

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.3 HALOGENOALKANES

SCORE

/296

PERCENTAGE

%

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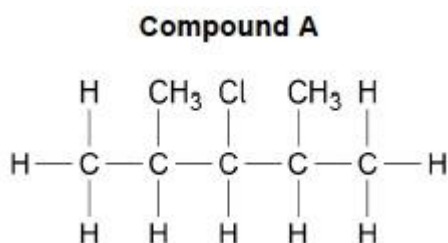
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Q1.

Compound **A** is a halogenoalkane.



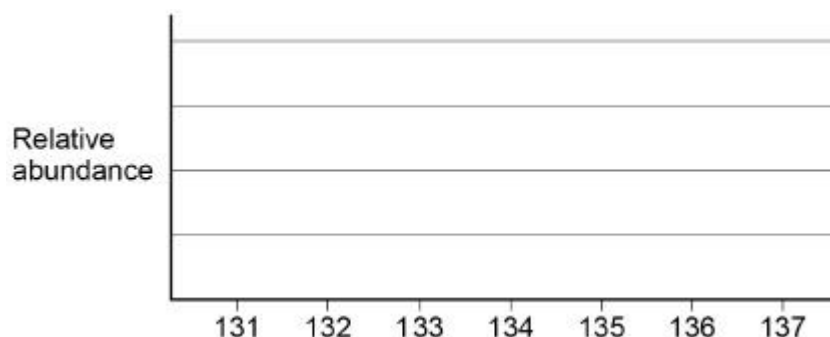
- (a) Name Compound **A**.

(1)

- (b) Compound **A** has a relative molecular mass (M_r) of 134.5
The main isotope of hydrogen is ^1H
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 A^+ ions.

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

Figure 1



(2)

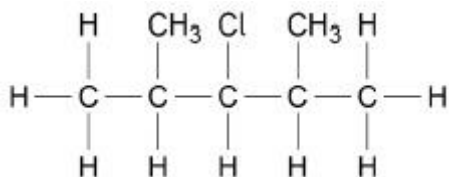
- (c) Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

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



(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.

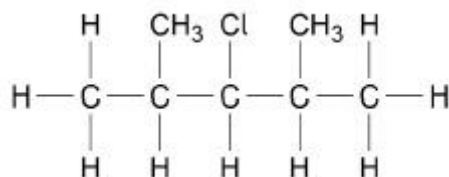
Outline the mechanism using the structure of **A** shown.

Include the structure of the product, alkene **C**.

Mechanism _____

Role of hydroxide ions _____

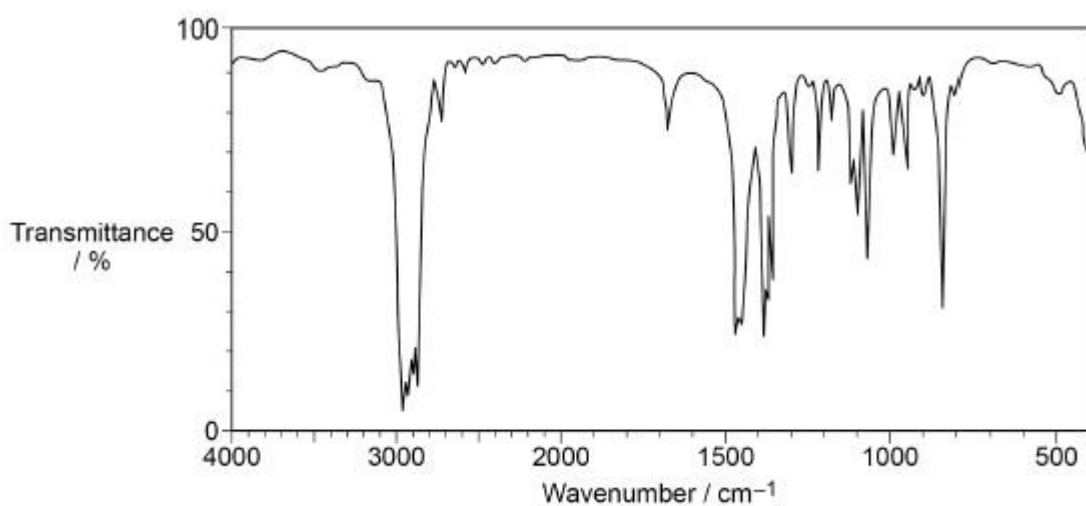
Outline of mechanism



(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.

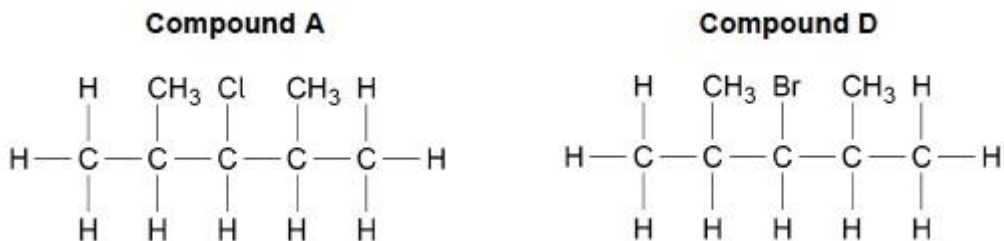
Explain your answer with reference to a bond and the wavenumber of its absorption.

Alcohol **B** ☐ Alkene **C** ☐

Explanation _____

(1)

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



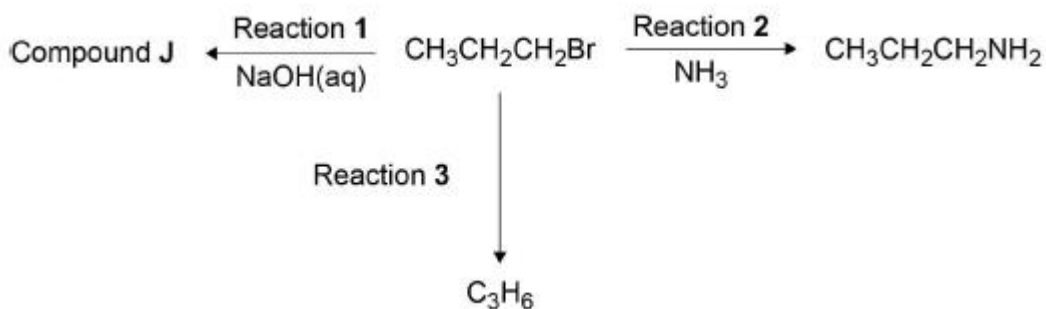
Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

(1)

(Total 15 marks)

Q2.

The diagram shows some compounds made from a halogenoalkane.



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

(1)

- (b) Name the mechanism for Reaction **2** and give an essential condition used to ensure that $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ is the major product.

Name of mechanism _____

Condition _____

(2)

- (c) Calculate the mass, in grams, of $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ produced from 25.2 g of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ 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 $\text{C}_9\text{H}_{21}\text{N}$ 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

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 _____

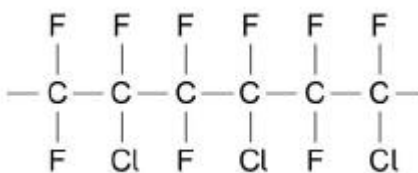
(2)

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

Name of mechanism _____

Mechanism

- (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 ^{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 abundances 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.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

(6)

(Total 15 marks)

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 _____

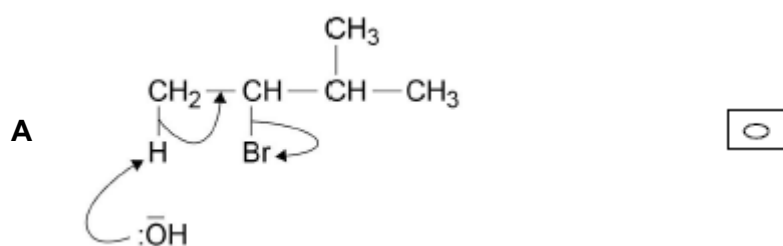
Mechanism

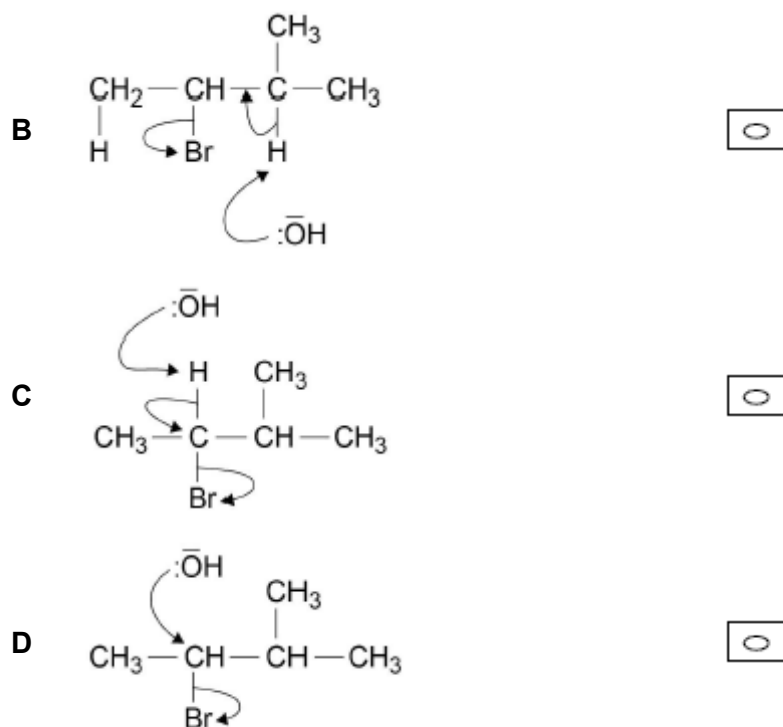
(5)

(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?

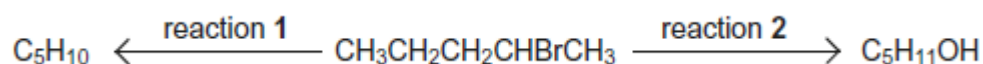




(Total 1 mark)

Q7.

Two reactions of 2-bromopentane, ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CHBrCH}_3$) are shown.



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.

- (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.

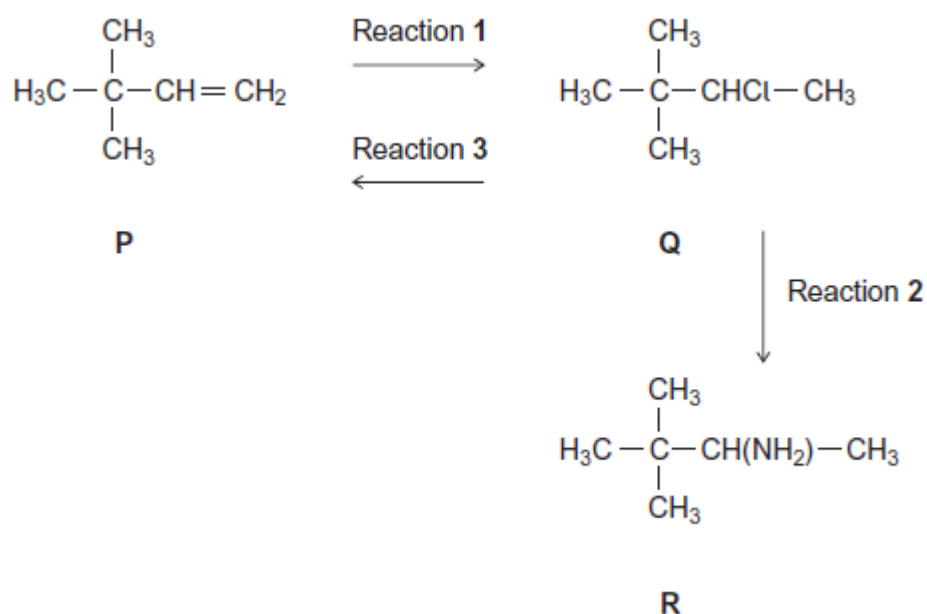
- (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

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.

(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 NH₃

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**.

(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.



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 $\text{C}_5\text{H}_{12}\text{O}$ 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**.

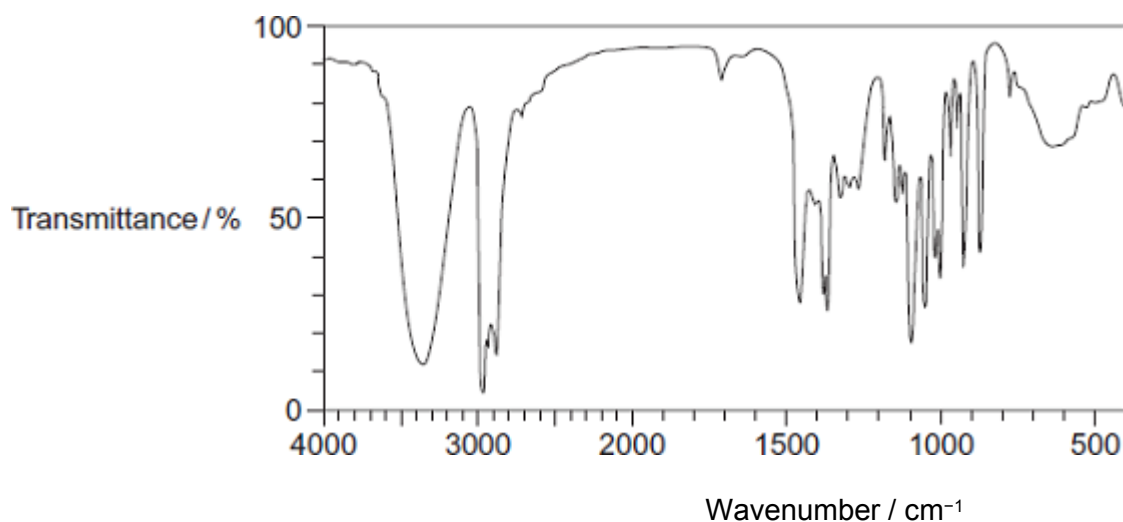
(1)

- (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.

