UNIT 1

TOPIC 4 : INTRODUCTORY ORGANIC CHEMISTRY AND ALKANES

SECTION A

Answer ALL questions. Write your answers in the spaces provided.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

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1.

A substance is labelled with the hazard symbol shown.



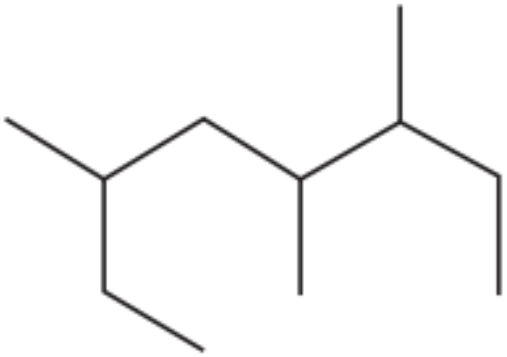
What is the meaning of this symbol?

- ☒ **A** gloves must be worn
- ☒ **B** corrosive
- ☒ **C** do not store with flammable substances
- ☒ **D** oxidising

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2.

What is the IUPAC name of this alkane?



- ☒ **A** 2-ethyl-4,5-dimethylheptane
- ☒ **B** 6-ethyl-3,4-dimethylheptane
- ☒ **C** 3,4,6-trimethyloctane
- ☒ **D** 3,5,6-trimethyloctane

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3.

Petrol, bioethanol and hydrogen are fuels.

All three of these fuels

- ☒ **A** burn to produce greenhouse gases
- ☒ **B** are overall carbon neutral
- ☒ **C** are overall sustainable
- ☒ **D** biodegrade rapidly

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4.

Cyclopentane undergoes free radical substitution with bromine.

(a) Which of these is an overall equation for this reaction?

(1)

- ☒ **A** $C_5H_8 + Br_2 \rightarrow C_5H_8Br_2$
- ☒ **B** $C_5H_{10} + Br_2 \rightarrow C_5H_{10}Br_2$
- ☒ **C** $C_5H_{10} + Br_2 \rightarrow C_5H_8Br_2 + H_2$
- ☒ **D** $C_5H_{10} + Br_2 \rightarrow C_5H_9Br + HBr$

(b) Which statement is **not** correct about this reaction system?

(1)

- ☒ **A** only the initiation step involves homolytic bond fission
- ☒ **B** only some bromine is converted to free radicals in the initiation step
- ☒ **C** propagation forms more product than termination
- ☒ **D** further substitution reactions are likely to occur

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(c) Which free radical is **least** likely to form in a propagation step in this reaction system?

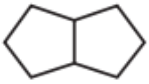
(1)

- ☒ **A** $C_5H_9^{\bullet}$
- ☒ **B** $Br^{\bullet}$
- ☒ **C** $C_5H_8Br^{\bullet}$
- ☒ **D** $H^{\bullet}$

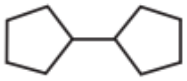
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(d) Which alkane could be formed in a termination step in this reaction system?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

5.

When $C_{20}H_{42}$ is cracked, each molecule produces one molecule of ethene, one molecule of butane and two molecules of hydrocarbon **E**.

What is the molecular formula of **E**?

☒ **A** C_7H_{13}

☒ **B** C_7H_{14}

☒ **C** $C_{14}H_{26}$

☒ **D** $C_{14}H_{28}$

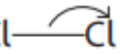
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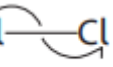
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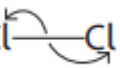
Methane reacts with excess chlorine in UV light.

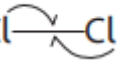
(a) Which process occurs in the initiation step?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

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(b) Which of these molecules could **not** be formed in a termination step?

(1)

- ☒ **A** C_2H_6
- ☒ **B** CH_3Cl
- ☒ **C** CH_2Cl_2
- ☒ **D** HCl

7.

Ethane reacts with bromine in the presence of ultraviolet radiation.

(a) What is the equation for the reaction?

(1)

- ☒ **A** $C_2H_6 + Br_2 \rightarrow C_2H_4Br_2 + H_2$
- ☒ **B** $C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$
- ☒ **C** $C_2H_6 + Br_2 \rightarrow 2CH_3Br$
- ☒ **D** $C_2H_6 + Br_2 \rightarrow CH_4 + CH_2Br_2$

(b) The ultraviolet radiation is needed for

(1)

- ☒ **A** homolytic breaking of a Br—Br bond
- ☒ **B** heterolytic breaking of a Br—Br bond
- ☒ **C** homolytic breaking of a C—H bond
- ☒ **D** heterolytic breaking of a C—H bond

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8.

