F322: Chains, Energy and Resources

2.1.2 Alkanes.

1. Kerosene is used as a fuel for aeroplane engines.

Kerosene is obtained from crude oil.

Name the process used to obtain kerosene from crude oil **and** explain why the process works.

.....

.....

.....

[Total 2 marks]

2. Some of the hydrocarbons in kerosene have the formula $C_{10}H_{22}$.

(i) What is the name of the straight chain hydrocarbon with the formula $C_{10}H_{22}$?

.....

[1]

(ii) Draw the skeletal formula of one branched chain isomer with the formula $C_{10}H_{22}$.

[1]

(iii) Explain why the straight chain isomer of $C_{10}H_{22}$ has a higher boiling point than any of its branched chain structural isomers.

.....

.....

.....

.....

.....

[2]

(iv) Explain why the straight chain isomer of $C_{10}H_{22}$ is converted by the petroleum industry into its branched chain isomers.

.....

.....

[1]

[Total 5 marks]

3. Kerosene is used as a fuel for aeroplane engines.

When kerosene burns in an aeroplane engine very little carbon monoxide, CO, is formed but a significant amount of nitrogen monoxide, NO, is formed.

(i) Construct the equation to show the **complete** combustion of $C_{10}H_{22}$.

.....

[2]

(ii) Suggest, with the aid of an equation, how NO is formed within an aeroplane engine.

.....

.....

.....

[1]

[Total 3 marks]

4. A reaction mechanism shows the individual steps that take place during a reaction.

Methane reacts with bromine in the presence of ultraviolet radiation to form several products.
Two of these products are bromomethane and hydrogen bromide.

(i) Write an equation for the reaction between methane and bromine to make bromomethane and hydrogen bromide.

.....

[1]

(ii) Name one other bromine-containing organic product which is formed when methane reacts with bromine.

.....

[1]

(iii) The mechanism for this reaction is called radical substitution.

Describe the mechanism for the radical substitution of methane by bromine to make bromomethane.

Use the mechanism to suggest why a small amount of ethane is also formed.

In your answer, you should organise your answer and use the correct technical terms.

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[7]

[Total 9 marks]

5. Alkenes are a very useful series of hydrocarbons used widely in synthesis. Alkenes are more reactive than alkanes.

What is the name of the process used to convert long chain alkanes into more useful shorter chain alkenes?

.....

[Total 1 mark]

6. 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]

[Total 2 marks]

7. 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.

[Total 2 marks]

8. Catalysts are increasingly being used in chemical processes.

A catalyst speeds up a reaction without being consumed by the overall reaction.
A catalyst provides an alternative reaction route with a lower activation energy.

(i) Chlorine radicals, $Cl^{\bullet}$, catalyse some reactions.

Choose a reaction that you have studied that is catalysed by chlorine radicals.

Write down an equation for the overall reaction and show how chlorine radicals are **not** consumed by the overall reaction.

.....

.....

.....

.....

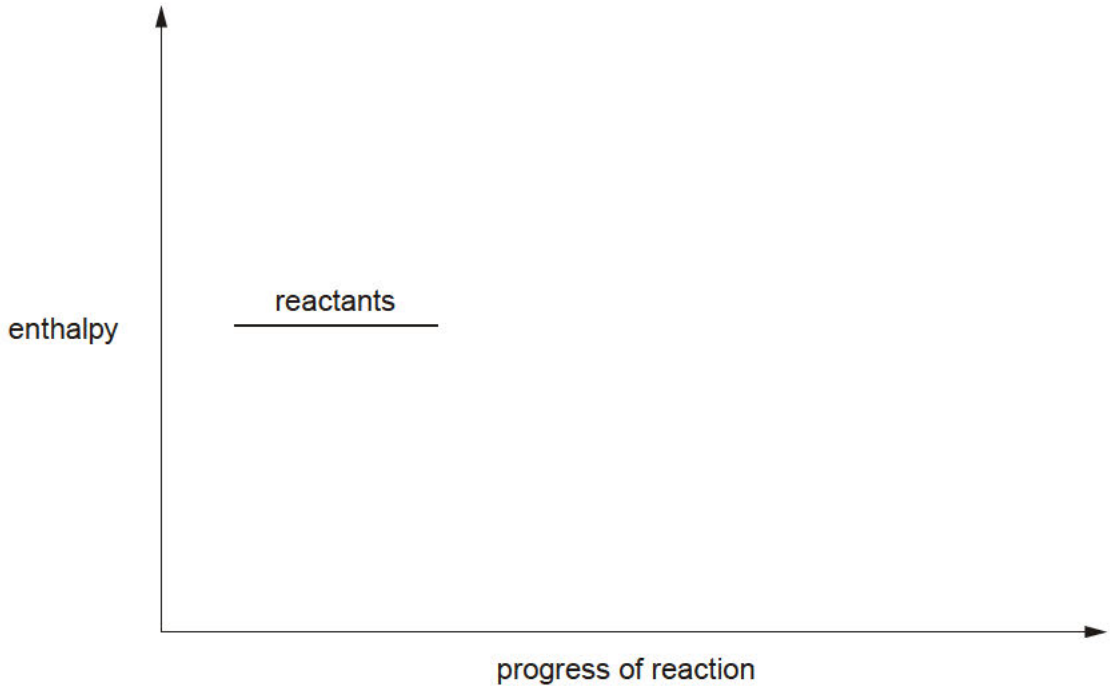
.....

