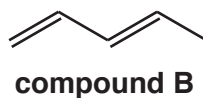
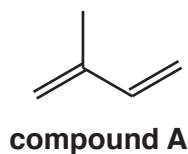


1 This question is about unsaturated hydrocarbons.

(a) Compound **A** and compound **B** are isomers.



Compound **A** has a lower melting point than compound **B**.

Suggest why.

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

(b) Compound **C**, $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{OH}$, exists as *cis* and *trans* stereoisomers.

(i) Name compound **C**.

..... [1]

(ii) Define the term *stereoisomers*.

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

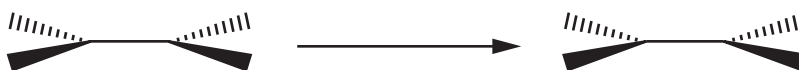
(iii) Draw the structures of the *cis* and *trans* stereoisomers of compound **C**.

<i>cis</i>	<i>trans</i>

[2]

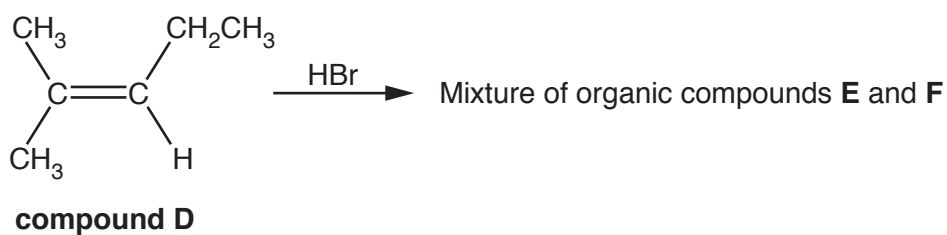
(c) The C=C group in an alkene contains a π -bond.

Complete the diagram below to show how p-orbitals are involved in the formation of a π -bond.



[1]

- (d) Compound **D**, shown below, reacts with hydrogen bromide by electrophilic addition. A mixture of two organic compounds, **E** and **F**, is formed.



- (i) Suggest how an HBr molecule can act as an electrophile.

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

- (ii) Draw the structures of the two organic compounds **E** and **F**.

E	F

[2]

- (iii) Outline the mechanism of the reaction between compound **D** and hydrogen bromide to form **either** compound **E** **or** compound **F**.

Include curly arrows and relevant dipoles.

[3]

- (iv) Which of **E** or **F** is the major organic product?

Explain your answer.

Major organic product

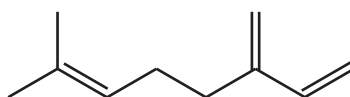
Explanation

.....

.....

..... [1]

- (e) Myrcene, $C_{10}H_{16}$, is a naturally occurring hydrocarbon containing more than one carbon-carbon double bond.



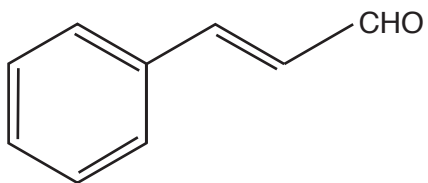
myrcene

- (i) Reaction of 204 mg of myrcene with hydrogen gas produces a saturated alkane.
- Calculate the volume of hydrogen gas, in cm^3 and measured at RTP, needed for this reaction.
- Show your working.

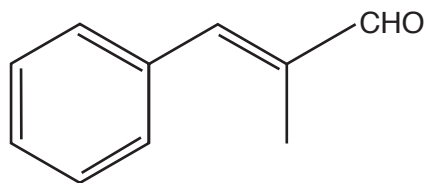
volume = ... cm^3 [2]

- (ii) β -Carotene is a naturally occurring unsaturated hydrocarbon found in carrots. A β -carotene molecule contains 40 carbon atoms, has two rings, and a branched chain.
- 0.0200 mol of β -carotene reacts with $5.28 dm^3$ of hydrogen gas to form a saturated hydrocarbon.
- Using molecular formulae, construct a balanced equation for this reaction.
- Include relevant calculations and reasoning.