All alkanes have the same

- ☒ **A** empirical formula
- ☒ **B** general formula
- ☒ **C** molecular formula
- ☒ **D** structural formula

9.

A single molecule of decane, $C_{10}H_{22}$, is cracked.

Which of these mixtures could **not** be formed?

- ☒ **A** pentene and pentane
- ☒ **B** ethene, butene and butane
- ☒ **C** propene, propane and butene
- ☒ **D** hexene and propane

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10.

How many structural isomers have the formula $C_3H_6Cl_2$?

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

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11.

Which pollutant **cannot** form when alkane fuels are burned in car engines?

- ☒ **A** hydrogen chloride
- ☒ **B** sulfur dioxide
- ☒ **C** carbon particulates
- ☒ **D** carbon monoxide

12.

When carrying out chemical experiments, the hazards and risks must be considered.

For a given chemical

- ☒ **A** the hazard is fixed but the risk varies
- ☒ **B** the hazard varies but the risk is fixed
- ☒ **C** both hazard and risk are fixed
- ☒ **D** both hazard and risk vary

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13.

Heterolytic fission produces

- ☒ **A** free radicals only
- ☒ **B** ions only
- ☒ **C** free radicals and positive ions only
- ☒ **D** free radicals and negative ions only

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14.

A hydrocarbon **X** has a molar mass of 98 g mol^{-1}. When a sample of **X** is shaken with bromine water, the colour of the bromine water does **not** change.

Which of these could be the structure of **X**?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

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15.

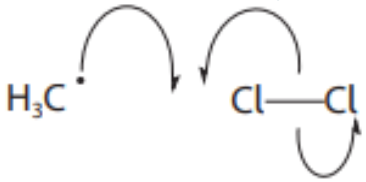
Which of these atmospheric pollutants is **not** emitted during the combustion of alkane car fuels?

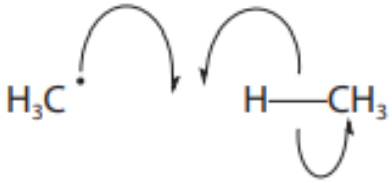
- ☒ **A** ammonia
- ☒ **B** nitrogen dioxide
- ☒ **C** sulfur dioxide
- ☒ **D** octane

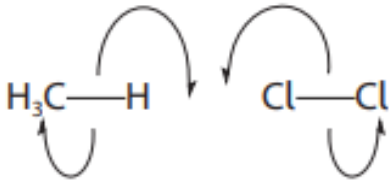
16.

Which of these occurs in a **propagation** step in the reaction of methane with chlorine?

- ☒ **A** 

- ☒ **B** 

- ☒ **C** 

- ☒ **D** 

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17.

The partial oxidation of butane in the presence of a catalyst has been investigated as a possible source of hydrogen.

$$C_4H_{10}(g) + 2O_2(g) \rightarrow 4CO(g) + 5H_2(g)$$

(a) What is the most significant hazard associated with the pollutant CO(g)?

(1)

- ☒ **A** it is a major contributor to the formation of acid rain
- ☒ **B** it strongly absorbs infrared radiation
- ☒ **C** it is toxic at low concentrations
- ☒ **D** it is the main cause of ozone layer depletion

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18.

Octane, C_8H_{18}, reacts with bromine in the presence of ultraviolet radiation.

(a) What is the role of ultraviolet radiation in the reaction?

(1)

- ☒ **A** to break the Br—Br bond only
- ☒ **B** to break a C—H bond only
- ☒ **C** to break a C—C bond only
- ☒ **D** to break both the Br—Br and a C—H bond

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(b) One of the steps of the reaction is shown.

$$C_8H_{17}^{\bullet} + Br_2 \rightarrow C_8H_{17}Br + Br^{\bullet}$$

What is the name of this step and the type of bond breaking that takes place in the bromine molecule?

(1)

	Name of step	Type of bond breaking
☒ **A**	initiation	heterolytic
☒ **B**	initiation	homolytic
☒ **C**	propagation	heterolytic
☒ **D**	propagation	homolytic

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(c) What is the overall equation for the reaction of octane with bromine?

(1)

☒ **A** $C_8H_{18} + Br_2 \rightarrow C_8H_{16}Br_2 + H_2$

☒ **B** $C_8H_{18} + Br_2 \rightarrow C_8H_{17}Br + HBr$

☒ **C** $C_8H_{18} + Br_2 \rightarrow 2C_4H_9Br$

☒ **D** $C_8H_{18} + 3Br_2 \rightarrow 2C_4H_7Br + 4HBr$

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19.