.....

[3]

(ii) Using the axes below, sketch an enthalpy profile diagram for an exothermic reaction to show how a catalyst provides an alternative reaction route with a lower activation energy. Include on your diagram labels for:

- enthalpy change, ΔH;
- activation energy for the catalysed route, E_c;
- activation energy for the uncatalysed route, E_a.



[3]

9. The table below lists the boiling points of some alkanes.

alkane	number of carbon atoms	molecular formula	boiling point /°C
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6	C_6H_{14}	69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(i) Predict the boiling point of octane.

.....

[1]

(ii) State and explain the trend in the boiling points of these alkanes.

.....

.....

.....

[2]

[Total 3 marks]

10. Long chain alkanes, such as nonane, are cracked into shorter chain alkanes and alkenes.

Write a balanced equation for the cracking of nonane into heptane and ethene.

.....

[Total 1 mark]

11. Straight chain alkanes such as heptane, C_7H_{16}, are processed into branched-chain alkanes and cyclic compounds. These products are required to make petrol burn better in car engines than when using unbranched alkanes.

(i) Draw the skeletal formula of a branched structural isomer of heptane and state its name.

skeletal formula:

name: .....

[2]

(ii) Write a balanced equation to show the formation of the cyclic compound methylcyclohexane from heptane.

[2]

[Total 4 marks]

12. Butane, C_4H_{10}, reacts with chlorine to produce a chloroalkane with molecular formula C_4H_9Cl.

The reaction is initiated by the formation of chlorine radicals from chlorine.

(i) What is meant by the term *radical*?

.....

[1]

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2.

.....

[1]

(iii) State the type of bond fission involved in the formation of the chlorine radicals.

.....

[1]

(iv) The chlorine radicals react with butane in several steps to produce C_4H_9Cl.

Write equations for the two propagation steps.

.....

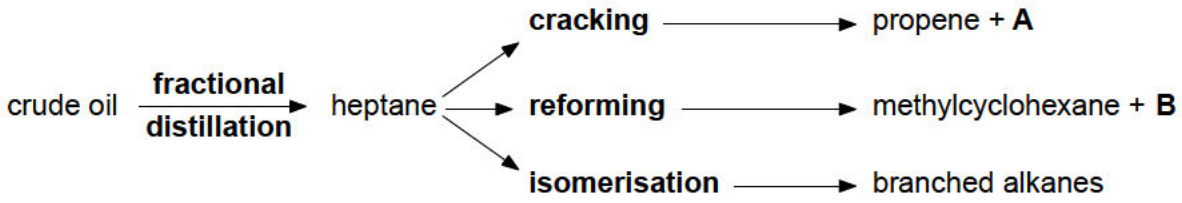
.....

[2]

[Total 5 marks]

13. Crude oil is first separated by fractional distillation. The fractions can then be refined further by cracking, reforming and isomerisation.

The reaction sequence below shows the production of heptane, C_7H_{16}, from fractional distillation of crude oil, followed by cracking, reforming and isomerisation.



(a) What is meant by the term *fractional distillation?*

.....

.....