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



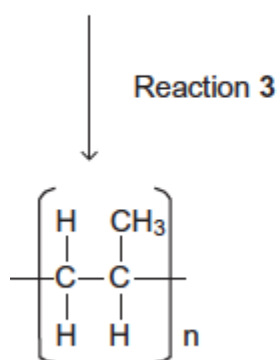
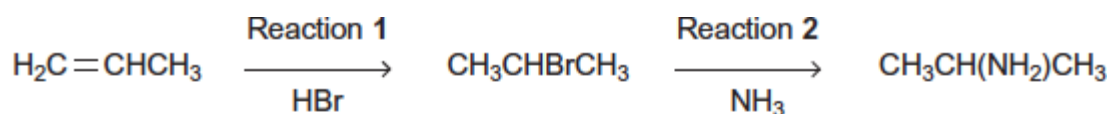
Feature _____

(1)

(Total 10 marks)

Q10.

Consider the following reactions.



substance X

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

Name of mechanism _____

Mechanism

(5)

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

Name of mechanism _____

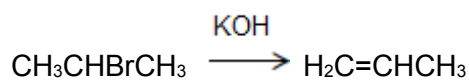
Mechanism

(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.



Outline a mechanism for this conversion.

(3)

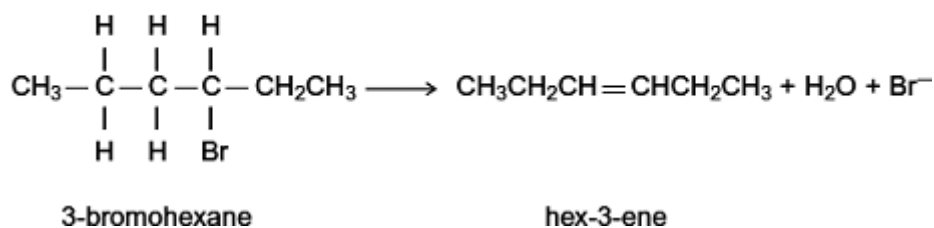
(Total 15 marks)

Q11.

Alkenes are useful intermediates in the synthesis of organic compounds.

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

HO^- :



(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.



Outline a mechanism for this reaction.

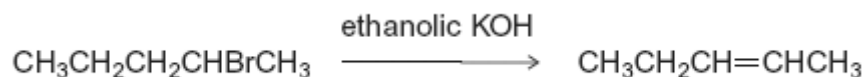
(4)

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.

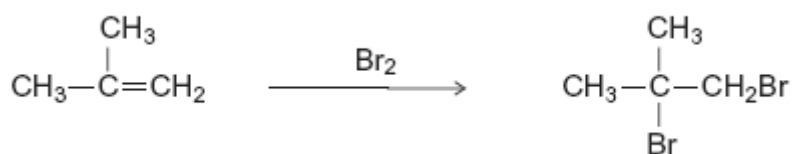


(4)

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

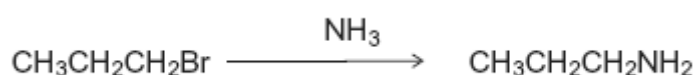
(1)

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



(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.

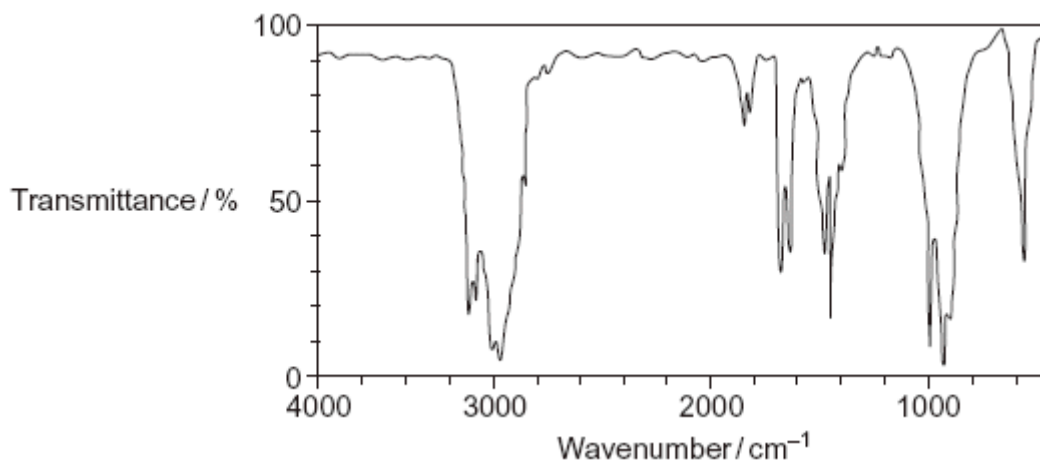
- (a) Explain the meaning of each of the following terms in the information given above.

- (i) *nucleophile*

- _____
- _____
- (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 ($\text{CH}_3\text{CHBrCH}_3$) 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.

(3)

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



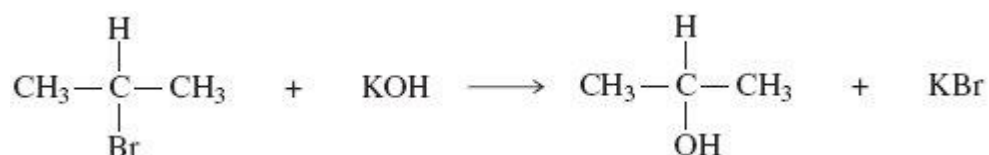
Use information from the infrared spectrum to state and explain how the student deduced that the product was an alkene.
You may find it helpful to refer to **Table 1** on the Data Sheet.

(2)

(Total 11 marks)

Q14.

- (a) Consider the following reaction.



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

Name of mechanism _____

Mechanism

(3)

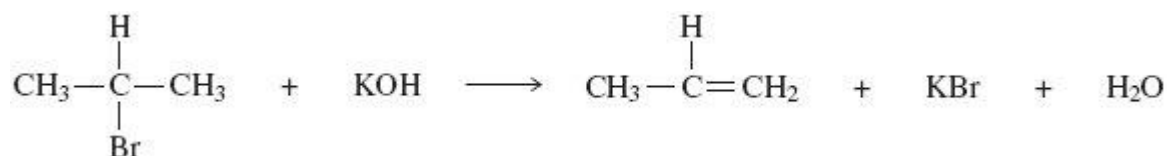
- (ii) Name the haloalkane in this reaction.

(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).

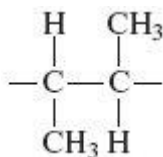
(1)

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

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

(1)

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



Name of alkene _____

(1)

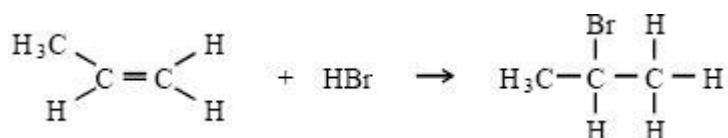
(Total 12 marks)

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

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

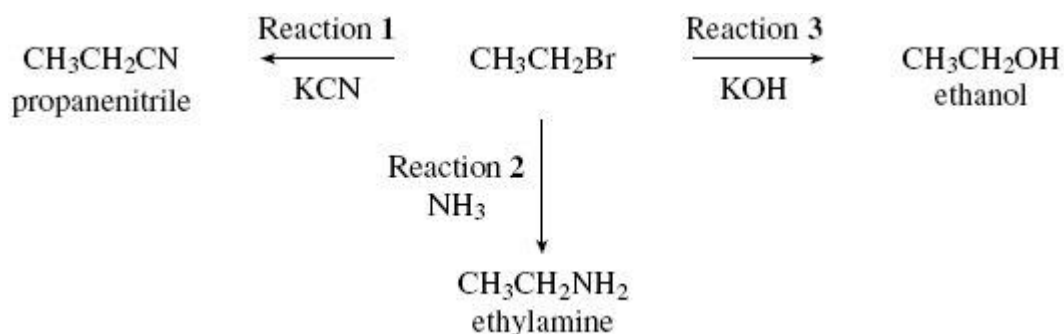
- (ii) State the role of sodium hydroxide in this reaction

(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).

(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, $(\text{CH}_3)_2\text{C}=\text{CH}_2$

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

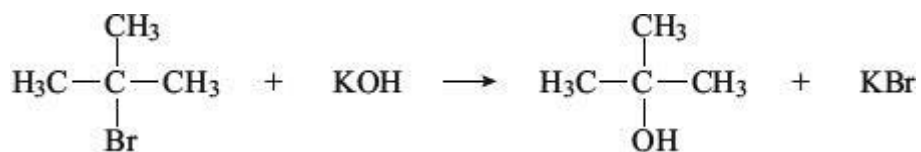
Stereoisomer 2

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)

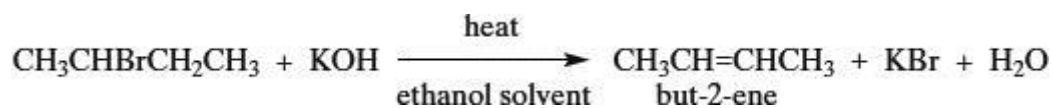
- (d) Write an equation for the reaction that occurs when $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ reacts with an excess of ammonia. Name the organic product of this reaction.

Equation _____

Name of product _____

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.

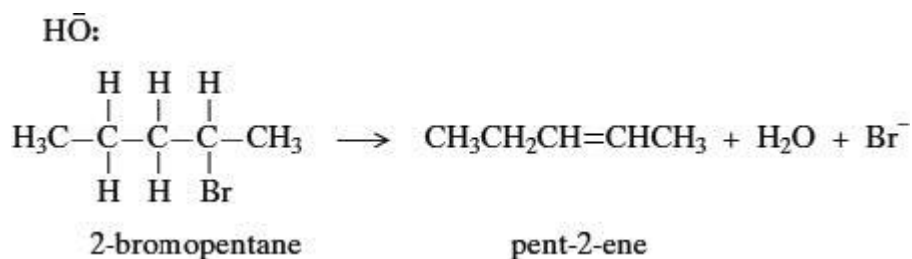
- (i) State what is meant by the term *structural isomers*.

- (ii) Draw the structure of this other alkene.

(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.

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

(7)
(Total 12 marks)

Q21.

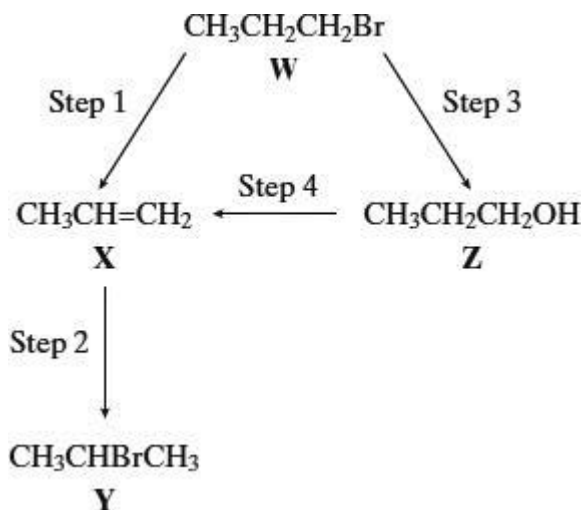
How many different alkenes are formed when 2-bromo-2-methylbutane reacts with ethanolic potassium hydroxide?

- A 2
B 3
C 4
D 5

(Total 1 mark)

Q22.

For this question refer to the reaction scheme below.



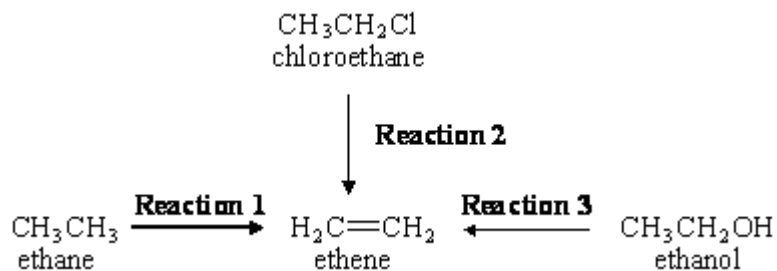
Which one of the following reagents would **not** bring about the reaction indicated?

- 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)

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.

(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.

[illegible]

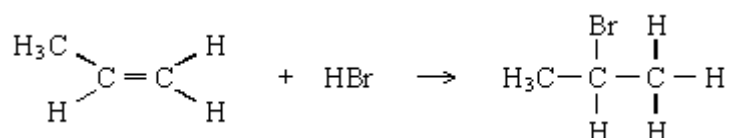
(6)

(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.

- (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

(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.

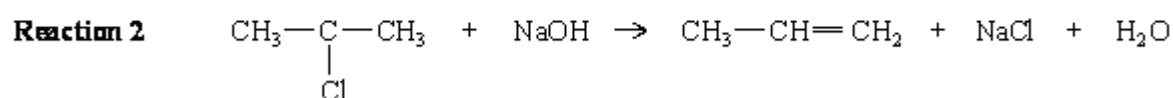
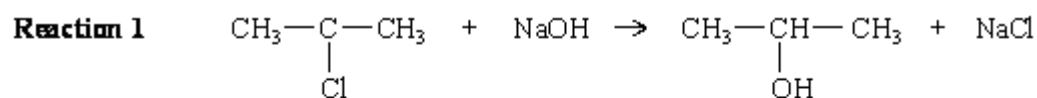
Isomer 1

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.



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

Mechanism

Role of the hydroxide ion _____

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

Mechanism

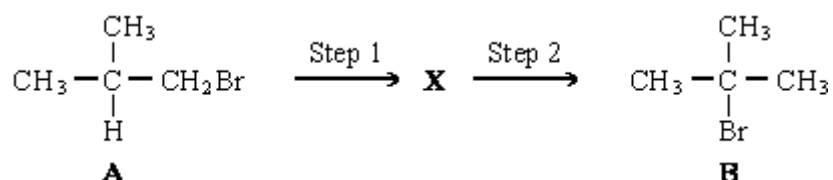
Role of the hydroxide ion _____

(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)

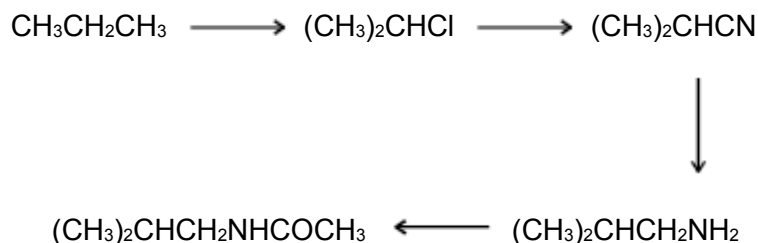
- (b) For each step in this conversion, give the reagents and essential conditions required and outline a mechanism.

