Q1. How many isomers have the molecular formula C_5H_{12}?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q2. How many structural isomers have the molecular formula C_4H_9Br?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q3. How many secondary amines have the molecular formula $C_4H_{11}N$?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q4. Which one of the following can exhibit both geometrical and optical isomerism?

A $(CH_3)_2C=CHCH(CH_3)CH_2CH_3$

B $CH_3CH_2CH=CHCH(CH_3)CH_2CH_3$

C $(CH_3)_2C=C(CH_2CH_3)_2$

D $CH_3CH_2CH(CH_3)CH(CH_3)C=CH_2$

(Total 1 mark)

Q5. How many different alkenes are formed when 2-bromo-3-methylbutane reacts with ethanolic potassium hydroxide?

A 2

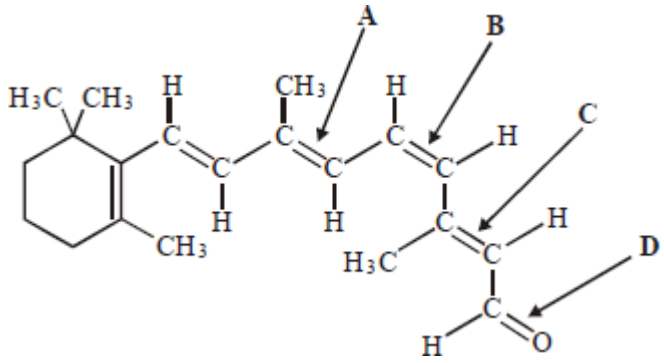
B 3

C 4

D 5

(Total 1 mark)

Q6. The compound *cis*-retinal is shown below.



Which one of the labelled bonds leads to the prefix in the name?

(Total 1 mark)

Q7. Which one of the following is a pair of functional group isomers?

A $CH_3COOCH_2CH_3$ and $CH_3CH_2COOCH_3$

B $(CH_3)_2CHCH(CH_3)_2$ and $(CH_3)_3CCH_2CH_3$

C $CH_3CH_2OCH_3$ and $(CH_3)_2CHOH$

D $ClCH_2CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_2Cl$

(Total 1 mark)

Q8. Propanone can be reduced to form an alcohol. A functional group isomer of the alcohol formed is

A $CH_3CH_2CH_2OH$

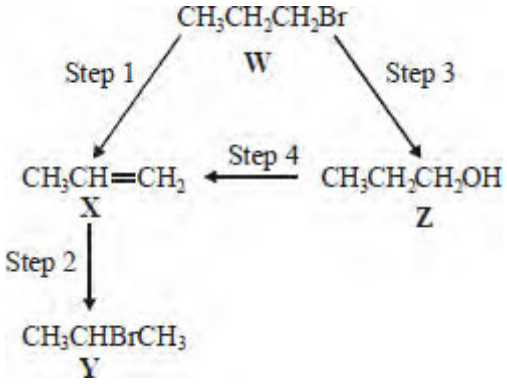
B CH_3CH_2CHO

C $CH_3OCH_2CH_3$

D CH_3COCH_3

(Total 1 mark)

Q9. For this question refer to the reaction scheme below.



Which one of the following statements is **not** correct?

A **W** and **Y** are structural isomers.

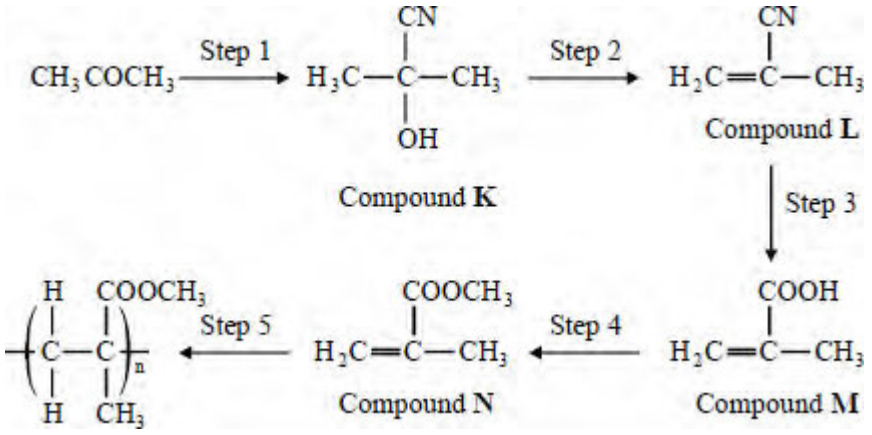
B **Z** is a primary alcohol.