[1]

(b) The cracking of heptane produces propene and **A**.

Write a balanced equation for this cracking of heptane.

.....

[1]

(c) The reforming of heptane produces methylcyclohexane and **B**.

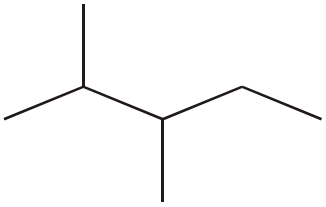
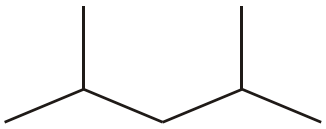
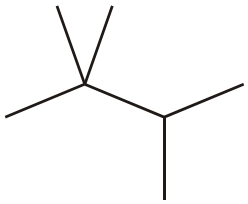
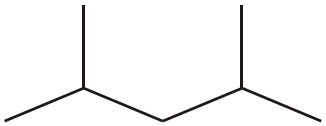
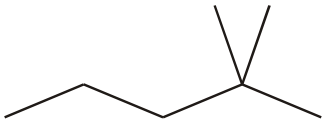
(i) Show the structural formula of methylcyclohexane.

[1]

(ii) Write a balanced equation for this reforming.

[1]

(d) The isomerisation of heptane produces **seven** branched alkanes, five of which are shown below.

2,3-dimethylpentane 	2,4-dimethylpentane 
2,2,3-trimethylbutane 	2,4-dimethylpentane 
compound **C** 	

(i) Name compound **C**.

.....

[1]

(ii) In the boxes above, draw skeletal formulae for the other **two** branched alkanes formed by isomerisation of heptane.

[2]

(iii) Predict which of 2-methylhexane, 2,3-dimethylpentane and 2,2,3-trimethylbutane has the lowest boiling point.

.....

[1]

(iv) Explain why 2-methylhexane, 2,3-dimethylpentane and 2,2,3-trimethylbutane have different boiling points.

.....

.....

.....

[2]

[Total 10 marks]

14. Butane, C_4H_{10}, under certain conditions, reacts with Cl_2 to form a mixture of chlorinated products. One possible product is C_4H_9Cl.

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

(a) (i) State the conditions.

.....

[1]

(ii) Write equations to show the mechanism of this reaction.

initiation .....

propagation .....

.....

[3]

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

.....

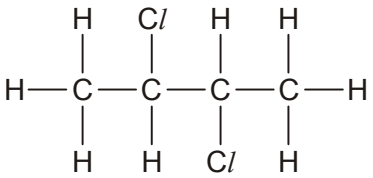
[1]

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

[1]

(b) One other possible product of the reaction between butane and chlorine is compound **J**, $C_4H_8Cl_2$, shown below.

compound **J**



(i) Name compound **J**.

.....

[1]

(ii) Draw the skeletal formula of compound **J**.

[1]

(iii) In addition to compound **J**, suggest **one** other possible structural isomer of $C_4H_8Cl_2$ that could have been formed in this reaction.

[1]

[Total 9 marks]

15. In this question, one mark is available for the quality of use and organisation of scientific terms.

- Describe, with the aid of a suitable diagram, the formation of the π-bond in propene.
- State the shape, and an approximate value for the bond angles, around each carbon atom in propene.
- Describe, with the aid of a suitable example, why some alkenes show *cis-trans* isomerism.

[9]

Quality of Written Communication [1]

[Total 10 marks]

16. Hexane reacts with Br_2 in the presence of ultraviolet light.

$$C_6H_{14} + Br_2 \rightarrow C_6H_{13}Br + HBr$$

(i) State the type of reaction.

.....

[1]

(ii) Identify the three possible structural isomers of the product, $C_6H_{13}Br$, that could be formed from this reaction with hexane.

[3]

[Total 4 marks]

17. In this question, one mark is available for the quality of spelling, punctuation and grammar.

The fractions from crude oil can be processed by cracking, reforming and isomerisation.

