1 Fractional distillation is used in industry to obtain alkanes from crude oil.

(a) (i) On what physical property of alkanes does this process depend?

(1)

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(ii) The alkanes are then processed by **cracking** or **reforming** to produce other hydrocarbons.
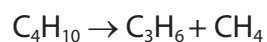
Explain the meaning of these terms.

(2)

Cracking

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Reforming

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(iii) The equation for a cracking reaction of butane is

$$C_4H_{10} \rightarrow C_3H_6 + CH_4$$

Use the following standard enthalpy changes of combustion to calculate the enthalpy change of this cracking reaction. Show your method, which may involve the use of a Hess cycle. Include a sign and units in your answer.

Compound	Standard enthalpy change of combustion / kJ mol^{-1}
butane	−2877
propene	−2058
methane	−890

(3)

(iv) Butane can also be cracked to form products other than propene and methane. Write an equation for this reaction.

(1)

(b) (i) The enthalpy change of combustion of a liquid hydrocarbon, pentane, was determined in an experiment.

A sample of pentane was burned in a spirit burner and the energy produced used to heat water in a calorimeter.

The results of the experiment are as follows:

Mass of spirit burner and pentane at start	85.6 g
Mass of spirit burner and pentane after burning	84.6 g
Mass of water in calorimeter	200 g
Initial temperature of water	22.0 °C
Final temperature of water	56.0 °C
Mass of 1 mole of pentane	72.0 g

Heat energy transferred (J) = mass of water × temperature change × 4.18

Calculate the enthalpy change of combustion of pentane. Include a sign and units in your answer.

(3)

(ii) Give **one** reason, other than heat loss, why the enthalpy change determined in this experiment differs substantially from the Data Booklet value.

(1)

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(iii) Suggest a reason why this experiment would be too hazardous to carry out in a school laboratory.

(1)

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....

(c) (i) Write an equation for the complete combustion of pentane. State symbols are not required.

(1)

(ii) Identify the type and number of bonds broken and formed during the combustion of a molecule of pentane.

(2)

(iii) Explain why the enthalpy change of combustion of pentane is exothermic.

(1)

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(Total for Question = 16 marks)

2 This question is about ethane and ethene.

(a) Ethane reacts with chlorine by a free radical mechanism.

(i) Explain what is meant by the term **free radical**.

(1)

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....

(ii) Complete the equation for the formation of free radicals from one molecule of chlorine. Use appropriate curly arrows to show electron movements.

(1)

Cl—Cl   →

(iii) Write an equation for the reaction between ethane and a chlorine free radical, and name the type of step in the mechanism where this occurs. Curly arrows are not required.

(2)

Type of step ....
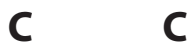
(iv) Give an equation for a termination step in this mechanism in which an **organic** compound other than chloroethane is formed.

(1)

(b) Ethene contains a carbon-carbon double bond.

   (i) Complete the diagram below showing the σ and π bonds in the
        carbon-carbon double bond in ethene.

        (2)

                    C   C

   *(ii) Describe and explain what happens to the σ and π bonds in ethene in an
         addition reaction.

         (3)

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   (iii) One test for a carbon-carbon double bond is the reaction with acidified
         potassium manganate(VII), $KMnO_4$.

         Give the colour change if this reaction was carried out with ethene. Draw the
         displayed formula of the product.

         (2)

From .... to ....

Displayed formula

   (iv) Describe another test for a carbon-carbon double bond and give the colour
        change for the positive result.

        (2)

Test..

From .... to ....

(v) Ethene reacts with hydrogen bromide. Write the mechanism for this reaction, showing any relevant dipoles.

(4)

Mechanism:

(c) But-1-ene is an alkene with properties similar to ethene.

Write an equation, using **skeletal** formulae for the organic compounds, showing the conversion of but-1-ene to butane. State the essential condition needed.

(2)

Condition..

(Total for Question = 20 marks)

3 Crude oil is composed mainly of alkanes, which are saturated hydrocarbons.

(a) (i) Define the term **hydrocarbon**.

(1)

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....

(ii) State what is meant by the term **saturated**, as applied to a hydrocarbon.

(1)

....

....

(b) Crude oil can be separated into fractions.

(i) What property allows crude oil to be separated by fractional distillation?

(1)

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(ii) Many chemists are of the opinion that we should use fuels such as biodiesel rather than petrol and diesel.

Suggest **one** reason to support this opinion.

(1)

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(c) A molecule of a hydrocarbon, **X**, can be cracked to form one molecule of pentane, C_5H_{12}, and two molecules of ethene only.

(i) Deduce the molecular formula of **X**.

(1)

(ii) Give **one** reason why cracking reactions are carried out in industry and suggest why high temperatures are used in this process other than to speed up the reaction.

(2)

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(d) Butane, C_4H_{10}, is a hydrocarbon which is used as a fuel. It is a gas under standard conditions.

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

(1)

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....

(ii) Write an equation for the **complete** combustion of butane under standard conditions. Include state symbols in your answer.

(2)

(iii) Write an equation for the **incomplete** combustion of butane to form carbon monoxide and water only. State symbols are not required.
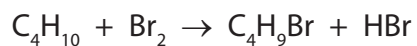
(1)

(iv) Under what conditions would you expect incomplete combustion to occur?

(1)

....

....

(e) Butane can react with bromine, in the presence of ultraviolet radiation, according to the following equation.

$$C_4H_{10} + Br_2 \rightarrow C_4H_9Br + HBr$$

(i) Calculate the atom economy by mass for the formation of C_4H_9Br.
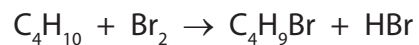Use the expression

$$\text{atom economy} = \frac{\text{molar mass of the desired product}}{\text{sum of the molar masses of all products}} \times 100\,\%$$

Use the Periodic Table as a source of data.

(2)

Final answer...%

*(ii) Describe the mechanism of the reaction between butane and bromine that forms the products given in the equation below.

$$C_4H_{10} + Br_2 \rightarrow C_4H_9Br + HBr$$

In your answer you should include

- equations for each step of the mechanism (curly arrows are **not** required)
- the name of each step occurring in the mechanism.

(7)

(Total for Question = 21 marks)