(11)

- (2)

Q27.

Page 34 of 82



- 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.

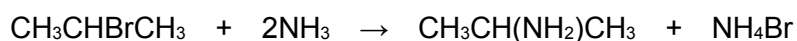
(5)

- 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)

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



Name and outline the mechanism involved.

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)

Mark schemes

Q1.

- (a) 3-chloro-2,4-dimethylpentane

This answer only apart from slips with commas and dashes

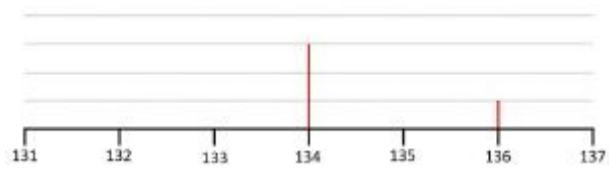
1

- (b) **M1** lines at 134 and 136

M1 is for drawing the correct two lines (if other lines are drawn, penalise **M1** (but ignore any additional very small lines at 135 or 137))

1

- M2** line at 134 to be three times higher than line at 136

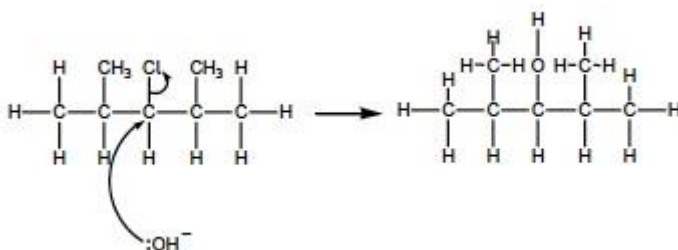


M2 is for the line at 134 being three times as big as the one at 136 (ignore other lines)

Accept cross to represent top of lines; if bars drawn – they should be narrow (less than 10% of division) and clear which value they refer to.

1

- (c) **M1** nucleophilic substitution



1

- M2** curly arrow from lone pair on O of OH⁻ to C of C–Cl

For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else

If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3**

1

- M3** curly arrow from C–Cl bond to the Cl

Penalise **M3** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms

For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

If SN1 mechanism given (loss of Cl first followed by attack by OH⁻) then:

M2 curly arrow from C–Cl bond to the Cl

M3 curly arrow from lone pair on O of OH⁻ to positive C atom of correct carbocation

*penalise **M2** for any additional arrow(s) to/from the Cl to/from anything else*

*penalise **M3** for any additional arrow(s) on NaOH*

1

M4 correct structure of alcohol (in any form)

***M4** is independent*

***M4** ignore presence of non-organic products*

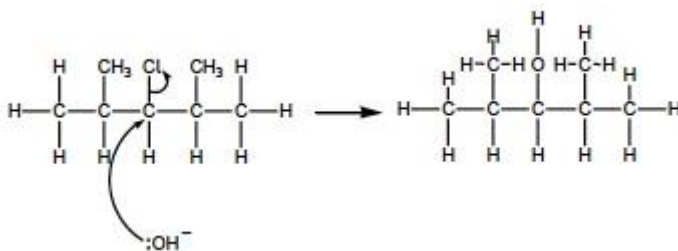
1

(d) **M1** elimination

***M1** allow base elimination (but nothing else)*

1

M2 base



***M2** allow proton acceptor*

1

M3 curly arrow from lone pair on O of OH⁻ to H on one of the C atoms adjacent to the C–Cl

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M4 curly arrow from a correct C–H bond adjacent to the C–Cl to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in **M3**

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M5 curly arrow from C–Cl bond to the Cl (mark is independent)

*Penalise **M5** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms*

1

M6 correct structure of alkene (in any form)

***M6** is independent*

***M6** ignore presence of non-organic products*

If E1 mechanism given (loss of Cl first followed by attack by OH⁻) then:

M3 curly arrow from C–Cl bond to the Cl

M4 curly arrow from lone pair of OH⁻ to a correct H on the correct C adjacent to C⁺ on the carbocation

M5 curly arrow from a correct C–H bond to a correct C–C bond

penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else

penalise **M4** for any additional arrow(s) on KOH

1

- (e) C as C=C 1620-1680 cm⁻¹ OR no O–H 3230-3550 cm⁻¹

need the correct compound and an explanation

full wavenumber range or value(s) within the range

on this occasion candidates do not need to refer to the O–H bond being O–H alcohol as opposed to O–H acid – just reference to O–H with wavenumbers is required

1

- (f) C–Br is weaker than C–Cl or

C–Br has lower bond enthalpy than C–Cl or

C–Br breaks more easily C–Cl

Must compare the C–Br and C–Cl bonds specifically

Ignore references to bond length, size of atoms, shielding, electronegativity and polarity

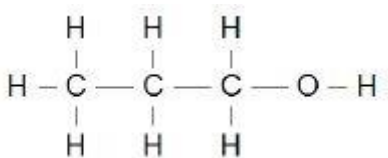
Penalise idea that bromine is more reactive than chlorine

1

[15]

Q2.

- (a)



Must be displayed

1

- (b) Nucleophilic substitution

1

Excess NH₃

Ignore aqueous, alcoholic, conc, dil, temp, heat, pressure

1

- (c) Amount of CH₃CH₂CH₂Br 25.2/122.9 (=0.205) (mol)

M1

Amount of CH₃CH₂CH₂NH₂ M1 × 0.75 (= 0.154) (mol)

M2

Mass $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$

$M2 \times 59.0 = 9.07\text{g}$ Must be 3sf

M3

If either Mr incorrect or used incorrectly then only award 1 mark for 75% yield calculation

(ignore rounding to 123 for $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$)

OR

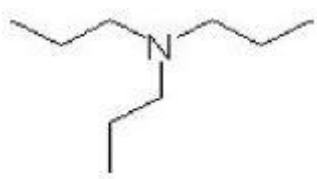
Max mass amine = $M1 \times 59.0 (= 12.1)$ (g)

Actual mass = $M2 \times 0.75 = 9.07\text{g}$ Must be 3sf

Allow 9.09 but if 9.08 check for AE

18.9 scores 1 for 75%

(d)



Must be skeletal

Ignore lone pair

1

tertiary amine or 3° amine (only award if a tertiary amine shown)

1

(e) NaOH/ ethanol or KOH / ethanol (both required)

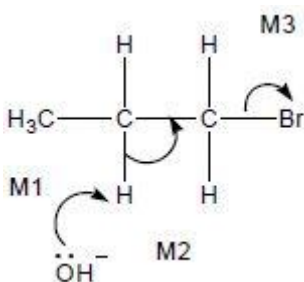
NOT aqueous

Ignore heat, temp, conc., dil,

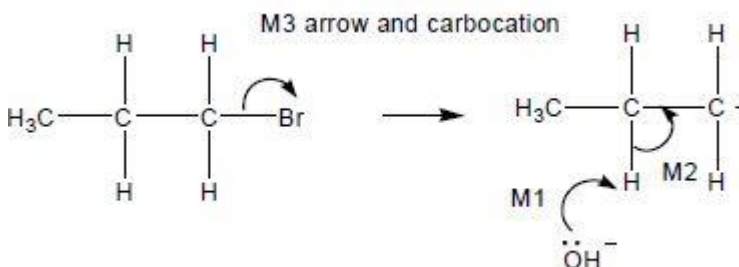
Accept alcoholic for ethanol

1

(f) (Basic) Elimination



Also credit E1 mechanism



1

M1 arrow from lone pair on O of hydroxide to correct H (or to space mid way between hydroxide O and H)

M2 arrow from C-H bond to C-C bond following attack by OH⁻ on the correct H

M3 arrow from C-Br bond to Br

If nucleophilic substitution shown then allow M3 only in mechanism

If wrong haloalkane used then Max 2 for mechanism

M3 curly arrow for loss of Br⁻ & structure of carbocation

M1 arrow from lone pair on O of hydroxide to H (or to space mid way between hydroxide O and H) (same as E2)

M2 arrow from C-H bond to C-C bond (same as E2)

3

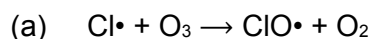
[13]

Q3.

A

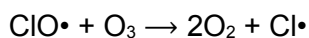
[1]

Q4.



Allow dot in free-radical on either O or Cl.

1



1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

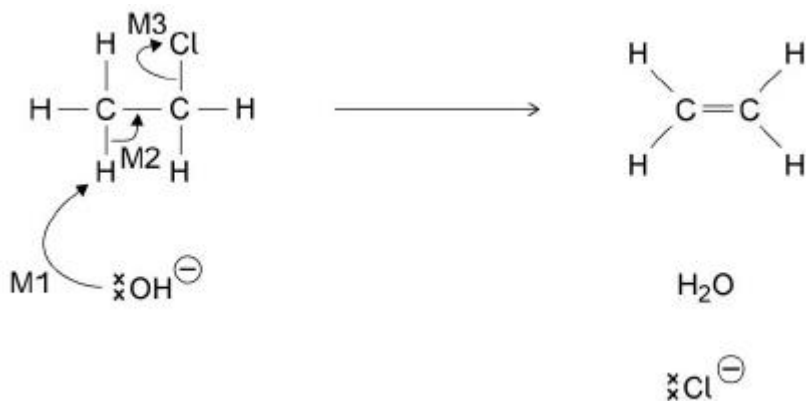
Allow product of reaction between KOH and propan-1-ol / $\text{CH}_3\text{CH}_2\text{CH}_2\text{O}^-$ acts as base.

1

(c) (Name of mechanism) Elimination

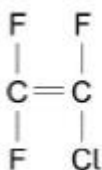
1

mechanism: 3 arrows (1 mark each).



3

(d)



1

- (e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

If the formulae of the three molecular ions are not correct (2d) then the student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).

5-6 marks

Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.

3-4 marks

Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

OR

Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1 (determines empirical formula)

1a 16.3% carbon

1b Divide by A_r

1c Divide by smallest (0.904)

1d Convert ratio in simplest integer (x 2)

C	Cl	F
$\frac{16.3}{12.0} = 1.358$	$\frac{32.1}{35.5} = 0.904$	$\frac{51.6}{19.0} = 2.716$
$\frac{1.358}{0.904}$	$\frac{0.904}{0.904}$	$\frac{2.716}{0.904}$
3	2	6

Stage 2 (determines formulae of three molecular ions)

2a For E.F. M_r (corresponds to the molecule) = 221

2b since $M_r = 221$ lies within molecular ion range 220–224

2c Thus empirical formula = molecular formula

2d Three correct formulae

2e Correct M_r for each of three molecules

$C_3^{35}Cl_2F_6^+$	$C_3^{35}Cl^{37}ClF_6^+$	$C_3^{37}Cl_2F_6^+$
220	222	224

Stage 3 (explains the ratio of 3 molecular ion peaks)

3a Working

2b Correct (simplified) ratio **9:6:1**

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

$C_3^{35}Cl_2F_6^+$	$C_3^{35}Cl^{37}ClF_6^+$	$C_3^{37}Cl_2F_6^+$
220	222	224

$^{35}\text{Cl}_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$	$^{35}\text{Cl}^{37}\text{Cl} \text{ and } ^{37}\text{Cl}^{35}\text{Cl} = 2 \times \frac{1}{4} \times \frac{3}{4} = \frac{6}{16}$	$^{37}\text{Cl}_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$
--	---	--

[15]

Q5.

- (a) (Compounds with the) same molecular formula but different structural / displayed / skeletal formula

1

- (b) (basic) elimination

1

Mechanism points:

Correct arrow from lone pair on :OH⁻ to H on C adjacent to C-Br

1

Correct arrow from C-H bond to C-C

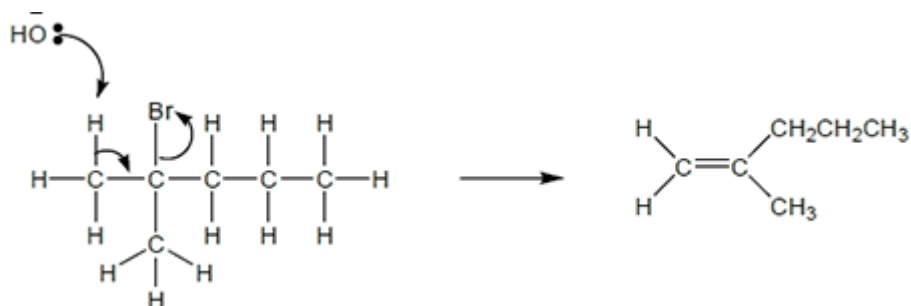
1

Correct arrow from C-Br bond to Br

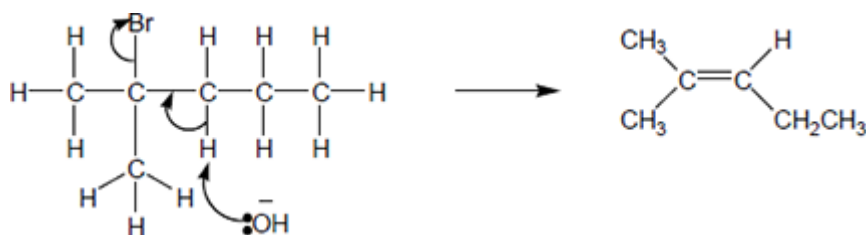
1

Structure of chosen product

1



OR



[6]

Q6.

B

[1]

Q7.