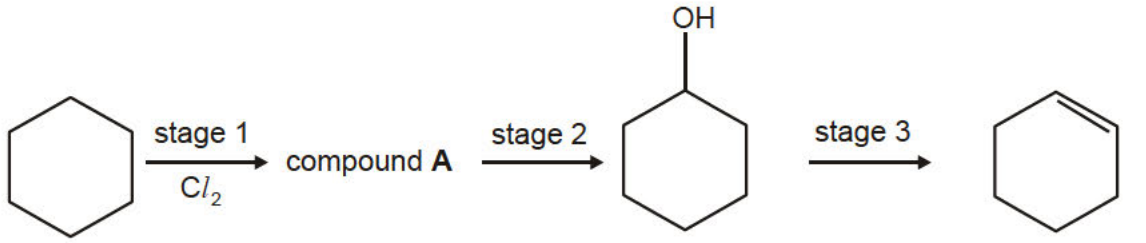
- Outline these processes with the aid of suitable equations.
- State clearly the industrial importance of the products formed in each process.

[8]

Quality of Written Communication [1]

[Total 9 marks]

18. (a) Cyclohexane can be converted into cyclohexene via a three-stage synthesis.



cyclohexane **cyclohexanol** **cyclohexene**

(i) In stage 1, cyclohexane reacts with chlorine to form the organic product, compound **A**.

Show the structure of compound **A**.

[1]

(ii) Stage 3 involves the dehydration of an alcohol.

State a suitable reagent for dehydrating an alcohol.

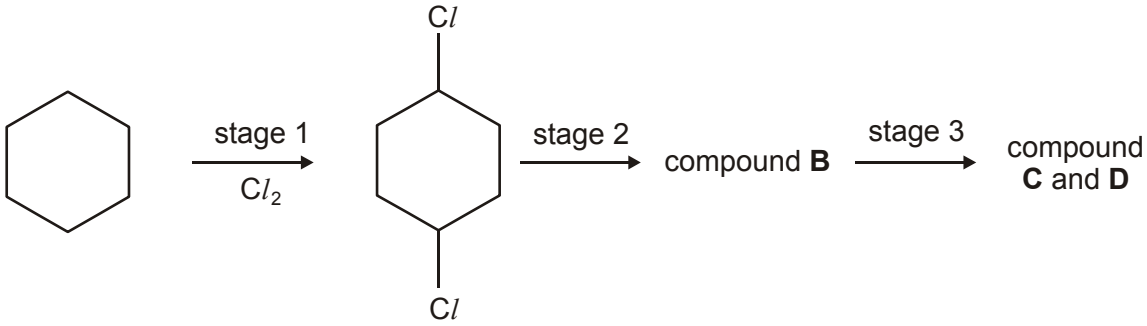
.....

[1]

(iii) Write a balanced equation for the dehydration of cyclohexanol, $C_6H_{11}OH$.

[1]

(b) The reaction in stage 1 is difficult to control. One other possible chlorinated product is 1,4-dichlorocyclohexane.This is shown below.



cyclohexane **1,4-dichlorocyclohexane**

1,4-Dichlorocyclohexane reacts in the same way as compound **A** in stages 2 and 3.

(i) Suggest the structure of compound **B**.

[1]

(ii) Two cyclic alkenes, **C** and **D** are formed in stage 3. **C** and **D** are structural isomers. Suggest the structures of **C** and **D**.

[2]

[Total 6 marks]

19. Crude oil is a complex mixture of hydrocarbons. Initial separation is achieved by fractional distillation. The separate fractions are then further refined to produce hydrocarbons such as decane.

(a) (i) State what is meant by the term *hydrocarbon.*

.....

.....

[1]

(ii) A molecule of decane contains ten carbon atoms. State the molecular formula of decane.

.....

[1]

(iii) Deduce the empirical formula of decane. .....

[1]

(b) Dodecane, $C_{12}H_{26}$, is a straight chain alkane that reacts with chlorine to produce a compound with molecular formula $C_{12}H_{25}Cl$.

$$C_{12}H_{26} + Cl_2 \rightarrow C_{12}H_{25}Cl + HCl$$

The reaction is initiated by the formation of chlorine free radicals from chlorine.

(i) What is meant by the term *free radical*?

.....

[1]

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2.

.....

[1]

(iii) State the type of bond fission involved in the formation of the chlorine free radicals.

.....

[1]

(iv) The chlorine free radicals react with dodecane to produce $C_{12}H_{25}Cl$. Write equations for the **two** propagation steps involved.

.....

.....

