $(CH_3)_3CCH=CH_2$ and bromine.

The structure of $(CH_3)_3CCH=CH_2$ has been provided.

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



name of mechanism..... **[5]**

(b). The alkene $(CH_3)_3CCH=CH_2$ can be polymerised to form a polymer.

i. Draw **one** repeat unit for this polymer.

[1]

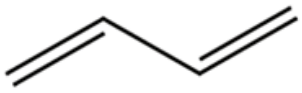
ii. State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of a polymer after it has exceeded its useful life.

Advantage

Disadvantage

[1]

28. What is the number of σ-bonds in the molecule below?



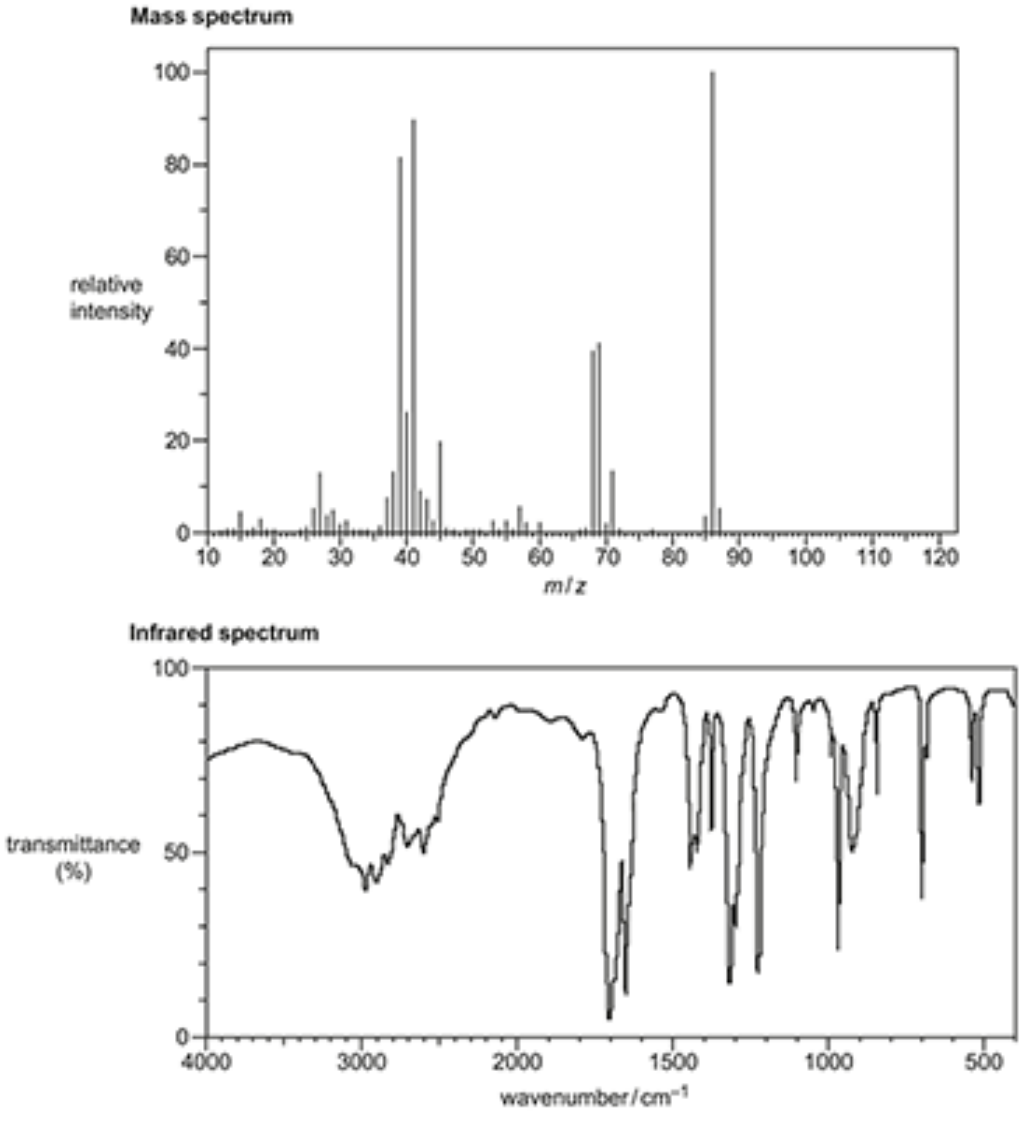
A 1
B 3
C 7
D 9

Your answer ☐ **[1]**

29. * The organic compound **A** is unsaturated and is a *trans* stereoisomer.

Compound **A** has the following composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and the infrared spectrum of compound **A** are shown below.



Use the information to determine the structure of compound **A**.

Explain your reasoning and show your working.

[6]

30(a). 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 butane with bromine (**Reaction 5.1**).

$CH_3CH_2CH_2CH_3 + Br_2 \rightarrow CH_3CH_2CHBrCH_3 + HBr$ **Reaction 5.1**

The reaction is initiated by the formation of bromine radicals from bromine.

i. State the conditions for the formation of bromine radicals from bromine.

---

[1]

ii. Write two equations for the propagation steps in the mechanism for **Reaction 5.1**.

Use structural formulae for organic species and dots (·) for unpaired electrons on radicals.

$CH_3CH_2CH_2CH_3$ + ... → ..... + ...

..... + ... → ..... + ...

[2]

iii. The yield of $CH_3CH_2CHBrCH_3$ is only 30%.

Suggest **two** reasons why the yield of $CH_3CH_2CHBrCH_3$ is so low.

1

2

[2]

(b). 2-Bromobutane can also be prepared by reacting but-2-ene, $CH_3CH=CHCH_3$, with hydrogen bromide, HBr (**Reaction 5.2**).

$CH_3CH=CHCH_3 + HBr \rightarrow CH_3CH_2CHBrCH_3$ **Reaction 5.2**

Explain, in terms of atom economy, why **Reaction 5.2** is more sustainable than **Reaction 5.1**.

Include calculations to justify your answer.

---

[2]

END OF QUESTION PAPER