Prop-2-en-1-ol is flammable, toxic and an environmental hazard.

Which hazard symbols should be shown on its container?

☐ **A** 

☐ **B** 

☐ **C** 

☐ **D** 

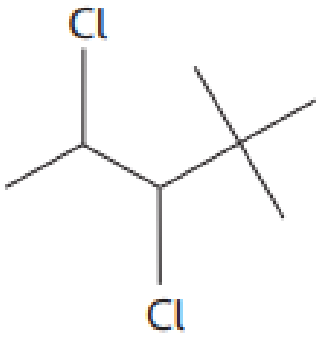
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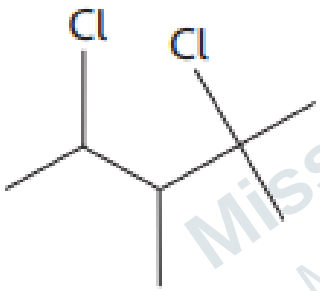
20.

Which is the skeletal structure for 3,4-dichloro-2,2-dimethylpentane?

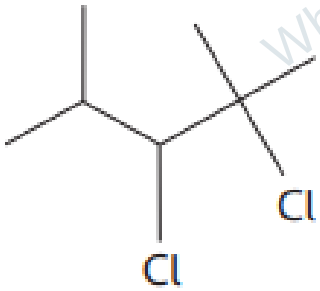
☒ **A**



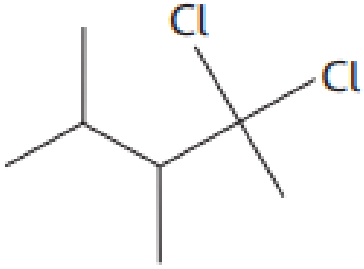
☒ **B**



☒ **C**



☒ **D**

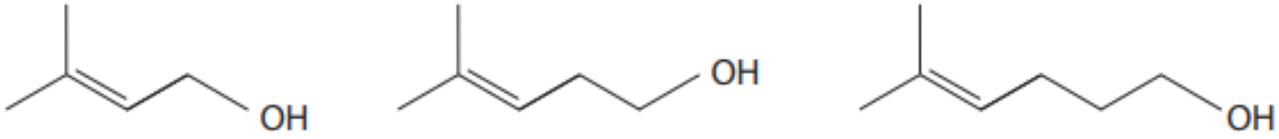


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21.

What is the name of a series such as the one shown?



- ☒ **A** addition
- ☒ **B** heterolytic
- ☒ **C** homologous
- ☒ **D** homolytic

22.

Which is **not** a step in the reaction of chlorine with propane in ultraviolet radiation?

- ☒ **A** $C_3H_7^{\bullet} + Cl^{\bullet} \rightarrow C_3H_7Cl$
- ☒ **B** $C_3H_7^{\bullet} + C_3H_7^{\bullet} \rightarrow C_6H_{14}$
- ☒ **C** $C_3H_7^{\bullet} + Cl_2 \rightarrow C_3H_7Cl + Cl^{\bullet}$
- ☒ **D** $C_3H_7^{\bullet} + HCl \rightarrow C_3H_7Cl + H^{\bullet}$

23.

Why does free radical substitution have limited use in industrial chemistry?

- ☒ **A** the reactions only occur in the upper atmosphere
- ☒ **B** initiation requires ultraviolet radiation
- ☒ **C** further substitution products are formed
- ☒ **D** termination reactions produce unwanted products

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24.

The reaction of methane with chlorine is a free radical substitution.

Which termination step does **not** occur?

☒ **A** $CH_3\bullet + CH_3\bullet \rightarrow C_2H_6$

☒ **B** $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$

☒ **C** $CH_3\bullet + H\bullet \rightarrow CH_4$

☒ **D** $Cl\bullet + Cl\bullet \rightarrow Cl_2$

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25.

What is the number of structural isomers with the molecular formula C_5H_{12}?

