# Alkanes

## Question Paper 2

| | |
|---|---|
| **Level** | International A Level |
| **Subject** | Chemistry |
| **Exam Board** | CIE |
| **Topic** | Hydrocarbons |
| **Sub-Topic** | Alkanes |
| **Paper Type** | Theory |
| **Booklet** | Question Paper 2 |

**Time Allowed:** **77 minutes**

**Score:** **/64**

**Percentage:** **/100**

**Grade Boundaries:**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | 777.5% | 70% | 62.5% | 57.5% | 45% | <45% |

**1** In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, **A**, from the ground near Florence in Italy.
They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

**(a)** What is meant by the term *molecular formula*?

.....

.....

..... [2]

Davy and Faraday deduced the formula of **A** by exploding it with an excess of oxygen and analysing the products of combustion.

**(b)** Complete and balance the following equation for the complete combustion of a hydrocarbon with the formula $C_xH_y$.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow \text{.....} + \text{.....}$$

[2]

**(c)** When 10 $cm^3$ of **A** was mixed at room temperature with 50 $cm^3$ of oxygen (an excess) and exploded, 40 $cm^3$ of gas remained after cooling the apparatus to room temperature and pressure.
When this 40 $cm^3$ of gas was shaken with an excess of aqueous potassium hydroxide, KOH, 30 $cm^3$ of gas still remained.

**(i)** What is the identity of the 30 $cm^3$ of gas that remained at the end of the experiment?

.....

**(ii)** The combustion of **A** produced a gas that reacted with the KOH(aq).

What is the identity of this gas?

.....

**(iii)** What volume of the gas you have identified in **(ii)** was produced by the combustion of **A**?

..... $cm^3$

**(iv)** What volume of oxygen was used up in the combustion of **A**?

..... $cm^3$ [4]

**(d)** Use your equation in **(b)** and your results from **(c)(iii)** and **(c)(iv)** to calculate the molecular formula of **A**.
Show all of your working.

[3]

[Total: 11]

**2** Crude oil is a naturally occurring flammable liquid which consists of a complex mixture of hydrocarbons. In order to separate the hydrocarbons the crude oil is subjected to fractional distillation.

**(a)** Explain what is meant by the following terms.

**(i)** *hydrocarbon* .....

.....

**(ii)** *fractional distillation* .....

..... [2]

**(b)** Undecane, $C_{11}H_{24}$, is a long chain hydrocarbon which is present in crude oil.
Such long chain hydrocarbons are 'cracked' to produce alkanes and alkenes which have smaller molecules.

**(i)** Give the conditions for **two different** processes by which long chain molecules may be cracked.

process 1 .....

.....

process 2 .....

.....

**(ii)** Undecane, $C_{11}H_{24}$, can be cracked to form pentane, $C_5H_{12}$, and an alkene.
Construct a balanced equation for this reaction.

..... [3]

Pentane, $C_5H_{12}$, exhibits structural isomerism.

**(c)** **(i)** Draw the three structural isomers of pentane.

| | | |
|---|---|---|
| | | |
| isomer **B** | isomer **C** | isomer **D** |

**(ii)** The three isomers of pentane have different boiling points.

Which of your isomers has the highest boiling point?

isomer .....

Suggest an explanation for your answer.

.....

.....

..... [6]

The unsaturated hydrocarbon, **E**, is obtained by cracking hexane and is important in the chemical industry.

The standard enthalpy change of combustion of **E** is –2059 kJ mol$^{-1}$.

**(d)** Define the term *standard enthalpy change of combustion*.

.....

..... [2]

When 0.47 g of **E** was completely burnt in air, the heat produced raised the temperature of 200 g of water by 27.5 °C. Assume no heat losses occurred during this experiment.

**(e)** **(i)** Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment.

**(ii)** Use the data above and your answer to **(i)** to calculate the relative molecular mass, $M_r$, of **E**.

[4]

**(f)** Deduce the molecular formula of **E**.

[1]

[Total: 18]

**3** Alkanes such as methane, $CH_4$, undergo few chemical reactions. Methane will, however, react with chlorine but not with iodine.

Relevant standard enthalpy changes of formation for the reaction of methane with chlorine to form chloromethane, $CH_3Cl$, are given below.

| | $\Delta H_f^{\ominus}$/kJ mol$^{-1}$ |
|---|---|
| $CH_4$ | –75 |
| $CH_3Cl$ | –82 |
| $HCl$ | –92 |

**(a) (i)** Use the data to calculate $\Delta H_{reaction}^{\ominus}$ for the formation of $CH_3Cl$.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

**(ii)** The corresponding reaction with iodine does **not** take place.

Use bond energy data from the *Data Booklet* to calculate a 'theoretical value' for $\Delta H_{reaction}$ for the following equation.

$$CH_4 + I_2 \rightarrow CH_3I + HI$$

**(iii)** Suggest why this reaction does **not** in fact occur.

.....

.....

[5]

**(b)** **(i)** By using equations, describe the mechanism of the reaction between chlorine and methane to form chloromethane, $CH_3Cl$.

Identify, by name, the separate steps of the overall reaction.

.....

.....

.....

.....