(a) NaOH/KOH

IGNORE OH-

NOT M1 if any mention of acidified/H⁺ in reagents or conditions

1

Reaction 1 = ethanolic/alcoholic **AND** reaction 2 = aqueous

IGNORE temp

NOT ethanoic

1

rxn 1 = base/proton acceptor

1

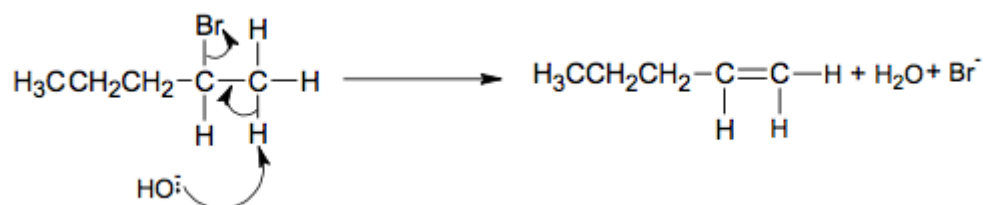
rxn 2 = nucleophile/lone pair donor/electron pair donor

1

(Base) Elimination

NOT nucleophilic

1



M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

M7 must show an arrow from a correct C-H bond on C adjacent to the C of the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M6**

M8 is independent provided it is from their original molecule and shows curly arrow from C-Br to Br

ALLOW correct E1 mechanism

IGNORE incorrect inorganic products

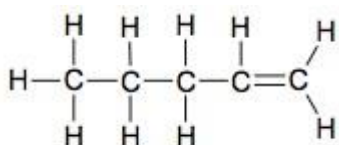
If forming pent-2-ene can award M8 only even if arrows in mechanism correct

If C chain length or halogen wrong in reactant or product max 2/3

1

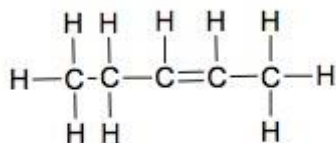
1

1



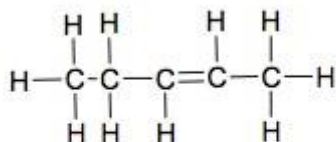
(b)

1



Z-pent-2-ene

1



E-pent-2-ene

1

If no M2 and M3 **ALLOW** 1 mark if both structures **OR** both names correct

NOT cis and trans

No free rotation around C=C

ALLOW no rotation of C=C

1

2 different atoms/groups on each of the C=C Cs owtte

IGNORE 'functional'

1

- (c) Same volume/amount of AgNO₃(aq) added to same volume/amount/no. of drops of haloalkane (in beaker/flask) in each experiment

Both volume references needed

IGNORE inappropriate volumes

1

Same temp **OR** same [AgNO₃] each time

1

record time to measure sensible observation about the amount of AgCl ppt

e.g. first appearance of ppt / ppt obscures mark / reading on a colorimeter

IGNORE colour of ppt

ALLOW silver mirror

NOT reference to same time if describing method based on timing how long (for ppt to form)

ALLOW gravimetric method based on same time for each experiment

1

Rate = amount/time **OR** proportional to 1/time **OR** reference to shorter time = higher rate/longer time = lower rate

ALLOW greater mass = higher rate if gravimetric method

1

[17]

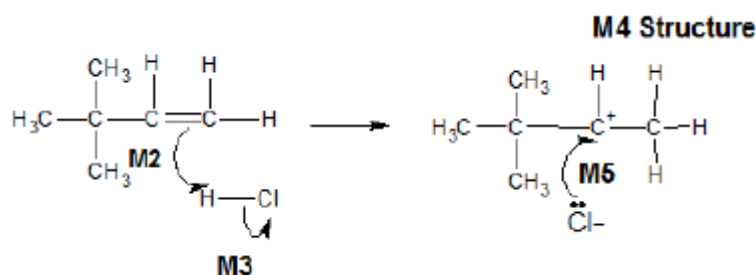
Q8.

- (a) **P** 3,3-dimethylbut-1-ene
OR
 accept 3,3-dimethylbutene
Ignore absence of commas, hyphens and gaps
Require correct spelling

- Q** 3-chloro-2,2-dimethylbutane
OR
 accept 2-chloro-3,3-dimethylbutane
In Q, "chloro" must come before "dimethyl"

2

- (b) **M1** Electrophilic addition



M2 must show an arrow from the double bond towards the H atom of HCl

M3 must show the breaking of the H-Cl bond

M4 is for the structure of the carbocation

M5 must show an arrow from the lone pair of electrons on the negatively charged chloride ion towards the positively charged carbon atom on their carbocation.

NB The arrows here are double-headed

M1 both words required

For the mechanism

M3 Penalise incorrect partial charge on H-Cl bond and penalise formal charges

Ignore partial negative charge on the double bond.

Maximum 3 of 4 marks for a correct mechanism using HBr or the wrong organic reactant or wrong organic product (if shown) or a primary carbocation

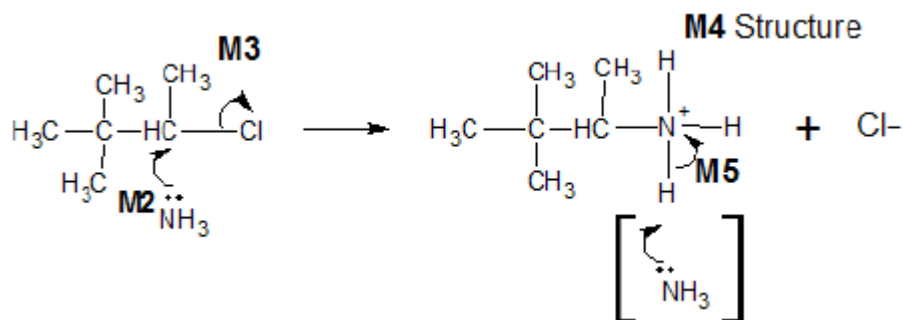
Penalise once only in any part of the mechanism for a line and two dots to show a bond

Credit the correct use of "sticks"

For M5, credit attack on a partially positively charged carbocation structure, but penalise M4

5

- (c) **M1** Nucleophilic substitution
For M1, both words required.
Accept phonetic spelling



M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom

M3 must show the movement of a pair of electrons from the C–Cl bond to the Cl atom. Mark **M3** independently provided it is from their original molecule

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on, or close to, the N atom.

M5 is for an arrow from the N–H bond to the N atom

Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

NB These are double-headed arrows

For the mechanism

Penalise **M2** if NH₃ is negatively charged.

Penalise **M3** for formal charge on C of the C–Cl or incorrect partial charges on C–Cl

Penalise **M3** for an additional arrow from the Cl to something else

The second mole of ammonia is not essential for **M5**; therefore ignore any species here

Penalise once only for a line and two dots to show a bond

Maximum 3 of 4 marks for the mechanism for wrong organic reactant OR wrong organic product if shown

Accept the correct use of “sticks”

5

(d) **M1** (base) elimination

M1 Dehydrohalogenation

M2 KOH OR NaOH

M3 Must be consequential on a correct reagent in **M2**, but if incomplete or inaccurate attempt at reagent (e.g. hydroxide ion), **penalise M2 only and mark on**

Any **one** from

- high temperature OR hot OR heat / boil under reflux
- concentrated
- alcohol / ethanol (as a solvent) / (ethanolic conditions)

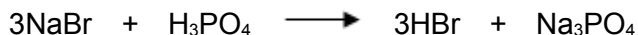
M3 not “reflux” alone

M3 if a temperature is stated it must be in the range 78C to 200 °C

Ignore “pressure”

3

(e) **M1**



M1 Credit correct ionic species in the equation

M2 and M3

SO_2 and Br_2 identified

M4

Concentrated sulfuric acid

- is an oxidising agent
- oxidises the bromide (ion) or Br^- or NaBr or HBr
- is an electron acceptor

In M2 and M3 the two gases need to be identified. If equations are used using sulfuric acid and the toxic gases are not identified clearly, allow one mark for the formulas of SO_2 and Br_2

- apply the list principle as appropriate but ignore any reference to HBr
- the marks are for identifying the two gases either by name or formula

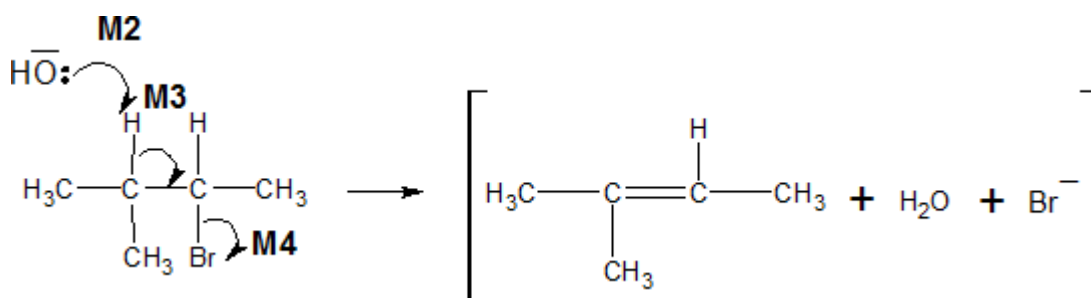
4

[19]

Q9.

(a) (i) **M1 Elimination**

M1 Credit "base elimination" but no other prefix.



Penalise **M2** if covalent KOH

Penalise **M4** for formal charge on C or Br of C-Br or incorrect partial charges on C-Br

M2 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

Ignore other partial charges

M3 must show an arrow from a correct C-H bond adjacent to the C-Br bond to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M2**

Penalise **once only** in any part of the mechanism for a line and two dots to show a bond

M4 is independent provided it is from their original molecule, **BUT CE=0 for the mechanism (penalise M2, M3 and M4 only) if nucleophilic substitution mechanism is shown**

Maximum any 2 of 3 marks for the mechanism for wrong organic reactant or wrong organic product (if shown).

Credit the correct use of "sticks" for the molecule except for

the C-H being attacked

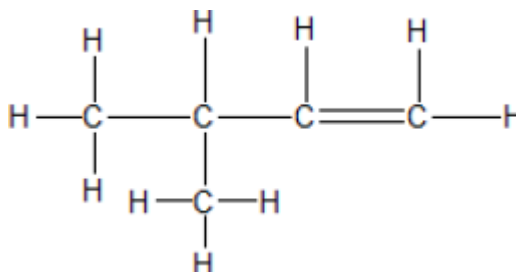
Award full marks for an E1 mechanism in which **M4** is on the correct carbocation

Penalise **M4**, if an additional arrow is drawn from Br eg to K⁺

NB These are double-headed arrows

4

- (ii) Displayed formula for 3-methylbut-1-ene



All bonds and atoms must be drawn out, but ignore bond angles

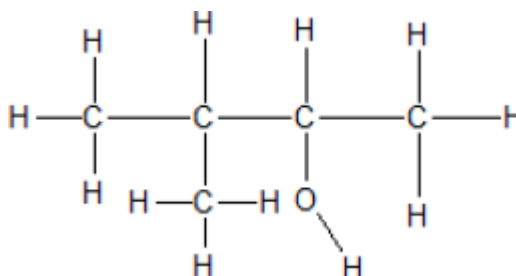
1

- (iii) Position(al) (isomerism or isomer)

Penalise any other words that are written in addition to these.

1

- (b) (i) Displayed formula for 3-methylbutan-2-ol



All bonds and atoms must be drawn out, but ignore bond angles.

1

- (ii) Any **one** from

- Lower / decreased temperature **OR** cold
- Less concentrated (comparative) **OR** dilute KOH
- Water (as a solvent) / (aqueous conditions)
Ignore "pressure".

1

- (iii) Nucleophilic substitution

Both words needed - credit phonetic spelling.

1

- (iv) (Strong / broad) absorption / peak in the range **3230 to 3550** cm⁻¹ or

specified value in this range or marked correctly on spectrum

Allow the words “dip” OR “spike” OR “trough” OR “low transmittance” as alternatives for absorption.

1

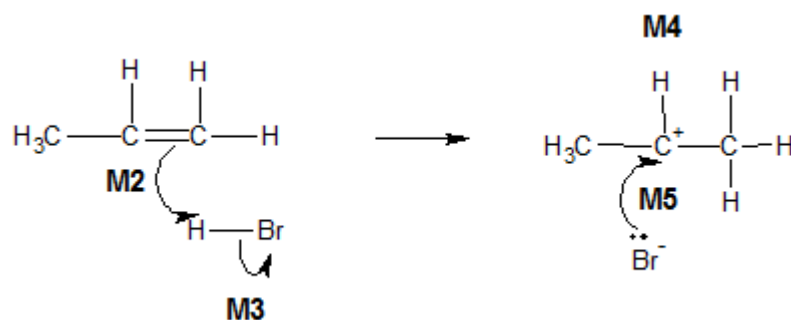
[10]

Q10.

(a) **M1 electrophilic addition**

For M1, both words required

Accept phonetic spelling



For the mechanism

M2 Ignore partial negative charge on the double bond

M2 must show an arrow from the double bond towards the H atom of the H-Br molecule

M3 Penalise partial charges on H-Br bond if wrong way and penalise formal charges

M3 must show the breaking of the H-Br bond

Penalise once only in any part of the mechanism for a line and two dots to show a bond

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom

Maximum any 3 of 4 marks for the mechanism for wrong (organic) reactant OR wrong organic product (if shown) OR primary carbocation

Accept the correct use of sticks

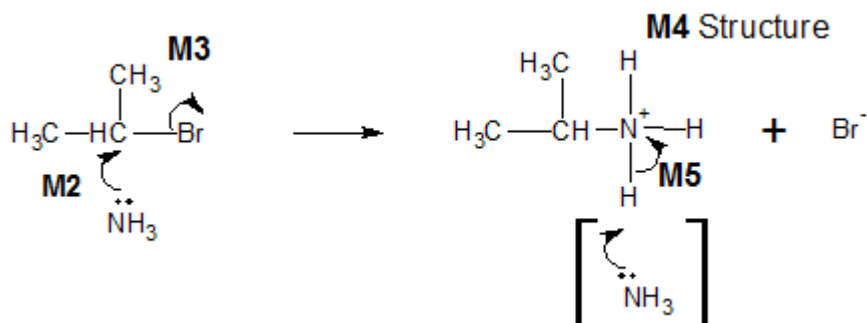
NB These are double-headed arrows

5

(b) **M1 Nucleophilic substitution**

For M1, both words required

Accept phonetic spelling



For the mechanism

Penalise M2 if NH₃ is negatively charged

M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom

Penalise M3 for formal charge on C of the C–Br or incorrect partial charges on C–Br

Penalise M3 for an additional arrow from the Br to something else

M3 must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from their original molecule

The second mole of ammonia is not essential for M5; therefore ignore any species here

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on / or close to, the N atom

Penalise once only for a line and two dots to show a bond

M5 is for an arrow from the N–H bond to the N atom

Maximum any 3 of 4 marks for the mechanism for wrong organic reactant **OR** wrong organic product if shown

Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

Accept the correct use of “sticks”

NB These are double-headed arrows

5

- (c) M1 (addition) polymerisation OR poly-addition

Ignore “additional”

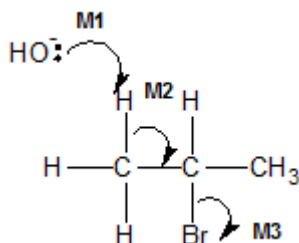
Credit polyprop-1-ene and polypropylene

M2 poly(propene) / polypropene

Penalise “condensation polymerisation”

2

- (d)



Penalise **M1** if covalent KOH

M1 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

Penalise **M3** for formal charge on C of C-Br or incorrect partial charges on C-Br.