C **Y** gives two peaks in its proton n.m.r. spectrum.

C **X** has geometrical isomers.

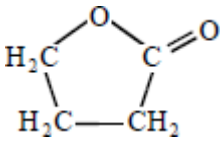
(Total 1 mark)

Q10. This question concerns the preparation of the plastic poly(methyl 2-methylpropenoate) (*Perspex*), starting from propanone.

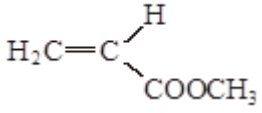


Which one of the following is **not** a structural isomer of Compound **M**?

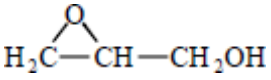
A



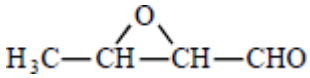
B



C

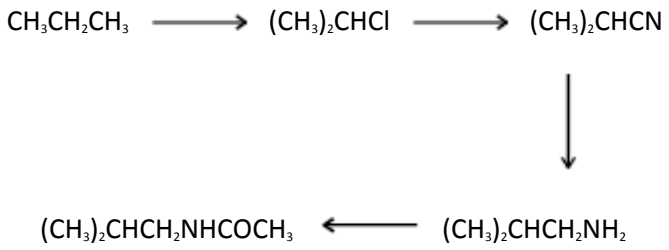


D



(Total 1 mark)

Q11. Which one of the following types of reaction mechanism is **not** involved in the above sequence?



A free-radical substitution

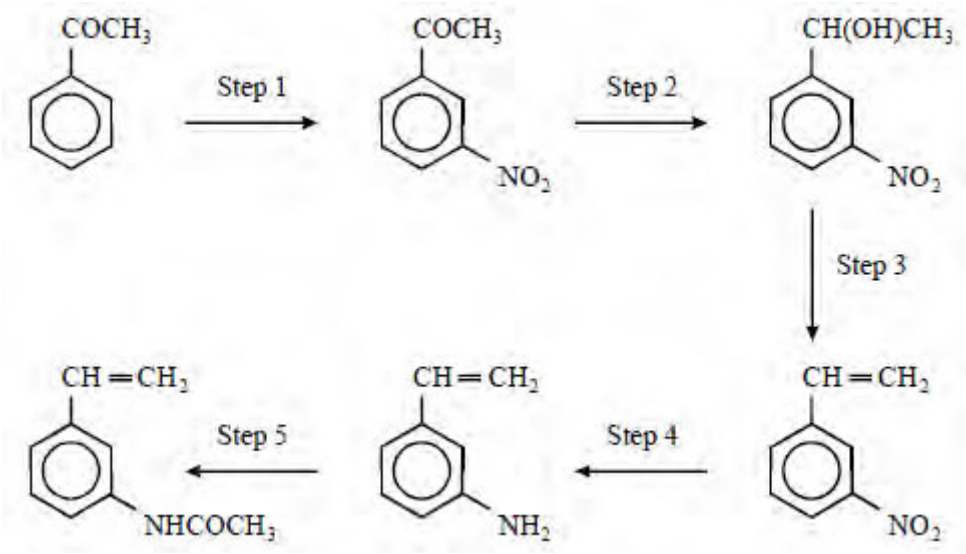
B nucleophilic substitution

C elimination

D nucleophilic addition-elimination

(Total 1 mark)

Q12. Refer to the following reaction sequence:



Which one of the following types of reaction mechanism is **not** involved in the above sequence?

A electrophilic addition

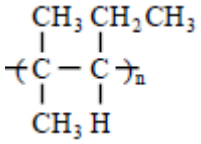
B electrophilic substitution

C addition–elimination

D elimination

(Total 1 mark)

Q13. The correct name for the alkene monomer which forms the polymer shown below is



A 2-methyl-3-ethylpropene

B 2-methylpent-2-ene

C 2-methylpent-3-ene

D 4-methylpent-2-ene

(Total 1 mark)

Q14. The number of structural isomers of $C_3H_2Cl_6$ is

A 2

B 3

C 4

D 5

(Total 1 mark)

Q15. Which one of the following mechanisms is **not** involved in the reaction sequence below?