- 2 Cinnamaldehyde and methylcinnamaldehyde are naturally occurring organic compounds.



cinnamaldehyde



methylcinnamaldehyde

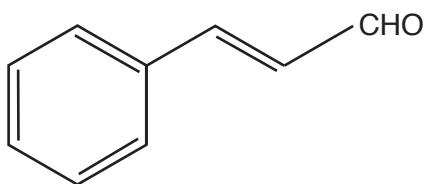
- (a) Methylcinnamaldehyde is an *E* stereoisomer.

Explain this statement in terms of the Cahn-Ingold-Prelog (CIP) rules.

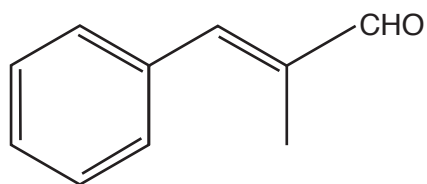
.....

.....

- (b) A student plans to carry out some chemical tests on both cinnamaldehyde and methylcinnamaldehyde.



cinnamaldehyde



methylcinnamaldehyde

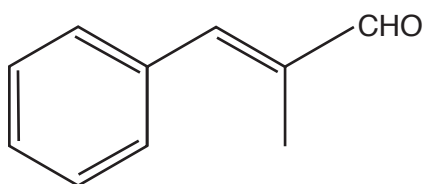
- (i) Suggest a suitable chemical test to confirm that both compounds contain an unsaturated carbon chain.

Your answer should include the reagent and observations.

.....

..... [1]

- (c)* Methylcinnamaldehyde reacts with iodine monochloride, ICl , by electrophilic addition. The reaction produces a mixture containing two different organic products.



methylcinnamaldehyde

The electronegativity values of chlorine and iodine are given in the table below.

	Pauling electronegativity value
Cl	3.0
I	2.5

Outline the mechanism, using the 'curly arrow' model, for the formation of **one** of the organic products and explain which of the two possible organic products is more likely to be formed.

In your mechanism, you can show the phenyl group as C_6H_5 .

[6]

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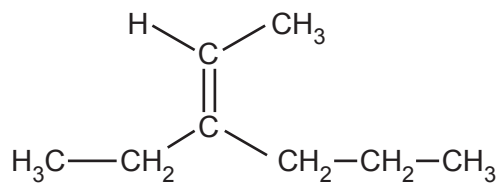
.....

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.....

.....

3 What is the name of the compound below?



A 3-Propylpent-2-ene

B 3-Propylpent-3-ene

C 3-Ethylhex-2-ene

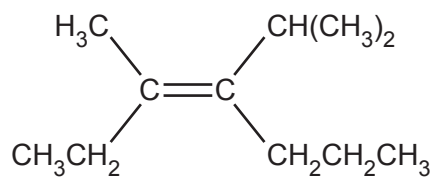
D 4-Ethylhex-4-ene

Your answer

[1]

4

The structure of a stereoisomer is shown below.



Which term correctly describes this stereoisomer?

- A** *cis*-
- B** *trans*-
- C** *E*-
- D** *Z*-

Your answer

[1]

5 Which types of bonds are broken and formed in the reaction of ethene and bromine?

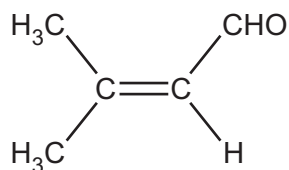
	Types of bond broken	Types of bond formed
A	σ	π
B	π	σ
C	σ and π	π
D	σ and π	σ

Your answer

[1]

6 This question is about unsaturated aldehydes and alcohols.

(a) 3-Methylbut-2-enal, shown below, is used as a food flavouring.



3-methylbut-2-enal

3-Methylbut-2-enal is reacted with hydrogen bromide, forming a mixture of two organic products.

One of the organic products forms in a much greater quantity than the other organic product.

(i) Outline the reaction mechanism for the formation of **one** of the organic products.

