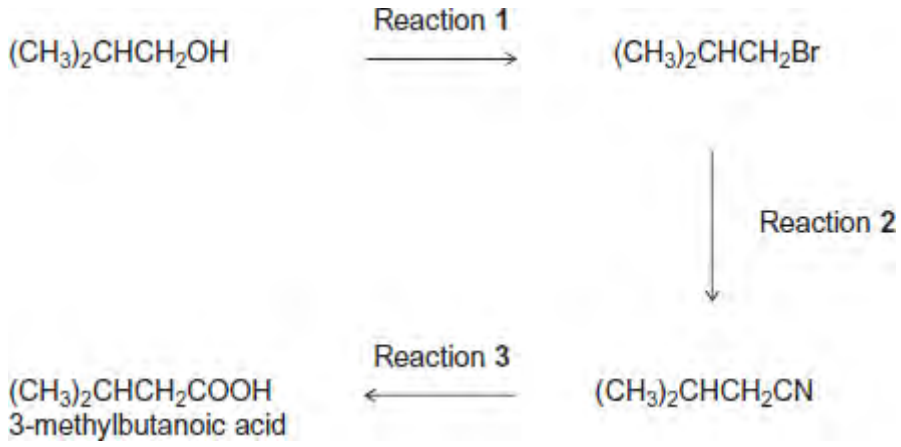
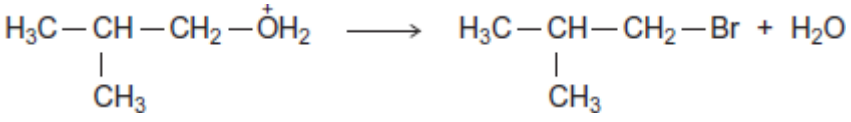
Q1. The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes.
The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



(a) One of the steps in the mechanism for Reaction **1** involves the replacement of the functional group by bromine.

(i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.

Br^-:



(2)

(ii) Deduce the name of the mechanism in part (i).

Give the IUPAC name of $(CH_3)_2CHCH_2Br$

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(2)

(b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(CH_3)_2CHCH_2CN$ and a **different** bond in $(CH_3)_2CHCH_2COOH$ that can be used with infrared spectroscopy to distinguish between each compound. For each of these bonds, give the range of wavenumbers at which the bond absorbs.
Use **Table A** on the Data Sheet when answering this question.

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(3)

(c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.

$$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons \underset{\text{an ester}}{(CH_3)_2CHCH_2COOCH_2CH_3} + H_2O$$

The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

(i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

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(Extra space) .....

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(3)

(ii) Explain how a catalyst increases the rate of a reaction.

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(Extra space) .....

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(2)
(Total 12 marks)

Q2.(a) The hydrocarbon but-1-ene (C_4H_8) is a member of the homologous series of alkenes. But-1-ene has structural isomers.

(i) State the meaning of the term *structural isomers*.

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(2)

(ii) Give the IUPAC name of the **position** isomer of but-1-ene.

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(1)

(iii) Give the IUPAC name of the **chain** isomer of but-1-ene.

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(1)

(iv) Draw the displayed formula of a **functional group** isomer of but-1-ene.

(1)

(b) But-1-ene burns in a limited supply of air to produce a solid and water only.

(i) Write an equation for this reaction.

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(1)

(ii) State **one** hazard associated with the solid product in part (b)(i).

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(1)

(c) One mole of compound **Y** is cracked to produce two moles of ethene, one mole of but-1-ene and one mole of octane (C_8H_{18}) only.

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

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(1)

(ii) Other than cracking, give **one** common use of **Y**.

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(1)

(d) In cars fitted with catalytic converters, unburned octane reacts with nitrogen monoxide to form carbon dioxide, water and nitrogen only.

(i) Write an equation for this reaction.

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(1)

(ii) Identify a catalyst used in a catalytic converter.

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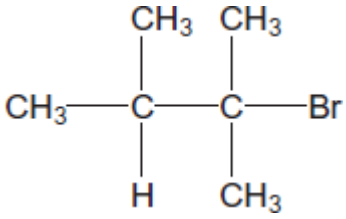
(1)
(Total 11 marks)

Q3.(a) The structure of the bromoalkane **Z** is



Give the IUPAC name for **Z**.