$CH_3CH_3 \rightarrow CH_3CH_2Cl \rightarrow CH_3CH_2OH \rightarrow CH_2{=}CH_2 \rightarrow CH_3CH_2Br$

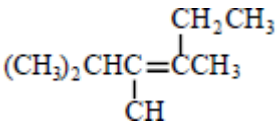
A electrophilic addition

B electrophilic substitution

C nucleophilic substitution

D free-radical substitution

(Total 1 mark)

Q16. The correct systematic name for  is

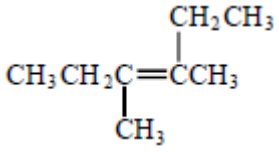
A 2-ethyl-3,4-dimethylpent-2-ene

B 4-ethyl-2,3-dimethylpent-3-ene

C 2,3,4-trirnethylhex-3-ene

D 3,4,5-trimethylhex-3-ene

(Total 1 mark)

Q17. The correct systematic name for  is

A 2,3-diethylbut-2-ene

B 2-ethyl-3-methylpent-2-ene

C 4-ethyl-3-methylpent-3-ene

D 3,4-dimethylhex-3-ene

(Total 1 mark)

Q18. How many structural isomers, which are aldehydes, have the molecular formula $C_5H_{10}O$?

A 2

B 3

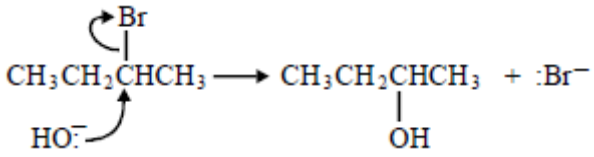
C 4

D 5

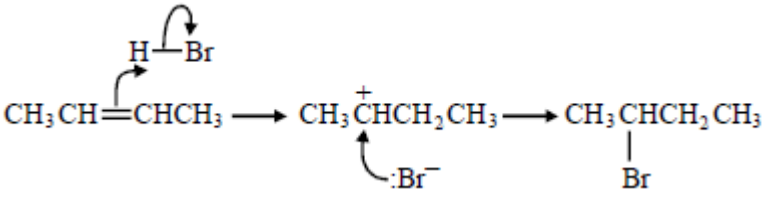
(Total 1 mark)

Q19. In which of the following is a curly arrow used incorrectly?

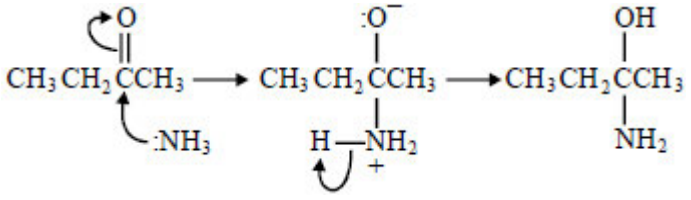
A



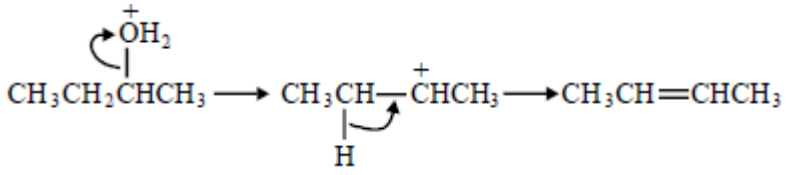
B



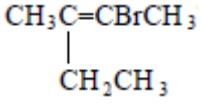
C



D



(Total 1 mark)

Q20. Which one of the following is the correct name for  ?

A 2-bromo-3-methylpent-2-ene

B 2-bromo-3-ethylbut-2-ene

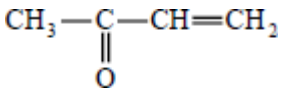
C 3-bromo-2-ethylbut-2-ene

D 4-bromo-3-methylpent-3-ene

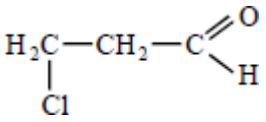
(Total 1 mark)

Q21. Which one of the following can react both by nucleophilic addition and by nucleophilic substitution?