Include curly arrows and relevant dipoles.

[4]

(ii) Explain why one of the organic products forms in a much greater quantity than the other organic product.

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

- 7 Which statement about bonds is correct?
- A** The C=C bond in ethene is more polar than the C–C bond in ethane.
- B** A σ -bond is stronger than a π -bond.
- C** The H–C–H bond angle in ethane is greater than the H–C–H bond angle in ethene.
- D** A σ -bond is formed from sideways overlap of p orbitals.

Your answer

☐

[1]

- 8 But-1-ene, $\text{H}_2\text{C}=\text{CHCH}_2\text{CH}_3$, and buta-1,3-diene, $\text{H}_2\text{C}=\text{CH}-\text{CH}=\text{CH}_2$, are unsaturated compounds used to make many organic products.

(a) But-1-ene and buta-1,3-diene have σ -bonds and π -bonds.

(i) Explain what is meant by the terms **σ -bond** and **π -bond**.

σ -bond:

.....

π -bond:

.....

[2]

(ii) How many σ - and π -bonds are in one molecule of buta-1,3-diene?

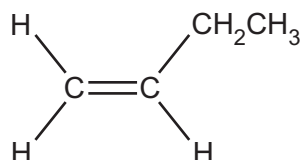
σ -bonds: π -bonds: [2]

(b) But-1-ene is reacted with hydrogen bromide, forming a mixture of two saturated organic products.

One of the organic products is formed in a much greater quantity than the other organic product.

(i) Outline the reaction mechanism for the formation of this **major** organic product. The structure of but-1-ene has been provided.

Include curly arrows and relevant dipoles.



[4]

- (ii) Explain why one organic product is formed in a much greater quantity than the other organic product.

.....

 [2]

- (iii) Buta-1,3-diene is reacted with an excess of hydrogen bromide, forming a mixture of saturated organic products.

How many saturated organic products could be present in this mixture?

..... [1]

- (c) A student thought that buta-1,3-diene can show stereoisomerism.

The student drew out skeletal formulae for the stereoisomers of buta-1,3-diene:



- (i) Explain the term **stereoisomerism**.

.....
 [1]

- (ii) Explain, with a reason, whether the student is correct or incorrect.

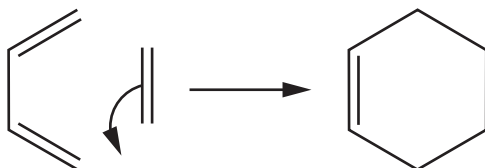
.....
 [1]

(d) 'Diels-Alder' reactions are used in the synthesis of many important organic compounds.

The Diels-Alder reaction of buta-1,3-diene with ethene is shown below.