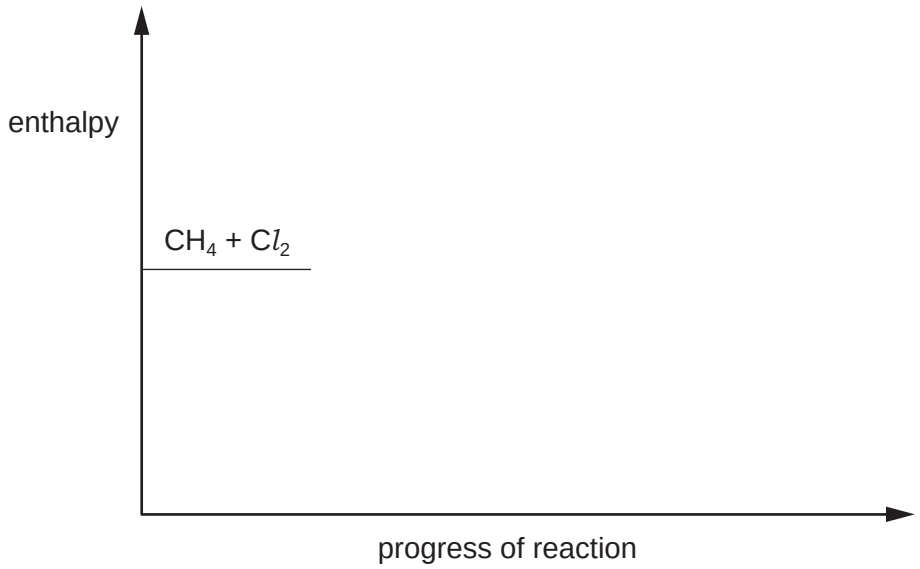
.....

.....

**(ii)** What is the intermediate organic species in this reaction?

..... [7]

**(c)** The energy of activation for the formation of $CH_3Cl$ is 16 kJ $mol^{-1}$.
Use this figure and your answer to **(a)(i)** to complete the reaction pathway diagram below showing the formation of $CH_3Cl$ from $CH_4$ and $Cl_2$.
Show clearly the intermediate organic species and the final products.
Indicate on your sketch the relevant enthalpy changes and their values.




[4]

[Total: 16]

**4** **(a)** The viscosity of engine oil can be improved by the addition of certain medium chain-length polymers.

A portion of the chain of one such polymer is shown below.

$$–CH_2CH(CH_2CH_2CH_3)CH_2CH(CH_2CH_2CH_3)CH_2–$$

On average, the molecules of the medium-chain polymer contain 40 carbon atoms.

**(i)** Suggest the structure of the monomer.

.....

**(ii)** How many monomer units are incorporated into the average molecule of the polymer?

.....

[2]

**(b)** Used car engine oil can be recycled for use as a fuel by the processes of distillation and cracking.

**(i)** Assuming a typical molecule of engine oil has the formula $C_{40}H_{82}$, suggest an equation for a cracking reaction that could produce diesel fuel with the formula $C_{16}H_{34}$ and other hydrocarbons only.

.....

**(ii)** What conditions are needed for this cracking reaction?

.....

**(iii)** Considering only the bonds broken and the bonds formed during the reaction, use the *Data Booklet* to calculate the enthalpy change for the reaction you wrote in **(b)(i)**.

.....

.....

.....

**(iv)** Comment on how the conditions you described in **(b)(ii)** relate to the enthalpy change you calculated in **(b)(iii)**.

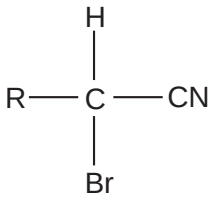
.....

.....

[4]

[Total: 6]

**5** Compound **G**, in which R– represents the rest of the molecule, was made for use as a tear gas in World War 2.




compound **G**

Compound **G** was made by the following sequence of reactions.

$$R\text{–}CH_3 \xrightarrow{\text{stage I}} R\text{–}CH_2Cl \xrightarrow{\text{stage II}} R\text{–}CH_2CN \xrightarrow{\text{stage III}} R\text{–}CHBrCN$$

**(a)** **(i)** For stage I **and** for stage II, state the reagent(s) and condition(s) used to carry out **each** change.

stage I reagent(s) .....

condition(s) .....

stage II reagent(s) .....

condition(s) .....

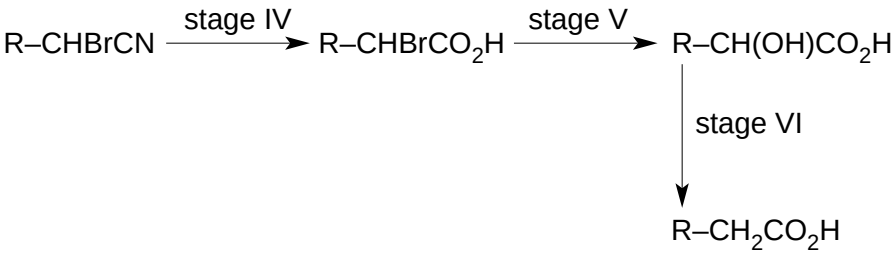
**(ii)** Suggest the reagent(s) and condition(s) necessary to carry out stage III.

reagent(s) .....

condition(s) .....

[6]

Compound **G** was not actually used in World War 2 and stocks of it had to be destroyed safely. The following sequence of reactions was used in this process.




**(b)** For stage IV **and** for stage V state the reagent(s) and condition(s) necessary to bring about **each** reaction.

stage IV reagent(s) .....

condition(s) .....

stage V reagent(s) .....

condition(s) ..... [4]

**(c)** The full sequence of stages I to VI involves some compounds which contain chiral centres.

**(i)** Explain what is meant by the term *chiral centre*.

.....

.....

**(ii)** Draw displayed formulae for the isomers of **one** compound in the full sequence of stages I to VI which you consider to be chiral.

[3]

[Total: 13]