AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.3 HALOGENOALKANES

SCORE	PERCENTAGE
/296	%

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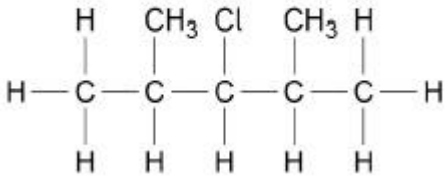
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Q1.

Compound **A** is a halogenoalkane.

Compound A



(a) Name Compound **A**.

_____

(1)

(b) Compound **A** has a relative molecular mass (Mr) of 134.5
The main isotope of hydrogen is ^{1}H
The main isotope of carbon is ^{12}C
Chlorine consists of two common isotopes, ^{35}Cl and ^{37}Cl, of which 75% is ^{35}Cl
The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form $\mathbf{A}^{+}$ ions.

Draw, on **Figure 1**, the peaks for the main molecular ions in the mass spectrum of **A**.

Figure 1



(2)

(c) Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

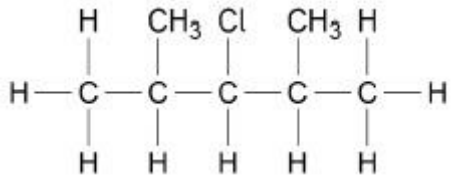
Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alcohol **B**.

Mechanism _____

Outline of mechanism

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(4)

(d) Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

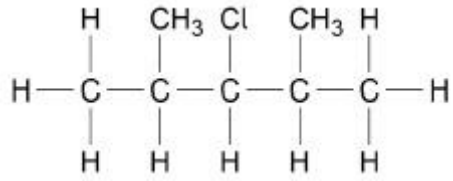
Name the mechanism for this reaction.
State the role of the hydroxide ions.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alkene **C**.

Mechanism _____

Role of hydroxide ions _____

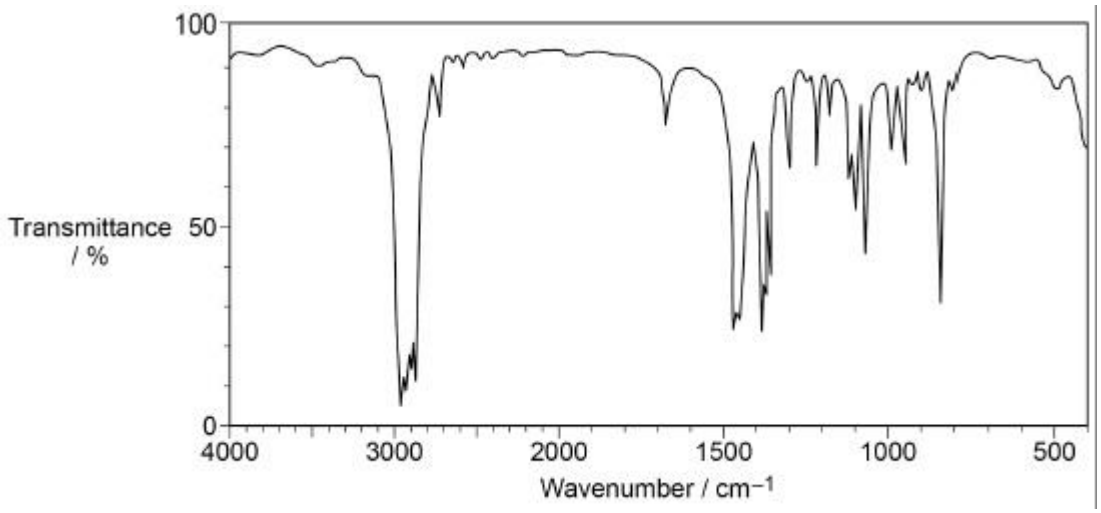
Outline of mechanism



(6)

(e) The infrared spectrum in **Figure 2** is that of either alcohol **B** or alkene **C**.

Figure 2



Tick the box that shows the correct compound.
Explain your answer with reference to a bond and the wavenumber of its absorption.

Alcohol **B** ☐ Alkene **C** ☐

Explanation _____

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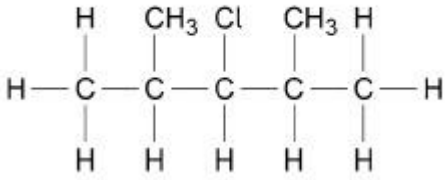
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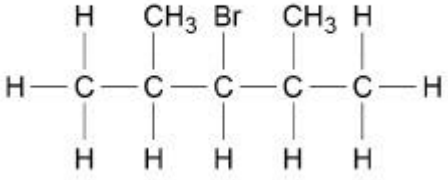
(1)

(f) Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.

