1 Crude oil is a complex mixture of hydrocarbons. Initial separation is achieved by fractional distillation of the crude oil. The separate fractions are further refined to produce hydrocarbons such as decane, $C_{10}H_{22}$.

(a) Give the general formula of alkanes.

(1)

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

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

(1)

(ii) Explain why incomplete combustion can occur.

(1)

.....

.....

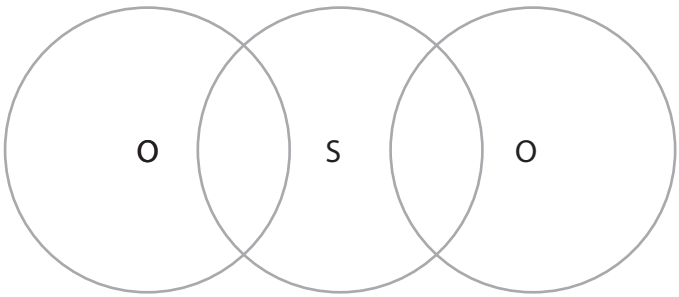
(c) 'Low-sulfur fuel' is now supplied to petrol stations. The removal of sulfur from diesel and petrol reduces the emission of toxic oxides of sulfur from vehicle exhausts. One such oxide is sulfur dioxide, SO_2.

The bonding in sulfur dioxide may be represented as shown below.

$$O = S \rightarrow O$$

Complete the dot and cross diagram below for the SO_2 molecule, showing only outer shell electrons. Use dots to represent the oxygen electrons and crosses to represent the sulfur electrons.

(3)



(d) Another alkane produced from crude oil is heptane, C_7H_{16}. The reforming of heptane produces methylcyclohexane and only one other product. A methylcyclohexane molecule is made from a ring of six carbon atoms bonded to a methyl group.

(i) Use the information given above to give the **skeletal** formula of methylcyclohexane.

(1)

(ii) Write a balanced equation, using **molecular** formulae, for the reforming of heptane into methylcyclohexane and one other product. State symbols are not required.

(1)

(iii) Suggest a reason why oil companies reform alkanes such as heptane.

(1)

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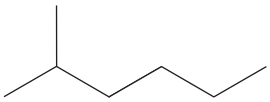
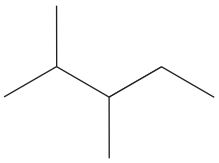
(e) Five branched-chain isomers of heptane are shown in the boxes below.

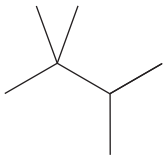
2-methylhexane



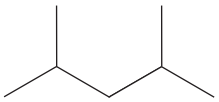
2,3-dimethylpentane



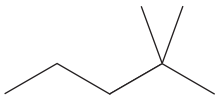
2,2,3-trimethylbutane



2,4-dimethylpentane



isomer **A**



(i) Give the systematic name of isomer **A**.

(1)

(ii) In the empty boxes above, draw skeletal formulae for two other **branched-chain** isomers of C_7H_{16}, with no side-chain having more than one carbon atom.

(2)

(f) Butane, C_4H_{10}, reacts with chlorine, Cl_2, at room temperature and pressure.

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$

(i) What other condition is essential for this reaction?

(1)

.....

(ii) Write an equation for the initiation step of the mechanism for the above reaction. Curly arrows are not required.

(1)

(iii) State the type of bond fission involved in the initiation step.

(1)

.....

(iv) Write equations for the two propagation steps of this mechanism. Curly arrows are not required.

(2)

First propagation step:

Second propagation step:

(v) Write **one** equation for a reaction that would terminate this mechanism.

(1)

(Total for Question = 18 marks)

2 This question is about hydrocarbons.

(a) Liquefied petroleum gas (LPG) is a fuel sold as an alternative to petrol. It is a mixture of liquefied C_3 and C_4 alkanes.

(i) Suggest a reason why the alkanes are liquefied.

(1)

(ii) There are two C_4 alkanes.

Draw **skeletal** formulae of each of the C_4 alkanes in the spaces provided.

Name each alkane.

(4)

First skeletal formula	Second skeletal formula
Name:	Name:

(iii) Complete the following sentence.

(1)

Compounds with the same molecular formula but different structural formula are called .

(b) Propane, C_3H_8, reacts with chlorine, Cl_2, in a substitution reaction.

$$C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$$

The mechanism for this reaction is described in three stages.

(i) Give the **initiation step** for this reaction and state the condition necessary for this step to occur.