☒ **A** six

☒ **B** five

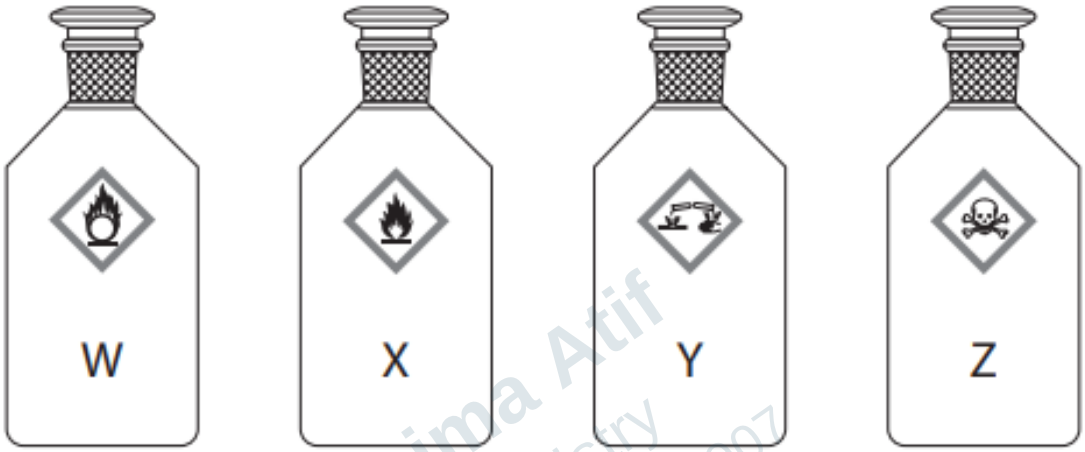
☒ **C** four

☒ **D** three

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26.

A technician is asked to store four reagent bottles safely. The only information about each substance is the hazard label on the bottle.



Based on the hazard labels alone, which two bottles should **never** be stored together?

- ☒ **A** W and Z
- ☒ **B** Y and Z
- ☒ **C** W and X
- ☒ **D** Y and X

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27.

How many structural isomers have the formula C_6H_{14}?

- ☒ **A** 3
- ☒ **B** 4
- ☒ **C** 5
- ☒ **D** 6

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28.

Which mixture could be formed when a **single** molecule of $C_{12}H_{26}$ is cracked?

- ☒ **A** butene, pentane and propene
- ☒ **B** hexane, butene and ethane
- ☒ **C** nonane and ethene
- ☒ **D** propene and decane

29.

The substances formed from the combustion of petrol in car engines include

- ☒ **A** water, carbon dioxide and hydrogen
- ☒ **B** water, carbon monoxide and hydrogen chloride
- ☒ **C** water, carbon dioxide and sulfur dioxide
- ☒ **D** water, carbon particulates and hydrogen

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30.

What is the best definition of a hydrocarbon?

- ☒ **A** a compound containing carbon, hydrogen and oxygen
- ☒ **B** a compound containing carbon and hydrogen only
- ☒ **C** a compound that contains single carbon to carbon bonds
- ☒ **D** a mixture containing carbon and hydrogen only

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31.

Cycloalkanes undergo free radical substitution reactions by the same mechanism as methane. Three isomeric cycloalkanes are shown.



Isomer **X** Isomer **Y** Isomer **Z**

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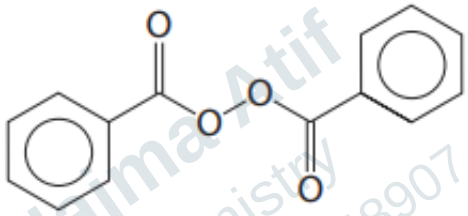
Which react with chlorine to produce four different monochlorinated products?

- ☒ **A** All 3 isomers
- ☒ **B** Isomer **X** and Isomer **Z** only
- ☒ **C** Isomer **Y** and Isomer **Z** only
- ☒ **D** Isomer **X** only

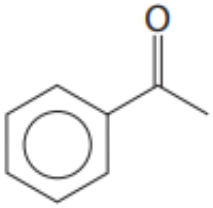
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32.

Polymerisation of alkenes occurs via a free radical mechanism.
This reaction is started by the addition of small amounts of another compound.
The structure of one of these compounds is shown.



This can be represented as R—O—O—R where R— is



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Which step in the mechanism is an initiation step?

☒ **A** $R—O—O—R \rightarrow 2R—O^{\bullet}$

☒ **B** $R—O—CH_2—CH_2^{\bullet} + CH_2{=}CH_2 \rightarrow R—O—CH_2—CH_2—CH_2—CH_2^{\bullet}$

☒ **C** $2R—O—CH_2—CH_2^{\bullet} \rightarrow R—O—CH_2—CH_2—CH_2—CH_2—O—R$

☒ **D** $R—O^{\bullet} + CH_2{=}CH_2 \rightarrow R—O—CH_2—CH_2^{\bullet}$

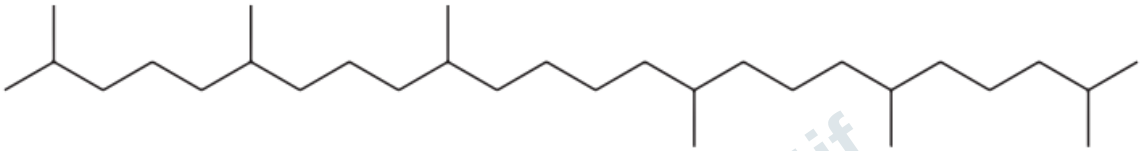
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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

QUESTION NO 1:

This question is about the production of squalane, a liquid alkane which occurs naturally in human skin and is used in cosmetics.



squalane

(a) Suggest **two** properties that make squalane useful in cosmetics.