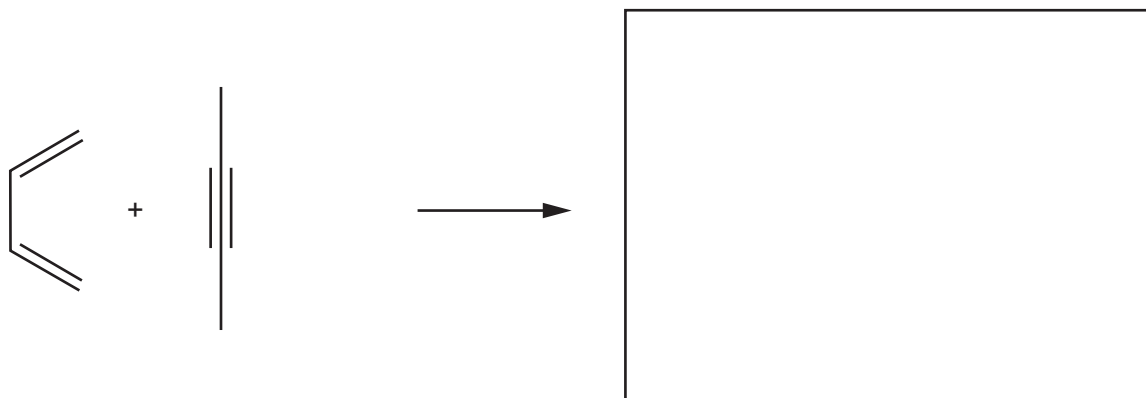
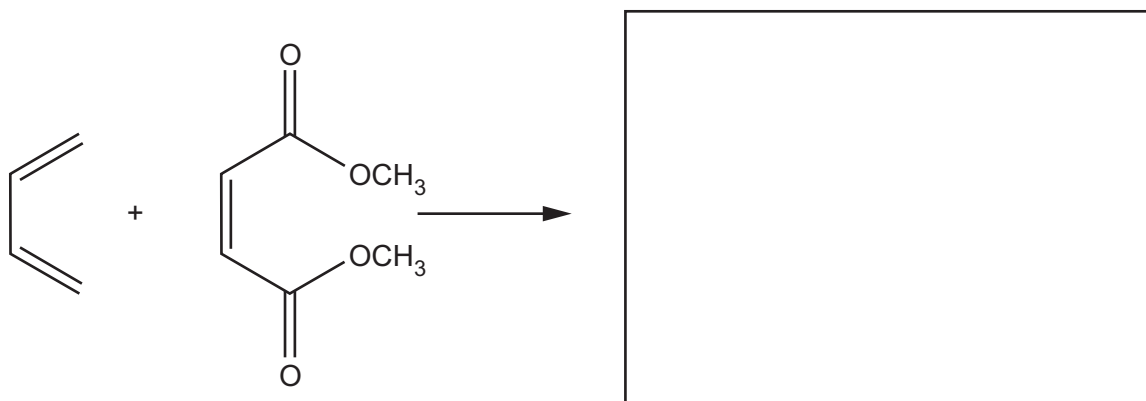
(i) Add curly arrows to the diagram below to complete the mechanism for this Diels-Alder reaction.



[2]

(ii) Two more Diels-Alder reactions of buta-1,3-diene are shown below.

In the boxes, draw the organic product of each reaction.



[2]

9(a)

An oligomer is a polymer with a low molecular mass and a small number of repeat units.

An oligomer made from 2-chloro-1,1,2-trifluoroethene is used as a lubricating oil.

(i) Draw the repeat unit of this oligomer.

[1]

(ii) The boiling point of the lubricating oil can be increased by increasing the number of repeat units.

Explain this statement.

.....

.....

.....

..... [2]

10 Which statement about absorption of radiation is correct?

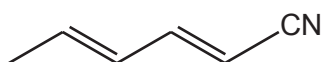
- A** Infrared radiation can result in the breakdown of the ozone layer.
- B** Ultraviolet radiation can cause some polymers to photodegrade to benefit the environment.
- C** Ultraviolet radiation is linked to global warming.
- D** Ultraviolet radiation is used in modern breathalysers to measure ethanol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

Your answer

[1]

11

The compound below reacts with hydrogen gas to form a saturated compound.



What is the volume of hydrogen, measured at room temperature and pressure, that reacts with 0.0500 mol of the compound?

A 2.40 dm³

B 3.60 dm³

C 4.80 dm³

D 6.00 dm³

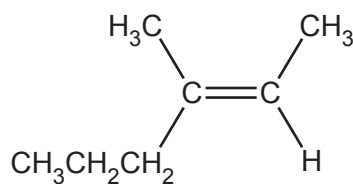
Your answer

[1]

12

This question is about unsaturated hydrocarbons.

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



Hydrocarbon A

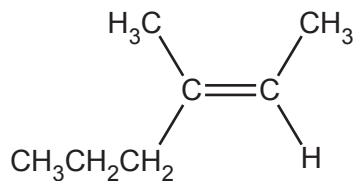
(i) What is the systematic name of hydrocarbon **A**?

..... [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.

(i) What is meant by the term **structural isomers**?

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

(ii) What is meant by the term **stereoisomers**?