Compound A



Compound D



Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

_____

_____

_____

_____

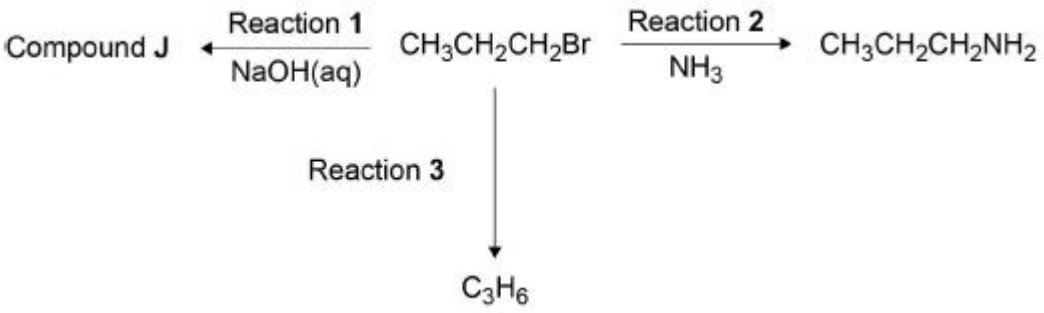
_____

(1)

(Total 15 marks)

Q2.

The diagram shows some compounds made from a halogenoalkane.



(a) Draw the displayed formula of compound **J**.

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(1)

(b) Name the mechanism for Reaction **2** and give an essential condition used to ensure that $CH_3CH_2CH_2NH_2$ is the major product.

Name of mechanism _____

Condition _____

(2)

(c) Calculate the mass, in grams, of $CH_3CH_2CH_2NH_2$ produced from 25.2 g of $CH_3CH_2CH_2Br$ in Reaction **2** assuming a 75.0% yield.

Give your answer to the appropriate number of significant figures.

Mass _____ g

(3)

(d) When Reaction **2** is carried out under different conditions, a compound with molecular formula $C_9H_{21}N$ is produced.

Draw the skeletal formula of the compound.

Identify the functional group in the compound including its classification.

Skeletal formula

Functional group including classification _____

(2)

(e) Identify the reagent and conditions used in Reaction **3**.

_____

(1)

(f) Name and outline a mechanism for Reaction 3.

Name of mechanism _____

Mechanism

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(4)

(Total 13 marks)

Q3.

Which of the following mechanisms does **not** occur in reactions of bromoethane?

A Electrophilic addition ⬭

B Elimination ⬭

C Nucleophilic substitution ⬭

D Radical substitution ⬭

(Total 1 mark)

Q4.

This question is about halogenoalkanes.

(a) Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

1. _____

_____

2. _____

_____

(2)

(b) Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

Role of potassium hydroxide _____

Role of propan-1-ol _____

(2)

(c) Name and outline a mechanism for the reaction in part **(b)** between chloroethane and potassium hydroxide to produce ethene.

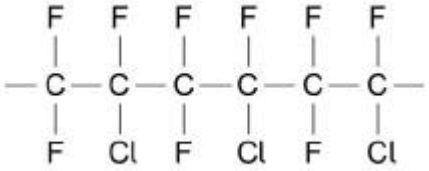
Name of mechanism _____

Mechanism

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(4)

(d) The structure of polymer **A** is shown.



Draw the structure of the monomer used to form polymer **A**.

(1)

(e) Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes, ^{35}Cl and $3^{37}Cl$, in the ratio 3:1
Fluorine only exists as one isotope, ^{19}F.

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at *m/z* = 220, 222 and 224.

Determine the formula of each of the three molecular ions of **B**.

Predict and explain the ratio of the relative abundancies of each of the three molecular ion peaks at *m/z* = 220, 222 and 224.

To gain full marks you must show all your working.

(6)

(Total 15 marks)

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Q5.

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

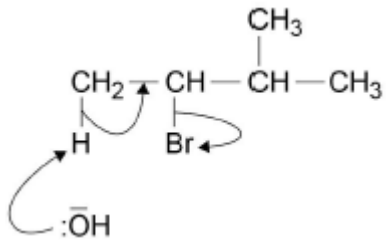
(5)

(Total 6 marks)

Q6.

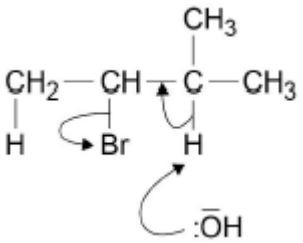
Which of the following is a correct mechanism for the formation of 2-methylbut-2-ene from 2-bromo-3-methylbutane?

A

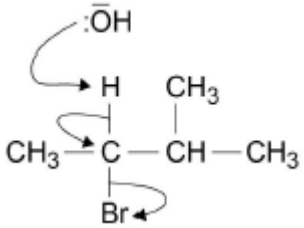


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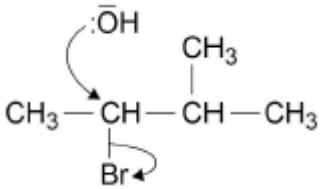
B



C



D



(Total 1 mark)

Q7.

Two reactions of 2-bromopentane, ($CH_3CH_2CH_2CHBrCH_3$) are shown.

C_5H_{10} ← reaction **1** — $CH_3CH_2CH_2CHBrCH_3$ — reaction **2** → $C_5H_{11}OH$

The C_5H_{10} formed in reaction **1** exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

(a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction **1** and reaction **2**.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction **1** for the formation of pent-1-ene.

_____

_____

_____

_____

_____

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(8)

(b) All three isomers of C_5H_{10} contain the same functional group.

Draw the displayed formula of pent-1-ene.

Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

(5)

(c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

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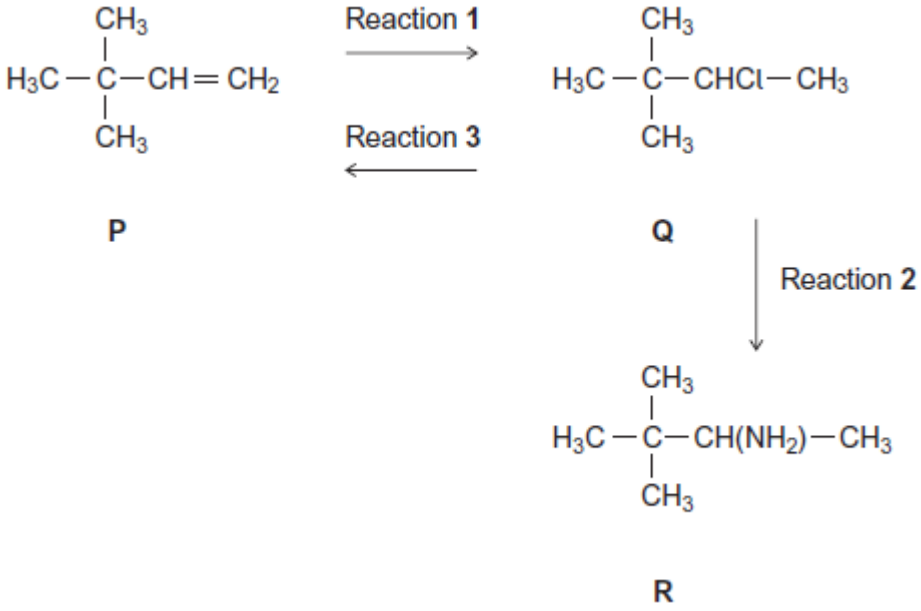
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(4)

(Total 17 marks)

Q8.

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)

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(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**.

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 19 marks)

Q9.

Haloalkanes are used in the synthesis of other organic compounds.

(a) Hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane to form two alkenes that are structural isomers of each other. The major product is 2-methylbut-2-ene.

(i) Name and outline a mechanism for the conversion of 2-bromo-3-methylbutane into 2-methylbut-2-ene according to the equation.

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$(CH_3)_2CHCHBrCH_3 + KOH \longrightarrow (CH_3)_2C=CHCH_3 + KBr + H_2O$

Name of mechanism _____

Mechanism

(4)

(ii) Draw the **displayed formula** for the other isomer that is formed.

(1)

(iii) State the type of structural isomerism shown by these two alkenes.

_____

(1)

(b) A small amount of another organic compound, **X**, can be detected in the reaction mixture formed when hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane.
Compound **X** has the molecular formula $C_5H_{12}O$ and is a secondary alcohol.

(i) Draw the **displayed formula** for **X**.

(1)

(ii) Suggest **one** change to the reaction conditions that would increase the yield of **X**.

_____

_____

(1)

(iii) State the type of mechanism for the conversion of 2-bromo-3-methylbutane into **X**.

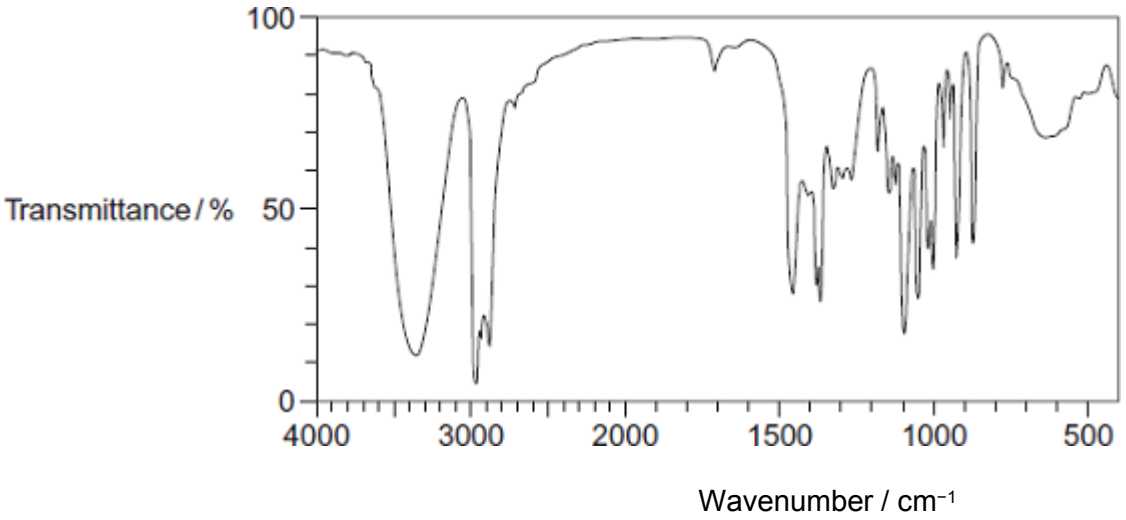
_____

(1)

(iv) Identify **one** feature of this infrared spectrum of a pure sample of **X** that may be used to confirm that **X** is an alcohol.

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You may find it helpful to refer to **Table 1** on the Data Sheet.