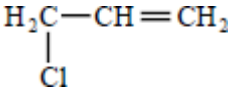
A



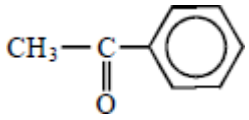
B



C



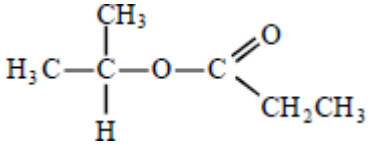
D



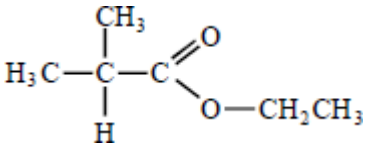
(Total 1 mark)

Q22. The structural formula of ethyl 2-methylpropanoate is

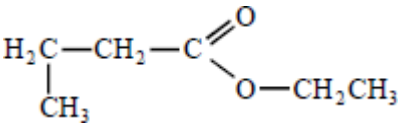
A



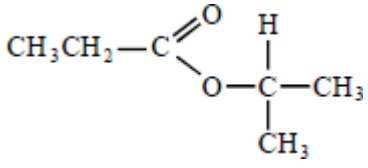
B



C



D



(Total 1 mark)

Q23. How many structural isomers, which are esters, have the molecular formula $C_4H_8O_2$?

A 2

B 3

C 4

D 5

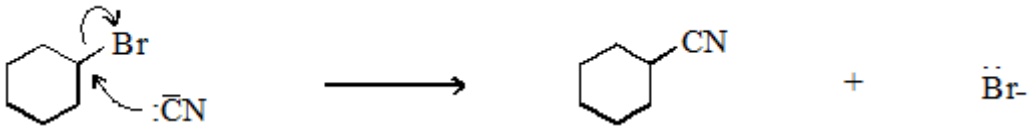
(Total 1 mark)

Q24. In which one of the following are the curly arrows **not** used correctly?

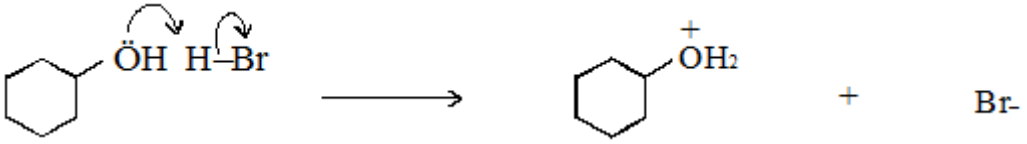
A



B



C



D



(Total 1 mark)

Q25. CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

Q26.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Isomers of the ester $HCOOCH_2CH_2CH_3$, include

(i) ethyl ethanoate

(ii) methyl propanoate

(iii) butanoic acid

(iv) butyl methanoate

(Total 1 mark)

Q27. The number of structural isomers of molecular formula C_4H_9Br is

A 5

B 4

C 3

D 2

(Total 1 mark)

Q1. Central heating fuel, obtained by the fractional distillation of crude oil, contains saturated hydrocarbons with the molecular formula $C_{16}H_{34}$

(a) Give the meaning of the terms **saturated** and **hydrocarbon** as applied to saturated hydrocarbons.

Saturated .....

.....

Hydrocarbon .....

.....

(2)

(b) If the boiler for a central heating system is faulty, a poisonous gas may be produced during the combustion of $C_{16}H_{34}$

Write an equation for the reaction that forms this poisonous gas and one other product only.

.....

(1)

(c) Explain why the sulfur compounds found in crude oil should be removed from the fractions before they are used for central heating fuel.

.....

.....

.....

.....

.....

(2)

(d) A hydrocarbon $C_{16}H_{34}$ can be cracked to form C_8H_{18}, ethene and propene.

(i) Write an equation to show this cracking reaction.

.....

(1)

(ii) Suggest **one** important substance manufactured on a large scale from

propene.

.....

(1)

(iii) Draw the **displayed formula** of the functional group isomer of propene.

(1)

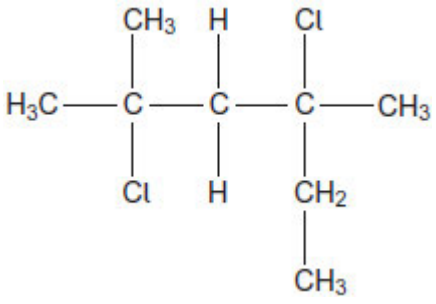
(e) There are many structural isomers with the molecular formula C_8H_{18}

Draw the structure of 2,3,3-trimethylpentane.