[2]

(v) How many different structural isomers can be formed when chlorine reacts with dodecane to form $C_{12}H_{25}Cl$?

answer .....

[1]

(c) Dodecane, $C_{12}H_{26}$, can be cracked into ethene and a straight chain alkane such that the molar ratio ethene: straight chain alkane is 2 : 1.

(i) Write a balanced equation for this reaction.

.....

[2]

(ii) Name the straight chain alkane formed.

.....

[1]

(d) Straight chain alkanes such as heptane, C_7H_{16}, can be isomerised into branched chain alkanes and reformed into cyclic compounds.

(i) Using **skeletal** formulae, write an equation to show the isomerisation of heptane into 2,2,3-trimethylbutane.

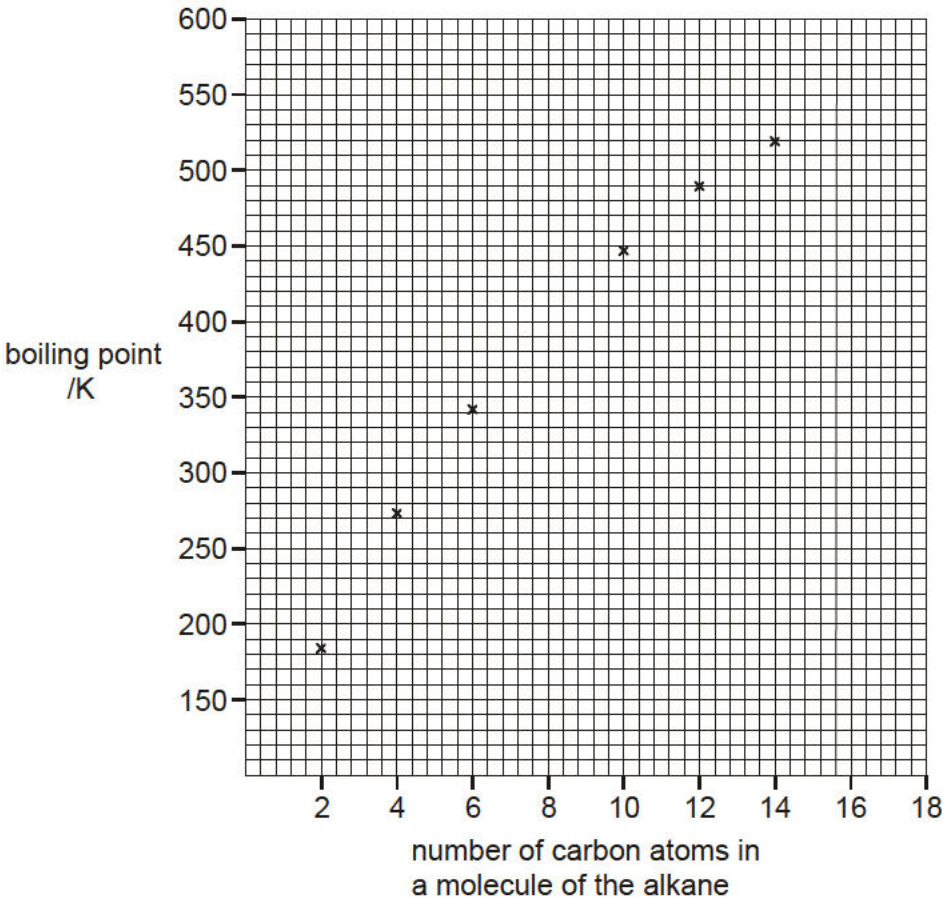
[2]

(ii) Write a balanced equation to show the reforming of heptane into methylcyclohexane.

[2]

[Total 16 marks]

20. The graph below shows the boiling points of some alkanes.



(a) Draw a smooth curve through the points on the graph and estimate the boiling points of

octane C_8H_{18}, ... hexadecane, $C_{16}H_{34}$ .....

[2]

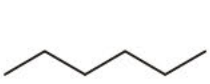
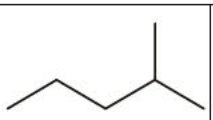
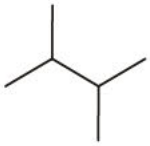
(b) State how decane, $C_{10}H_{22}$, can be separated from a mixture of the alkanes.

.....