Feature _____

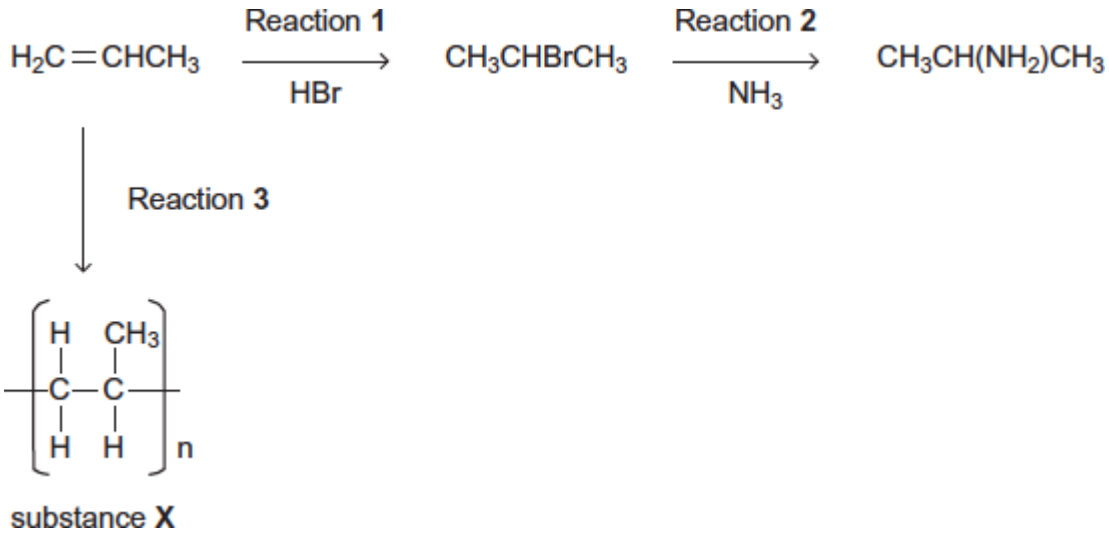
_____

(1)

(Total 10 marks)

Q10.

Consider the following reactions.



(a) Name and outline a mechanism for Reaction **1**.

Name of mechanism _____

Mechanism

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(5)

(b) Name and outline a mechanism for Reaction **2**.

Name of mechanism _____

Mechanism

(5)

(c) State the type of reaction in Reaction **3**.
Give the name of substance **X**.

_____

_____

_____

(2)

(d) The haloalkane produced in Reaction **1** can be converted back into propene in an elimination reaction using ethanolic potassium hydroxide.

$$CH_3CHBrCH_3 \xrightarrow{KOH} H_2C{=}CHCH_3$$

Outline a mechanism for this conversion.

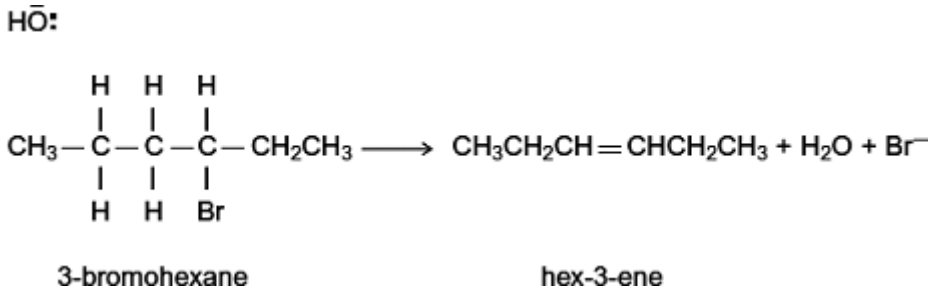
(3)
(Total 15 marks)

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Q11.

Alkenes are useful intermediates in the synthesis of organic compounds.

(a) (i) Complete the elimination mechanism by drawing appropriate curly arrows.



(3)

(ii) Draw structures for the E and Z stereoisomers of hex-3-ene.

E isomer of hex-3-ene Z isomer of hex-3-ene

(2)

(iii) State the meaning of the term *stereoisomers*.

_____

_____

_____

_____

_____

(2)

(b) The equation for the first reaction in the conversion of hex-3-ene into hexan-3-ol is shown below.

$CH_3CH_2CH{=}CHCH_2CH_3 + H_2SO_4 \longrightarrow CH_3CH_2CH_2CH(OSO_2OH)CH_2CH_3$

Outline a mechanism for this reaction.

(4)

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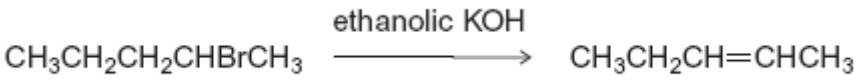
(Total 11 marks)

Q12.

Organic reaction mechanisms help chemists to understand how the reactions of organic compounds occur.
The following conversions illustrate a number of different types of reaction mechanism.

(a) When 2-bromopentane reacts with ethanolic KOH, two structurally isomeric alkenes are formed.

(i) Name and outline a mechanism for the conversion of 2-bromopentane into pent-2-ene as shown below.

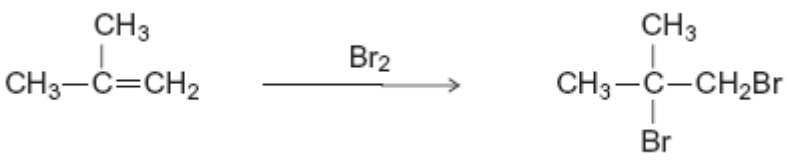


(4)

(ii) Draw the structure of the other structurally isomeric alkene produced when 2-bromopentane reacts with ethanolic KOH.