(1)

(f) A compound C_8H_{18} reacts with chlorine to give several haloalkanes.

Give the IUPAC name of the following haloalkane.



.....

(1)
(Total 10 marks)

Q2. How many structural isomers have the molecular formula C_4H_9Br?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q3. How many secondary amines have the molecular formula $C_4H_{11}N$?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q4. Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH{=}CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

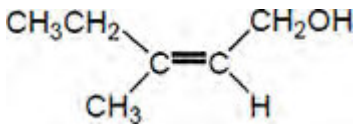
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

.....

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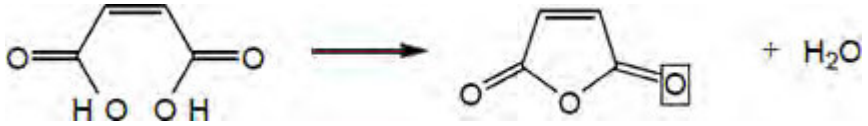
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(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment,10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

.....

.....

.....

(2)
(Total 10 marks)

Q5. How many isomers have the molecular formula C_5H_{12}?

A 2 ⬭

B 3 ⬭

C 4 ⬭

D 5 ⬭

(Total 1 mark)

Q6.2-bromo-2-methylpentane is heated with potassium hydroxide dissolved in ethanol. Two structural isomers are formed.

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

.....

.....

.....

(1)

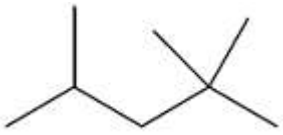
(b) Name and draw the mechanism for the formation of **one** of the isomers.

Name of mechanism .....

Mechanism

(5)
(Total 6 marks)

Q7. Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

.....

(1)

(b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5

6 ⬭

7 ⬭

8 ⬭

(1)

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

.....

(1)

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

.....

(1)

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers .....

Structure

(2)

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

(1)

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0
Calculate the M_r of this monochlorooctane.

M_r = ...

(2)

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds.
One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass.
Calculate the molecular formula of this compound.

Molecular formula = ...

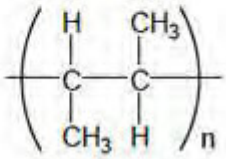
(3)
(Total 12 marks)

Q8. Dodecane ($C_{12}H_{26}$) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.

Reaction 1

$C_{12}H_{26} \longrightarrow C_2H_4 + C_4H_8 + \mathbf{X}$

Reaction 2

$nC_4H_8 \rightleftharpoons$ 

Polymer **Y**

(a) Name the homologous series that both C_2H_4 and C_4H_8 belong to.
Draw a functional group isomer of C_4H_8 that does **not** belong to this homologous series.

Name .....

Functional group isomer

(2)

(b) Identify compound **X**.

.....

(1)

(c) Name polymer **Y**.

.....

(1)

(d) Reaction **1** is an example of thermal cracking and is carried out at a temperature of 750 °C.

State **one other** reaction condition needed.

.....

(1)

(e) Reaction **2** is exothermic. A typical compromise temperature of 200 °C is used industrially for this reaction.

Explain the effect of a change of temperature on both the position of equilibrium and the rate of reaction, and justify why a compromise temperature is used industrially.

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.....

.....

(6)
(Total 11 marks)

Q1. Central heating fuel, obtained by the fractional distillation of crude oil, contains saturated hydrocarbons with the molecular formula $C_{16}H_{34}$

(a) Give the meaning of the terms **saturated** and **hydrocarbon** as applied to saturated hydrocarbons.

Saturated .....

.....

Hydrocarbon .....

.....

(2)

(b) If the boiler for a central heating system is faulty, a poisonous gas may be produced during the combustion of $C_{16}H_{34}$

Write an equation for the reaction that forms this poisonous gas and one other product only.

.....

(1)

(c) Explain why the sulfur compounds found in crude oil should be removed from the fractions before they are used for central heating fuel.

.....

.....

.....

.....

.....

(2)

(d) A hydrocarbon $C_{16}H_{34}$ can be cracked to form C_8H_{18}, ethene and propene.

(i) Write an equation to show this cracking reaction.

.....

(1)

(ii) Suggest **one** important substance manufactured on a large scale from

propene.

.....

(1)

(iii) Draw the **displayed formula** of the functional group isomer of propene.