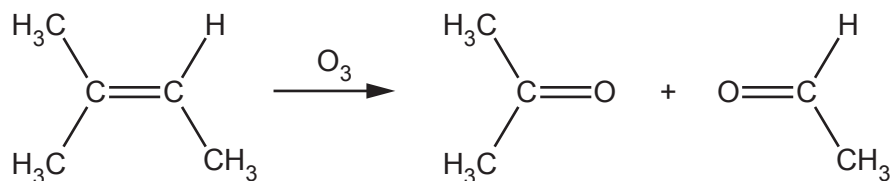
.....
.....
..... [1]

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

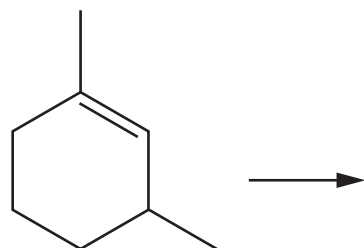
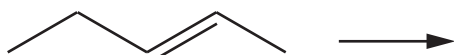
<i>cis</i> isomer	<i>trans</i> isomer

- (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.

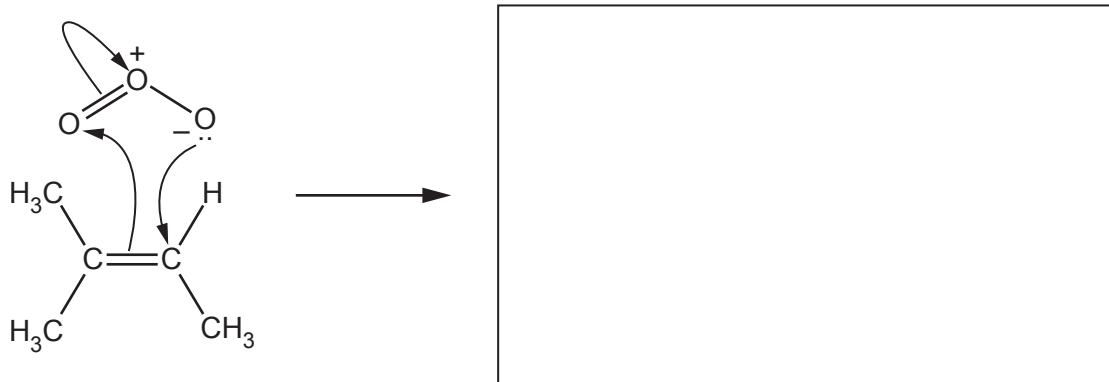


[2]

- (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]

13(a) This part is about polymers derived from carboxylic acid monomers.

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

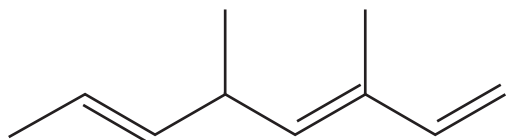
Draw the structure of pent-3-enoic acid and **two** repeat units of this polymer.

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

[2]

14

What is the systematic name for the compound below?

**A** 3,5-dimethylocta-1,3,6-triene**B** 3,5-dimethylocta-2,5,7-triene**C** 4,6-dimethylocta-1,3,6-triene**D** 4,6-dimethylocta-2,5,7-triene

Your answer

[1]

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

Why is this?

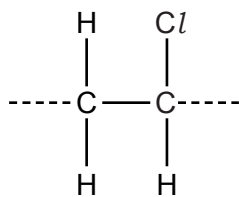
- A** Alkenes are polar molecules whereas alkanes are not.
- B** All atoms in an alkane have a full outer shell of electrons.
- C** The bond enthalpy of C–C σ bonds is **higher** than that of π bonds.
- D** The bond enthalpy of C–C σ bonds is **lower** than that of π bonds.

Your answer

[1]

16

Polymers, such as poly(chloroethene), shown below, are difficult to dispose of.



Poly(chloroethene)

Which statement(s) is/are true about poly(chloroethene)?

