

- 1 The alkanes are an homologous series of hydrocarbons.
The table shows information about some straight chain alkanes.

alkane	molecular formula	boiling point / °C
methane	CH ₄	-164
ethane	C ₂ H ₆	-89
propane	C ₃ H ₈	-42
butane	C ₄ H ₁₀	-1

- (a) (i) What is meant by an *homologous series*?

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

- (ii) Explain why the boiling points increase down the alkane homologous series.

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..... [2]

- (b) Alkynes are another homologous series of hydrocarbons.
The table gives the molecular formulae of the first five straight chain alkynes.

alkyne	molecular formula
ethyne	C_2H_2
propyne	C_3H_4
but-1-yne	C_4H_6
	C_5H_8
hex-1-yne	C_6H_{10}

- (i) Suggest the name of a straight chain alkyne with the molecular formula C_5H_8 .

..... [1]

- (ii) Deduce the general formula for an alkyne.

..... [1]

- (iii) The alkynes contain the $C\equiv C$ functional group.

Suggest the displayed formula for propyne.

[1]

- (iv) Hex-1-yne has many cyclic structural isomers.

Draw the skeletal structure of one of these cyclic structural isomers.

[1]

(c) Ethyne is commonly called acetylene.

It is used in an oxy-acetylene flame which is hot enough to cut through steel.

Ethyne completely combusts as shown in the equation below.

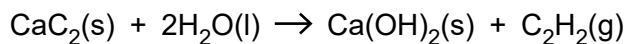


Calculate the enthalpy change of combustion of ethyne using the average bond enthalpies in the table below.

bond	average bond enthalpy / kJ mol ⁻¹
C-H	+415
C≡C	+837
O=O	+498
C=O	+805
O-H	+464

enthalpy change of combustion = kJ mol⁻¹ [3]

(d) Ethyne is formed when water reacts with calcium carbide, CaC_2 .



The standard enthalpy change of this reaction can be determined indirectly using standard enthalpy changes of formation.

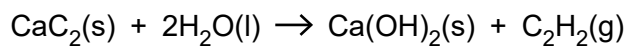
(i) What is meant by the term *standard enthalpy change of formation*, ΔH_f^\ominus ?
You should state the standard conditions in your answer.

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..... [3]

(ii) Standard enthalpy changes of formation are shown in the table below.

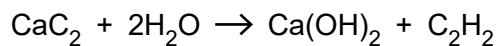
substance	standard enthalpy change of formation, $\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{CaC}_2(\text{s})$	-60
$\text{H}_2\text{O}(\text{l})$	-286
$\text{Ca}(\text{OH})_2(\text{s})$	-987
$\text{C}_2\text{H}_2(\text{g})$	+227

Calculate the standard enthalpy change of the reaction:



standard enthalpy change of reaction = kJ mol^{-1} [3]

- (e) A factory makes ethyne gas from calcium carbide, CaC_2 .
One of the waste products is calcium hydroxide.



Each day 1.00×10^6 grams of calcium carbide are used and $3.60 \times 10^5 \text{ dm}^3$ of ethyne gas, measured at room temperature and pressure, is manufactured.

- (i) Calculate the atom economy for this process using the relative formula masses in the table below.

compound	relative formula mass
CaC_2	64.1
H_2O	18.0
Ca(OH)_2	74.1
C_2H_2	26.0

atom economy = % [2]

- (ii) Calculate the amount, in moles, of CaC_2 used each day.

amount of CaC_2 = mol [1]

- (iii) Calculate the amount, in moles, of C_2H_2 made each day.

amount of C_2H_2 = mol [1]

- (iv) Calculate the percentage yield of C_2H_2 .

percentage yield = % [1]

(v) Comment on the percentage yield and the atom economy of this process in terms of sustainability.

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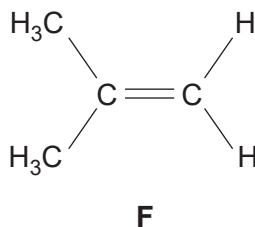
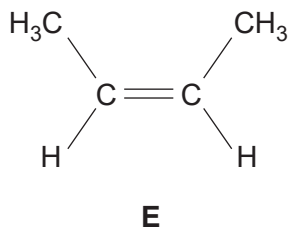
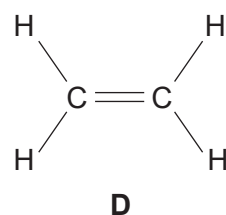
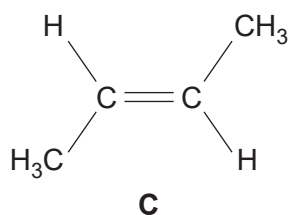
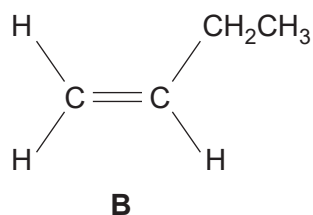
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[2]

[Total: 23]

2 Alkenes **B**, **C**, **D**, **E** and **F** are shown below.



You will have to refer to these alkenes throughout the question.

