1. Haloalkanes can be synthesised by reacting alkanes with halogens in the presence of ultraviolet radiation.

An alkane reacts with bromine to form 2-bromo-2-methylpropane.

i. Write the equation for this reaction, showing the structures of the organic compounds.

Name the reaction mechanism and the type of bond fission that occurs.

Equation

Name of reaction mechanism _____

Type of bond fission _____ **[3]**

ii. Describe **two** limitations of the synthesis of 2-bromo-2-methylpropane from an alkane and bromine.

1 _____

_____

_____

2 _____

_____

_____ **[2]**

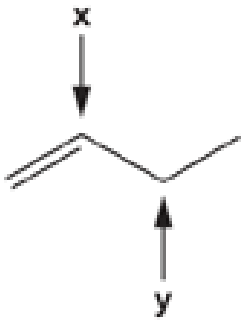
2. Hydrogen reacts much more readily with alkenes than with alkanes.

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]**

3. 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]**

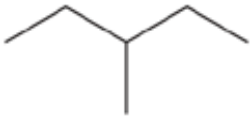
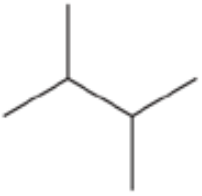
4. Which property explains the low reactivity of alkanes?

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]**

5(a). This question is about hydrocarbons.

The skeletal formulae and boiling points of three isomers of C_6H_{14} are shown in the table below.

Isomer	Molecular formula	Skeletal formula	Boiling point/°C
A	C_6H_{14}		69
B	C_6H_{14}		63
C	C_6H_{14}		58

State and explain the trend in the boiling points shown in the table.

Refer to the isomers **A**, **B** and **C** in your answer.

[4]

(b). The hydrocarbon C_2H_6 reacts with bromine, Br_2, to form C_2H_5Br under suitable conditions.

Complete the table below to show the mechanism for the three stages of the reaction of C_2H_6 with Br_2 to form C_2H_5Br.

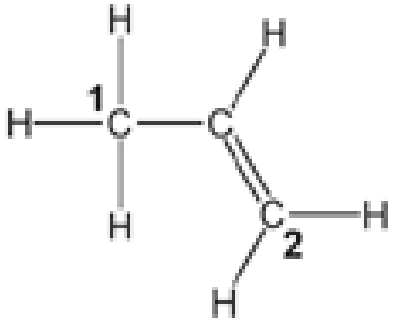
The equation for one of the possible reactions for termination has been completed.

In your equations, use molecular formulae and 'dots' (·) with any radicals.

Initiation	Conditions ..... Equation ..... → .....
Propagation	**1** ..... → ..... **2** ..... → .....
Termination	**1** $Br\cdot + Br\cdot \rightarrow Br_2$ **2** ..... → ..... **3** ..... → .....

[5]

(c). 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]

6. This question is about enthalpy changes.

In a petrol engine, alkanes undergo combustion.

i. Heptane is one of the alkanes in petrol.

Write the equation for the complete combustion of heptane.

State symbols are **not** required.

[2]

ii. In a petrol engine, polluting gases such as CO and NO are formed. These are mostly removed before being emitted from the exhaust.

The equation for the removal of CO and NO is shown below.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$ $\Delta H = -746$ kJ mol^{-1}

Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

On your diagram:

- Label the enthalpy change of reaction, ΔH.
- Include the formulae of the reactants and products.
- Label the activation energy, E_a.