(1)

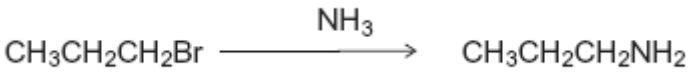
(b) Name and outline a mechanism for the following conversion.



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(5)

(c) Name and outline a mechanism for the following conversion.



(5)
(Total 15 marks)

Q13.

A student read the following passage on the Internet.

> Haloalkanes contain a polar covalent bond. The carbon atom of the polar covalent bond can be attacked by nucleophiles. Nucleophilic attack enables haloalkanes to undergo substitution reactions.
> A nucleophilic substitution reaction occurs when a haloalkane undergoes hydrolysis; the rate of hydrolysis of the haloalkane is influenced by the carbon–halogen bond enthalpy.

(a) Explain the meaning of each of the following terms in the information given above.

(i) *nucleophile*

_____

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_____

_____

(1)

(ii) *substitution,* as applied to nucleophilic substitution in a haloalkane

_____

_____

_____

(1)

(iii) *hydrolysis*

_____

_____

_____

(1)

(iv) *bond enthalpy,* as applied to a carbon–halogen bond.

_____

_____

_____

(1)

(b) Outline a mechanism for the nucleophilic substitution reaction in which 2-bromopropane ($CH_3CHBrCH_3$) reacts with potassium hydroxide to form propan-2-ol.

(2)

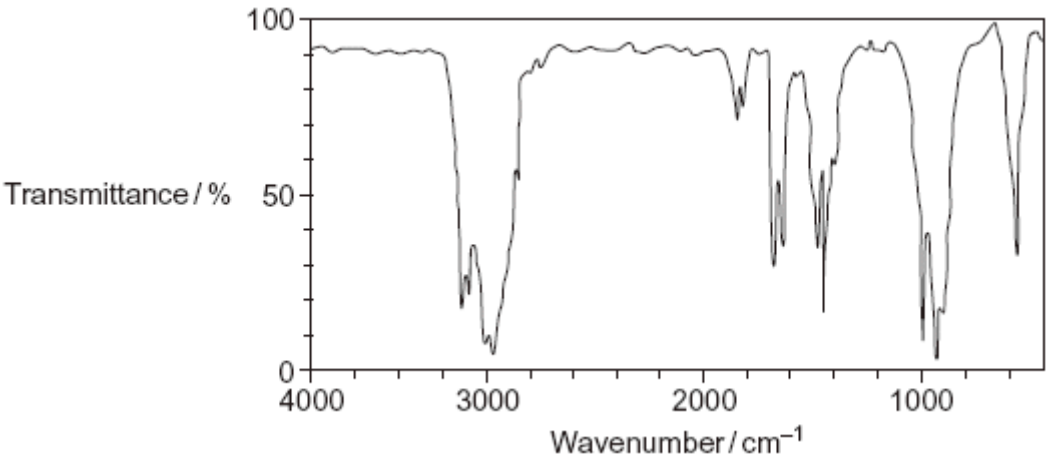
(c) Haloalkanes also undergo elimination reactions to produce alkenes.

(i) Outline a mechanism for the elimination reaction in which 2-bromopropane reacts with potassium hydroxide to form propene.

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(3)

(ii) A student obtained the following infrared spectrum for the product from this elimination reaction.



Use information from the infrared spectrum to state and explain how the student deduced that the product was an alkene.
You may find it helpful to refer to **Table 1** on the Data Sheet.

_____

_____

_____

_____

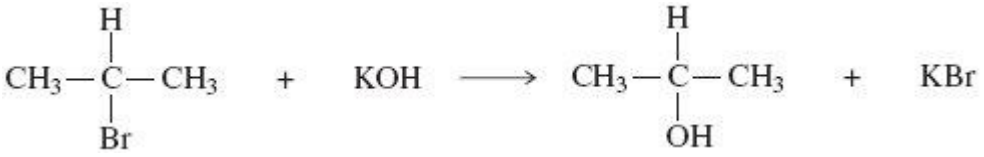
_____

(2)

(Total 11 marks)

Q14.

(a) Consider the following reaction.



(i) Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

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(3)

(ii) Name the haloalkane in this reaction.

_____

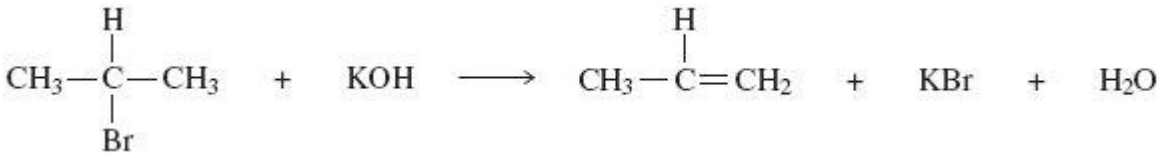
(1)

(iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

_____

(1)

(b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(4)

(c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

_____

(1)

(d) Alkenes can be polymerised to produce poly(alkenes).

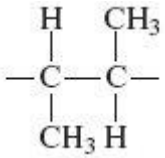
(i) State the type of polymerisation that alkenes undergo.