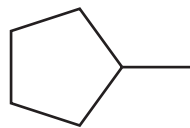
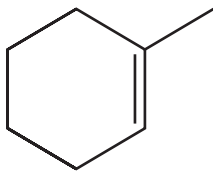
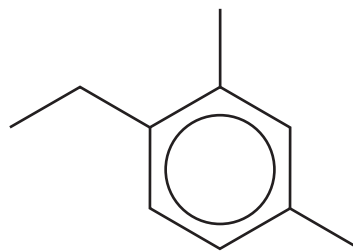
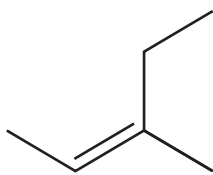
- 1 It is a photodegradable or biodegradable polymer.
 - 2 When incinerated, it produces toxic waste products which need to be removed.
 - 3 It can be recycled and processed for use as an organic feedstock.
-
- A 1, 2 and 3
 - B Only 1 and 2
 - C Only 2 and 3
 - D Only 1



17

This question is about hydrocarbons.

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

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

(a) Which hydrocarbons are unsaturated?

..... [1]

(b) Which hydrocarbons are alicyclic?

..... [1]

(c) Which hydrocarbons have the general formula C_nH_{2n} ?

..... [1]

(d) What is the systematic name of hydrocarbon **C**?

..... [1]

(e) Explain why hydrocarbon **D** is a *Z*-stereoisomer.

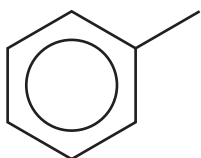
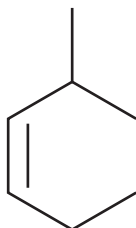
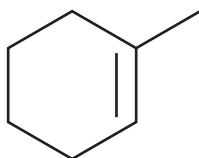
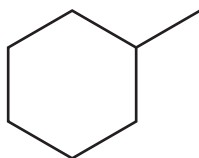
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..... [2]

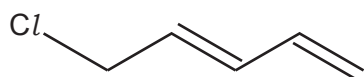
18

Which compound is alicyclic **and** unsaturated?**A****B****C****D**

Your answer

[1]

- 19 0.0200 mol of the compound below reacts with $\text{Br}_2(\text{aq})$ to make a saturated compound.
How many grams of Br_2 are needed for this reaction?



- A** 3.20
B 6.39
C 7.99
D 12.80

Your answer

[1]

20 Ethene can be reacted with hydrogen bromide.

Which statement about this reaction is correct?

- A** H^- acts as a nucleophile.
- B** Br^+ acts as an electrophile.
- C** $\text{H}^{\delta+}-\text{Br}^{\delta-}$ acts as an electrophile.
- D** $\text{H}^{\delta+}-\text{Br}^{\delta-}$ acts as a nucleophile.

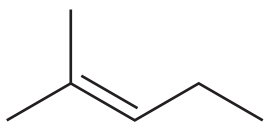
Your answer

[1]

21

This question is about hydrocarbons with six carbon atoms.

(a) Compound **A** is a hydrocarbon:



Compound A

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

..... [1]

(b) The table below shows incomplete information about two hydrocarbons.

Complete the table.

Skeletal formula		
Molecular formula		
Number of σ bonds		
Number of π bonds		

[3]

(c) Compound **B**, $\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$, exists as *E* and *Z* stereoisomers.

(i) Draw the structures of the *E* and *Z* stereoisomers of compound **B**.

<i>E</i>	<i>Z</i>

[2]

(ii) Explain why compound **B** can form *E* and *Z* stereoisomers.

.....

.....

.....

.....

.....

..... [2]

(d) Hexane, C_6H_{14} , is used as a fuel.