(2)

Initiation step

Condition

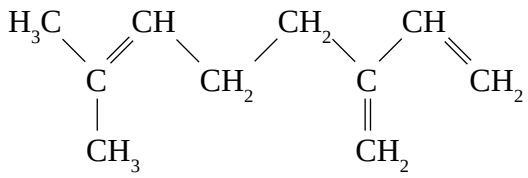
(ii) Give the TWO **propagation steps** for this reaction.

(2)

(iii) Give a possible **termination step** for this reaction.

(1)

(c) Myrcene, $C_{10}H_{16}$, is a naturally occurring compound which is used in perfumes.



Myrcene

(i) Name the functional group in myrcene.

(1)

(ii) What colour change would you observe when bromine, dissolved in an organic solvent, is added to myrcene?

(1)

From **To**

(iii) Classify the type and mechanism of the reaction that occurs when myrcene reacts with bromine, Br_2.

(2)

(iv) In an experiment, 1.36 g of myrcene (molar mass: 136 g mol^{-1}) was found to react with 0.72 dm^3 of hydrogen, H_2, in the presence of a nickel catalyst.

Use this information to draw the structural formula of the product of the reaction between myrcene and hydrogen.

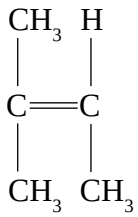
[Assume the molar volume of H_2 under the conditions of the experiment is 24 $dm^3 mol^{-1}$.]

(2)

Calculation

Hence structural formula of the product

(d) Myrcene is one of a group of compounds related to 2-methylbut-2-ene shown below.



2-methylbut-2-ene undergoes addition polymerization in a similar way to ethene.

Draw the structural formula of the repeat unit of the polymer formed.

(2)

(Total for Question = 19 marks)

3 This question is about the gas ethane, C_2H_6, and its reactions.

(a) Write the equation, including state symbols, which represents the reaction taking place when the standard enthalpy change of combustion of ethane is measured.

(2)

(b) Ethane can react with chlorine to form chloroethane and hydrogen chloride.

$$C_2H_6(g) + Cl_2(g) \rightarrow C_2H_5Cl(g) + HCl(g)$$

Bond	Bond enthalpy/kJ mol^{-1}
C—H	413
C—C	347
C—Cl	346
H—Cl	432
Cl—Cl	243

Rewrite this equation using displayed formulae.

Use the equation you have written, together with the bond enthalpy data, to calculate the enthalpy change for the reaction.

(4)

(c) This reaction takes place in a number of steps, some of which are shown below.

Step 1 $Cl_2 \rightarrow 2Cl\bullet$

Step 2 $CH_3CH_3 + Cl\bullet \rightarrow HCl + CH_3CH_2\bullet$

(i) State the type of reaction occurring in step 1 and the conditions needed for this step.

(2)

Type .....

Conditions .....

(ii) Complete the equation below for the third step of the reaction, and show the movement of electrons using the appropriate arrows.

(3)

$CH_3CH_2\bullet + Cl—Cl \rightarrow$

(iii) Write equations for **two** termination steps in this reaction.

(2)

(d) Ethane can be cracked in industry. Write an equation for the cracking of ethane.

(1)

(e) Suggest **two** reasons why cracking of larger alkane molecules is important in industry.

(2)

Reason 1: .....

.....

Reason 2: .....

.....

(Total for Question = 16 marks)

4 Chloroethane can be made from ethane and chlorine in the gas phase in the presence of ultraviolet light. The equation for the reaction is

$$CH_3CH_3 + Cl_2 \rightarrow CH_3CH_2Cl + HCl$$

(a) Complete the mechanism for the reaction. Two of the steps have been given for you.

(4)

Initiation: $Cl_2 \rightarrow 2Cl\cdot$

Propagation (two steps)

(i)

(ii)

Termination (three steps)

$2Cl\cdot \rightarrow Cl_2$

(iii)

(iv)

(b) This reaction gives a poor yield of chloroethane. Give the structural formula and name of another organic product, not included in your mechanism for part (a), which could be produced in the reaction.

(2)

Formula

Name .....

(c) Chlorine gas is extremely toxic and is therefore a significant hazard. The preparation must be performed so as to minimise the risk to the experimenter.

(i) Explain the difference between **hazard** and **risk**.

(2)

.....

.....

.....

.....

(ii) Give one precaution that you would use in this experiment to minimise the risk, other than the use of a laboratory coat and safety goggles.

(1)

.....

.....

(Total for Question 9 marks)