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_____

(1)

(ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene _____

(1)

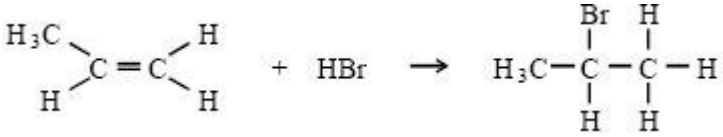
(Total 12 marks)

Q15.

Organic reaction mechanisms help to develop an understanding of how and why reactions occur.

(a) Propene reacts with hydrogen bromide by an electrophilic addition mechanism forming 2-bromopropane as the major product.

The equation for this reaction is shown below.



(i) Outline the mechanism for this reaction, showing the structure of the intermediate carbocation formed.

(ii) Give the structure of the alternative carbocation which could be formed in the reaction between propene and hydrogen bromide.

(5)

(b) A substitution reaction occurs when 2-bromopropane reacts with aqueous sodium hydroxide.

(i) Draw the structure of the organic product of this reaction and give its name.

Structure

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Name _____

(ii) Name and outline the mechanism for this reaction.

Name of mechanism _____

Mechanism

(5)

(c) Under different conditions, 2-bromopropane reacts with sodium hydroxide to produce propene.

(i) Name the mechanism for this reaction

_____

(ii) State the role of sodium hydroxide in this reaction

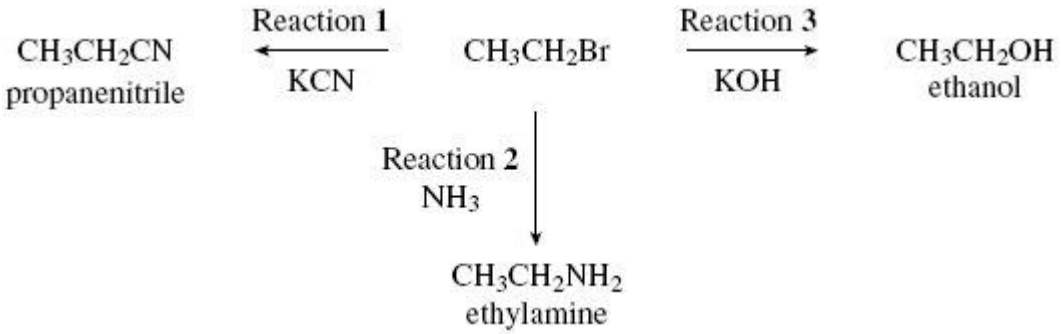
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(2)

(Total 12 marks)

Q16.

Nucleophiles react with bromoethane in substitution reactions. This type of reaction is illustrated in the following scheme.



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

_____

(1)

(b) Outline a mechanism for the reaction of potassium cyanide with bromoethane (Reaction **1**).

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(2)

(c) Explain why an excess of ammonia is needed in Reaction **2** to produce a high yield of ethylamine.

_____

_____

(1)

(d) When potassium hydroxide reacts with bromoethane, ethene can also be formed. Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(4)

(Total 8 marks)

Q17.

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)

Q18.

(a) Name and outline a mechanism for the reaction of 2-bromo-2-methylpropane with ethanolic potassium hydroxide to form the alkene 2-methylpropene, $(CH_3)_2C=CH_2$

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Name of mechanism _____

Mechanism

(4)

(b) Two stereoisomers of but-2-ene are formed when 2-bromobutane reacts with ethanolic potassium hydroxide.

(i) Explain what is meant by the term *stereoisomers*.

_____

_____

(ii) Draw the structures and give the names of the **two** stereoisomers of but-2-ene.

Stereoisomer 1 *Stereoisomer 2*

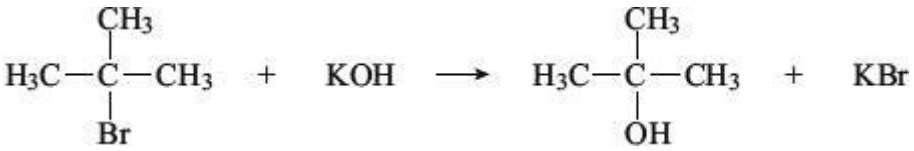
Name _____ *Name* _____

(iii) Name this type of stereoisomerism.

_____

(5)

(c) When 2-bromo-2-methylpropane reacts with aqueous potassium hydroxide, 2-methylpropan-2-ol is formed as shown by the following equation.



State the role of the hydroxide ions in this reaction.

_____

(1)

(d) Write an equation for the reaction that occurs when $CH_3CH_2CH_2CH_2Br$ reacts with an excess of ammonia. Name the organic product of this reaction.

Equation _____

Name of product _____

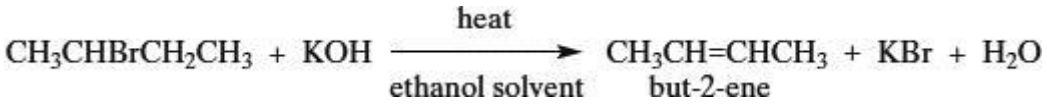
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(3)

(Total 13 marks)

Q19.

Consider the following reaction in which an alkene is formed from a haloalkane.



(a) Name the haloalkane used in this reaction.

_____

(1)

(b) Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(4)

(c) Another alkene, which is a structural isomer of but-2-ene, is also formed during this reaction.