(a) Describe, using the orbital overlap model, how the π -bond in alkene **D** is formed.

[2]

(b) Many alkenes show *E/Z* isomerism.

(i) Explain why *E/Z* isomerism is shown in some alkenes.

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..... [2]

(ii) Which **two** alkenes are a pair of *E/Z* isomers?

Choose from **B**, **C**, **D**, **E** and **F**.

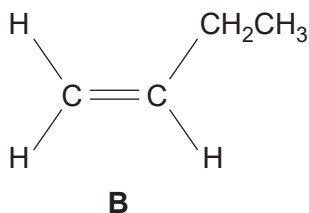
..... and

[1]

(c) What is the main organic product of the reaction between alkene **D** and steam in the presence of a phosphoric acid catalyst?

..... [1]

- (e) Alkenes are a major source of polymers.
Alkene **B** can be polymerised.



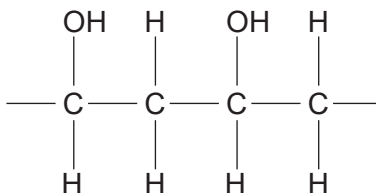
- (i) Draw a section of the resultant polymer showing **two** repeat units.

[1]

- (ii) Give the name of this polymer.

..... [1]

- (f) Poly(ethenol) is a very unusual polymer because it can dissolve in water under certain conditions.



- (i) Suggest why poly(ethenol) can dissolve in water.

.....

 [2]

- (ii) Waste poly(ethenol) does not cause many environmental problems.
Other polymers such as poly(ethene), PVC or PTFE cause significant environmental problems.

Outline **two** ways in which waste polymers can be processed to reduce their environmental impact.

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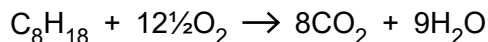
 [2]

[Total: 21]

3 Crude oil is a source of hydrocarbons which can be used as fuels or for processing into petrochemicals.

Octane, C₈H₁₈, is one of the alkanes present in petrol.

Carbon dioxide is formed during the complete combustion of octane.



(a) What is the general formula for an alkane?

..... [1]

(b) Carbon monoxide, CO, is formed during the incomplete combustion of octane.

(i) Write an equation for the incomplete combustion of octane, forming carbon monoxide and water.

..... [1]

(ii) Why does incomplete combustion sometimes take place?

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

(c) In cars fitted with a catalytic converter, two toxic gases, CO and NO, react together to form two non-toxic gases.

(i) Write an equation for the reaction between CO and NO in a catalytic converter.

..... [1]

(ii) Outline the stages that take place in a catalytic converter to allow CO to react with NO.

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..... [3]

- (d) Oil companies process hydrocarbons, such as octane, into branched and cyclic hydrocarbons that promote efficient combustion in petrol.

Draw the skeletal formulae of a branched hydrocarbon and a cyclic hydrocarbon, each containing eight carbon atoms.

[2]

- (e) Some scientists believe that increased CO_2 levels arising from the combustion of hydrocarbons lead to global warming because CO_2 is a greenhouse gas. Carbon capture and storage, CCS, is being developed as a method for removing CO_2 produced by combustion.

- (i) Different gases have different contributions to global warming.

State **two** factors that affect the contribution of a greenhouse gas to global warming.

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.....

[2]

- (ii) Outline **two** methods that could be developed to achieve carbon capture and storage, CCS.