M2 must show an arrow from a correct C-H bond adjacent to the C-Br bond to the appropriate C-C bond. Only award if an arrow is shown attacking the H atom of a correct C-H bond in **M1**

Ignore other partial charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond

M3 is independent provided it is from their original molecule, but **CE=0** if nucleophilic substitution

Maximum any 2 of 3 marks for wrong organic reactant

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

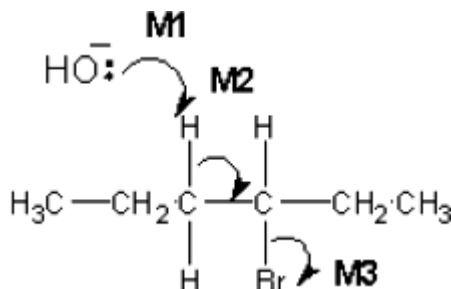
NB These are double-headed arrows

3

[15]

Q11.

(a) (i)



Penalise one mark from their total if half-headed arrows are used

Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br

Ignore other partial charges

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

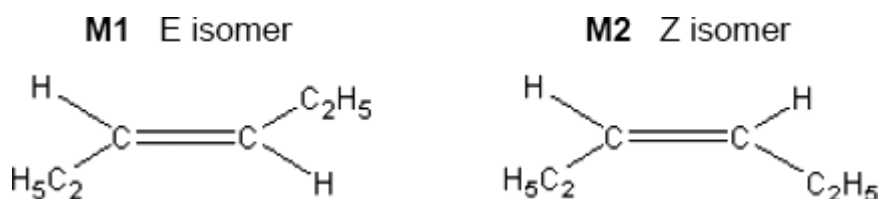
M2 must show an arrow from the correct C–H bond to the correct C–C bond. Only award if an arrow is shown attacking the H atom of the correct C–H bond in **M1**

M3 is independent but **CE=0** if nucleophilic substitution

N.B these are double-headed arrows

3

(ii)



Award 1 mark if both correct stereoisomers but in the wrong places

Accept no other alkenes.

Be reasonably lenient on the bonds to ethyl (or to CH₂CH₃) since the question is about E and Z positions but penalise once only if connection is clearly to the CH₃ of CH₂CH₃

Accept linear structures

2

(iii) **M1** (Compounds / molecules with) the same structural formula
*Penalise **M1** if “same structure”*

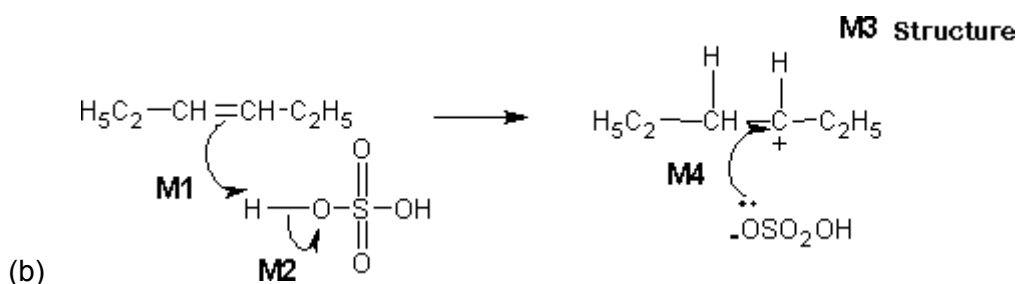
M2 with atoms/bonds/groups arranged differently in space
Ignore references to “same molecular formula” or “same empirical formula” or any reference to “displayed formula”

OR

atoms/bonds/groups that have different spatial arrangements / different orientation.

Mark independently

2



M1 must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H₂SO₄

M1 could be to an H⁺ ion and **M2** an independent O – H bond break on a compound with molecular formula for H₂SO₄

M1 Ignore partial negative charge on the double bond.

M2 must show the breaking of the O – H bond.

M2 Penalise partial charges on O – H bond if wrong way and penalise formal charges

In M2 do not penalise incorrect structures for H_2SO_4

M3 is for the structure of the carbocation.

M4 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards a correct (positively charged) carbon atom.

M4 NOT HSO_4^-

For **M4**, credit as shown or $^-\text{OSO}_3\text{H}$ ONLY with the negative charge anywhere on this ion

OR correctly drawn out with the negative charge placed correctly on oxygen

Penalise once only in any part of the mechanism for a line and two dots to show a bond

NB The arrows here are double-headed

Max 3 of any 4 marks for wrong organic reactant or wrong organic product (if shown)

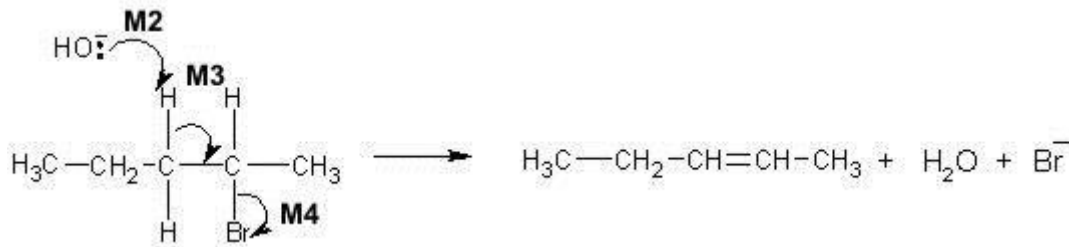
Accept the correct use of “sticks”

4

[11]

Q12.

(a) (i) **M1** Elimination



M2 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

M3 must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond.
Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H

M4 is independent provided it is from their original molecule

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

N.B. These are double-headed arrows

For M1, accept “Base elimination” but no other prefix.

Penalise **M2** if covalent KOH

Penalise **M4** for formal charge on C of C-Br or incorrect

partial charges on C-Br

Ignore other partial charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

Max any 2 of 3 marks for the mechanism for wrong reactant (or wrong product if shown).

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

4

(ii) **Structure for pent-1-ene**

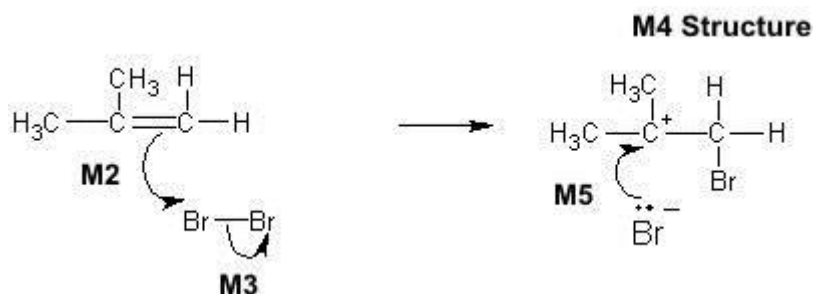


Penalise C_3H_7

Accept correct "sticks"

1

(b) **M1 Electrophilic addition**



M2 must show an arrow from the double bond towards the Br atom of the Br-Br molecule

M3 must show the breaking of the Br-Br bond.

M4 is for the structure of the tertiary carbocation with Br on the correct carbon atom.

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom.

N.B. These are double-headed arrows

For M1, both words required.

For the mechanism

M2 Ignore partial negative charge on the double bond.

M3 Penalise partial charges on Br-Br bond if wrong way and penalise formal charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond

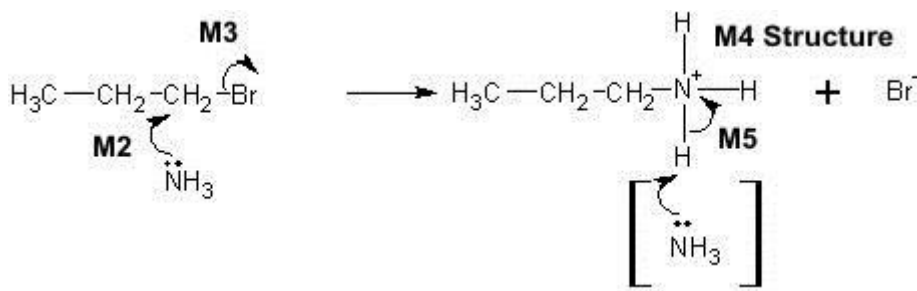
Max any 3 of 4 marks for the mechanism for wrong organic reactant or wrong organic product (if shown) or primary carbocation.

If HBr is used, max 2 marks for their mechanism

Accept the correct use of "sticks"

5

(c) **M1 Nucleophilic substitution**



M2 must show an arrow from the lone pair of electrons on the nitrogen atom of an ammonia molecule to the C atom.

M3 must show the movement of a pair of electrons from the C-Br bond to the Br atom. **M3** is independent provided it is from their original molecule

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge must be shown on/or close to, the N atom.

M5 is for an arrow from the N-H bond to the N atom.

Award full marks for an S_N1 mechanism in which M2 is the attack of the ammonia on the intermediate carbocation.

N.B. These are double-headed arrows

*For **M1**, both words required.*

*Penalise **M2** if NH₃ is negatively charged.*

*Penalise **M3** for formal charge on C or incorrect partial charges*

The second mole of ammonia is not essential for M5; therefore ignore any species here.

Penalise once only for a line and two dots to show a bond.

*Max any 3 of 4 marks **for the mechanism** for wrong organic reactant (or wrong organic product if shown)*

Accept the correct use of "sticks"

5

[15]

Q13.

- (a) (i) Electron pair donor

OR

Species which uses a pair of electrons to form a co-ordinate/covalent bond.

Credit "lone pair" as alternative wording

Credit "electron pair donator"

1

- (ii) Replacement of the halogen (atom) (by the nucleophile)

OR

The carbon-halogen bond/C-X breaks and a bond forms

with the nucleophile or between the carbon and the nucleophile
They must describe the idea of substitution in a haloalkane.
Accept the idea that a nucleophile replaces the halogen which becomes a halide ion
Penalise reference to "halogen molecule" and penalise the idea that the haloalkane contains a halide

1

(iii) Splitting molecules using/by water

OR

breaking/splitting/dissociating (C₁VX) bond(s)/using/by water
NOT simply the reaction with water or simply the addition of water.
Ignore "compound"

1

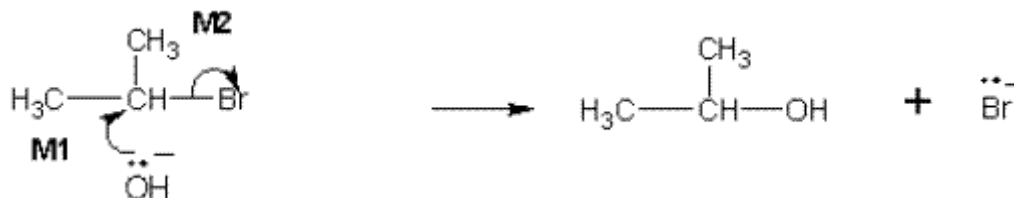
(iv) (Heat) energy/enthalpy required/needed/absorbed (at constant pressure) to break/split it/the (carbon-halogen) bond

OR

(Heat) energy/enthalpy required/needed/absorbed (at constant pressure) for homolysis of the (C–X/the carbon-halogen) bond
Ignore bond formation
Ignore "average"

1

(b)



M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

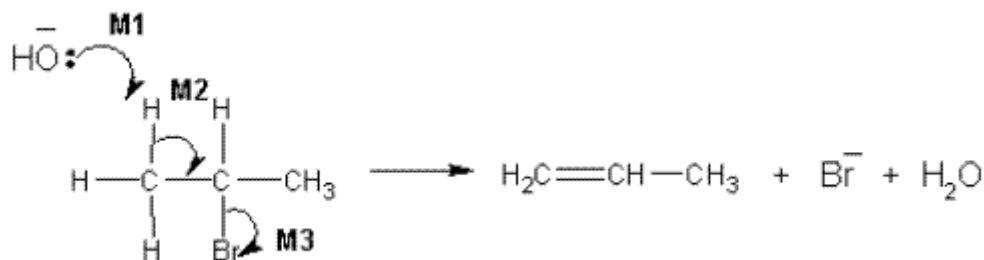
Penalise once only for a line and two dots to show a bond.

Max 1 mark for the wrong reactant

Accept the correct use of "sticks"

2

(c) (i)



- M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom
- M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1
- M3** is independent provided it is from the original molecule

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks for wrong reactant

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

3

- (ii) **M1** Stated that the spectrum has an absorption/absorbance/ peak in the range 1620 cm⁻¹ to 1680 (cm⁻¹) or specified correctly in this range from the spectrum
- M2** depends on correct range or wavenumber being specified
- M2** (Infrared absorption) due to C=C OR carbon-carbon double bond
QoL for correct M1 statement which includes both the word absorption (or alternative) and the correct range or wavenumber
Allow "peak" OR "dip" OR "spike" OR "trough"
OR "low transmittance" as alternatives for absorption.
For M2 it is not sufficient simply to state that an alkene has C=C
M2 could be on the spectrum
Ignore reference to other absorptions

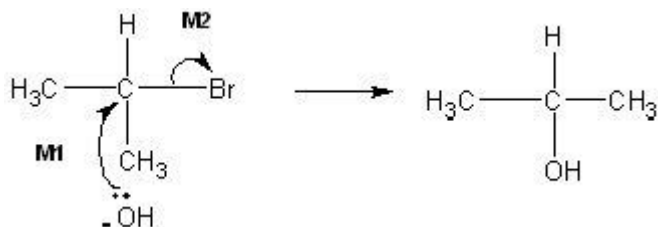
2

[11]

Q14.