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

_____

_____

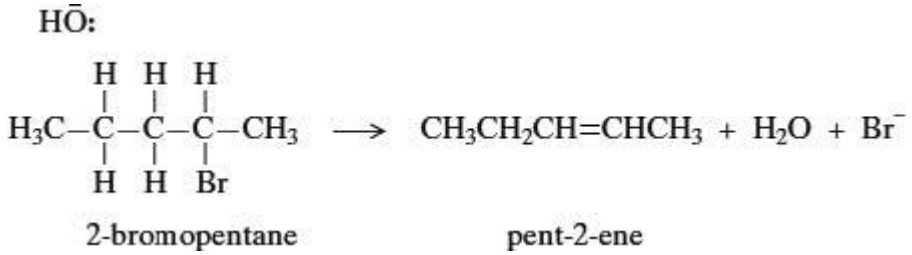
(ii) Draw the structure of this other alkene.

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(2)
(Total 7 marks)

Q20.

(a) Complete the mechanism below by drawing appropriate curly arrows.



(3)

(b) Draw and name the geometrical E-Z isomers of pent-2-ene.

Isomer 1 *Isomer 2*

Name _____ *Name* _____

(2)

(c) Pent-1-ene reacts with hydrogen bromide to produce 2-bromopentane as the major product.

(i) Outline the mechanism for this reaction.

(ii) Identify the minor product formed in this reaction.

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_____

(iii) Explain why 2-bromopentane is the major product of this reaction.

_____

_____

_____

(7)

(Total 12 marks)

Q21.

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

A 2

B 3

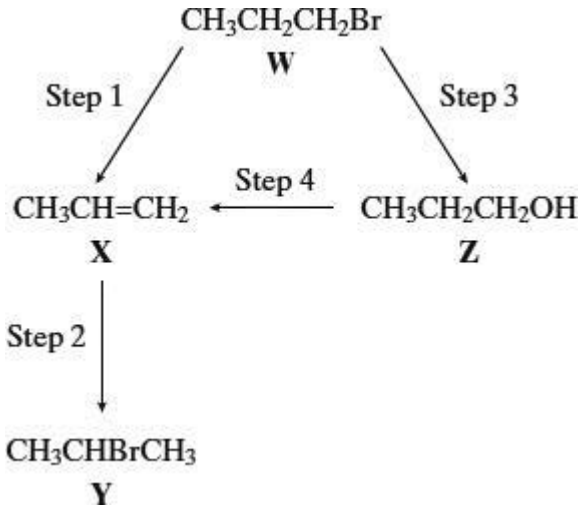
C 4

D 5

(Total 1 mark)

Q22.

For this question refer to the reaction scheme below.



Which one of the following reagents would **not** bring about the reaction indicated?

A Step 1 : alcoholic KOH

B Step 2 : aqueous Br_2

C Step 3 : aqueous NaOH

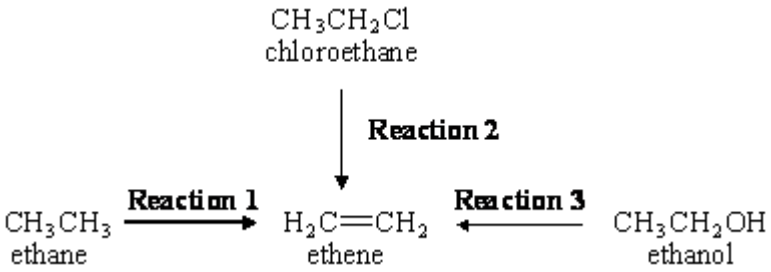
D Step 4 : concentrated H_2SO_4

(Total 1 mark)

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Q23.

Ethene is an important starting point for the manufacture of plastics and pharmaceutical chemicals. Most of the ethene used by industry is produced by the thermal cracking of ethane obtained from North Sea gas (**Reaction 1**). It is also possible to make ethene either from chloroethane (**Reaction 2**) or from ethanol (**Reaction 3**).



(a) Give essential conditions and reagents for each of **Reactions 2** and **3**.

(4)

(b) Name and outline a mechanism for **Reaction 2**. Suggest a reason why chloroethane is **not** chosen by industry as a starting material to make ethene commercially.

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(5)

(c) Name and outline a mechanism for **Reaction 3**. Suggest why this route to ethene may become used more commonly in the future as supplies of North Sea gas begin to run out.

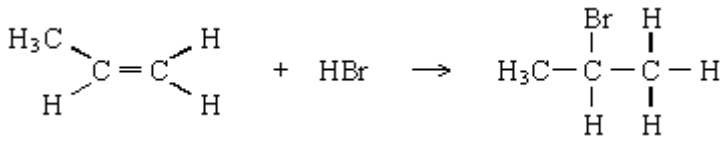
(6)

(Total 15 marks)

Q24.

(a) Propene reacts with hydrogen bromide by an electrophilic addition mechanism forming 2-bromopropane as the major product.

The equation for this reaction is shown below.



(i) Outline the mechanism for this reaction, showing the structure of the intermediate carbocation formed.

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(ii) Give the structure of the alternative carbocation which could be formed in the reaction between propene and hydrogen bromide.

(5)

(b) A substitution reaction occurs when 2-bromopropane reacts with aqueous sodium hydroxide.