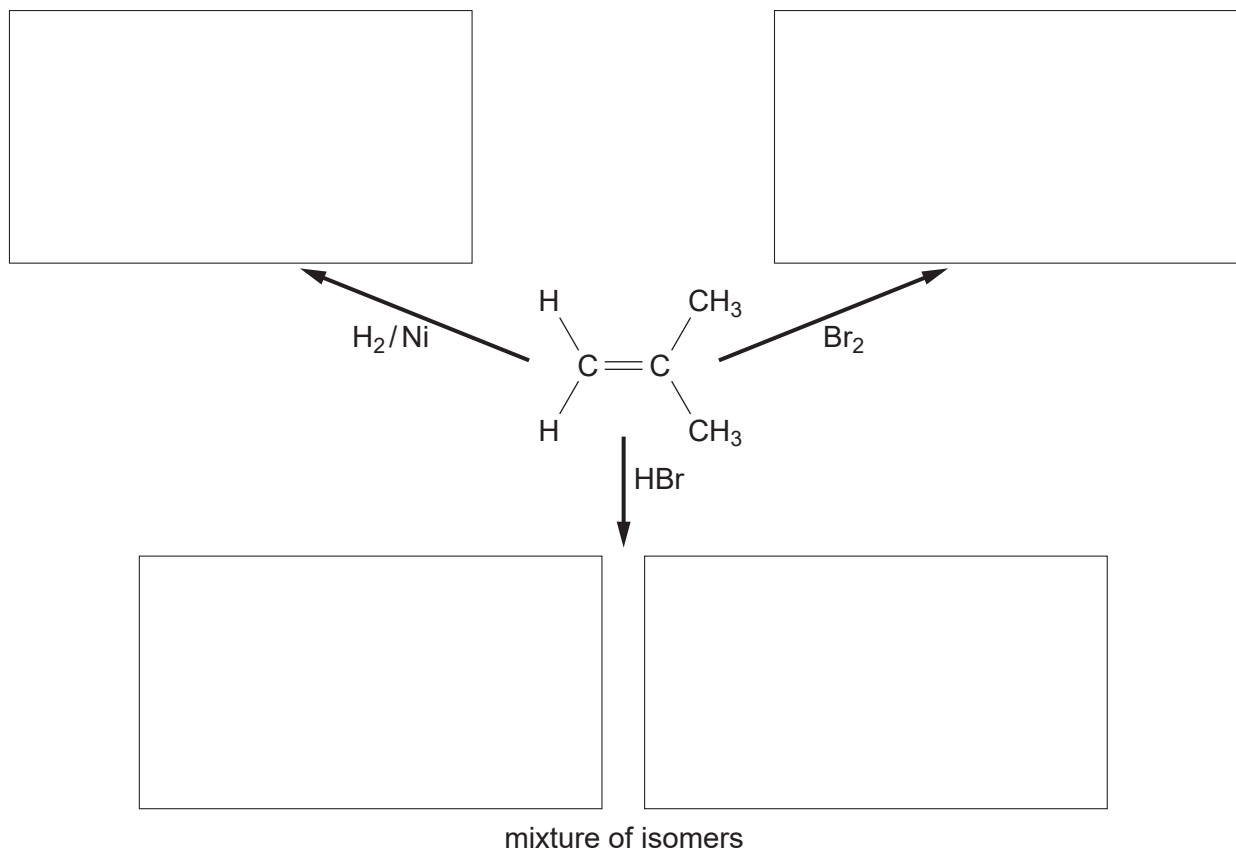
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[2]

[Total: 13]

4 Alkenes are unsaturated hydrocarbons used in the industrial production of many organic compounds.

(a) Complete the flowchart below to show the organic product formed in each addition reaction of methylpropene.

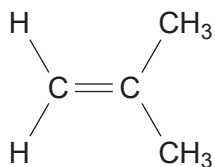


[4]

(b) Curly arrows are used in reaction mechanisms to show the movement of electron pairs during chemical reactions.

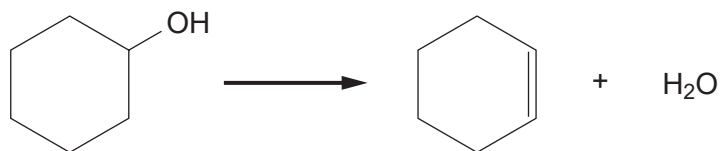
Use curly arrows to outline the mechanism for the addition reaction of methylpropene with bromine. The structure of methylpropene has been drawn for you.

Include relevant dipoles in your answer.



[4]

- (c) Alkenes can be prepared by the dehydration of alcohols with an acid catalyst. Cyclohexene can be prepared by the dehydration of cyclohexanol, shown below.



A student reacted 7.65 g of cyclohexanol, $C_6H_{12}O$, and obtained 0.0268 mol of cyclohexene.

- (i) What is the molecular formula of cyclohexene?

..... [1]

- (ii) Calculate the percentage yield of cyclohexene.

answer = % [3]

- (d) Percentage yield has been used for many years to measure the 'success' of a reaction. Recently, chemists have turned their thoughts also to the atom economy of a reaction.

- (i) Explain the term *atom economy*.

.....
 [1]

- (ii) Cyclohexene can also be prepared by the reaction below.



Explain why the atom economy of this cyclohexene preparation is higher than that from cyclohexanol in (c).

.....

 [2]

[Total: 15]