Give the general formula of the homologous series of straight-chain bromoalkanes that contains one bromine atom per molecule.

Suggest **one** reason why 1-bromohexane has a higher boiling point than **Z**.

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(Extra space) .....

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(3)

(b) Draw the displayed formula of 1,2-dichloro-2-methylpropane.

State its empirical formula.

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(2)
(Total 5 marks)

Q4. Pentane is a member of the alkane homologous series.

(a) Give the general formula for the homologous series of alkanes.

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(1)

(b) One of the structural isomers of pentane is 2,2-dimethylpropane.

Draw the displayed formula of 2,2-dimethylpropane.

State the type of structural isomerism shown.

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(2)

(c) A molecule of hydrocarbon **Y** can be thermally cracked to form one molecule of pentane and two molecules of ethene only.

Deduce the molecular formula of **Y**.

State why high temperatures are necessary for cracking reactions to occur.

Give **one** reason why thermal cracking reactions are carried out in industry.

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(Extra space) .....

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(3)

(d) Write an equation for the incomplete combustion of pentane to form a solid pollutant.

Suggest why this solid pollutant is an environmental problem.

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(Extra space) .....

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(2)

(e) Pentane can react with chlorine as shown in the following equation.

$$C_5H_{12} + Cl_2 \rightarrow C_5H_{11}Cl + HCl$$

Calculate the percentage atom economy for the formation of $C_5H_{11}Cl$

Deduce how many straight-chain isomers of $C_5H_{11}Cl$ could be formed.

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(Extra space).....

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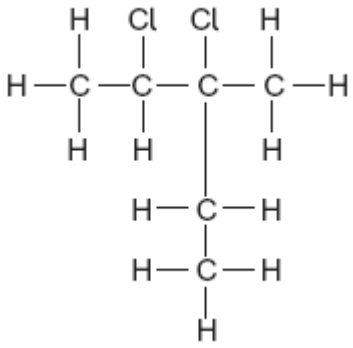
(3)

(f) Consider the following compound.



Name this compound.

Deduce the empirical formula of this compound.

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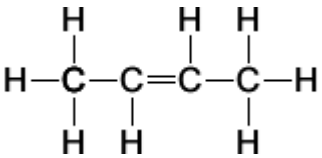
(2)
(Total 13 marks)

Q5. Compound **X** is shown below. It is a member of a homologous series of hydrocarbons.



(a) (i) Deduce the general formula of the homologous series that contains **X**.

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(1)

(ii) Name a process used to obtain a sample of **X** from a mixture containing other members of the same homologous series.

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(1)

(b) There are several isomers of **X**.

(i) Give the IUPAC name of the position isomer of **X**.

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(1)

(ii) Draw the structure of a functional group isomer of **X**.

(1)

(c) At high temperatures, one molecule of $C_{15}H_{32}$ can be converted into two molecules of **X** and one molecule of another compound.

(i) Write an equation for this reaction.

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(1)

(ii) State the name of the process used to obtain a high yield of **X** from $C_{15}H_{32}$
Give **one** reason why this process is used in industry.

Name .....

Reason .....

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(2)

(iii) State why high temperatures are needed for this process.

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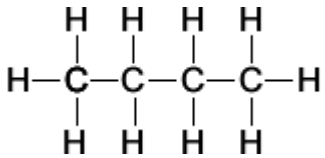
(1)

(d) Compound **X** can be converted into compound **Y**.
Compound **Y** is shown below.



(i) Suggest the formula of a reagent that could be added to **X** in order to convert it into **Y**.

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(1)

(ii) Give **one** use of **Y**.

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(1)

(iii) Write an equation to show the reaction of **Y** in a limited supply of air to produce a solid and water only.

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(1)

(iv) When a sample of **Y**, contaminated with CH_3SH, is burned completely in air, a toxic gas is formed.
Identify this toxic gas and suggest a compound that could be used to remove the toxic gas from the products of combustion.

Toxic gas .....

Compound used to remove toxic gas .....

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(2)

(v) Suggest the name of the process that occurs when the toxic gas in part (d)(iv) is removed.

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(1)

(e) Explain why the boiling points of **X** and **Y** are similar.

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(2)
(Total 16 marks)