[1]

(c) Isomerisation of hexane, C_6H_{14}, produces a mixture of structural isomers, three of which are shown in the boxes below.

(i) Draw, using skeletal formulae, **two** other structural isomers of hexane.

				
isomer **A**	isomer **B**	isomer **C**		

[2]

(ii) Name isomer **B**. .....

[1]

(iii) Isomers **A**, **B** and **C** have different boiling points. In the boxes below, list the isomers **A**, **B** and **C** in order of their boiling points.

lowest boiling point | | | | highest boiling point

[1]

(iv) Explain the order given in **(c) (iii)**.

.....

.....

.....

[2]

(d) Hexane can be reformed to produce cyclohexane as one of the products.

(i) Draw the structural formula of cyclohexane.

[1]

(ii) Write a balanced equation for the reforming of hexane into cyclohexane.

[1]

(iii) Suggest **one** reason why oil companies reform alkanes such as hexane.

.....

.....

[1]

(e) Oxygen-containing compounds can be added to improve the efficiency and performance of fuels.

In Formula One racing cars, it is common practice to add oxygen-containing compounds, such as 2-methylpropan-2-ol, $(CH_3)_3COH$. The amount of oxygen-containing compounds added is strictly controlled by the Federation Internationale de l'Automobile, FIA.

(i) Calculate the percentage by mass of oxygen in $(CH_3)_3COH$. Give your answer to three significant figures.

answer ……

[2]

(ii) Write a balanced equation for the complete combustion of $(CH_3)_3COH$.

[2]

[Total 16 marks]

21. Cyclohexane, C_6H_{12}, reacts with chlorine to produce chlorocyclohexane, $C_6H_{11}Cl$.

$$C_6H_{12} + Cl_2 \rightarrow C_6H_{11}Cl + HCl$$

The mechanism for this reaction is a free radical substitution.

(i) Write an equation to show the initiation step.

.....

[1]

(ii) State the conditions necessary for the initiation step.

.....

[1]

(iii) The reaction continues by **two** propagation steps resulting in the formation of chlorocyclohexane, $C_6H_{11}Cl$.

Write equations for these **two** propagation steps.

step 1 .....

step 2 .....

[2]

(iv) State what happens to the free radicals in the termination steps.

.....

[1]

[Total 5 marks]

22. In this question, one mark is available for the quality of use and organisation of scientific terms.

Different cars require different grades of petrol. The first stage in the production of petrol in an oil refinery is to fractionate the crude oil. After that, refineries carry out further processes.

- Outline, with the aid of equations, **three** of these processes in the production of petrol.
- Explain why, in the long term, ethanol could replace oil-based fuels.
- Write an equation for the combustion of ethanol.

[10]

Quality of Written Communication [1]

[Total 11 marks]

23. The table below lists the boiling points of some alkanes.

alkane	number of carbon atoms	molecular formula	boiling point / °C
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6		69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(a) What is the molecular formula of hexane?.....

[1]

(b) (i) State the trend in the boiling points of the alkanes.

.....

.....

[1]

(ii) Explain the trend in the boiling points of the alkanes.

.....

.....

[1]

(iii) Predict the boiling point of octane. ..... °C

[1]

[Total 4 marks]

24. Long chain alkanes, such as nonane, can be cracked into shorter chain alkanes and alkenes.

(i) Write a balanced equation for the cracking of nonane into heptane and ethene.

.....

[1]

(ii) Much of the ethene is then converted into ethanol.

Write a balanced equation for the conversion of ethene into ethanol. State the essential conditions.

equation .....

[1]

conditions .....

.....

[2]

[Total 4 marks]

25. (a) Heptane can be isomerised to produce branched chain alkanes such as 2-methylhexane or 2,3-dimethylpentane.

The equation below shows the isomerisation of heptane into 2-methylhexane.

(i) Using skeletal formulae, complete the balanced equation for the isomerisation of heptane into 2,3-dimethylpentane.

[1]

(ii) The boiling point of 2,3-dimethylpentane is 84 °C.