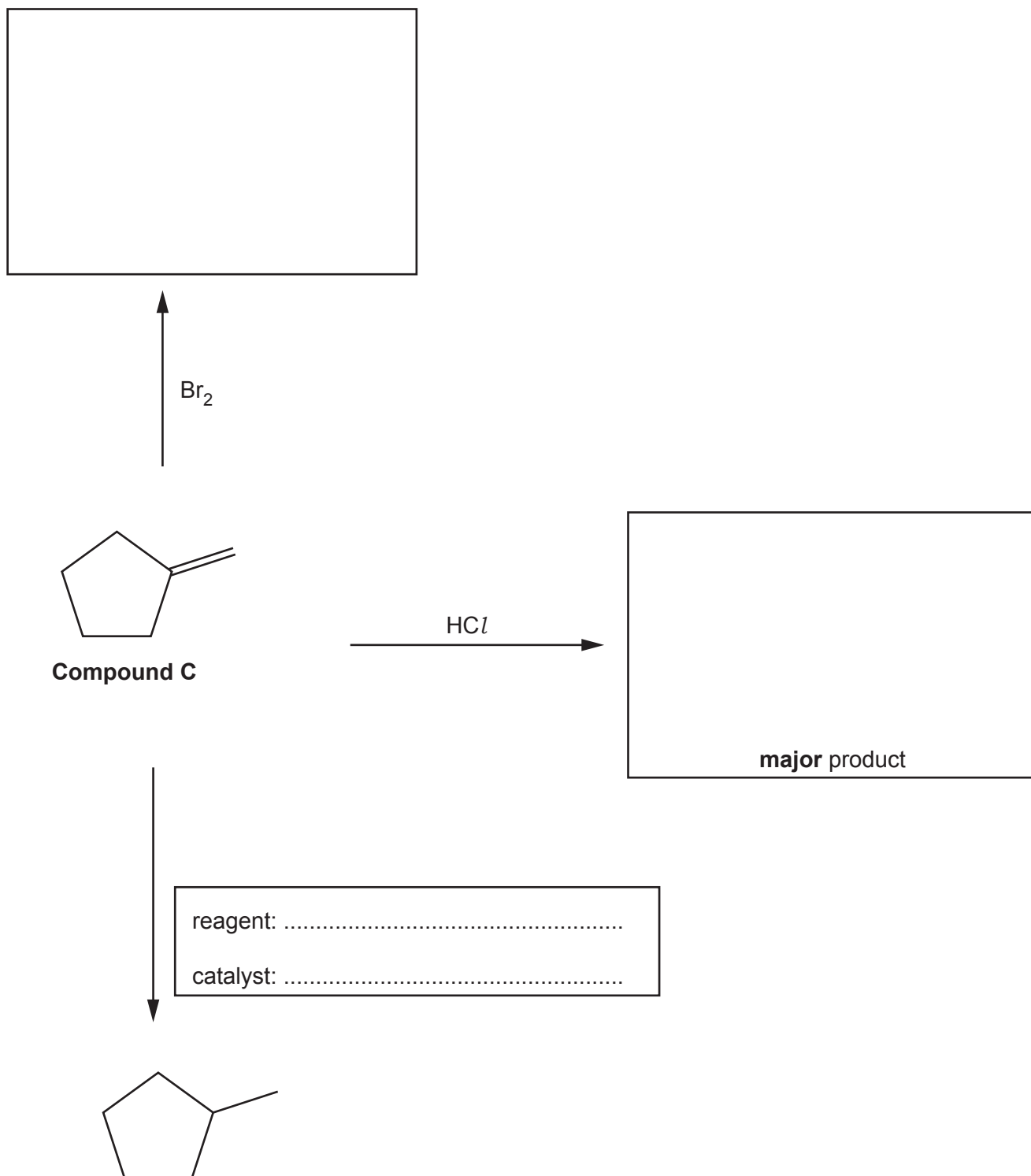
1.0 mol of hexane is mixed with 6.0 mol of oxygen and combusted.

Construct an equation for the **incomplete** combustion of 1.0 mol of hexane with 6.0 mol of oxygen.

..... [1]

(e) The flowchart below shows some reactions of compound **C**.

Complete the flowchart to show the missing reagent, catalyst and the structures of the organic products.



[3]

22(a) The disposal of polymers containing chlorine is a major challenge.

Suggest why a polymer made from monomers containing chlorine, such as 1-chlorobut-2-ene, is difficult to dispose of by incineration.

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