(1)

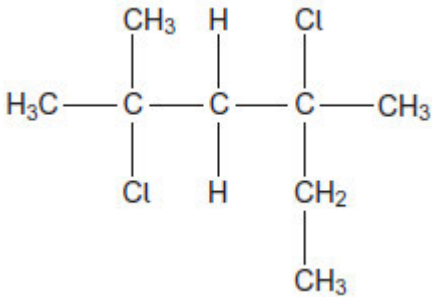
(e) There are many structural isomers with the molecular formula C_8H_{18}

Draw the structure of 2,3,3-trimethylpentane.

(1)

(f) A compound C_8H_{18} reacts with chlorine to give several haloalkanes.

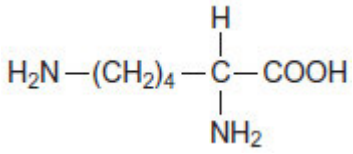
Give the IUPAC name of the following haloalkane.



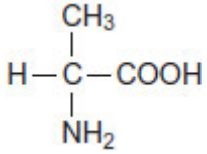
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(1)
(Total 10 marks)

Q2. Lysine and alanine are two amino acids.



lysine



alanine

(a) Give the IUPAC name of lysine.

.....

(1)

(b) Draw structures to show the product formed in each case when lysine reacts with

(i) an excess of aqueous HCl

(1)

(ii) an excess of aqueous NaOH

(1)

(iii) methanol in the presence of a small amount of concentrated H_2SO_4

(1)

(c) The mass spectrum of alanine gives a major peak at $m / z = 44$

Write an equation for the fragmentation of the molecular ion of alanine to give an ion that produces this peak.
In your answer, draw the displayed formula for this fragment ion.

(2)

(d) Draw a dipeptide formed from one molecule of lysine and one molecule of alanine.

(1)

(e) The dipeptide in part (d) is hydrolysed in acid conditions and the mixture produced is analysed by column chromatography. The column is packed with a resin which acts as a polar stationary phase.

Suggest why lysine leaves the column after alanine.

.....

.....

.....

.....

(2)

(Total 9 marks)

Q3. Compound **J**, known as leaf alcohol, has the structural formula $CH_3CH_2CH{=}CHCH_2CH_2OH$ and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

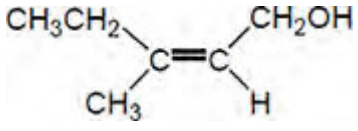
(a) Give the structure of the *E* isomer of **J**.

(1)

(b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)

(c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

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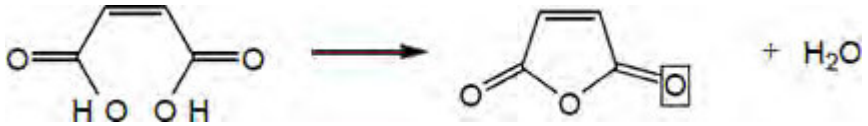
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(6)

(d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment,10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

.....

.....

.....

(2)
(Total 10 marks)

Q4. Some oil-fired heaters use paraffin as a fuel.
One of the compounds in paraffin is the straight-chain alkane, dodecane ($C_{12}H_{26}$).

(a) Give the name of the substance from which paraffin is obtained.
State the name of the process used to obtain paraffin from this substance.

Substance .....

Process .....

(2)

(b) The combustion of dodecane produces several products.

Write an equation for the **incomplete** combustion of dodecane to produce gaseous products only.

.....

(1)

(c) Oxides of nitrogen are also produced during the combustion of paraffin in air.

(i) Explain how these oxides of nitrogen are formed.

.....

.....

.....

.....

(2)

(ii) Write an equation to show how nitrogen monoxide in the air is converted into nitrogen dioxide.

.....

(1)

(iii) Nitric acid (HNO_3) contributes to acidity in rainwater.

Deduce an equation to show how nitrogen dioxide reacts with oxygen and water to form nitric acid.

.....

(1)

(d) Dodecane ($C_{12}H_{26}$) can be cracked to form other compounds.

(i) Give the general formula for the homologous series that contains dodecane.

.....

(1)

(ii) Write an equation for the cracking of one molecule of dodecane into equal amounts of two different molecules each containing the same number of carbon atoms.
State the empirical formula of the straight-chain alkane that is formed.
Name the catalyst used in this reaction.

Equation .....

Empirical formula of alkane .....

Catalyst .....

.....