Predict the boiling point of 2-methylhexane. ..... °C

[1]

(b) Heptane can be reformed to produce methylcyclohexane which is a cycloalkane. Write a balanced equation to show the reforming of heptane to obtain methylcyclohexane

[2]

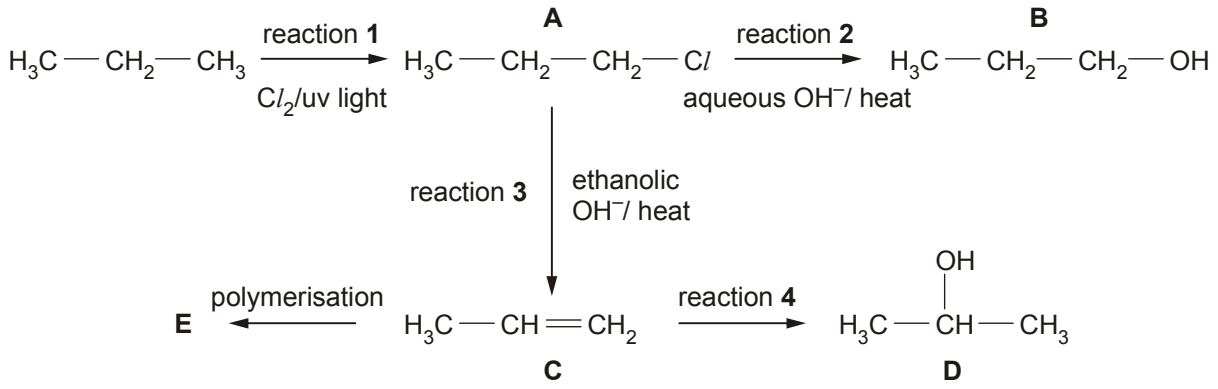
(c) State why branched chain alkanes and cycloalkanes are more useful than straight chain alkanes.

.....

[1]

[Total 5 marks]

26. Propane, C_3H_8, is used in the reaction sequence shown below.



(a) The reaction sequence shows several important reaction mechanisms. Select from reactions **1** to **4**, the reaction that shows

(i) free radical substitution, reaction .....

[1]

(ii) electrophilic addition, reaction .....

[1]

(iii) elimination, reaction .....

[1]

(b) In reaction **2**, the aqueous OH^- acts as a nucleophile.

(i) State what is meant by the term *nucleophile*.

.....

[1]

(ii) Complete, with the aid of curly arrows, the mechanism involved in reaction **2**. Show any relevant dipoles.

$H_3C-CH_2-CH_2-Cl \longrightarrow H_3C-CH_2-CH_2-OH \quad + \quad .....$

OH^-

[4]

(c) Compounds **B** and **D** are structural isomers of each other.

(i) State what is meant by the term *structural isomers*.

.....

.....

[2]

(ii) Draw the skeletal formulae of compounds **B** and **D**.

Compound **B**	Compound **D**

[2]

(d) Compound **C** can be polymerised to form compound **E**.

(i) State the type of polymerisation. .....

[1]

(ii) Name compound **E**. .....

[1]

(iii) Draw a section of compound **E**. Show **two** repeat units.

[1]

[Total 15 marks]

27. Isomer **L**, C_5H_{10}, reacts with Cl_2 in the presence of UV light to produce the organic product $C_5\mathbf{H}_9Cl$. The reaction takes place in three stages: initiation, propagation and termination.

(i) The reaction is initiated by the fission of Cl_2. State the type of fission involved.

.....

[1]

(ii) Write an equation to illustrate the fission of Cl_2 in (i).

.....

[1]

(iii) The fission of Cl_2 leads to a chain reaction involving two propagation steps. Complete the equations for the two propagation steps.

C_5H_{10} + ... → $\bullet C_5H_9$ + ...

[1]

$\bullet C_5H_9$ + ... → ..... + ...

[1]

[Total 4 marks]

28. In this question, one mark is available for the quality of written communication.

Alkanes can be separated from crude oil because they have different boiling points. The table below shows the boiling points of some alkanes.

alkane	boiling point/°C	M_r
ethane	–89	30
propane	–42	44
butane	0	58
pentane	36	72
2-methylbutane	28	72
2,2-dimethylpropane	10	72

Explain the variation in boiling points of the alkanes shown.

[5]

Explain why, in industry, alkanes such as octane are processed by isomerisation.

[3]

Illustrate your answers by referring to suitable examples. Write equations where appropriate.

Quality of Written Communication [1]

[Total 9 marks]