- (a) (i) Nucleophilic substitution

1



2

M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks"*

Ignore product

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

(iii) Polar C—Br **OR** polar carbon–bromine bond **OR** dipole on C—Br
OR δ^+ (δ^-)
 C atom of carbon–bromine bond is δ^+ /electron deficient **OR** C—Br

(Credit carbon–halogen bond as an alternative to carbon–bromine bond)

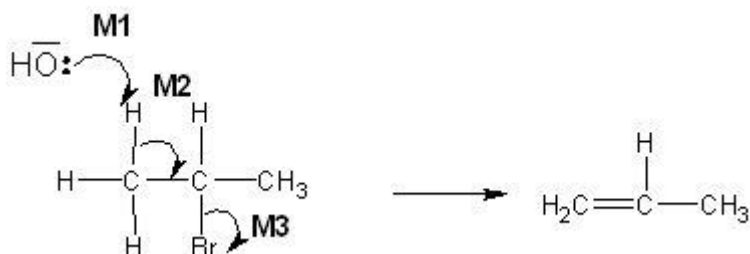
*It must be clear that the discussion is about the carbon atom of the C—Br bond. NOT just reference to a polar molecule.
 Ignore X for halogen*

1

(b) Elimination

*Credit "base elimination" but NOT "nucleophilic elimination"
 No other prefix.*

1



3

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

M2 must show an arrow from the correct C-H bond to the C-C bond

and should only be awarded if an attempt has been made at M1
M3 is independent.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks **for the mechanism** for wrong reactant and/or "sticks"

Ignore product

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

(c) Any one condition from this list to favour elimination;

Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide **OR** concentrated KOH/hydroxide
Ignore "aqueous"
- high temperature or hot or heat under reflux or $T = 78$ to 100°C
Ignore "excess"

1

(d) (i) Addition (polymerisation) ONLY

Penalise "additional"

1

(ii) But-2-ene ONLY (hyphens not essential)

Ignore references to *cis* and *trans* or *E/Z*

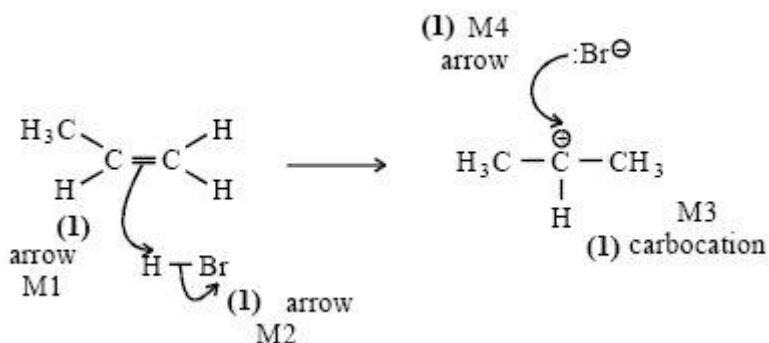
Ignore butane

1

[12]

Q15.

(a) (i)



If wrong carbocation, lose structure mark
If wrong alkene, lose structure mark

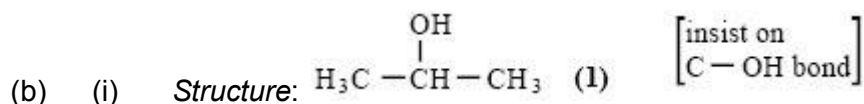
Can still score $\frac{3}{4}$ i.e. penalise M3
 Penalise M2 if polarity included incorrectly
 no bond between H and Br
 bond is shown as $\overset{\cdot}{\text{H}}-\overset{\cdot}{\text{Br}}$ or $\overset{\cdot}{\text{H}}-\overset{\cdot}{\text{Br}}$

4

- (ii) $\oplus$
 $\text{CH}_3\text{CH}_2\text{CH}_2$
 credit secondary carbocation here if primary carbocation has been used in (i)

Ignore attack on this carbocation by $\ddot{\text{Br}}^\ominus$

1



1

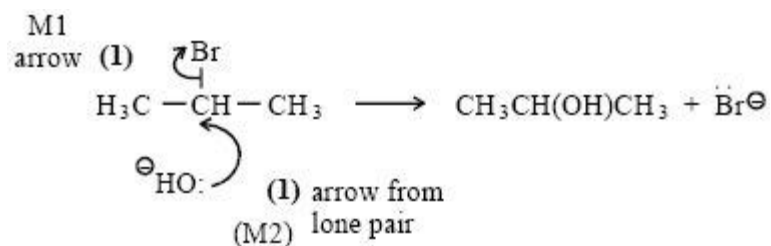
Name: propan-2-ol
 Not 2-hydroxypropane

1

- (ii) Name of mechanism: nucleophilic substitution (both words)
 (NOT $\text{S}_{\text{N}}1$ or $\text{S}_{\text{N}}2$)

1

Mechanism:



penalise incorrect polarity on C-Br (M1)
 Credit the arrows even if incorrect haloalkane
 If $\text{S}_{\text{N}}1$, both marks possible

2

- (c) (i) elimination

1

- (ii) base
 OR proton acceptor
 NOT nucleophile

1

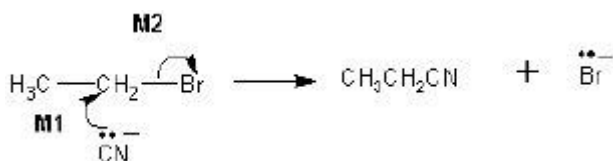
[12]

Q16.

- (a) Electron pair donor
OR
 Species which uses a pair of electrons
 to form a co-ordinate / covalent bond.

QoL

(b)



M1 Must show an arrow from the lone pair of electrons on the carbon atom of the negatively charged cyanide ion to the central C atom.

M2 Must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the cyanide ion on the intermediate carbocation.

Penalise M1 if covalent KCN is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 1 mark for the wrong reactant or "sticks"

2

(c) Ethylamine / $\text{CH}_3\text{CH}_2\text{NH}_2$ is a nucleophile

OR

Ethylamine could react further

OR

Ethylamine could make secondary / tertiary amines

OR

To make reaction with ammonia more likely

OR

To minimise further substitution

OR

The idea of releasing free amine from the salt

OR

The idea of removing a proton from the intermediate alkylammonium ion

OR

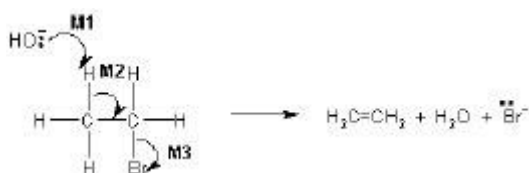
The idea that ammonia acts both initially as a nucleophile and then as a base

Do not credit a simple reference to the equation or the mechanism requiring two moles of ammonia.

1

(d) **Elimination**

Credit "base elimination" but NOT "nucleophilic elimination"
No other prefix.



- M1** Must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom
- M2** Must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1
- M3** Is independent.

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks **for the mechanism** for wrong reactant or "sticks"

3

[8]

Q17.

A

[1]

Q18.

- (a) (base) elimination

(penalise other words before 'elimination' e.g. nucleophilic)

1

M1: curly arrow from lone pair of electrons on oxygen of hydroxide ion
(insist on a lone pair of electrons on the oxygen atom and a negative charge, but only credit this mark if the attack is to a correct H atom)

1

M2: curly arrow from the middle of the C-H bond to the middle of the C-C bond

1

(only credit this mark if the arrow originates from the correct C-H bond and if an attempt has been made at M1)

M3: curly arrow from the middle of the C-Br bond towards/alongside the Br atom

(credit M3 independently unless the bond breaking is contradicted by an additional arrow)

(penalise curly arrow if the C-Br has a formal positive charge)

(credit full marks for an E1 mechanism, with M2 awarded for a correct curly arrow on the correct carbocation)

(award a maximum of two marks for either an incorrect

haloalkane or an incorrect organic product)
(maximum 2 marks for use of 'sticks' for the haloalkane, unless RE from 2(b), when credit can be given)

- (b) (i) **M1:** compounds with the same structural formula 1
- M2:** but the bonds/groups/atoms have different spatial arrangements or orientation or configuration/are arranged differently in space/3D
(ignore reference to the same molecular formula for M1) 1
- (ii) **M1:** correct structural representation for cis-but-2-ene and its name or its identification as the cis isomer 1
- M2:** correct structural representation for trans-but-2-ene and its name or its identification as the trans isomer
(accept representations which are 90° to linear)
(award one mark for two correct structures but either wrong/no names)
(maximum 1 mark for an incorrect alkene) 1
- (iii) geometric(al) or cis-trans 1
- (c) nucleophile or electron pair donor
(penalise 'base') 1
- (d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$
(M1 correct product)
(M2 balanced equation using 2NH_3 and leading to NH_4Br)
(penalise M1 for use of $\text{C}_4\text{H}_9\text{NH}_2$ or for incorrect haloalkane, but allow consequent correct balancing of equation with 2 moles of ammonia) 2
- (1-)butylamine
(credit 1-aminobutane and butyl-1-amine)
(award QoL mark for correct spelling) 1

[13]

Q19.

- (a) 2-bromobutane; 1
- (b) Elimination;
(penalise "nucleophilic" OR "electrophilic" before the word "elimination") 1

M1: curly arrow from lone pair on oxygen of hydroxide ion to H atom on correct C-H adjacent to C-Br;

(penalise M1 if KOH shown as covalent with an arrow breaking the bond)

1

M2: curly arrow from single bond of adjacent C-H to adjacent single bond C-C;

(only credit M2 if M1 is being attempted to correct H atom)

1

M3: curly arrow from C-Br bond to side of Br atom;

(credit M3 independently unless arrows contradict)

(Credit possible repeat error from 2(c)(iii) for M3)

(If the wrong haloalkane is used OR but-1-ene is produced, award MAX. 2 marks for the mechanism)

(If E1 mechanism is used, give full credit in which M1 and M2 are for correct curly arrows on the correct carbocation)

- (c) (i) (structural) isomers/hydrocarbons/compounds/they have the same molecular formula, but different structural formulas/different structures; 1

(penalise statements which are not expressed in good

English and which do not refer clearly to structural isomers i.e. plural)

(penalise statements which refer to "different (spatial) arrangements")

(credit "different displayed formulas")

(Q of L mark)

- (ii) Correct structure for but-1-ene;

1

[7]

Q20.

- (a) M1 curly arrow from lone pair on oxygen of hydroxide ion to H atom on C-H adjacent to C-Br

1

M2 curly arrow from single bond of adjacent C-H to adjacent single bond C-C

(only credit M2 if M1 is being attempted to correct H atom)

1

M3 curly arrow from C-Br bond to side of Br atom

(credit M3 independently)

1

- (b) M1 credit a correct structure for either geometrical E-Z isomer and its designation as either *cis* or *trans*.
OR credit two correct geometrical E-Z isomer structures (ignore the names)
OR credit two correct names for *cis* pent-2-ene and *trans* pent-2-ene (ignore the structures)

1

M2 credit a second mark if all four parts of the required structures and

names are correct.

(credit "linear" structures)

(insist on the alkyl groups being attached clearly by C-C bonds)

1

- (c) (i) M1 curly arrow from middle of C = C bond to H atom on H-Br
(penalise M1 if partial negative charge or formal positive charge on H)
(penalise M1 if pent-2-ene is used)

1

M2 curly arrow from H-Br bond to side of Br atom

1

M3 correct structure for correct secondary carbocation

1

M4 curly arrow from lone pair on bromide ion to the positive carbon of carbocation, ensuring that bromide ion has a negative charge.

(with the exception of pent-2-ene, if the wrong alkene is used, only penalise the structure M3)

(penalise the use of two dots in addition to a covalent bond, once only)

1

- (ii) 1-bromopentane

1

- (iii) M1 2-bromopentane is formed *via* the secondary (or 2°) carbocation

1

OR 1-bromopentane is formed *via* the primary (or 1°) carbocation

M2 a secondary carbocation is more stable than a primary carbocation -

award this mark only if the quality of language justifies the award.

(the argument must involve clear statements about carbocations)

1

[12]

Q21.

A

[1]

Q22.

B

[1]

Q23.