(2)

(c) Squalane can be produced from squalene, an alkene present in shark liver oil, by reaction with hydrogen gas in the presence of a suitable catalyst.

(i) Give the name of a suitable catalyst for the hydrogenation of squalene.

(1)

(d) Globally, 2.8 million dm^3 of squalene is used each year.
Traditionally squalene was obtained exclusively from shark liver oil, which is a mixture of liquids.

The liver of a shark yields 300 g of squalene.

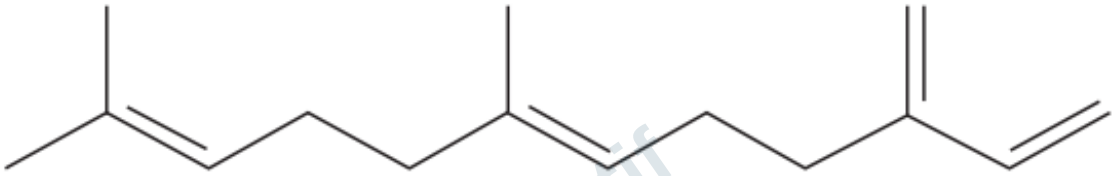
(i) Suggest the name of a suitable technique to obtain squalene from shark liver oil.

(1)

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(e) The *E*-isomer of beta-farnesene can also be obtained from corn starch.



E-beta-farnesene

(i) Explain why beta-farnesene exhibits geometric isomerism and has only two geometric isomers.

You may label the structure and use this in your answer.

(2)

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(ii) Draw the **skeletal** formula of the geometric isomer of *E*-beta-farnesene, giving a reason why this is named the *Z*-isomer.

(2)

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(f) The compound alpha-farnesene, $C_{15}H_{24}$, is a structural isomer of beta-farnesene.

The structural formula of alpha-farnesene is

$$(CH_3)_2C{=}CHCH_2CH_2C(CH_3){=}CHCH_2CH{=}C(CH_3)CH{=}CH_2$$

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

(2)

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(ii) State the number of **geometric** isomers of alpha-farnesene.

(1)

(iii) Complete the diagram to show another structural isomer of $C_{15}H_{24}$.

(1)



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TOTAL MARKS FOR QUESTION 1: 12

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QUESTION NO 2:

Heptane, C_7H_{16}, is an alkane found in crude oil.

(a) Heptane can undergo incomplete combustion.

(i) Give a reason why incomplete combustion sometimes occurs.

(1)

.....

.....

.....

(ii) Write the equation for the incomplete combustion of heptane, forming carbon monoxide and water as the **only** products.
State symbols are not required.

(1)

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(b) Heptane is reformed into branched-chain and cyclic hydrocarbons that are used in petrol.

(i) Draw the **skeletal** formulae of a branched-chain alkane and a cycloalkane, each containing **seven** carbon atoms.

(2)

Branched-chain alkane
Cycloalkane

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(ii) Write the equation for the reforming of heptane into a cycloalkane. Use molecular formulae.

(1)

(iii) Give a reason for adding cycloalkanes to petrol.

(1)

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(c) Heptane, C_7H_{16}, reacts with chlorine in the presence of ultraviolet radiation.

(i) State the type and mechanism of this reaction.

(2)

.....

(ii) Give the mechanism for the reaction to produce $C_7H_{15}Cl$, $C_{14}H_{30}$ and HCl as the **only** products.

Include the name of each of the steps in your mechanism.

Curly half-arrows are **not** required.

(7)

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TOTAL FOR QUESTION 2: 15

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QUESTION NO 3:

(d) New uses for waste aluminium cans are being investigated. One possible use is to make nanoparticle alloys to produce hydrogen for fuel.

(i) Aluminium nanoparticles react with water to produce aluminium oxide and hydrogen.

Complete the following equation. State symbols are not required.

(1)

..... Al + ... H_2O → ..... + ...