(3)

(iii) Explain why the melting point of dodecane is higher than the melting point of the straight-chain alkane produced by cracking dodecane.

.....

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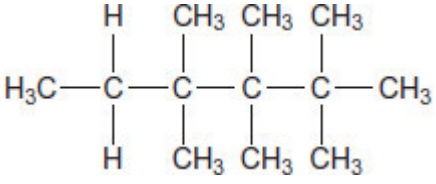
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(2)

(e) Give the IUPAC name for the following compound and state the type of structural isomerism shown by this compound and dodecane.



IUPAC name .....

Type of structural isomerism .....

(2)

(f) Dodecane can be converted into halododecanes.

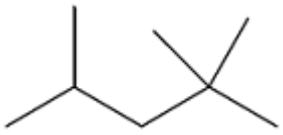
Deduce the formula of a substance that could be reacted with dodecane to produce 1-chlorododecane and hydrogen chloride only.

.....

(1)

(Total 16 marks)

Q5. Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



(a) Give the IUPAC name for isooctane.

.....

(1)

(b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5 ⬭

6 ⬭

7 ⬭

8 ⬭

(1)

(c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

.....

(1)

(d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

.....

(1)

(e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers .....

Structure

(2)

(f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.

Draw the **skeletal formula** of this monochloro compound.

(1)

(g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0
Calculate the M_r of this monochlorooctane.

M_r = ...

(2)

(h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds.
One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass.
Calculate the molecular formula of this compound.

Molecular formula = ...

(3)
(Total 12 marks)

Q1. There are many uses of halogenated organic compounds despite environmental concerns.

(a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

(i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step

.....

(4)

(ii) State **one** condition necessary for the initiation of this reaction.

.....

(1)

(b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

(i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

$$CBrF_3 \longrightarrow \text{.....} + Br^{\bullet}$$

(1)

(ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

.....

.....

.....

(1)

(iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone.
The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst.

Equation 1

.....

Equation 2

.....

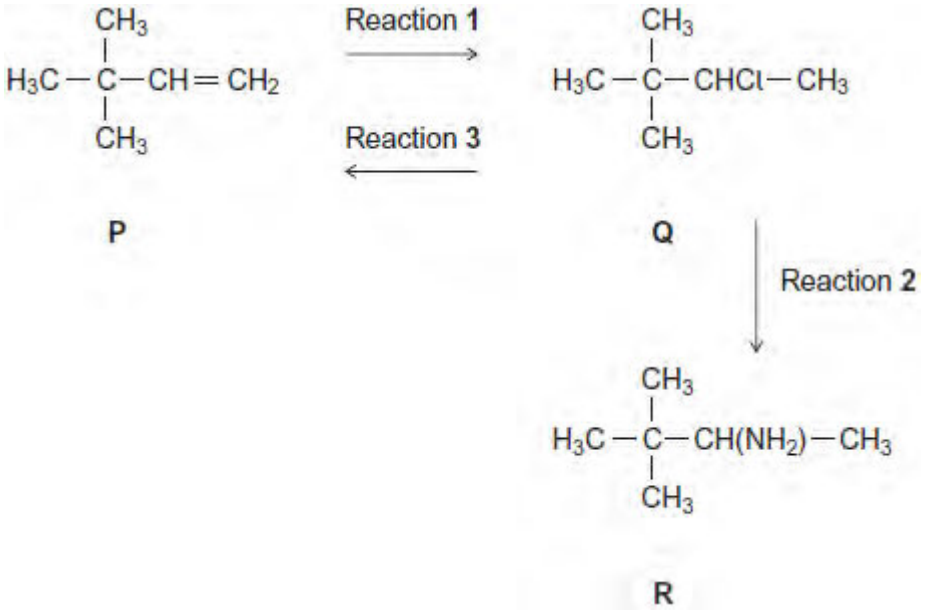
Explanation .....

.....

.....

(3)
(Total 10 marks)

Q2. Consider the following scheme of reactions.



(a) Give the IUPAC name for compound **P** and that for compound **Q**.

P .....

Q .....

(2)

(b) The conversion of **P** into **Q** in Reaction **1** uses HCl

Name and outline a mechanism for this reaction.

.....

(5)

(c) The conversion of **Q** into **R** in Reaction **2** uses NH_3

Name and outline a mechanism for this reaction.

.....