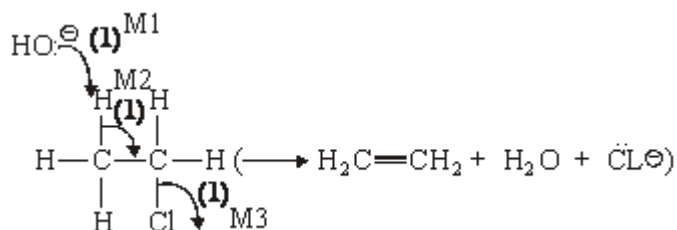
- (a) Reaction 2: NaOH OR KOH (1) M1 alcohol (ic) OR ethanol (ic)(1) M2
 ignore heat
 Condition mark linked to correct reagent but award M2 if OH- or base or alkali mentioned

Reaction 3: concentrated H₂SO₄ OR H₃PO₄ M1 (1) heat (1) M2
 OR 150°C - 200°C

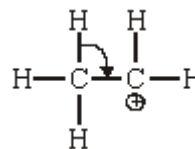
Condition mark linked to correct reagent but award M2 if H₂SO₄ or H₃PO₄, but not concentrated
 Penalise reagent and condition if dilute H₂SO₄ / H₃PO₄

4

- (b) Mechanism:



Award M3 (C-Cl) independently
 M1 and M2 must be to / from correct places



E1 mechanism possible in which M2

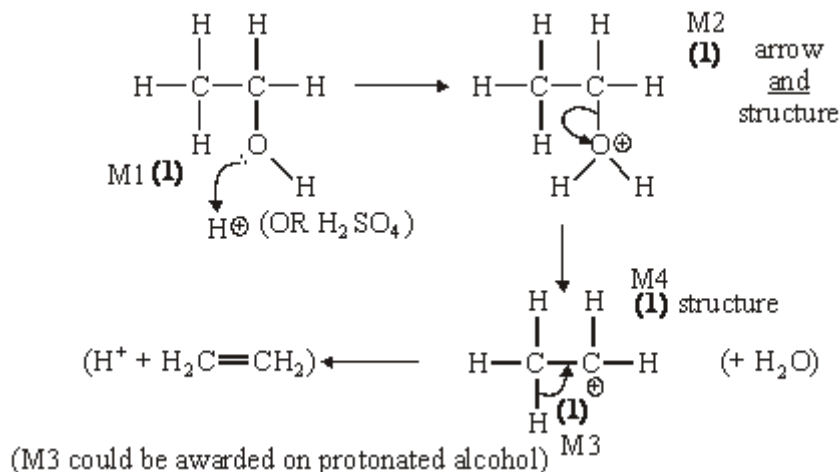
Name: of mechanism = elimination (1)
 NOT dehydrohalogenation
 Ignore "base" OR "nucleophilic" before elimination

Reason: Reaction 2 has (very) low yield (1)

5

QoL OR chloroethane has to be made (from ethane)
 OR chloroethane is expensive
 OR chloroethane is not readily available

- (c) Mechanism:



Name of mechanism = elimination (1)

NOT dehydration alone

Reason: Ethanol could come from (fermentation of) renewable

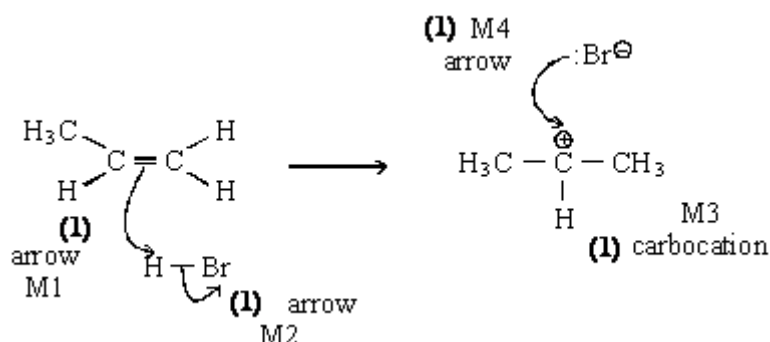
QoL sugars / glucose / carbohydrates / sources (1)

6

[15]

Q24.

(a) (i)



If wrong carbocation, lose structure mark

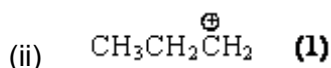
If wrong alkene, lose structure mark

Can still score $\frac{3}{4}$ i.e. penalise M3

Penalise M2 if polarity included incorrectly

no bond between H and Br

bond is shown as $\text{---}\div\text{---}$ or $\text{---}\text{---}$

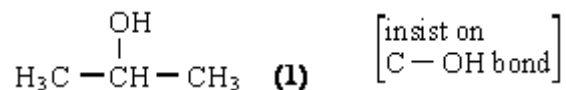


credit secondary carbocation here if primary carbocation has been used in (i)

Ignore attack on this carbocation by Br^-

5

(b) (i) *Structure:*

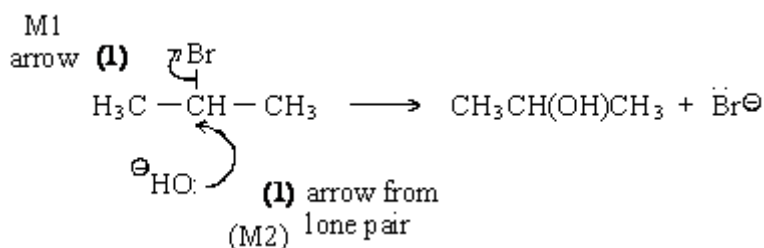


No credit for propan-1-ol even when named correctly
Credit propane-2-ol

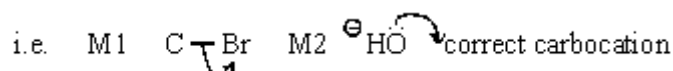
Name: propan-2-ol (1)
 Not 2-hydroxypropane

- (ii) Name of mechanism: nucleophilic substitution (1) (both words)
 (NOT S_N1 or S_N2)

Mechanism:



penalise incorrect polarity on C-Br (M1)
Credit the arrows even if incorrect haloalkane
If S_N1, both marks possible



5

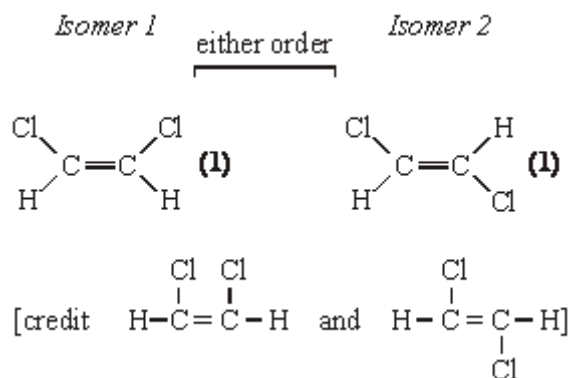
- (c) (i) elimination (1)
Ignore nucleophilic elimination
Penalise electrophilic elimination
- (ii) base (1)
OR proton acceptor
NOT nucleophile (base)

2

[12]

Q25.

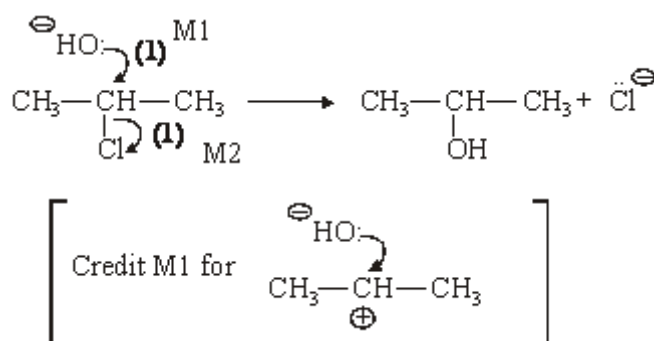
- (a) (i)



(ii) restricted rotation OR no rotation OR cannot rotate (1)

3

(b) (i) *Mechanism:*



M1 and M2 independent

Curly arrows must be from a bond or a lone pair

Do not penalise sticks

Penalise M1 if $\text{Na}-\text{OH}$ precedes (penalise this once)

Penalise incorrect $\delta+$ $\delta-$ for M2

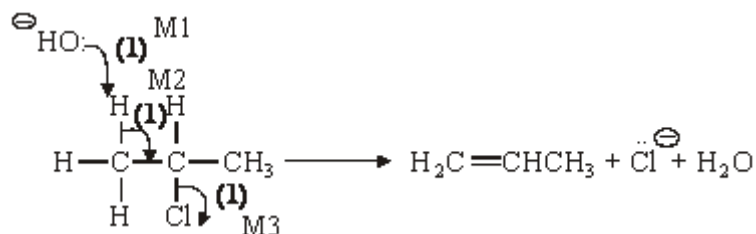
Penalise + on C atom for M2

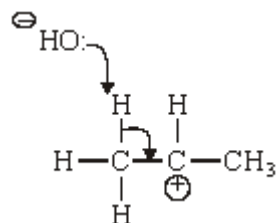
Only allow M1 for incorrect haloalkane

Role of the hydroxide ion: nucleophile (1)
electron pair donor
lone pair donor

NOT nucleophilic substitution

(ii) *Mechanism:*





Only allow M1 and M2 for incorrect haloalkane unless RE on (i)

+ charge on H on molecule, penalise M1

M3 independent

M2 must be to correct C–C

M1 must be correct H atom

Credit M1 and M2 via carbocation mechanism

No marks after any attack of C[⊕] by OH[−]

Role of the hydroxide ion: base (1)

proton acceptor

accepts H⁺

7

[10]

Q26.

- (a) Identity of X; 2-methylpropene (1)

Absorption at 1650 cm^{−1} indicates an alkene present (1)

OR a chemical answer e.g. Br₂ (aq) brown to colourless

2

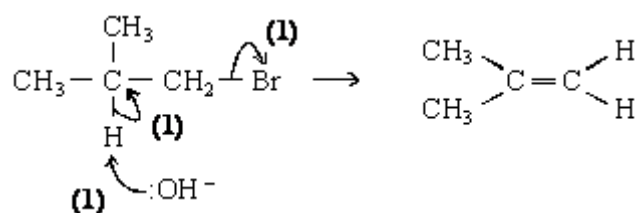
- (b) Reagents

Step 1 KOH (allow NaOH) (1) alcoholic (1) warm (1)

Only allow solvent and warm if reagent correct

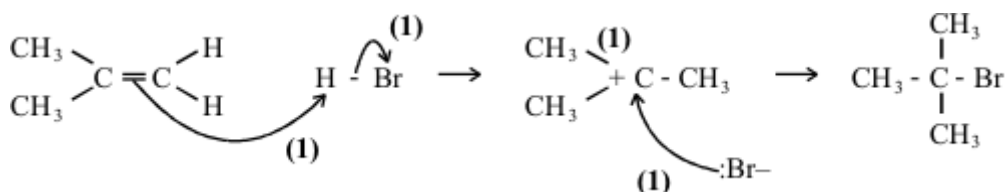
Step 2 HBr (1)

Mechanism: A → X



Or a carbocation mechanism

Mechanism X → B



11

- (c) A gives three peaks (1)

B gives one peak (1)

Allow one for "A has more peaks than B" when no number of peaks is given

2

[15]

Q27.

C

[1]

Q28.

- (a) Alcohol: Reaction = Substitution (/ hydrolysis) (1)

Ignore reference to nucleophilic, but electrophilic give zero

Alcohol: Role = nucleophile (/ lone pair donor) (1)

Alkene: reaction = elimination (1)

Ignore ref to nucleophilic or electrophilic

Alkene: base (/ proton acceptor) (1)

If no indication of order in (a) assume as in question.

If order is wrong can still score 'role' mark.

4

- (b) Alcohol: Role = butan-2-ol (1)

Not 2-hydroxybutane or but-2-ol

Appropriate structure for $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ (1)

Brackets not essential

$\text{S}_{\text{N}}2$ version

$\text{S}_{\text{N}}1$ version

$\delta^+ \quad \delta^-$
 $\text{C}-\text{Br}$ bond is polar

$\text{C}-\text{Br}$ bond is polar (1)

Lone pair of OH^-

$\text{C}-\text{Br}$ bond breaks (1)

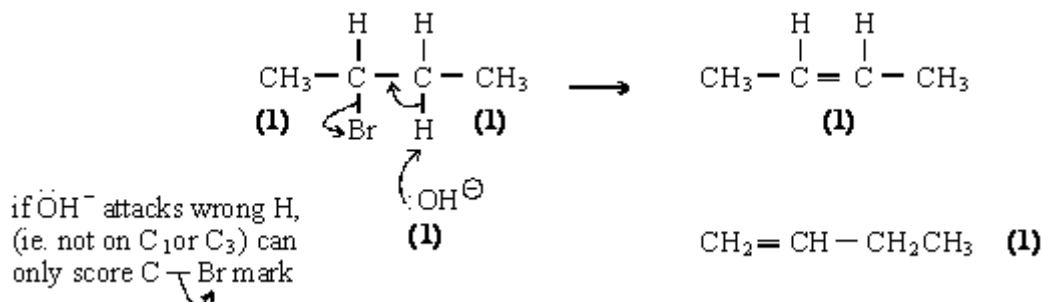
Attacks the $\text{C}^{\delta+}$

forming carbocation / carbonium ion (1)

M1 can be scored from a diagram, M2 and M3 from written explanation only

5

- (c)



If but-2-ene not given here it may be obtained from cis / trans

isomer

H lost from different carbon atoms (1)

H removes from C¹ and C³ to give two isomers (1)

Draws clear Cis and trans isomers for but-2-ene

Can score these marks from a diagram



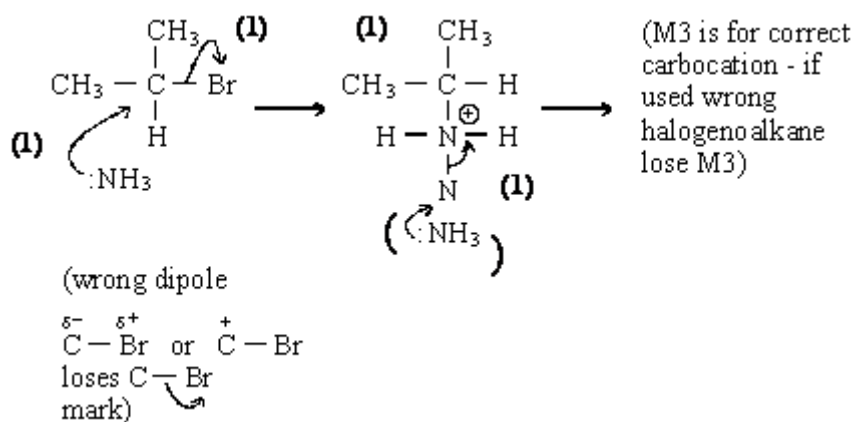
8

[17]

Q29.

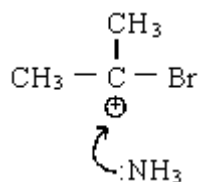
(a) Name of mechanism: nucleophilic substitution (1)

Mechanism:



Marks S_N1 using same points

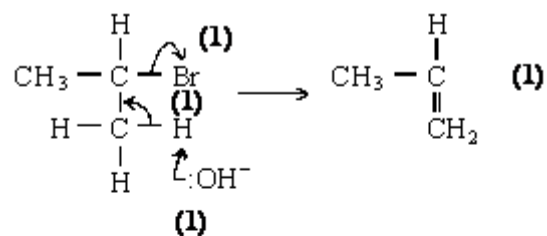
∴ M2 requires



5

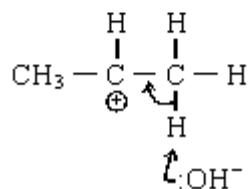
(b) Role of potassium hydroxide: Base (1)

Mechanism:



Mark E1 using same points

∴ M2/M3



5

[10]

Examiner reports

Q1.