(ii) Give **two** possible reasons for producing hydrogen from aluminium rather than from fossil fuels.

(2)

.....

.....

.....

.....

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TOTAL FOR QUESTION 3: 3

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QUESTION NO 4:

Alkanes and alkenes are obtained from crude oil.

(a) Describe how a sample of octadecane can be obtained from a mixture of alkanes.

(2)

(b) (i) Octadecane can be cracked to produce butene and **one** other product.

Complete the equation. State symbols are not required.

$$C_{18}H_{38} \rightarrow 2C_4H_8 \quad +$$

(1)

(ii) Explain the main hazard when using butane as a fuel in a portable heater in an enclosed space.

(2)

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QUESTION NO 5:

Organic waste may be disposed of by landfill or incineration.
Both processes produce gases.

(a) The main gases produced from a typical landfill are shown in the table.

Gas	Percentage by volume / %
methane	50
carbon dioxide	45
nitrogen	4
sulfur compounds	1

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(i) Name the process that forms these gases in landfill.

(1)

(ii) State the **main** environmental problem caused by landfill gases, identifying the gas or gases responsible.

(2)

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(b) Suggest **two** advantages of incineration over landfill.

(2)

(c) Environmental groups prefer recycling to both landfill and incineration.

Suggest **one** advantage of recycling.

(1)

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QUESTION NO 6:

This question is about hydrocarbons obtained from crude oil.

(a) Petrol used in cars has a high proportion of the alkane iso-octane. Iso-octane can be formed by heating octane to 400 °C in the presence of a catalyst.



octane iso-octane

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(i) Give the IUPAC name for iso-octane.

(1)

(ii) Name the industrial process used to convert octane into iso-octane.

(1)

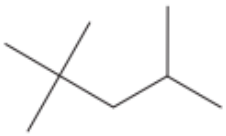
(iii) Give a reason why petrol needs a high proportion of iso-octane.

(1)

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QUESTION NO 7:

The structure of a compound **X** is shown. **X** is present in petrol.



(a) (i) Give the molecular formula and IUPAC name for **X**.

(2)

.....

.....

(ii) Name the industrial process used to produce **X** from the straight-chain isomer.

(1)

.....

(b) Heptane is also present in petrol.

(i) Write an equation for the **complete** combustion of heptane.
Include state symbols.

(2)

(ii) Identify, by name or formula, a pollutant that may result from the **incomplete** combustion of heptane.

(1)

.....

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(c) Recently, sales of electric cars have increased.

Give **two** environmental benefits of using electric cars.
Justify your answers.

(2)

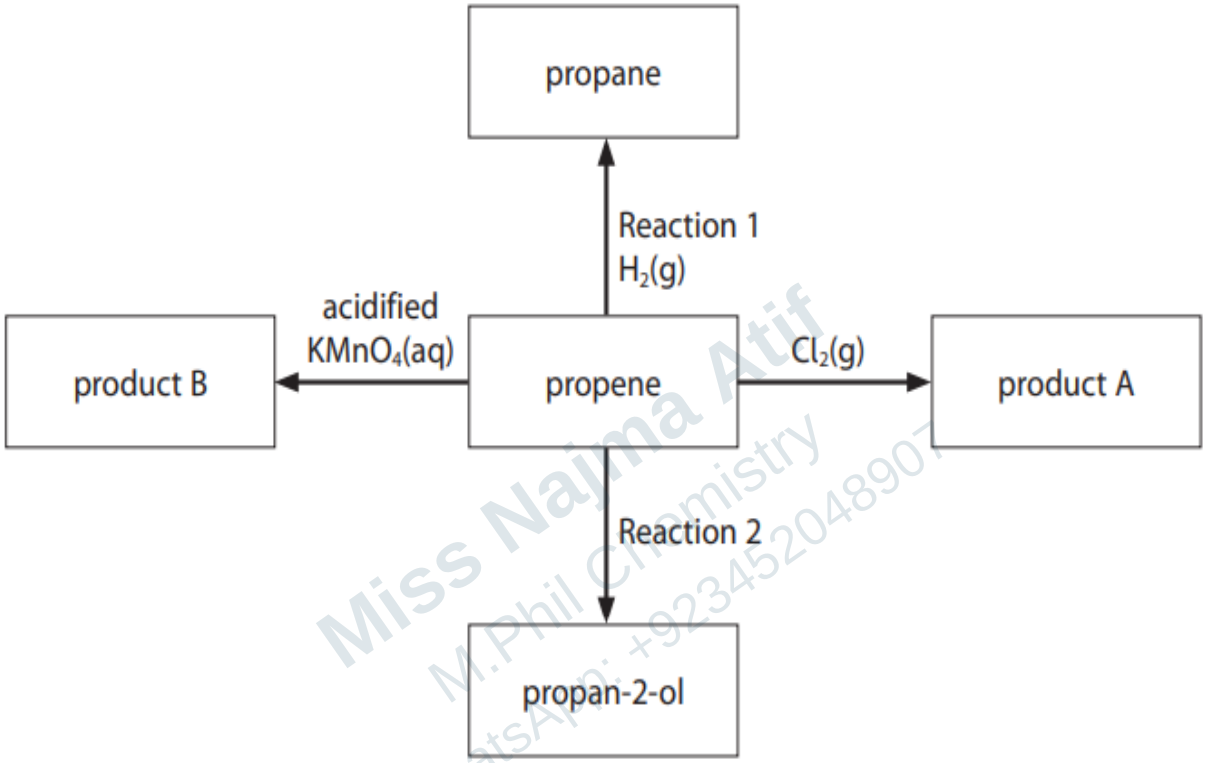
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QUESTION NO 8:

This question is about propene and some related compounds.

(a) Some reactions of propene are shown.



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(i) Identify, by name or formula, the catalyst needed for Reaction 1.

(1)

(ii) Name product A.

(1)

(iii) Identify, by name or formula, the substances needed for Reaction 2.

(2)

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(iv) Draw the **displayed** formula of product B.

(1)

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(b) (i) Propene can undergo addition polymerisation.

Write the equation for the polymerisation of propene.

(2)

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QUESTION NO 9:

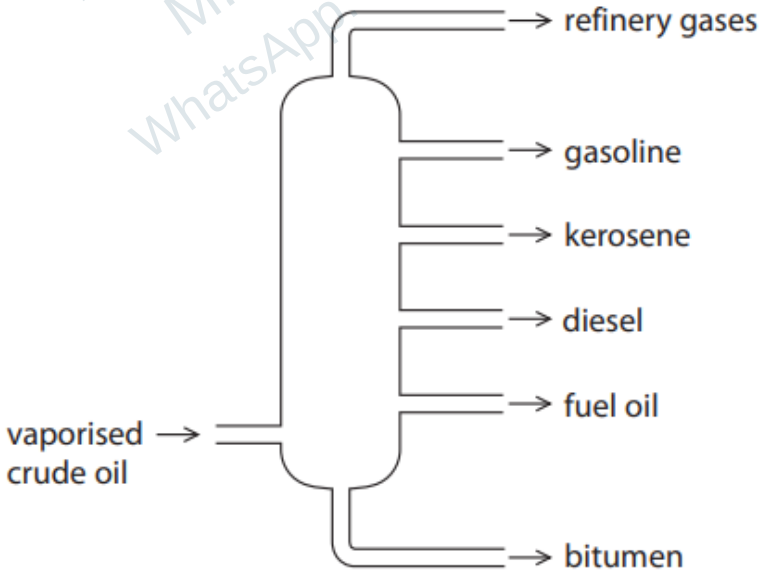
Oxygen is vital in the treatment of respiratory diseases. Oxygen is traditionally produced by the fractional distillation of air.

(a) Suggest **one** difference between the fractional distillation of air and of crude oil.

(1)

QUESTION NO 10:

Crude oil is mainly a mixture of saturated hydrocarbons that can be separated by fractional distillation.
The diagram shows, in a simplified form, the products of fractional distillation.



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(a) (i) State what is meant by a saturated hydrocarbon.

(2)

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(ii) Describe how the fractions in crude oil are separated during fractional distillation.

(2)

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(c) Octane, C_8H_{18}, is found in the gasoline fraction of crude oil.

(i) Write an equation for the complete combustion of octane.
Include state symbols.

(2)

(ii) Give **two** reasons why alternative fuels, such as bioethanol, are being developed to replace those produced from crude oil.

(2)

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(iii) Straight-chain alkanes, such as octane, are converted into branched-chain alkanes to improve the performance of petrol in car engines.

Name this conversion process.

(1)

(iv) Give an equation using skeletal formulae for the conversion of octane into 2,5-dimethylhexane.
State symbols are not required.

(1)

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(d) In steam cracking, a mixture of hydrocarbons and steam is heated to 850 °C for a very short time in the absence of oxygen.

(i) Give a reason why oxygen should be excluded during steam cracking.

(1)

(ii) Ethene is the major product.

State one use of ethene.

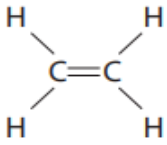
(1)

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(e) Ethene reacts with hydrogen bromide to form bromoethane.