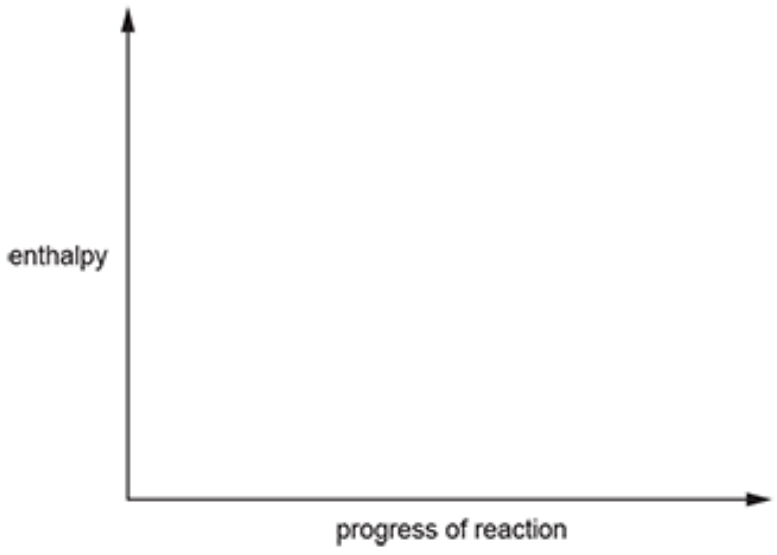


Fig. 23.1

[2]

iii. CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

Refer to your enthalpy profile diagram in **Fig. 23.1** in your answer.

[2]

7. This question is about hydrocarbons.

Butane reacts with bromine by radical substitution to form a mixture of organic products.

The reaction needs UV radiation for the initiation stage.

Write equations for the propagation stage that follows to form 2-bromobutane.

Use skeletal formulae and 'dots' (•) to show the position of any radicals.

8(a). 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]

(b). 2-methylpentane reacts with bromine by radical substitution.

2-methylpentane

A mixture of organic products is formed, including 3-bromo-2-methylpentane, and compounds **A** and **B**.

i. Complete the table below to show the mechanism for the formation of 3-bromo-2-methylpentane and **three** possible equations for termination.

In your equations, use **structural or skeletal formulae** and 'dots' (•) for the position of radicals.

Initiation	Equation: ..... Conditions: .....
Propagation	→ →

Termination	→ → →

[6]

ii. Organic compound **A** is formed by the substitution of **all** 14 H atoms in 2-methylpentane by Br atoms.

Write the equation, using **molecular formulae**, for the formation of compound **A** from 2-methylpentane.

---

[2]

iii. Organic compound **B** is formed by the substitution of **some** of the 14 H atoms in 2-methylpentane by Br atoms.

0.8649 g of compound **B** is heated until it is vaporised.

Under the conditions used:

- compound **B** has a volume of 72.0 cm^3
- the molar gas volume is 40.0 $dm^3\ mol^{-1}$.

Determine a possible molecular formula of compound **B**.

molecular formula = ... **[3]**

9. For complete combustion, 0.100 mol of an alkane requires 22.8 dm^3 of O_2, measured at RTP.

Which alkane has undergone complete combustion?

A pentane
B hexane
C heptane
D octane

Your answer ☐ **[1]**

10. Which equation(s) could be part of the propagation step in the radical substitution of C_5H_{12} to form $C_5H_{11}Cl$?

1 $C_5H_{11}\bullet + Cl_2 \rightarrow C_5H_{11}Cl + Cl\bullet$
2 $C_5H_{12} + Cl\bullet \rightarrow C_5H_{11}Cl + H\bullet$
3 $C_5H_{11}\bullet + Cl\bullet \rightarrow C_5H_{11}Cl$

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

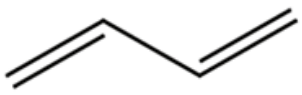
Your answer ☐ **[1]**

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

A 7
B 10
C 12
D 15

Your answer ☐ **[1]**

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



A 1
B 3
C 7
D 9

Your answer ☐ **[1]**

13. Complete combustion of an alkane forms 30 cm^3 of carbon dioxide and 40 cm^3 of water vapour, under the same conditions of temperature and pressure.

Which alkane has undergone complete combustion?

A butane
B ethane
C heptane
D propane

Your answer ☐ **[1]**

14(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]

15. 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]**

END OF QUESTION PAPER