- (a) Most students (56.1%) could name compound **A** correctly.
- (b) This question proved to be demanding. The calculation of the M_r of individual molecules containing different isotopes was a challenge for many students. 61.8% of students either failed to score or made no attempt; 33.4% did, however, score both marks.
- (c) The nucleophilic substitution mechanism was well-answered; 45.6% of students scored full marks here.
- (d) The elimination mechanism was more challenging, and many students did not know the role of the hydroxide ion. This question discriminated particularly well.
- (e) Just under half of students could determine that the IR spectrum was of an alkene rather than an alcohol and explain this by reference to the absorption for a bond and its wavenumber range.
- (f) Students struggled to explain the relative rates of reaction of the halogenoalkanes. The most common answer incorrectly referred to the reactivity of the elements bromine and chlorine, rather than looking at the C-Br and C-Cl bond strengths. Only 28.6% of students gained this mark.

Q2.

- (a) Although most students identified compound **J** as propan-1-ol, a surprising number failed to show the O-H bond as is necessary in a displayed formula.
- (b) Most students could name the mechanism, but the condition proved more difficult.
- (c) This calculation was done well and 56% of students scored full marks. The main errors were in working out or using the correct M_r values.
- (d) Only 30% of students scored both marks here. Others drew a primary amine or a non-skeletal structure.
- (e) Both the reagent (which must be a complete compound) and a condition were needed to score the mark; several omitted the condition.
- (f) This was a high scoring question for many. For others, the main errors were missing the negative sign or the lone pair on the hydroxide ion, or showing attack on the wrong hydrogen atom.

Q7.

The lack of structure in part (a) caused problems for some students and they needed to be clearer in some cases whether they were referring to reaction 1 or reaction 2. The mechanism was generally done well although showing attack by OH⁻ at the wrong C-H lost some marks. In part (b) very few students appreciated the need for two different groups on each C of the C=C in addition to the lack of free rotation.

In part (c) it was expected that an experiment based on a 'disappearing cross' approach would be familiar to most students as would the general idea of a 'fair test'. There were,

however, many elaborate and often unworkable methods suggested. There was also too much emphasis on things such as 'the same person observing' or 'the same stopwatch being used' instead of making suggestions to ensure that the only variable was the identity of the chloroalkane and that other conditions should be kept constant such as temperature, volumes of solutions and concentration of silver nitrate solution.

Q8.

Part (a) was answered quite well. The naming of P and Q was a challenge for some with a demand both for correct spelling and correct use of the alphabet for functional groups and this led to only 48% scoring both marks. This question included two curly arrow mechanisms and these questions always result in the best discrimination of student performance. Part (b) and part (c) provided an excellent distribution across the full range of marks with the usual errors seen, such as an incorrect carbocation in part (b), a negative charge on ammonia in part (c) and, in both parts, a failure to use either a lone pair of electrons or a bond as the origin of a pair of electrons. It was essential in part (d) to identify a reagent, in order to be able to access the reaction condition mark and some excellent responses were seen. It is worth reminding students that as a general guide, a reagent is something that you get out of a bottle; for example, sodium hydroxide and not hydroxide ion. Part (e) also discriminated well with most students able to write the equation and then to identify sulfur dioxide as one of the toxic gases.

Q9.

Mechanisms continue to discriminate well and over two-thirds of all students scored at least two marks in part (a)(i). Two displayed formulas were required in this question in parts (a)(ii) and (b)(i) and 37% and 25%, respectively, scored the mark in each part. Part (b)(ii) was relatively demanding, whereas the remainder of part (b) was very high-scoring.

Q10.

Organic reaction mechanisms discriminate well. Schools and colleges still need to heed the advice that full marks will only be awarded in a mechanism such as that in part (b) if the positive charge on the intermediate alkylammonium ion is placed on the N atom and not on or adjacent to a hydrogen atom. Over 80% scored at least 3 marks on both parts (a) and (b). A surprising number of students were unable to name substance X correctly in part (c).

Q11.

Providing the students with the basic information for the elimination reaction in part (a)(i) enabled most students to score at least one mark and more than half scored full marks. Structures of *E* and *Z* isomers were generally well understood and many students could score at least one mark in their answers to the meaning of the term *stereoisomers*.

The mechanism in part (b) is demanding and discriminated very well

Q12.

Putting three mechanisms together proved to be very discriminating. Weaker candidates were able to score some marks and the best candidates scored all 15. There is always a concern that in these longer Section B questions, candidates might forget to record the name of a mechanism and there was some evidence of that happening here. Partial credit was given in part (a)(i) for a mechanism that used an incorrect starting or finishing compound with much of the focus concentrated on the curly arrows. This guiding principle was applied to good effect in parts (b) and (c). In part (c), centres need to appreciate that

full marks will only be awarded in a mechanism of this type if the positive charge on the intermediate is placed on the N atom and not on or adjacent to a hydrogen atom.

Q13.

It was surprising to see that the term “nucleophile” was still not well known when all that was required was “an electron pair donor”. Part (a)(ii) was well answered but part (a)(iii) was answered surprisingly poorly given that a similar question was included on the paper in June 2010. The remainder of this question was well answered by most candidates.

Q14.

Candidates are able to tackle organic reaction mechanisms with confidence and this question was well answered. The most demanding part was part (a)(iii) in which they had to indicate that the carbon-bromine bond was polar.

Q16.

While some very good answers were seen for all parts of this question, the general impression was that some candidates found this question demanding. Relatively few candidates were able to state correctly the meaning of the term *nucleophile*, but almost 70% could gain at least half of the marks in the nucleophilic substitution mechanism in part (b). Part (c) was recognised by examiners to be a difficult question and only a minority of candidates were successful. Part (d) discriminated very well with the full range of marks seen and more than half the candidates were able to score at least half of the marks.

Q18.

The name of the mechanism in part (a) was usually known, although some candidates lost the mark by writing words such as “nucleophilic” or “electrophilic” in front of the correct name, elimination. Most candidates gained at least one mark from the mechanism and a great many well-presented correct answers were seen. Candidates who chose an incorrect haloalkane were still able to score two out of the three marks. In part (b), correct definitions of stereoisomers were seen, but the idea of these isomers having the same structural formula, but different spatial arrangements of atoms or groups was not well understood by many candidates. Drawing and naming the two geometric isomers of but-2-ene caused few problems for the majority of candidates and the role of hydroxide ions in part (c) was well known. In part (d), to gain full credit it was necessary to draw and name butylamine correctly and to balance the equation with two moles of ammonia leading to the formation of ammonium bromide.

Q19.

This question was often relatively high scoring despite having a mechanism which has caused problems on previous papers. Part (a) was usually well answered, although it was a surprise to see “bromine” as an answer on several scripts. The name of the mechanism in part (b) was often well known, although some candidates incorrectly prefaced the word “elimination” with electrophilic or nucleophilic. The mechanism itself usually yielded at least one mark from C-Br bond breakage and some complete and very well presented answers were seen. In part (c), many candidates struggled to state that *structural isomers* have the same molecular formula, but different structural formulae and the mark was often lost from one or the other part of this statement. Problems arose, because candidates appeared to confuse the idea with stereoisomers and referred to different (spatial) arrangements of atoms or groups. This latter point was compounded by some candidates drawing *cis* and/or *trans* isomers of but-2-ene in part (c)(ii), while others chose to draw

methylpropene. Even those who knew that the answer was but-1-ene, too often failed to complete their structure correctly.

Q20.

Part (a) of this question took a familiar mechanism but presented it in a format different from previous papers. Candidates have had problems in the past with this mechanism, usually to do with drawing the organic compound or failing to use a lone pair of electrons on the hydroxide ion. It was decided to try to help candidates by drawing the organic structure and presenting the hydroxide ion in a position appropriate for a reaction to occur. There is no doubt that a larger proportion of the entry than hitherto were able to have a go at this mechanism as a consequence of this strategy. Regrettably, there was some evidence that a small minority of candidates appear to have missed this part of the question completely and left it blank.

In part (b), rather too many poor responses were seen and there was evidence to suggest that the idea of geometrical isomerism was not as well known as had been expected. Part (c)(i) was generally well answered with clear structures and mechanisms. Few candidates had problems with part (c)(ii) and the answers to part (c)(iii) were often well expressed. Candidates should be discouraged from using arguments which involve the Markownikoff rule and in their discussion of carbocations, they should be encouraged to make a clear link between the product formed and each of the possible intermediates.

Q23.

Overall, this question discriminated well and allowed the more able candidates to show what they knew and understood and answers with full marks to one, two or all three parts of the question were seen. The weakest candidates had difficulty scoring more than a few marks. In part (a) there was confusion by some candidates between Reaction 2 and Reaction 3 and even when these candidates were able to discriminate between these two elimination reactions, the reagent given was rarely correct. For Reaction 2, reference simply to hydroxide ions would not gain any credit and candidates need to be advised to identify a whole substance, such as potassium or sodium hydroxide, in this case, when asked for a reagent. Similarly in Reaction 3 it is necessary to use concentrated sulphuric acid for the reaction to work. In part (b), most candidates had a go at the mechanism and among those producing reasonable attempts, the main errors included a missing charge on the hydroxide ion or the failure either to include or to use a lone pair of electrons on oxygen. Many candidates thought that the reason for not using chloroethane was due either to the "toxicity of chlorine" or "the release of toxic hydrogen chloride into the atmosphere". Some candidates correctly recognised either that chloroethane would have to be manufactured first or that the yield of Reaction 2 would be very low. In part (c) the mechanism is described in the specification as an elimination and the word "dehydration" alone is an insufficient response. Many candidates gained some marks from the mechanism producing at least one correct intermediate, which was often the carbocation. The synchronous loss of a proton and water from the protonated alcohol resulted in the loss of one mark out of four for this mechanism. The relatively straightforward final mark in this question was not always scored because candidates failed to indicate that ethanol could be made from renewable sources, such as the fermentation of sugars.

Q24.

The poor use of curly arrows and the failure to use a lone pair of electrons on the bromide ion were common problems in the mechanism in part (a). The use of both a line and two dots to indicate a single covalent bond was penalised. Candidates who had the two carbocations the wrong way around were given credit in part (a)(ii), although this was seen less often than the candidates who failed to answer the question correctly and gave a structure for 1-bromopropane as the answer to (a)(ii), rather than a carbocation. Part (b)

was generally well answered, marks tending to be lost from a poorly presented structure with badly positioned bonds and from mechanisms with incorrect curly arrows or the absence of either a lone pair or the negative charge on the hydroxide ion or the inclusion of a formal positive charge on the carbon atom of the C-Br bond. A good deal of guesswork characterised some of the responses to part (c) with (c)(ii) causing the greater difficulty.

Q25.

Part (a) proved straightforward for most candidates, although some of the weakest did have problems in knowing which compounds they were trying to draw. While the most able found part (b) of this question relatively trivial and scored full marks, it is clear that mechanisms continue to be a challenge for the less able candidates. Almost all of the candidates attempted the questions and a large majority were able to score at least 3 of the 7 marks available in part (b). The usual difficulties associated with the position and direction of curly arrows and either incomplete hydroxide ions or attempts to use an apparently covalent sodium hydroxide resulted in the loss of marks. The mechanism in (b)(ii) is one of the more demanding parts of the specification and the weakest candidates struggled to score any marks here.

Q26.

Many candidates identified compound **X** correctly as 2-methylpropene and used the infra-red data to deduce the presence of the carbon-carbon double bond. Identifying the reagents and essential conditions for the conversion of **A** into **X** proved much more difficult. Some of the candidates who did give the correct reagent then failed to give the correct mechanism for the reaction. The conversion of **X** into **B** was rather better answered and most candidates gave the correct reagent, HBr, and a correct mechanism for this reaction. Part (c) was generally well answered. No statement of peak splitting was required and candidates who made errors when describing splitting patterns were not penalised.

Q28.

This question was often, but not universally, well done. The reaction types in part (a) were quite well known, although it was quite common for the first type to be described as 'nucleophilic substitution'. Some candidates having quoted this as the type then went on to give the role of potassium hydroxide as, for example, 'oxidising agent'. 'Nucleophilic substitution' earned the mark for the type of reaction but did not earn the mark for the role of potassium hydroxide. This mark was earned only by a specific reference to the role being that of a nucleophile. Many candidates recognised the formation of an alkene as being an elimination reaction but the role of potassium hydroxide as a base was less well known. Most candidates correctly deduced the name and structure of the product in part (b). Some candidates wasted time here by drawing the mechanism for the substitution reaction. The polarity of the C-Br bond was frequently shown or described but the attraction of the partial positive charge on the carbon atom for the hydroxide ion was less often seen. Better candidates described the attack of a lone pair from the hydroxide ion on the δ^+ carbon. Part (c) was well done by many candidates and high scores were common. The mechanism was generally well known and clear explanations for the formation of two structurally isomeric products were quite common. Successful candidates either tackled the explanation by showing an alternative mechanism or by identifying the possibility of proton removal at C¹ or at C³. Appropriate structures showing the cis/trans isomers of but-2-ene were very common. Errors in the position and direction of curly arrows were quite common and in some instances, the charge was omitted from the hydroxide ion. Some candidates, mainly those who outlined an E1 mechanism, incorrectly explained the formation of structural isomers in terms of the formation of different carbocations. Also, it

was not unusual to see a mechanism in which butan-2-ol was formed which then underwent dehydration.

Q29.

Overall, this question was quite well answered, with many candidates producing clear and accurately drawn mechanisms. There were, however, some quite common errors. In part (a), a fair number of candidates showed the NH_3 molecule carrying a negative charge. Also, the central carbon in 2-bromopropane was sometimes shown carrying a full positive charge or the positive charge on the intermediate was omitted. In part (b), it was not unusual to see the hydroxide ion removing the wrong hydrogen atom, or for an incorrect E1 mechanism to be offered. Again, poorly drawn curly arrows, which did not start at a bond/lone pair, or which did not end at a bond/atom, were quite common. The name of the mechanism was generally well known but a variety of incorrect names were seen. The role of potassium hydroxide, in part (b), was less well known, with 'nucleophile' being suggested by some candidates, while others attempted to describe the mode of action of the reagent.