Draw the mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

(3)





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QUESTION NO 11:

Many cars use fuels containing ethanol as well as hydrocarbons. The E numbers of these fuels show the percentage by volume of ethanol in the fuel. For example, an E5 fuel contains 5% ethanol and 95% hydrocarbons by volume.

(a) A brand of E10 fuel contains 92.2% hydrocarbons and 7.80% ethanol **by mass**.

The energy density is the amount of energy released per kg of a fuel burned. The energy densities of the two components of this brand of fuel are shown.

energy density of hydrocarbons = 46.5 $MJ\,kg^{-1}$

energy density of ethanol = 29.7 $MJ\,kg^{-1}$

(i) Calculate the **mean** energy density of this E10 fuel in $MJ\,kg^{-1}$.
Give your answer to an appropriate number of significant figures.

(2)

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(ii) The density of the E10 fuel is 0.729 g cm^{-3}.

Calculate the mass of 1500 cm^3 of the fuel.

(1)

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(iii) Calculate the energy released when 1500 cm^3 of the E10 fuel is burned in excess oxygen, using your answers from (a)(i) and (a)(ii).

[If you did not calculate a value for the **mean** energy density of the E10 fuel in (a)(i), use a value of 38.1 MJ kg^{-1}. This is not the correct value.]

(1)

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(b) Many countries are gradually replacing E5 fuels with E10 fuels.

Explain how this change might result in a more sustainable fuel.

(3)

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(c) The straight-chain alkane hexane can be reformed to give a range of products.
It was suggested that one such reaction may produce a cyclic hydrocarbon and hydrogen gas as the only products.
The cyclic hydrocarbon contains a ring of five carbon atoms.

(i) Write the equation for this reaction using molecular formulae.
State symbols are not required.

(1)

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(ii) Draw the structure of the cyclic hydrocarbon formed in this reaction.

(1)

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(d) Hexane will react with chlorine in the presence of ultraviolet light to form a number of products.

(i) Describe the role of the ultraviolet light in the initiation step of this reaction.

(2)

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(ii) The alkane dodecane, $C_{12}H_{26}$, is formed in this reaction.
Write equations for the propagation step and for the termination step for the formation of this product.
Use molecular formulae in your equations.

(2)

Propagation step

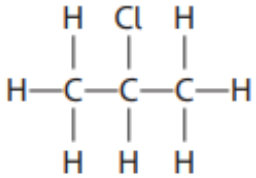
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Termination step

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QUESTION NO 12:

This question is about 2-Chloropropane.



(b) 2-Chloropropane can be produced by reacting propane with chlorine in a homolytic free radical reaction.

$$CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CHClCH_3 + HCl$$

(i) Show the initiation step of this reaction.
Include appropriate arrows and the conditions necessary for this step.

(2)

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(ii) Using your answer to (b)(i), state what is meant by the terms homolytic and free radical.

(2)

homolytic

.....

.....

free radical

.....

.....

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(iii) Suggest why this method has limited use in the synthesis of organic compounds.

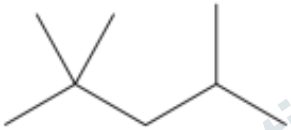
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QUESTION NO 13:

Molecules of isooctane, found in petrol, have eight carbon atoms.
The skeletal formula of isooctane is shown.



(a) Give the molecular formula, empirical formula and IUPAC name for isooctane.

(3)

Molecular formula .....

Empirical formula .....

IUPAC name .....

(b) Isooctane and octane are isomers that are both found in crude oil.
Octane has a boiling temperature of 125 °C, and isooctane has a boiling temperature of 99 °C.

This difference in boiling temperature can be used to separate the two isomers in a laboratory.
The technique is the same as that used to separate crude oil.

(i) Name the technique that could be used for this separation.

(1)

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(ii) Describe how this technique separates isooctane from octane.

(2)

(c) Isooctane is added to petrol to increase its octane rating.
Some high-performance engines need fuel with a higher octane rating.

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

(1)

(ii) Carbon monoxide and nitrogen monoxide are both pollutants produced in car engines.
Describe how each pollutant is formed in car engines, including the conditions required.
You may include appropriate equations.

(4)

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(iii) Identify another pollutant, other than carbon dioxide, carbon monoxide and nitrogen monoxide, produced in car engines.

(1)

.....

(d) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds containing the same number of carbon atoms as isooctane.

(i) State the type and mechanism of this reaction.

(1)

.....

(ii) Give the essential condition required.

(1)

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