(i) Draw the structure of the organic product of this reaction and give its name.

Structure

Name _____

(ii) Name and outline the mechanism for this reaction.

Name of mechanism _____

Mechanism

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(5)

(c) Under different conditions, 2-bromopropane reacts with sodium hydroxide to produce propene.

(i) Name the mechanism for this reaction.

_____

(ii) State the role of sodium hydroxide in this reaction.

_____

(2)

(Total 12 marks)

Q25.

(a) Compounds with double bonds between carbon atoms can exhibit geometrical isomerism.

(i) Draw structures for the two geometrical isomers of 1,2-dichloroethene.

Isomer 1 *Isomer 2*

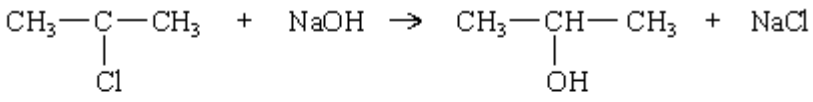
(ii) What feature of the double bond prevents isomer 1 from changing into isomer 2?

_____

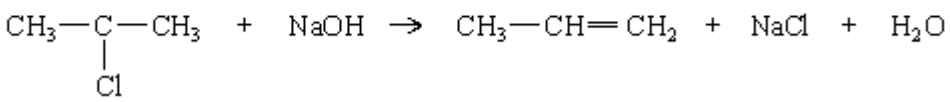
(3)

(b) When 2-chloropropane reacts with sodium hydroxide, two different reactions occur. Each reaction produces a different organic product.

Reaction 1



Reaction 2



(i) Outline a mechanism for **Reaction 1** and state the role of the hydroxide ion in this reaction.

Mechanism

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Role of the hydroxide ion _____

(ii) Outline a mechanism for **Reaction 2** and state the role of the hydroxide ion in this reaction.

Mechanism

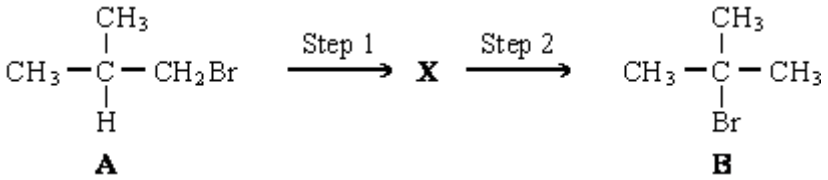
Role of the hydroxide ion _____

(7)

(Total 10 marks)

Q26.

The conversion of compound **A** into compound **B** can be achieved in two steps as shown below.



The intermediate compound, **X,** has an absorption at 1650 cm^{-1} in its infra-red spectrum.

(a) Identify compound **X**. Explain your answer.

_____

_____

_____

_____

(2)

(b) For each step in this conversion, give the reagents and essential conditions required and outline a mechanism.

_____

_____

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(11)

(c) Show how the number of peaks in their proton n.m.r. spectra would enable you to distinguish between compounds **A** and **B**.

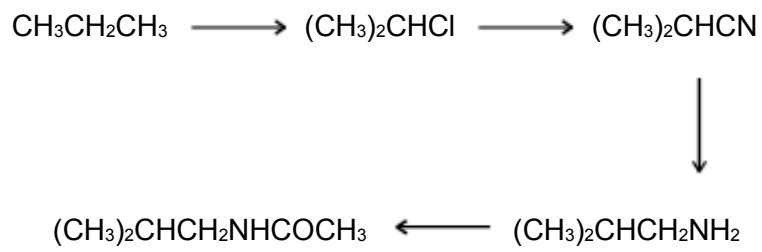
(2)

(Total 15 marks)

Q27.

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

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A free-radical substitution

B nucleophilic substitution

C elimination

D nucleophilic addition-elimination

(Total 1 mark)

Q28.

Reaction of 2-bromobutane with potassium hydroxide can produce two types of product depending on the solvent used. In aqueous solution, the formation of an alcohol, **E**, is more likely but in ethanolic solution the formation of alkenes is more likely.

(a) For each type of product, name the type of reaction occurring and state the role of the potassium hydroxide.

(4)

(b) Name alcohol **E** and draw its structural formula. By reference to the structure of the halogenoalkane, explain why the initial step in the mechanism of the reaction producing the alcohol occurs.

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(5)

(c) When 2-bromobutane reacts with ethanolic potassium hydroxide, two structurally isomeric alkenes are produced, one of which shows stereoisomerism.

Outline the mechanism for the formation of one of the structurally isomeric alkenes. Explain why two structurally isomeric alkenes are formed and draw the structure of the second structural isomer. Draw the structural formulae of the two stereoisomers.

(8)

(Total 17 marks)

Q29.

(a) The equation below shows the reaction of 2-bromopropane with an excess of ammonia.

$$CH_3CHBrCH_3 + 2NH_3 \rightarrow CH_3CH(NH_2)CH_3 + NH_4Br$$

Name and outline the mechanism involved.

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Name of mechanism _____

Mechanism

(5)

(b) When 2-bromopropane is heated with ethanolic potassium hydroxide, an elimination reaction occurs. State the role of potassium hydroxide and outline a mechanism for this reaction.

Role of potassium hydroxide _____

Mechanism

(5)
(Total 10 marks)

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