(5)

(d) State the type of reaction shown by Reaction **3**.

Identify a reagent for this reaction.

Give **one** condition necessary for a high yield of product when **Q** is converted into **P**.

.....

.....

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.....

.....

(3)

(e) Hydrogen bromide (HBr) could be used in the overall conversion of **P** into **R**, instead of using HCl
Hydrogen bromide is made by the reaction of NaBr with concentrated phosphoric acid.
Concentrated sulfuric acid is **not** used to make HBr from NaBr

Write an equation for the reaction of NaBr with H_3PO_4 to produce HBr and Na_3PO_4 only.

Identify **two** toxic gases that are formed, together with HBr, when NaBr reacts with concentrated H_2SO_4

State the role of H_2SO_4 in the formation of these two toxic gases.

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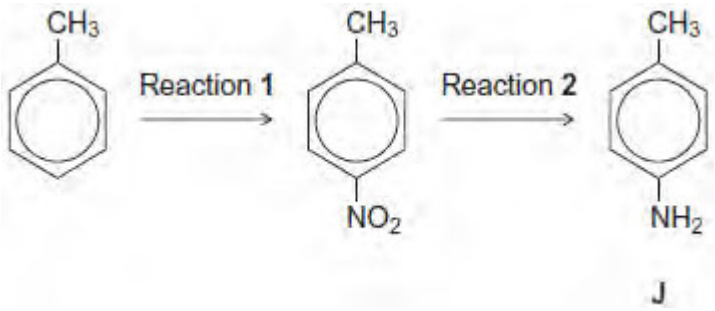
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(4)
(Total 19 marks)

Q3. Consider the following reaction sequence starting from methylbenzene.



J

(a) Name the type of mechanism for reaction **1**.

.....

(1)

(b) Compound **J** is formed by reduction in reaction **2**.

(i) Give a reducing agent for this reaction.

.....

(1)

(ii) Write an equation for this reaction. Use [H] to represent the reducing agent.

.....

(1)

(iii) Give a use for **J**.

.....

(1)

(c) Outline a mechanism for the reaction of bromomethane with an excess of compound **J**.
You should represent **J** as RNH_2 in the mechanism.

(4)

(d) Compound **K** ($C_6H_5CH_2NH_2$) is a structural isomer of **J**.

Explain why **J** is a weaker base than **K**.

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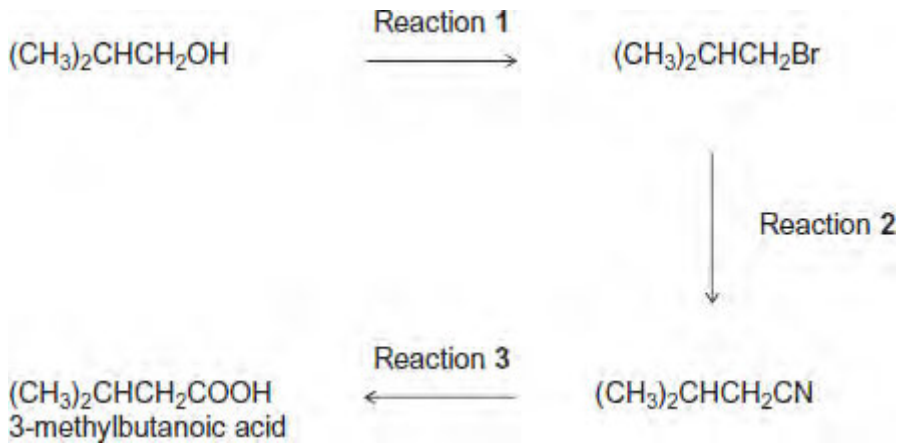
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(3)
(Total 11 marks)

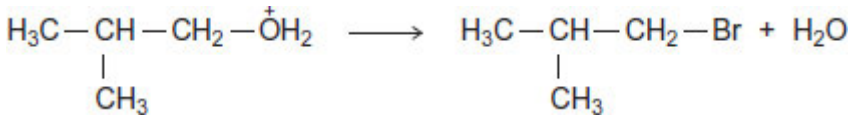
Q4. The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes.
The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



(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 $(CH_3)_2CHCH_2Br$

.....

.....

.....

(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.

$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons (CH_3)_2CHCH_2COOCH_2CH_3 + H_2O$

an ester

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) .....

.....

(2)

(Total 12 marks)